Optimization of the length of dispatching polygon sections railways

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Abstract. The article deals with the organization of work of the dispatcher's office on directions with a high intensity of mixed cargo and passenger traffic. The North Caucasus Railway, which serves the ports of the Azov-Black Sea basin of Russia, and its main busy routes, was chosen as the research site. A methodological approach to determining the length of dispatching sections at the railway landfill within the framework of the Road Traffic Control Center has been developed. At the initial stage of studying the content of the work of train dispatchers, the algorithms developed by the authors are used solving operational management tasks. The analysis of non-optimal actions of the train dispatcher that cause losses in the transportation process is used further to develop a method for estimating losses in operators of problem algorithms based on the interval estimation method by solving a linear programming problem. As a result, based on the assessment of the capabilities of the operational personnel of the railway polygon of the road and the technological cost of delays in movement due to its suboptimal actions, a methodological approach is proposed to determine the length of dispatching sections that provide regulatory control, load level of the dispatcher device.

1 Relevance of the work

A special feature of the transport system in the South of Russia is its focus on export cargo transportation. Currently, the third part of the export cargo flow Russian Federation arrives at ports The Azov-Black Sea Basin (ABSB) with the participation of railway transport. According to the forecast data of JSC "Russian Railways" by 2025, the volume of cargo transportation through the Southern port terminals and portside stations will increase to 125 million tons per year. The cargo base is expected to grow further until 2030, including through the introduction of new transshipment facilities at the Taman port. Taking into account the increase in cargo flows on the main railway lines, the load on the transport infrastructure is increasing, and the technological regulations for dispatching personnel to manage the operational work of directions are changing.

The organization of transport work in heavy-duty areas of the railway network and the test site of the North Caucasus Railway (NCR) with a high intensity of passenger and freight traffic has specific features:

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as a rule, such railway sections are located in the system of international transport corridors at the approaches to major transport hubs and seaports, which requires determining priorities for passing trains of various categories, building regular and accelerated delivery services;

these destinations have restrictions in the capacity and carrying capacity of the infrastructure;

the dispatcher's office on railway sections with intensive joint freight and passenger traffic has an increased load, it requires increased attention to traffic safety, organization of repair and reconstruction works on infrastructure using the "in alignment" technology on long-distance routes.

Taking into account these features of the operation of landfills of portside railways, with an increase in the volume of transport work, studies of the dispatching control process at a railway landfill become relevant. Based on which it is necessary to provide for algorithmization of the control actions of the train dispatcher, as well as to evaluate his non-optimal actions in the technological aspect. The results obtained will make it possible to assess and then adjust the map of dispatching sections in the current operational situation at railway landfills, taking into account the dispatcher's workload of the device.

2 Research methods

The works of many scientists were devoted to the issues of improving transport work at railway landfills, organizing the work of the dispatcher's office in conditions of heavy traffic, while the research area covers such areas as the development of the management structure of railway companies [1-2], assessment of existing and development of new technological solutions in the field of organization, management of the transportation process, including train traffic [3-8]; organization and technology of transport production at port railway landfills, transport management production in the interaction of modes of transport [9], automation, informatization and optimization of transportation management processes [10-15].

Currently, the main link in the traffic management structure of Russian Railways is a centralized system based on transportation management centers. In the existing 3-level structure, the transport management functions are performed at the level of the Central Directorate of Traffic Management, a branch of Russian Railways, by the Transport Management Center, and at the road level by the Dispatching Transport Management Center (DTMC). For example, DTMC NCR was established in 2001. DTMC fully covers the railway landfill with an operational management system and during different periods, it included a different number of dispatching stations. DTMC NCR includes a number of administrative districts, for example, Rostov, Krasnodar and others. Districts include a number of dispatching stations where the train dispatcher is the traffic manager. The number of dispatching stations is constantly being optimized based on the growth in traffic volume and the load of train dispatchers (DNC). For example, in the following conditions: conducting a survey The Sochi-Alpika-Olympic Park and Adler-Krasnaya Polyana control areas were established after the 2014 Winter Olympic Games (XXII Winter Olympic Games in Sochi). At the beginning of 2014, the borders of the Taman and Timashevsky dispatching areas and the Bataysky junction were changed (Figure 1).

An important role in automating the management of the transportation process is assigned to the dispatching centralization system (DC) on sections. To date, the length of dispatching circles equipped with this system is almost a large proportion of the length of the railway network and is continuously increasing. At the same time, the technical capabilities of the system and its equipment are being improved – the capacity of remote control and tele – signalization channels is increasing, the speed of transmitting orders is
increasing, a modern elementary base is being used, and the reliability of equipment is increasing.

