Analysis of the Interaction of Technical and Economic Indicators in Improving the Efficiency of Operational Activities of Railway Transport

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Abstract. The article identifies factors that contribute to the optimization of the transportation process on the railroad tracks, to ensure the stable movement of goods on the railroad tracks and to develop a methodology to reduce the negative factors that lead to the decline of the transportation process.

1 Introduction

Since the advent of railroading, a number of problems have arisen in its operation that have hindered the stable movement of trains. Studies of train traffic have shown that as train traffic has increased, so has its speed. This, in turn, could increase the need for locomotive fleets and locomotive crews, as well as increase transportation costs. Since the 1990s, relations between the Commonwealth of Independent States countries have weakened and production has declined. As a result, the volume of rail transport has declined. The emergence of such conditions has brought to the forefront the issue of reducing the cost of unused infrastructure and rolling stock.Rising research on the use of the carrying capacity and carrying capacity of railroad tracks lost its relevance. A certain portion of production volume began to go to international markets, and a wide range of products began to be exported to neighboring countries. In addition, imported products became widespread in our country's markets. As a result, the volume of freight traffic by railroads began to change.

In order to achieve the goal, the following tasks were defined:

- development of methods for determining the factors positively affecting the regularity of freight trains, and methods of economic evaluation of measures to ensure the uniformity of the transportation process;

- determine statistical and analytical correlations between sectional train speeds, the number and timing of receiving and sending tracks at technical stations, the number of freight trains and the number of locomotives;

- identify the main factors affecting the stability of train traffic;

- evaluate the impact of variable locomotives on station operation, taking into account the technical and technological support of locomotive service points (LSP) and managerial decisions of the dispatcher's office when organizing locomotive rotation on the section.

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It is established that in modern conditions of railway transport, taking into account changes in the composition of the train flow, weight standards and length of trains increases the length of areas served by locomotives and locomotive crews, railway transport and railway transport. transport. capacity of railway lines requires a degree of expansion and renewal in the spread of factors that destabilize the load in many directions.

2 Materials and methods

The study is based on popular theories of the organization of the transport process, ensuring traction train traffic and economic analysis. The study was based on factor analysis of changes in statistical indicators of railroad performance, mathematical statistics and methods of mathematical analysis. Works of Russian scientists in the field of transport processes management were used: V.I. Apatsev, A.M. Baranov, A.P. Baturin, A.F. Borodin, P.S. Gruntov, Y.V. Dyakov, V.E. Kozlova, P.A. Kozlova, V.A. Kudryavtseva, D.Y. Levina, A.M. Makarochkina, V.P. Graves, V.I. Nekrashevich, A.T. Osminina, Y.O. Pazoysky, E.A. Sotnikova, E.D. Feldman, I.N. Shapkin, V.A. Sharov, etc.The work applies the method of observation, abstract-logical thinking, grouping, systematic analysis of technical-economic indicators.

"Observation is a method of collecting primary information by direct and direct recording by the researcher of events and conditions in the field. Observations are divided into two varieties according to their location: field observations; laboratory observations.

Field observations are carried out in natural conditions, and laboratory observations are carried out in artificial, i.e. pre-created conditions. Laboratory observations are common in psychology, including social psychology" [7].

Laboratory observations are used in the work. Information about the development of heavy traffic in the world was collected by the method of laboratory research.

"With abstract-logical thinking, we connect different phenomena to each other and build them into a general picture in order to use the conclusions obtained in practice.

Abstract-logical thinking consists of concepts, judgments, and inferences. When a person begins to think abstractly, he or she goes through all three forms in sequence and comes to a general conclusion as a result" [8]. By the method of abstract-logical thinking the results of information collection were compared, that is, was made an abstract-logical analysis of the parameters of the railroads of the compared countries.

"In the method of technical and economic calculation of the indicators are calculated directly with in-depth analysis, based on economic norms" [9]. With the help of technical and economic methods the average density of freight traffic on a certain section of the railroad of the compared countries was calculated.

