Planning of qualitative indexes of railroad operational work in polygon technologies

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Abstract. Increase of transit traffic volume demands application of new technological solutions structured in accordance with the tight schedule of the movement of freight trains. The forms of organizing traffic volumes based on the tight schedule are the intersectional and group trains and technical routes of regular service requiring specially organized reception of groups of wagons at their railroad yard.

Now there are quite a few optimizing models aimed at describing and researching of the uniform object – a freight transportation control system. Many of them give the individual formal description of the system, while being closed to further specification and development.

One of the main goals of transport processes control consists in optimum performance of cargo transportation of the predefined volume determined at a certain time interval, using the existing technical, information and steering complexes.

1. Introduction

Currently, railroads across the entire network of the Russian Federation are switching to polygon technologies. Their use has come a long way from management of traction resources at limited sections between single stations to coordination of interactions of several roads. Furthermore, these technologies have proven their feasibility and the ability to quickly respond to changes in both external influences and internal factors.

The carrying capacity of all the polygon in general directly depends on the number of the limiting sites in independence regardless of a type of these restrictions (technical, technological, organizational). Thus, the occurrence of any problematic situation in the Far East, Transbaikal or the East Siberian Railway will quickly affect other railroads of the Russian Railways network [1].

Let us dwell in more detail on the Eastern polygon, the most advanced in the whole network.

The operational length of the railroads of the Eastern polygon is 17207 km, including the length of the electrified lines - 9196 km (53.4%). The share of two-acceptable routes is 7525 km (43.7%). 12144 kms (70.6%) of the main directions are equipped with automatic blocking. 9669 kms (56.2%) are equipped with the centralized traffic control. There are 810 railway stations at the polygon, including 8 classifying sections, 6 passenger stations, 58 sectional stations, 109 cargo stations, 629 intermediate stations.

There are 15 operational car repair sheds at the polygon. Sections of warranty passage of freight wagons reach to 1300 - 1400 km. There are 4 infrastructure maintenance control centers (ICC) at a polygon.
Transportation work at the Eastern polygon is characterized by permanent increase in freight turnover, with the main freight flows subsequently directed to sea trade ports, such as Vostok, Nakhodka, Vanino, Vladivostok, Posyot [2].

Further growth of loading volumes is provided in ports of the Far East with increase in a cargo flow at the Trans-Siberian Railway and BAM for 30% in the 2020 perspective. Providing subdivisions with resources needs to be supported by implementation of the corresponding technologically sufficient organizational structures within the Eastern polygon borders.

The handling of heavy trains with the increased length in large numbers will be implemented after lifting restrictions of infrastructure, first of all, on traction power supply and overhead system devices [3].

It is also necessary to mention the fact of decrease in sectional speed and performance of locomotives during the current year at the Eastern polygon, which can be objectively justified. Fig. 1 shows the dynamics of accomplishment of local speed in 2018.

**Figure 1.** The dynamics of accomplishment of local speed in 2018 at the Eastern polygon.

Since 2010 Russian Railways have been administering a policy which is directed to increase the train mass and use of heavy trains in cargo transportations. In 2015 the company presented the program for development of heavy train service till 2020. Its goal is to increase the number of heavy trains on the lines and introduce the trains with weight of 9 thousand tons to various directions.

If we speak objectively about the infrastructure of the Russian Railway, it should be recognized that possibilities of increase in the train-handling capacity are exhausted and we need new technology solutions supported with the information component. Transition to the organization of the movement of freight trains according to the schedule is one of options. While organizing the movement of freight trains according to the schedule, local and group trains (including three or four selected groups) and regular technical routes can become the main forms [4], [9], [10].

However, the development of a system of making up of two- and three-group trains will promote reduction of classification work, personnel decrease, acceleration of freight delivery and increase in speed of trains. Group trains allow saving costs for accumulation of wagons and rationally distributing interstation classification work.