![Diagram](https://example.com/diagram.png)

Fig. 1. Parameters of dispatching sections on the SCR

The research conducted by the authors shows that the DC system provides the train dispatcher with an insufficient amount of necessary information. Information about the train position on the section is displayed by the dispatcher on the DC monitor screens. It reads information of a directive nature mainly from the regulatory traffic schedule and other documents. Receiving a large amount of information in this way, the dispatcher is forced to process it "manually". The intensity of the information functions performed by the dispatcher is indicated by the fact that 60-80% of the dispatcher's working time is spent collecting and processing information. As a result, the dispatcher does not have enough time to perform the most important management function – decision-making. This is one of the reasons for its suboptimal actions in the operational management of train traffic on the section, which result in losses in the transportation process – downtime of trains, locomotives, trains, an increase in train travel time along the section, unproductive use of shunting facilities. Another reason for suboptimal actions of the dispatcher is the late receipt of operational information. This is a consequence of "human behavior", factor" and insufficient level of automation of dispatching control and management functions.

Clear, well-coordinated actions of the dispatcher's office on the organization of transportation work to transport hubs and sea terminals, this is a necessary condition for meeting the increased standards for unloading wagons on cargo fronts. The quality level of train traffic management is assessed by other criteria: optimal decision making, timely development and completeness of implementation decisions. Failure to meet these criteria, possible errors of the train dispatcher cause losses in operational work, which may lead to a decrease in the local speed of trains, the operating mode of locomotive crews may be disrupted, and so on. Therefore, within the framework of this study, the following tasks were set: to analyze changes in the information support of train dispatchers and evaluate the
effectiveness of improving information support in the dispatching centralization system, to assess the load of the dispatching apparatus at the NCR taking into account the length of dispatching sections.

3 Analysis efficiency of improving information support in the dispatcher centralization system

The analysis of the work of the SCR dispatcher unit showed a significant increase in the load of dispatchers on a number of railway sections of communication with the transition of a number of stations to dispatcher centralization. The train dispatcher is supposed to work using automated workplace (AW), which should free dispatchers from manual collection of information in train and freight work and automate its provision. Due to the development of modern information technologies, the initial task of providing and systematizing the necessary information to the dispatcher has been completed. When creating software and hardware complexes in dispatching centers, a large number of information systems were used, the most famous being "ASOOP", "Ural-VNIIZHT"GUIDE, and "OSCAR".

The technical and technological base of DTMC NCR is built on the basis of dispatching centralization of a new generation (DC YUG), which includes a microprocessor complex and a program complex of the train dispatcher's workplace with remote control from the PVM, functioning in conjunction with devices of the automated transportation management system (ATMS), as well as a top-level information system based on the "Portal of the transportation service", the Ural-VNIIZHT GUIDE, OSCAR and OSCAR-M, as well as query systems of ASOOP.

The automated DC YUG system allows you to:
- effectively organize the process of monitoring and managing train traffic at dispatching stations;
- opt out of manually maintaining a GUIDE (schedule of completed traffic);
- Automate data analysis;
- carry out "feeding from the wheel" of top-level information and control systems.

Significant assistance in organizing the work of train dispatchers is provided by the Ural-VNIIZHT GUIDE system, which allows you to get information about all trains and calculate the train position, get a forecast train model, and you can also indicate the cause and culprit in case of a train delay by setting a mark on the graph. For high-quality control of managerial decision-making at any level, the main requirement is the reliability of the initial information transmitted to the system from the points and devices of its origin. The reliability of information coming from the SCB devices is ensured by special diagnostic equipment. The greatest problems arise with information, the formation of which involves the direct participation of performers, when unprofessional actions or inattention lead to errors and distortion of primary data. The analysis shows that suboptimal actions of the dispatcher cause various losses in the transportation process. The source of statistical data on losses can be the results of analyzing the schedule of completed train traffic and decoding the speed-measuring tapes of train locomotives. In solving this problem, a detailed study of the content of the train dispatcher's work was performed, which made it possible to determine a set of operational tasks and create algorithms for solving them. Next, we investigated the suboptimal actions of dispatchers that lead to delays in movement that cannot be compensated for using various methods of dispatching control. Speed-measuring tapes determine the fact of a train delay and estimate its duration and cost. Analyzing the traffic schedule allows you to determine the cause of errors made by the dispatcher. Investigation of the cause of an error allows you to identify the problem that caused it, and according to its algorithm – the block of algorithm elements (operators)
responsible for this block. It is difficult to obtain sufficient statistics of dispatchers’ errors when they identify all management tasks by analyzing traffic schedules and deciphering speed-measuring tapes due to the large amount of time spent. Therefore, to assess losses in other operators, a methodology based on an expert survey of dispatchers was used. The result of mathematical processing of statistical and expert data on the consequences of dispatcher errors allows you to set only the duration of movement delays.