The paper uses the method of least squares. The least-squares method is a crucial statistical method that is practised to find a regression line or a best-fit line for the given pattern. This method is described by an equation with specific parameters. The method of least squares is generously used in evaluation and regression. In regression analysis, this method is said to be a standard approach for the approximation of sets of equations having more equations than the number of unknowns.

The method of least squares actually defines the solution for the minimization of the sum of squares of deviations or the errors in the result of each equation.

The least-squares method is often applied in data fitting. The best fit result is assumed to reduce the sum of squared errors or residuals which are stated to be the differences between the observed or experimental value and corresponding fitted value given in the model.

There are two basic categories of least-squares problems:

-Ordinary or linear least squares

-Nonlinear least squares

These depend upon linearity or nonlinearity of the residuals. The linear problems are often seen in regression analysis in statistics. On the other hand, the non-linear problems are generally used in the iterative method of refinement in which the model is approximated to the linear one with each iteration. Exploitation of heavy-duty rolling stock can lead to changes in a number of volume and quality indicators of railway operation, freight plan indicators.

The density of traffic on routes is determined by the graphical or tabular method of matching loads between stations. Although the graphical method is considered more accurate, its application is limited. The tabular method is more widely used. The reason is that it uses a standard table of the following indicators for each route: cargo arrival at the station and cargo departure from the station.

One of the effective ways to increase the capacity of railroad sections is the formation of heavy-duty trains, including the use of heavy-duty cars with bulletproof cargos.

Studies have shown that technical and economic efficiency can be achieved in the formation and operation of heavy freight trains. However, the assessment is proposed in the context of natural and cost criteria [11]:

1. Technological efficiency - an increase in the weight of cargo in heavy bullet wagons reduces the total volume of freight train traffic, and therefore reduces the required volume of freight train sections. If the available carrying capacity does not change, it leads to a decrease in the overload factor by carrying capacity.
2. Economic efficiency - with an increase in the weight of cargo on high-bulk wagons, there is a reduction in operating costs associated with the passage of the total volume of freight trains.

The technological impact is assessed by two indicators:

1. Decrease in the total volume of freight train traffic with an increase in the weight of cargo in high-bulk wagons:

$$\Delta N = \mathrm{G}_{pon}(1-\alpha_{netto}) \tag{1}$$

Where:

G_{pon} – is the freight flow for freight trains consisting of high-bulk wagons, t net/day;

α_{netto} – is he ratio of freight trains consisting of high-bulk wagons to the net weight of freight trains consisting of conventional wagons.

α_{netto} – is defined as follows:

$$\alpha_{netto} = \frac{Q_{netto}}{Q_{netto}^{pon}} \tag{2}$$

Where:

Q_netto, Q_netto^PON are the net weight of freight trains composed of conventional wagons and freight trains composed of heavy bullet wagons, respectively, net tons.

The total volume of freight trains composed of cars with heavy bullets:

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The total volume of freight trains composed of cars with heavy bullets:

$$\sum N = N_{\mathrm{p}} - \Delta N = \frac{G}{Q_{netto}} + \mathrm{G}_{PON}(\alpha_{netto}-1) \tag{3}$$

Where:

N_g - is the volume of freight trains consisting of conventional cars, train/day;

G - total volume of freight traffic in freight trains on the section in question, t net/day.

In addition, based on the above indicators, it is possible to determine the required and actual freight capacity, as well as the coefficient of overload capacity of the section or route.

3 Results and discussion

Below we can observe the dynamics of some technical and economic indicators of Uzbekistan Temir Yullari JSC. Cargo turnover is an indicator of the volume of operational activity of the railway transport, which reflects the cycle of work performed on the railway transport. The number of mainline locomotives includes mainline locomotives and mainline locomotives. That is, the fleet of train locomotives. The average sectional speed of the locomotive fleet and freight train is an indicator of the quality of railroad operations.

Table 1. State of technical and economic indicators of Uzbekistan Temir Yullari JSC.

