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Maintenance of Low-Intensity Railways in Modern Conditions

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ABSTRACT

The article is devoted to clarification of the structure of maintenance of low-intensity railways by optimising infrastructure maintenance operational personnel using the example of Mikunsky infrastructure section of the Northern Infrastructure Directorate of Russian Railways. As an example of the distance for operation of infrastructure, the article considers Berlin section of infrastructure of German railways. The task of organising the activities of the infrastructure linear enterprise of the track complex, including track section workers (PC), signalling, centralisation and blocking (SCB) maintenance section personnel working within enlarged teams and emergency repairs teams equipped with service trains and KamAZ vehicles, is considered. For the analysis of information uncertainty, an information model is proposed, for which the risk is considered in the form of determining losses. At the stage of preliminary calculations, a change in the number of maintenance personnel will make it possible to obtain a reduction in operating costs.

Keywords: *railway, low-intensity railway lines (LRL), enlarged section, maintenance, infrastructure linear enterprises, track complex, PC workers, SCB and communication personnel, enlarged brigade, track repairs, emergency work team, information uncertainty, the price of risk.*

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Background.

Reducing costs for the main types of activities, primarily low-intensity railway lines (hereinafter referred to as LRL), is possible by changing the organizational structure of linear enterprises of maintenance of the railway track and all interconnected infrastructure. As a further improvement, JSC Russian Railways considers creation of infrastructure linear enterprises (hereinafter referred to as IL), combining the activities of track maintenance workers (hereinafter referred to as TM workers), personnel for maintenance of signaling devices, centralized blocking (hereinafter referred to as SCB and communication personnel) and power engineering specialists (hereinafter referred to as PE specialists) [1].

The existing domestic and foreign experience of current maintenance of railway lines by infrastructural linear enterprises (IL) points out the difference in the sections by the nature of transportation. Similar differences are noted in foreign practices [2–4].

The analysis of foreign experience of operating low-intensity railway lines established the following characteristics of such lines [5–8]:

• the presence of one, or, as an exception, two main tracks on the hauls;

• sidings with no more than three tracks are operated as run-off points;

• at most of the run-off points, there is practically no cargo and shunting operations.

An example of the section for operation of infrastructure is Berlin section of the DB infrastructure [9], which maintains 100 km of the extended length of the ballastless railway track, on which high-speed passenger traffic is carried out. The service personnel of the section comprises 250 employees of SCB and communication, 100 specialists of track facilities and 100 specialists in power engineering.

The section personnel should supervise the track, artificial structures, turnouts and elimination of minor malfunctions arising during operation.

For such track sections, faults detected by diagnostic tools should be repaired within six weeks. In case of a break in rails, they are reinforced with brackets with a clamp, and speed is limited to 120 km/h. The next day, the defective point is cut out by the workers of the infrastructure section, and a cut rail section is installed. As a temporary measure, the contractor may perform aluminothermic welding of the rail section at ambient temperature and humidity that meet specifications. In the future, for continuous operation of the track, in the process of performing scheduled preventive work, this rail cut section is replaced with a rail insert welded in by an electric resistance method.

All works on the track to replace the elements of the track superstructure are carried out in Russia by contractors that won the tender for the work [10].

One of the main problems on the railway network of JSC Russian Railways when using the sectional method of current track maintenance is untimely delivery of labour, machinery and equipment to the work site and their return to the base of deployment. A similar problem is noted by foreign researchers [2; 5 9].

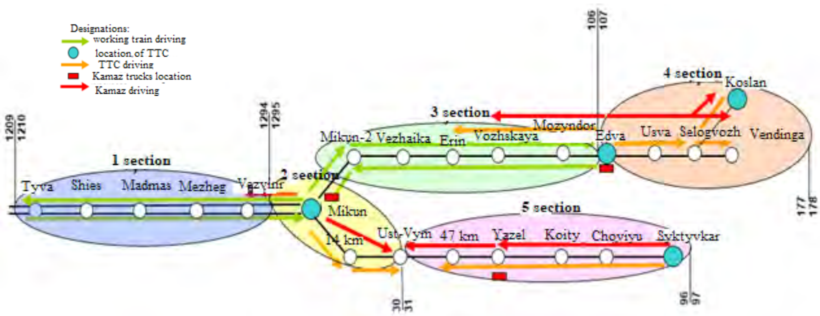
Based on the positive international experience in maintenance of railway lines by infrastructural linear enterprises, the management of JSC Russian Railways has been considering over the past 8–10 years a possibility of using structural units similar to Germany and other countries within JSC Russian Railways [11–14].

The first experimental IL was formed in 2014 on the basis of Sochi track section of the North Caucasus Directorate of Infrastructure. This IL brought together TM workers, signalling and communication personnel, and specialists in power engineering who were normally located in one and the same settlement. Sochi IL had shown positive operational results. At present, Sochi IL includes TM workers and personnel of SCB and communication.

Based on the positive experience gained at Sochi IL, the management of JSC Russian Railways is solving the problem of organizing similar structural divisions in the territories of all the 16 regional Infrastructure Directorates – branches of JSC Russian Railways (hereinafter referred to as ID).