Since 2011 the increase of average mass of freight cars made up about 4%, and the number of heavy trains was increased on various highways. For example, for 6 months in 2018, 49 thousand trains were handled on the Southern Ural railway, which is 20% more as opposed to 2017. With all aforesaid, there wasn’t a single day on the railway without equipment failures. Just in 10 months of 2018, 37,024 warnings were issued on the railway to limit the speed of freight trains by 29,620.7 km, which is 3168 restrictions and 5,805.6 km higher than the same period in 2017.
The increasing complexity of management functions in railway transport led to the restructuring of the sector’s purposes and tasks. Within the Comprehensive program of optimization of operational work, a number of the major tasks have been formulated, among which are the creation and introduction of efficient methods of organizing and controlling freight transportation.

Today the train handling reserves are almost exhausted on the Russian Railways network. In turn, it demands application of the new technological solutions based on the tight schedule of movement of freight trains. The forms of the organization of train service which are based on the tight schedule are: group trains (including mutually coordinated exchange of groups at stations) and the technical routes of regular service requiring strictly organized reception of groups of wagons at their railroad yard [5]. A coordinated (controlled) supply of wagons with a scheduling of movement of specialized transfers, scheduling of the loading by destination as well as controlled supply of empty wagons under the planned loading should be provided for this purpose.

At the same time, upon transition to the organization of movement of freight trains according to the schedule there is an opportunity not only to keep, but also to increase average weight of the freight train by 5–10% taking the following measures:

- the organization of movement of trains of the increased weight and length using specially developed "train paths", including the organization of make-up and further handling of train sets on the short tracks;
- replacing individual trains with group trains;
- organizing the delivery of local cargo with the possibility of the attachment of wagons to transit trains, provided that all technological times for processing and the norms of weight and length on the section are maintained;
- the automatic calculation of train make-up process using the seat booking system in train sets with the efficient application of empty "train paths".

The models and algorithms developed during the planned management of transportation do not allow making practical decisions to achieve the goal in modern conditions.

Therefore in recent years much attention was paid to a research of technological process of freight transportation, creation of new criteria of effectiveness, optimizing models of scheduling and control, the analysis of organizational and structural, economic and other process flow diagrams.

As a result, at present there are a fairly large number of the optimizing models aimed at describing and a researching of a uniform object - a freight transportation control system. Many of them give the individual formal description of system, at the same time being closed for further development.

The main goal of managing transport processes is the optimal implementation of freight transportation of the given volume determined at a specific time frame, with application of the existing technical, informational and operating systems.

To achieve this goal, various models are used in railway transport to optimize the main technological process of operational work – the make-up of trains.

The make-up of trains is one of the major processes in the operation of the station. Its parameters are of great importance, both in the organization of work of the station, and for all directions. It necessitates a sufficiently detailed description of regularities of train accumulation.

2. Problem definition

In railway transport there are also standard control models that can optimize the transportation process in terms of operational work.

Issues of organizing car flows in trains can be considered and implemented by various methods, but two are most widely used:

- a method of modeling the sequence of intervals between the moments of the end of accumulation of train sets on the basis of the considered cumulative distribution function;
- a method of modeling the decomposition of the broken-up train sets according to the plan of formation with the subsequent summation of groups of wagons to the whole trains.

In the first method, there is no process of the train make-up. This makes it impossible to use the model to study the operation of stations in the conditions of high loadings of its elements.
The considered model implements the second method to describe the process of train make-up. One track (in case of applying strict specialization), or group of tracks (assigned to each appointment in the yard when using of the fluctuating specialization).

It is known that the processing of wagons at the station is random, due to a number of the external and internal reasons, such as non-uniform arrival of trains at the station, non-uniform accumulation of wagons and processing of trains [6], [11], [12].

So emergence of wagons of various purposes in train sets is considered random events.

With that, the current value of magnitudes of separate groups of wagons is determined by the following formula:

$$m_{gr}=m_{avr}\left[\ln F(m_{gr})\right]$$

$$F(m_{gr})=Z_i$$

where $Z_i$ is a randomly distributed number from the set of random numbers which are evenly distributed in the range from 0 to +1;

$m_{avr}$ is the average magnitude of a group of wagons of $i$ destination equal to:

$$m_{av}=N_i/n=(19-0.1k_{dead})N/0.4n_{reh}$$

where $N_i$ is a wagon flow under consideration of $i$ destination;

$k_{dead}$ is the total number of destinations according to the plan of the train make-up;

$n$ is the total number of trains arriving for the breaking-up.