Indicators	2015	2016	2017	2018	2019	2020	2021
Cargo turnover, billion tons-km	22.94	22.94	22.94	22.94	23.4	23.9	23.6
Number of mainline locomotives	160	175	175	180	180	203	205
Average sectional speed of freight trains, km/h	31.4	30.0	30.4	31.1	31.3	32	32.2

Between 2015 and 2021, the average sectional speed of freight trains increased by only 0.8 km/h, an increase of 2.5%. However, the work performed on the railroad increased by 2.9%. This indicates that the railroad's record-keeping conditions do not match actual conditions.

Fig. 1 shows the change in the average sectional speed of Uzbek railroads from 2015 to 2021. According to him, 2016 was down 4.5% from 2015. From 2016 to 2021, there is only an upward trend. The number of mainline locomotives increased by 28% from 2015 to 2021. In general, an increase in the number of locomotives positively affects railroad efficiency or negatively affects locomotive efficiency. The number of each locomotive added to the locomotive fleet should change in direct proportion to the increase in freight transported. It should also be noted that the growth rate of freight turnover should be higher than the growth rate of the locomotive fleet.

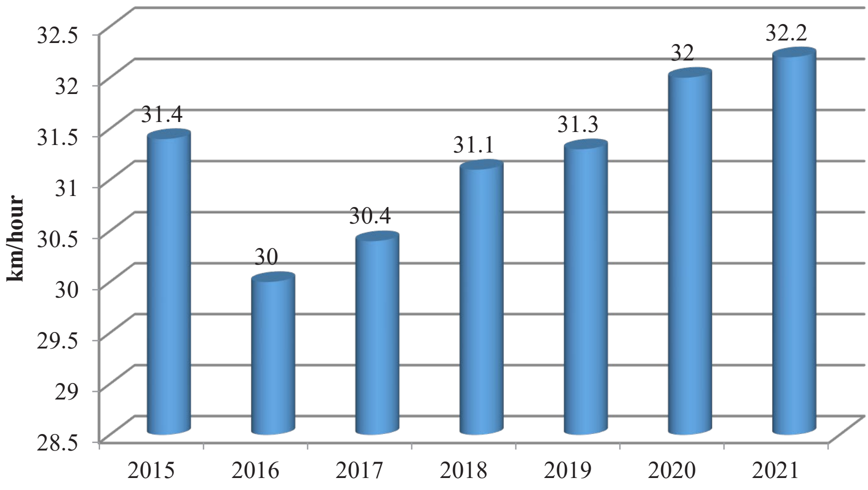

Fig. 1. Changes in the average speed of Uzbekistan Temir Yullari JSC for 2015-2021

The article deals with the factors of unstable train traffic, one of the main factors of which is a decrease in the speed of freight trains on the section. Based on a detailed analysis of changes in section speed over a period of time and on the train sections can be identified the main factors that impede or slow down the movement of trains on the section, and the most significant impact on the freight train. passage.

An analysis of changes in the sectional speed on the train sections of the track can gradually identify the following major factors affecting this indicator of quality: the intensity of traffic, "seasonality", the sufficiency of locomotives at the station of their replacement. Under "seasonality" is understood the period during which "windows" are repaired and reconstructed in the infrastructure.

Section speed is the average distance traveled by a train per hour, taking into account the time of stops at intermediate stations of the section. It also depends on the factors affecting the technical speed, except that the duration of downtime at intermediate stations is added. To increase the speed of the section it is necessary to increase the technical speed and reduce the number of stops at intermediate stations.

Increasing the speed will give a significant economic effect, as the cost of maintenance of locomotive crews will be reduced, repair costs will be reduced, the number of cars and locomotives will be taken out of service, capacity will be created, freight transportation will be accelerated and transportation costs will be reduced.

The above figures may vary in priority in certain areas. In other words, while "seasonality" has more of an effect on train speed in one area, excessive traffic in another area can have a negative effect on performance. If we look at the adequacy of locomotives at the replacement station, the greater the shortage of locomotives, the more negatively locomotive sectional speed will be affected, i.e., sectional speed will decrease.