To determine the number of errors made by the dispatcher for any period of time, the probability of occurrence of $P_{on}$ is determined, to estimate the value of which the theory of interval estimation is used. Next, the mathematical expectation of the number of errors is determined when $j$-when executing the corresponding block of statements, the cost of their consequences is found.

The results of expert evaluations show that errors in the execution of most operators can lead to a significant number of consequences, differing in the amount of losses. For each such error, a ranked series of probabilities of possible consequences is obtained

$$P_j \geq P_{j+1}, j = \bar{j,n}$$ and estimated loss values $C_j$  \hspace{1cm} (1)

The limit values of the confidence intervals of these probabilities are determined by solving linear programming problems of the form:

$$P_j^- = \min P_j \cup P_j^+ = \max P_j$$

and under restrictions $P_j \geq P_{j+1}$,

$$\sum_{j=1}^{n+1} P_j = 1$$ \hspace{1cm} (2)

Using the cost of losses for each consequence, errors, we find the limit values of the confidence interval of total losses, taking into account their probabilities. In this case, two other linear programming problems are solved, which, after transformation, are reduced to the following form:

$$C_{k}^+ = \max (\sum_j C_j P_j - M P_{2n+1})$$ and

$$C_{k}^- = \max (\sum_j C_j P_j + M P_{2n+1})$$

under restrictions $P_1 + P_{n+1} = P_1^+$

$$\sum_j P_j + P_{2n} = 1 - P_n$$ \hspace{1cm} (6)

$$\sum_j P_j + P_{2n+1} = 1$$ \hspace{1cm} (7)

Initially, these linear programming problems were solved by the simplex method, which required a significant amount of time for a large number of problems to be solved.

Research on problem solving has shown that the same results can be obtained in a simpler way. To do this, they are ranked $C_j P_j$ by value $C_j$.

When found $\max \sum_j C_j P_j$, in descending order $C_{j1} \geq C_{j2} \geq \cdots \geq C_{jn}$, and when found $\min \sum_j C_j P_j$ in ascending order $C_{j1} \leq C_{j2} \leq \cdots \leq C_{jn}$.

Next, the residuals $(1 - P_{ji})$ are investigated, with the corresponding $C_{ji}$, $i = \bar{1,nc}$, to get the values $P_{ji}$ within which the condition $\sum_i P_{ji} = 1$ is met. Summing the results of products $C_{ji}$ for $P_{ji}$ and gives the solution of the problem. Analysis of the results of solving these linear programming problems allows us to formulate a proposal:

Let a linear programming problem be given:

$$\text{to find } C_{k}^+ = \max \sum_{j=1}^{n} C_j P_j, \quad C_j \geq 0$$

with restrictions $\frac{1}{n} \leq P_1 \leq 1; 0 \leq P_k \leq \frac{1}{k} \sum_{j=1}^{n} P_j = 1$. \hspace{1cm} (9)
Then the solution of this problem has the following form:

$$C^+_k = C_{j1}P_{j1} + \sum_{l=2}^{l} C_{jl}P_{jl}^*,$$  \hspace{1cm} (11)

where $P_{jl}$ is determined by the above order.

To determine the mathematical expectation of the cost of losses, the method adopted in network planning was used. At the same time, it was found that the density of the distribution of the cost of losses obeys the beta distribution, for which the mathematical expectation is equal to:

$$C_k = 0.6C_k^- + 0.4C_k^+.$$  \hspace{1cm} (12)

As a result of calculations for each such error and subsequent use of the mathematical apparatus of regression analysis, calculated formulas for the cost of losses for a year for single-track ($C_1$) and double-track sections ($C_2$) not equipped and equipped with a DC system. The presence of a formalized algorithmic record of control tasks allows performing a subsequent analysis of the dependence of the cost of reducing losses in case of suboptimal actions of the dispatcher on the improvement of its information support.

For this purpose, operators of algorithms for control tasks that are affected by the improvement of the dispatcher's information functions were established by research. The use of the proposed method makes it possible to determine the cost of losses in the selected operators of algorithms for non-optimal actions of the dispatcher. Next, the share of reduced losses in the dispatcher's work was determined when introducing a new information device ($\alpha_k$).

