Methods for economic assessment of operational quality and its impact on railway delivery time

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Abstract. Transport is as important to the consumer of products as the production process, so the building of cost-effective options for freight delivery is a pressing economic challenge. Rail transport occupies a significant share of the transport market, the importance and efficiency of which increase when transporting a large flow of goods over long distances. Solving an important task of railway transport - full and timely satisfaction of the country's economy needs in transportation, requires providing further improvement of economic methods of analysis and planning of operational work. Effective management of operational work in freight transportation enables one to manage freight flows in an optimal way and to provide additional volumes of transportation by means of released resources. In this case, the implementation of measures aimed at increasing the speed of vehicles and, as a consequence, reducing the time to the delivery of the cargo is of great importance. As analysis has shown, the largest volume of penalties paid to customers for breach of contractual obligations are payments for failure to meet deadlines for cargo delivery. The results of analytical studies made it possible to identify systemic violations in the quality of the transportation process and to form measures to improve the quality of transport services to customers.

1 Introduction

Rail transport activities under capacity constraints need to be clearly planned, including special attention to the resourcing of the transport process. Resource planning is the basis for budgetary management in the company and enables the allocation of funds to ensure a continuous transportation process, as well as clearly coordinate the interaction of branches and units involved in it.

The efficiency of transport services to business entities is determined by the coordinated work of the branches of a transport company, each of which implements its organisational and economic functionality. It should be borne in mind that errors and failures in the work of one of the branches can cause failure in fulfilling one of the most important indicators - cargo delivery time.

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Cargo delivery time - this indicator has always represented the most important result of transportation, its theoretical study was carried out as early as the beginning of the XX century.

In 1911, the author G. Churilov in his book "Measures to eliminate delays in cargo delivery and ways of accounting for commercial speed of transportation" [1] gave proposals aimed at increasing speed, as well as the effects of increasing speed. The author considered that one of the most important problems in rail transport work is the excess of the necessary throughput capacity over the available capacity. The following technological solutions were proposed as measures:

- Classification of trains, establishing the order of their formation;
- lengthening the locomotive shoulders;
- marshalling yard layout;
- consolidation of consignments, reduction of marshalling operations;
- reduction of the ratio of empty wagon runs.

Railway engineer I.I. Vasiliev in his book "Dependence of commercial train speed on technical elements and work of railway sections", published in 1918 [2] named the main factors affecting speed (note: factors are given in the author's original description):

- The dependence of commercial speed on the number of trains, different approaches to determining speed for full and congested schedules;
- Impact of rush trains when the schedule is full, as the number of goods trains removed from the schedule, impact of rush trains as the extent to which goods trains are restricted
- location of stopping points;
- length of maximum haul and number of hauls per section;
- quality factor of train delays on the line and release of statistical data from this influence to obtain a net train operating quality factor;
- average time to work with one wagon, coefficient of speed on the number of overtaken wagons for the first section;
- number of overtaking goods trains by an urgent train, the value of average delay of a goods train when overtaking it by an urgent train.

Scientists of the Soviet period paid much attention to improving the plan and profile of the track, modernisation of car and locomotive fleets, re-equipment of signalling and power supply devices. The author of the book "Ways to improve speed on the railway transport" Ushakov S.S. [3] provides a scientific rationale for the impact of track profile on the full use of locomotive capacity. The author qualifies train delays at stations as the cause of useless aging of wagons and violation of cargo delivery time.

2 Materials and methods

The increasing volume and geographical expansion of traffic has led to more technological solutions, including those requiring financial investments in the development of the railway infrastructure. Railways have always sought to increase the speed of traffic on sections while making rational use of resources, offering technical innovations along with improvements in technology. Always the primary factor influencing the speed of movement of trains has always been the throughput capacity of railway sections and the occupancy of the schedule [4].

Over the years, science has evolved, proposing new approaches to identifying the factors that influence the speed of train movements and qualitative indicators of rolling stock use, and consequently, the costs for the implementation of the transportation process.