Based on this logic, the correlations between the number of locomotives and the sectional speed were approximated by the least-squares method [11]:

$$v(\Delta M) = 0.00181 * \Delta M^2 - 0.638 * \Delta M + 87.058 \quad (4)$$

When the value of function (1) is equal to the value of the section speed determined by the train schedule, the following equation can be solved to determine ΔM:

$$0.00181 * \Delta M^2 - 0.638 * \Delta M + 87.058 = v_g \quad (5)$$

The calculations show that if we assume that the number of locomotives is 205, then the speed of the section is required to be 33 km/h. This speed is also true for the case when the weight per vehicle axle is 25 and 27 pf [10].

Consider the characteristics of the factors affecting the increase in carrying capacity on the railroad sections.

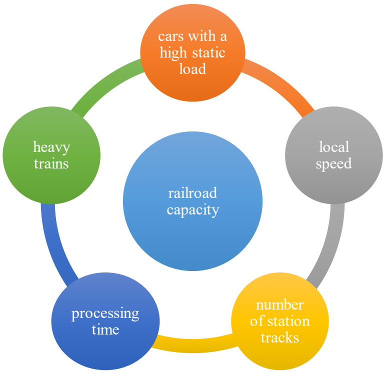

Fig. 2. The maximum weight per wagon axis within each country, pf/axle.

Technical re-equipment of rail transport in order to increase the capacity of the railroad, further increase the capacity of railroads on freight tracks, as well as increase the capacity of railway stations and hubs to improve the level and efficiency of freight track and train traffic organization, increase the role, improve the use of locomotives and railcars.

If you look at this picture, one of the main ways to increase capacity is to reduce the duration of these technological operations. Indeed, how many trains a station and stations pass in a given period of time is affected by the arrival of trains, how quickly they are processed at stations when departing, and how quickly formation and distribution operations are performed.

Due to various measures, it is possible to reduce the time of technological operations: organizational (use of intelligent technologies, changes in processing algorithms) and technical (use of more productive devices) [11].

The main task of wagon farms is to ensure operating condition that ensures uninterrupted and safe operation of the entire wagon fleet of railroads. Particular attention of farm workers should be paid to improving maintenance and repair of cars, reducing the downtime of cars in all types of repairs, as well as reducing the total time of cars in emergency condition. This, in turn, will improve the quality of railcars, speed up the transportation process and reduce the cost of transportation by rail.

Increasing the freight capacity of railcars is an important direction of scientific and technical progress associated with the reconstruction of the railcar fleet. One of the most effective ways to increase the carrying capacity of railroads is to reduce the weight and increase the carrying capacity of cars with better adaptation of loading and unloading operations to mechanization and automation. This will increase the processing capacity of stations, increase labor productivity, reduce transportation costs, and increase the competitiveness of transportation through additional income and profit.

Carrying capacity of wagons can be increased by increasing their length and the number of wheel pairs, reducing the technical wheel coefficient, increasing the load on the wheel pair and the wagon.

4 Conclusion

At present, with the growing production process, increasing the carrying capacity of railroad tracks or the use of freight capacity reserves remains one of the most urgent issues. It is also advisable to carry out special research to solve this problem. This article analyzes the factors influencing the increase of carrying capacity of railroads, which in one way or another directly affect the efficiency of the operational activity of railroads, including:

Factors affecting the increase in freight capacity on railroad sections - analyzed the methodology for determining the relationship between section speed and train traffic.

The factors influencing the increase in carrying capacity on the sections of the railroad were analyzed.

In addition to the results, the following measures can be proposed:

1. development of a methodology for identifying "problem areas" in order to stabilize train traffic on congested sections;
2. establishment of statistical and analytical relationships in which the main indicators of the quality and volume of railway work: the section speed, traffic intensity, intervals of trains, reception at technical stations and the number of tracks, freight train running time, maintenance of train locomotives;
3. determination of the main factor affecting track capacity - the flow of trains, the provision of locomotives at the border stations of their service areas, determining a reasonable reserve of locomotives at the stations of their replacement.

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