The final reduction in the average annual cost of losses when performing each of the selected operators in the context of improving the dispatcher's information support is represented by the following expression:

$$C_{cn} = \sum_{k=1}^{s} \alpha_k \Pi_k C_k N_k = \sum_{k=1}^{s} \alpha_k F_k,$$  \hspace{1cm} (13)

where $\Pi$ is the error rate in the K-th block of the problem algorithm;
$C_k$ is the cost of losses in case of an error in the K-th block of the problem algorithm;
$N_kF_k$ is the number of block implementations per year, taking into account factors that affect the frequency of its execution;
$s$ is the number of algorithm blocks affected by this device.

As a result of the conducted research, it was possible to obtain calculated expressions for the cost of reduced losses when transmitting the full amount of information to the dispatcher.

### 4 Calculation of the dispatcher unit load at the SKZHD training ground

Currently, the work and list of labor functions performed is significantly expanded due to the economic requirements of the freight transport market to increase the range of services provided to cargo owners, as well as internal regulations of Russian Railways aimed at improving the key performance indicators of the industry. So the train dispatcher is responsible for performing a number of important operational indicators, such as weight, train length, and section speed. Parallel to the production tasks performed, an economic analysis of the work is automatically performed DNC based on established parameters and key performance indicators. Additional requirements include responsibility for compliance
with commercial schedule threads, accelerated container trains, and other commercial services performed on the railway infrastructure.

The increase in the set of tasks solved by the dispatcher unit is not fully reflected in the calculations of the DNC load performed using classical regulatory methods. It does not take into account the existing unevenness of transport work during shifts, days, holidays when additional trains are introduced, and the time of year.

Taking into account the existing train traffic directions, time standards for operations, the availability of stations located on the dispatch centralization (DC), an analysis of the load of train dispatchers of the SCR was carried out.

The load factor of a train dispatcher is determined by the formula

\[
K_z = \frac{T_{sec}}{1440 - 2T_{br}},
\]

(14)

where \(T_{sec}\) – DNC costs for all types of work performed in the process of traffic control on the dispatcher section per day, min.;

1440 – duration of the day, min;

\(T_{br}\) – breaks related to physiological needs, including time for personal needs, a break for food, rest and additional rest when working with a computer, min.

**Fig. 2.** Requirements for DNC operation in modern conditions.

The labor costs of the DNC for each train section for all types of work performed in the process of traffic management per day are determined by the formula

\[
T_{sec} = \sum_{i=1}^{k}(T_{op.st} + T_{op.tr} + T_{r-c} + T_{rep}) + T_t, \text{ min.}
\]

(15)

\(T_{op.st}\) — elements of time spent by the dispatcher on operations to control train traffic at railway stations per day, min;

\(T_{op.tr}\) — elements of time spent by the dispatcher on operations to control train traffic in one direction of train traffic in the dispatcher’s section per day, min;
\( T_{n-c} \) — elements of the required time for managing operations performed at stations in one direction of the dispatching section per day, min;

\( T_{rep} \) — time spent on operations related to the organization of repair work in one direction of the dispatch area per day, min;

\( T_{e} \) — time spent on operations for receiving and handing over duty, transport work planning periods, min;

\( k \) — the number of directions of train traffic on the section.

Loading of the SCR dispatcher unit (train dispatchers) is shown in Table 1.

Table 1. Results of calculations of loading of train dispatchers.