Cluster analysis is widely used in railway transport analytics, which makes it possible to collect the results of statistical observations into homogeneous groups on the basis of

features that are specific to this group only. All information in sectoral statistical reports is subdivided according to the object of observation or vertical production activity.

- transport economy,
- locomotive economy
- Freight and commercial operations, etc.

Further, "clusters" of observation units are identified: trains, wagons, locomotives:

- for locomotives, operating times and running distances can be selected; in turn, times and distances are divided into states - in train head, single track, in pushing, in station. All operations are divided by types of traffic - passenger, freight, shunting, and service;
- for trains there are types of registration: transfer by joints, speed of movement, time on sections, on the polygons, by types: container, reefer, according to special schedules, etc.
- for freight: volume in tonnes, in wagons, by cargo nomenclature, with allocation of revenue, carriage charge and revenue rate, transport distances, by polygons of transit and local railways with division into inbound and outbound.

The clustering of "big data" allows a targeted selection of information, cutting out redundant data.

Factor analysis of operational work consists of reviewing train schedules, recording delays and identifying the reasons for them, and then consolidating this information into accounting forms. The statistics are generated at the end of the reporting period, with responsibility allocated to the branches.

3 Results and discussion

The analytics of the transportation process is primarily concerned with estimating the speed of traffic movement and analysing the reasons for its change.

The regulatory (consolidated) train schedule [5], based on the principles of integrated reinforcement and tasks to maximize the use of capacity and carrying capacity of railways, technical standards of operational work [6] and the basics of operational planning and regulation of transportation [7], is taken as a reference.

In most cases, for the analysis of the transportation process, time parameters are taken, i.e., the time of operations performed by the object of accounting and statistical observation, its deviation from the normative parameters, and also to the value of indicators developed in the past period. On the basis of these parameters, indicators reflecting the use of resources are compiled [8, 9].

In the factor analysis of operational activity, the first sources are schedules of executed train traffic [10] and of executed station work, as well as accounting forms of locomotive facilities.

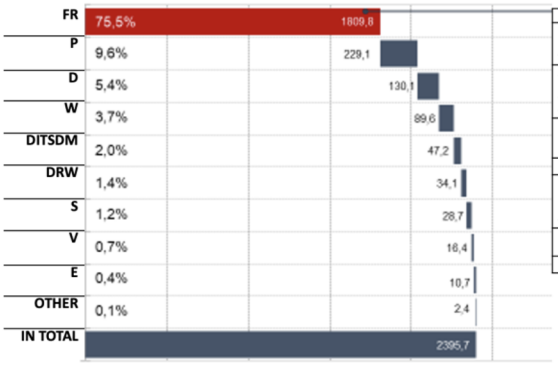
According to the reports on the value of train delays for the year 2021, the reasons are as follows:

- technical failures caused delays of goods trains - 214,000 hours;
- technological failures - 291.1 thousand hours,

A schematic distribution of the causes of goods train delays on the sections is shown in Figure 1.

Fig. 1. Factors influencing the implementation of the plot rate for 2021. Source: Compiled by the author

Analysis of non-scheduled time loss data shows that the largest share of violations (75.5%) is accounted for by locomotive maintenance divisions (in Figure 2 - marked as "T").



Cause	Hours	Percentage of total
Failure to achieve a running/stopping time due to the fault of the crew	1357.6	75%
Admission of pass/com/accelerated freight and other priority trains	299.5	16.6%
Malfunction of the locomotive at the station and in transit	72.7	4.0%
Special weather conditions	32.1	1.8%
Boarding/unloading of JSC "Russian Railways" employees who support the transport process	10.2	0.6%
Malfunction of the train brake control system	10.2	0.6%
Other causes	22.7	1.3%

Fig. 2. Analysis of train delays on the Arkhara-Izvestkovaya section in January 2021, highlighting the causes by locomotive complex. Source: Compiled by the author

Analysis of the causes attributed to the locomotive complex shows that 75.0% of losses attributed to the locomotive complex are attributed to the cause "Stoppage time/stop due to the fault of the locomotive crew".