All the daily fluctuations of the arrival of train flows and intraday non-uniformity, as a number of researches showed, are described by the normal distribution law. Model operation of number of the broken-up trains happens every time upon transition to imitation of the process for the next days. Its current value turns out with use of a random number of $Z_i$ and integral function of distribution:

$$N=N_{av}+kvN_{av}(\Sigma Z_i-3)$$

$N_{av}$ is an average daily number of the trains broken-up at the station;

$kv$ is a variation factor.

On the basis of the above provisions, the algorithm of the making-up of group trains is constructed.

In the course of accumulation and on its completion, the following magnitudes by each destination are counted: the parameter of accumulation of structures – $c$, the number of the accumulated train sets – $\Sigma N_{acc}$, the time of accumulation of structures – $\Sigma T_{acc}$, accumulation freight wagon-hours – $\Sigma B_{acc}$.

Using this algorithm, the values of the accumulation parameter at the make-up stations and the expectation parameter at the wagon group re-attachment stations for the following categories of group trains have been obtained by a method of modeling:

- group trains without constant weight of groups and not attached to permanent schedules;
- group trains with constant weight of groups and not attached to permanent schedules;
- group trains of the constant schedule with a variable of groups;
- group trains with constant weight of groups and attached to particular schedules.

In the course of measurements, further data processing as well as formalizations of results in the form of a mathematical model, errors occur and a part of information contained in the basic data is lost. Application of planning methods of an experiment makes it possible to define an error of a mathematical model and to judge its adequacy.

When scheduling an experiment, the complete factorial experiment was used in this work. The complete factorial experiment allows estimating effects of interaction quantitatively.

3. Conclusions
Following the results of processing of experimental data, the regression equations for the coded values of separate factors were obtained. The influence of each factor on the optimization parameter was determined by the available coefficients of interaction. In addition to the regression equations for the coded values of factors, the regression equations for natural values were retrieved.

According to the results of the experiments, the dependences of accumulation parameters and expectation parameter became available.

The obtained adequate linear model takes the form of a polynomial of the first degree. The coefficients of the polynomial are partial derivatives of the response function on the corresponding variables. Based on the obtained coefficients of interaction of bij, a measure of the influence of each of the factors on the optimization parameter was established. In addition to the regression equations for the coded values of factors, the creation of the equations of regression is of interest for natural values.

On the basis of the obtained dependences, the specified formulas were proposed to calculate the costs of freight wagon-hours and locomotive-hours for the group and single make-up of trains helping to make adjustments of the train make-up plan.

It should be noted that today the issues of development of the step-by-step instruction for the decision-making on the efficient updating of the make-up plan by the dispatching office of the stations and regional directorates with the list of an operations procedure on the development of offers and their coordination are especially topical.

It should be noted that in new working conditions it is necessary to analyze and identify the list of indicators, the value of which can be adjusted depending on a situation during this time for each railroad at the polygon [7], [13], [14].

For polygons, it is necessary to consider the following operation indicators:
- train traffic schedule performance regulations;
- locomotive run;
- the extent of equipment failures;
- overall wagon fleet.

The following actions should also be taken:
- to organize work on the redistribution of locomotive crews between structural divisions;
- to establish a task and to provide control of the running of locomotive crews at the extended service sections;
- to organize replenishment of trains at the local stations;
- to provide monitoring of expectation of locomotives.

The complex of the listed indicators well characterizes the transportation process organized in new working conditions on polygons and reflects market requirements in work of the main carrier of Russian Railways, however, their application demands further research, justifications and additions [8], [15].

The full range of actions for modernization of the general system of indicators of operational work should include the development of process models of the production block of the Russian Railway holding and also the formation of a new system of the indicators of the operational activity of polygons. In the nearest future it is necessary to define a set of indicators which are subject to monitoring and control in new conditions and allow providing the decision-making process with adequate and sufficient information.

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