<table>
<thead>
<tr>
<th>Name of the dispatch area</th>
<th>Train dispatcher's expenses</th>
<th>( K_z ) dispatcher section downloads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 «K-1» dispatching station</td>
<td>1098.68</td>
<td>0.90</td>
</tr>
<tr>
<td>2 Dispatch area «K-KAV»</td>
<td>807.92</td>
<td>0.66</td>
</tr>
<tr>
<td>3 Dispatch area «K-O»</td>
<td>678.52</td>
<td>0.56</td>
</tr>
<tr>
<td>4 Dispatch area «A-B»</td>
<td>894.92</td>
<td>0.73</td>
</tr>
<tr>
<td>5 Control station «B-T»</td>
<td>1247.61</td>
<td>1.02</td>
</tr>
<tr>
<td>6 «T-A» dispatch area</td>
<td>1002.61</td>
<td>0.82</td>
</tr>
<tr>
<td>Krasnodar Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Dispatch section «F-RZD 9 KM»</td>
<td>877.11</td>
<td>0.72</td>
</tr>
<tr>
<td>2 «KRASN-K» control station</td>
<td>1143.20</td>
<td>0.94</td>
</tr>
<tr>
<td>3 Dispatching station «KRASN. NOT»</td>
<td>1233.55</td>
<td>1.01</td>
</tr>
<tr>
<td>4 Control station «KRYMS-NOV»</td>
<td>837.78</td>
<td>0.69</td>
</tr>
<tr>
<td>5 «TIH-KRASN» control station</td>
<td>938.67</td>
<td>0.77</td>
</tr>
<tr>
<td>6 Dispatch section «RZD 9 KM-KAV»</td>
<td>779.78</td>
<td>0.64</td>
</tr>
<tr>
<td>7 Dispatching station «B-S-TIM»</td>
<td>970.50</td>
<td>0.80</td>
</tr>
<tr>
<td>Likhovskaya Street</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 «ZVO-NOVOCH» control station</td>
<td>985.96</td>
<td>0.81</td>
</tr>
<tr>
<td>9 Dispatching station «LIKH. KNOT»</td>
<td>1279.05</td>
<td>1.05</td>
</tr>
<tr>
<td>10 «LIKH-MON» dispatch station</td>
<td>646.97</td>
<td>0.53</td>
</tr>
<tr>
<td>11 Dispatch area «SOHR-LIKH»</td>
<td>1389.37</td>
<td>1.14</td>
</tr>
<tr>
<td>Mineralovodsky</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 «G-MAX-SAM» control station</td>
<td>766.70</td>
<td>0.63</td>
</tr>
<tr>
<td>13 «GROZ-KIZL-OL control station»</td>
<td>821.10</td>
<td>0.67</td>
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<td>14 Control station «PROKHIL-VL»</td>
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<tr>
<td>15 «KAVK-SV» control station »</td>
<td>604.68</td>
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<td>16 Dispatching station «MVODY-PR-Ch»</td>
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<td>0.66</td>
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<tr>
<td>17 Dispatch area «OV-MVODY»</td>
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<td>0.76</td>
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<td>Rostov region</td>
<td></td>
<td></td>
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<tr>
<td>19 Dispatching station «USP-BAT»</td>
<td>568.19</td>
<td>0.47</td>
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<tr>
<td>20 ROSTEC dispatch area</td>
<td>974.99</td>
<td>0.80</td>
</tr>
<tr>
<td>21 Dispatching station «S-T»</td>
<td>975.65</td>
<td>0.80</td>
</tr>
<tr>
<td>22 Dispatching station «S-KOT»</td>
<td>979.50</td>
<td>0.80</td>
</tr>
<tr>
<td>23 «BAT. UZ» dispatch area</td>
<td>876.79</td>
<td>0.72</td>
</tr>
<tr>
<td>24 Dispatching station «ROST. KNOT»</td>
<td>1003.08</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Analysis of the load of the SCR dispatcher unit showed that there are sections where the load factor is \( K_{zagr} \geq 1 \). So, for example, the direction Sokhranovka-Likhaya-Rostov is the main passenger train service - "Center-South of Russia". In the summer schedule in 2020, more than 70 pairs of passenger trains were laid down in this direction, and the passage of such a large number of passenger trains causes significant difficulties in the organization of freight traffic.

For dispatching sections where, according to the calculations performed, there is an excess of the recommended load factor value, it is necessary to form corrective measures to reduce the overall operator load up to revising the length of dispatching sections or introducing an additional dispatcher in the dispatching section (circle). Ongoing research confirms that, taking into account the current trend, increasing the size of traffic on a number of sections in the coming years requires a...
comprehensive review of dispatching management issues in heavy-duty areas with high traffic intensity.

5 Conclusion

In modern research on the organization of work of train dispatchers, along with the development of various methods for assessing the intensity of their work, it is increasingly important to combine previously proposed developments and analysis methods. The methods created in the modern computer environment that fully implement the issues under consideration, with the active use of computational, graphic and animation capabilities, make it possible to create a variety of dispatching control hardware, but within the limits of technological limitations.

The focus of such studies on the practice of the transportation process is expressed in the fact that when creating models for analyzing the work of the dispatcher link in various forms and degrees, the influence of different subjects of the management process is taken into account.

In this paper, we propose a methodology for studying the process of dispatching control at a railway landfill, which is based on algorithmization of the control actions of a train dispatcher, as well as an assessment of his suboptimal actions in the technological aspect. The results obtained make it possible to assess and then adjust the map of dispatching sections in the current operational situation at railway landfills, taking into account the load of the dispatcher unit, and to find more optimal options for organizing train traffic within the framework of the road traffic control center.

References