This cause is not objective, as it may be a consequence of the train following at a distance from the one ahead, or following the speed limits due to track conditions, as well as due to the locomotive crew's failure to comply with the train's driving schedule.

If we consider these losses in terms of unit responsibility, of the total number of hours of delays:

- 41.8% are the responsibility of the locomotive crews of TPE-11 Belogorsk of the Trans-Baikal Traction Directorate;
- 43.0% were the responsibility of locomotive crews of TPE-1 Obluchye of the Far East Traction Directorate;
- 15.2% are the responsibility of locomotive crews of TPE-2 Khabarovsk of the Far Eastern Traction Directorate.

To improve the quality of transport service for freight owners it is reasonable to calculate additional costs caused by disturbances in the quality of the transportation process.

The next step of analytical work is economic assessment of violations and measures aimed at improving the technology of work and improvement of technical facilities. Economic evaluation according to the cost-benefit method has been used quite rightly for decades. Today, approaches to the determination of cost rates are oriented to the current situation of the business practices of the production verticals and have a deeper focus on the allocation of costs and operations.

The valuation method consists in superimposing the parameters of the assessed metric on the cost rates developed for rail transport using the formula:

$$Y_{tot} = Y1 + Y2 + Y3 + Y4 + Y5 + Y6 + Y7$$

where Y_{tot} is the total damage from the incident causing the disruption of the train schedule, rub;

Y1 - damage component connected with restoration of railway rolling stock serviceability, rub;

Y2 - damage component connected with restoration of the infrastructure operability, rubles;

Y3 - additional expenses connected with train delays, rubles;

Y4 - component of damage connected with the carrier's penalties for delays of long-distance and local passenger trains, rubles;

Y5 - component of damage connected with the carrier's penalties in connection with violation of terms of cargo delivery to the recipient, rub;

Y6 - component of damage connected with the carrier's penalty for violation of terms of luggage and cargo-luggage delivery, rub;

Y7 - component of damage associated with labor costs for search and identification of damage to rolling stock and infrastructure, rubles.

Additional costs for transportation activities Y3 associated with train delays as a result of incidents causing disruption of the timetable are generally determined by the following formula:

$$Y3 = Y^{pass}3 + Y^{com}3 + Y^{fr}3$$

where Y3 is the additional cost of transportation activities from a schedule-disturbing incident related to train delays, rub;

$Y^{pass}3$ - additional costs associated with delays of long-distance and local passenger trains, rub.;

$Y^{com}3$ - additional costs associated with delays of suburban passenger trains, rub.;

$Y^{fr}3$ - additional costs associated with goods train delays, rub.

The additional cost associated with delays on long-distance passenger trains is determined by the following formula:

$$Y^{pass}3 = e^{pass}_{car-hour} \times \sum t_i$$

here $e^{pass}_{car-hour}$ - aggregated cost rate for 1 hour of downtime of a long-distance passenger train in the respective type of traction (electric or diesel locomotive), rub/hour;

t_i - duration of delay of the i-th passenger train delayed as a result of the incident, hours.

The additional cost of suburban passenger train delays is determined according to the following formula:

$$Y^{com}3 = e^{com}_{car-hour} \times \sum t_i$$

here $e^{com}_{car-hour}$ - an aggregated cost rate for 1 train hour of passenger train downtime in suburban traffic in the respective type of traction, rub./hour;

- duration of the delay of the i-th commuter passenger train delayed as a result of the incident, hour.

Additional costs associated with goods train delays are determined by the following formula:

$$Y^{fr}3 = e^{fr}_{car-hour} \times \sum t_i$$

here $e^{fr}_{car-hour}$ - The consolidated cost rate for 1 train hour of downtime of a goods train in the respective type of traction (electric or diesel locomotive), rub./hour;

t_i - the duration of the delay of the i-th goods train delayed as a result of the incident, hour.

Despite the fact that the expenditure rates combine all the variable costs of the participants of the transport operation, this method has the following disadvantages:

Firstly, attributing the responsibility for the delay to the Traffic Management Directorate, which provided the priority pass and catch-up of a delayed passenger train actually delayed by the responsibility of another branch.

Secondly, the cost rates summarise the costs of several branches, which makes it impossible to determine the impact of operating irregularities on the budgets of specific units:

- the expense rate per 1 train-hour of downtime includes the following expenses: per 1 car-km, per 1 locomotive-hour, per 1 locomotive-km, per 1 brigade-hour, consumption of fuel and energy resources and per 1 hour of occupation of 1 km of main (station) tracks. In fact, the practical application of this rate in actual budgets of branches is impossible, because the calculation based on infrastructure cost rates "per 1 car-km" and "per 1 hour of 1 km of main (station) track" will not allow to determine and present a specific overrun in the budgets of Infrastructure Directorate and Traffic Management Directorate. Application of unit consumption rates "per locomotive-hour" and "FER consumption" will not allow to adjust the budget of the Directorate of Traction, because the absence of a locomotive idling in the head of a delayed train on a section will not cause the exclusion of the locomotive from the operating fleet and savings due to reduced depreciation charges, nor will it reduce fuel and electricity consumption for train traction. In fact, the exclusion of such train delays will reduce the excess turnover rate of locomotive crews and reduce labour compensation in terms of overtime hours and only if such overtime hours of employees of a particular locomotive crew are recorded based on monthly performance (taking into account possible underwork, sick leave, holidays, etc.);

- the cost rate is based on the costs recorded two years ago, i.e. in most cases no longer relevant;

- the expenditure rate is based on performance measures actually in place two years ago. The period of two years is based on the following circumstances - it takes 1 year to calculate, agree and approve the expenditure rates. Directly, the calculation itself is based on information from the previous year;

- the expenditure rate is based on aggregated railway data, whereas within the boundaries of one railway there may be significant differences in prices for fuel, materials, and labour, including the application of different coefficients.

This method is valid and can be applied in the context of estimating generalized information, such as generalized non-productive losses in the activities of Russian Railways branches, the amount of train delays per month (quarter, year) within the boundaries of a railway or network, and also with an allocation of responsibility of one or another production branch. When it comes to estimating specific train delays, however, this method does not fully reflect the actual costs incurred that affected the structural division's budget.

Next, consider how the budgets of the branches are affected by operational and timetable irregularities.

Traffic Management - operational and timetable violations do not affect the budgets of the affiliates, as the number of these events does not affect the number of staff.

Infrastructure Directorate - the budget of the branch will change in terms of expenses for the transfer of faulty rolling stock from the place of detection (occurrence) of a technical equipment failure to the repair enterprise, expenses for materials and replacement equipment used to restore the serviceability of the rolling stock. Personnel costs will not change (note that the regulations take into account personnel work at an hourly wage rate).

Traction Directorate - maintenance costs for locomotive crews will change. Locomotive maintenance costs and depreciation charges will not change.

4 Conclusion

The increasing degree of influence of the production branches on operational work, namely on disturbances in operational work, is the reason for developing a technical and technological action plan.

The degree of wear and tear, the technical condition of the units, track facilities, and the locomotive fleet are constantly monitored by the involved units involved in the unified transport process. The proposed increase in responsibility will, first, help identify economic losses in operational work in the most comprehensive way and allocate responsibility for increased costs in the budgets of specific branches. Second, increased economic losses will not only entail the implementation of the Investment Plan for technical and technological measures upward, but will also make it possible to determine their economic necessity, providing for comprehensive modernisation, overhaul, or renewal.

Disturbances in the transportation process result in lower delivery speeds and reduce the share of cargo consignments delivered to consignees within the normative timeframe. This entails the risk of higher penalties being charged and paid for late delivery [11]. In this connection, it is very important to note that there is a difficult economic task of choosing a strategic decision, either to have a constant overconsumption of resources required for the transportation of presented cargo and to pay penalties due to late delivery or to upgrade technical facilities, which will significantly reduce technical and technological violations in operation.

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