In 2016, Mikunsky infrastructure section (hereinafter Mikunsky IL) was organized within the operation area of the Northern ID.

A distinctive feature of Mikunsky IL is the inclusion of TM workers and SCB and communication personnel, except for specialists in power engineering, into IL staff. First, such a combination is caused by the features of Mikunsky IL, which is designed to service low-intensity public railway lines with low traffic density and low operational efficiency, typical for this network segment of the Northern Infrastructure Directorate.



Pic. 1. Scheme of delivery of labor, mechanisms and tools for Mikunsky infrastructure linear enterprise.

Another feature of maintenance of this test site of Mikunsky IL is the use of diesel traction, and that also influenced the decision not to include specialists in power engineering into this IL's staff.

The formed Mikunsky IL has five operational sections (Pic. 1).

The organization of five sites on Mikunsky IL is due to convenience of organizing delivery of workforce, mechanisms, and tools.

The total number of the staff of Mikunsky IL is about 280 people, and of the total number of full-time workers of Mikunsky IL, workers make up 63 % (75,5 % of them belong to TM unit), and the personnel of SCB and communication represents 24,5 %.

The number of IL employees is explained by the significant range of the railway service area (Pic. 1). For example, a single-track line in the direction of Vendinga station has a length of more than 176 km, a single-track line in the direction of Syktyvkar station is more than 95 km long, and the length of double-track lines in the direction of Tyva station is more than 99 km.

A feature of organizing delivery of employees to the first, second and third operational sections of the track (Pic. 1) is the use of a work train that delivers teams of 62, 13 and 20 workers, respectively, to the place of work and back to the locations.

To optimise transportation time and reduce delivery costs, there are locations for KamAZ trucks at remote areas of the network area (second, fourth and fifth sections) (Pic. 1).

This type of vehicle is used in the operational areas for transportation of 24 workers from the station Mikun; of 27 people from Edva station, and of 10 people from Yazel station. For convenience of transportation of mechanisms, equipment, materials of the track superstructure, and so on, transport track carts (TTC-4) are used.

The proposed version of the number of IL personnel makes it possible to reduce the maintenance personnel, for example, at LRL network section with a total length of about 1217 km, approximately by 18÷20 people.

Materials and methods

For the analysis of information uncertainty (Piuc): for example, late delivery of employees, delays in delivery of mechanisms or materials, and so on – an information model is proposed, for which risk is considered as the possibility of determining losses (P), for example, expressed in delivery time or uncertainty of the start time (the end) of operations at the network site (L), arising because of making different control decisions under the conditions of uncertainty [15].

In addition, when assessing risk, it is recommended to consider individual risk tolerance (J), which is described by indifference or utility curves. Thus, the following three parameters can be used to describe the risk, formula (1):

$$Piuc = \{P; L; J\}. \qquad (1)$$

When conducting a comparative analysis of all the above-mentioned risk criteria, the advantages and disadvantages of their practical application were revealed. On the basis of the analysis, a generalized criterion is proposed which is the «cost of risk» (Crisk), characterising the amount of conditional losses that are possible during implementation of a management decision, and that are determined in accordance with [16]:

$$Crisk = \{Z; P\}, \qquad (2)$$

where Z is defined as the sum of direct losses from management decisions.

Results

To determine the cost of risk, such indicators are used that consider both coordinates of the «vector»: variance, standard deviation, coefficient of variation, and so on. An updated definition of the risk of the project under study (*IP*) is proposed.

IP risk (R_{IP}) is a system of factors that manifests itself in the form of a complex of risks that are individual for each *IP* participant both in quantitative and qualitative terms, formulas (3):

$$R_{IP}=\begin{bmatrix} R_{11},R_{12},R_{13},R_{14},\dots,R_{1n} \\ R_{21},R_{22},R_{23},R_{24},\dots,R_{2n} \\ \dots\dots\dots\dots\dots\dots\dots \\ R_{m1},R_{m2},R_{m3},R_{m4},\dots R_{mn} \end{bmatrix}, \quad (3)$$

where *n* – possible number of *IP* risks;

m – number of participants in the production process.

The emphasis in identifying risks is that *IP* risk is a complex system with numerous interrelationships that appear for each of *IP* participants in the form of an individual combination – a complex, that is, the risk of the *i*-th participant in the production process (R_i) will be described in the form of the formula (4):

$$R_i=\{R_{i1}, R_{i2}, R_{i3}; R_{i4}, \dots, R_{in}\}. \quad (4)$$

At the same time, the column of the matrix (3) shows that the value of any risk for each participant in the production process also manifests itself individually.

This approach serves as the basis for the risk management algorithm. It allows us to look at development of *IP* quantitative analysis tools. To solve the problems of this stage, an adequate, improved toolkit has been developed.

In particular, a toolkit for portfolio analysis of the production process has been developed, where it is proposed to use portfolio theory to solve investment design problems to predict efficiency of organization of production processes, which should include organization of IL activities.

For example, it can deal with calculating the discount rate when defining *IP* performance criteria. To calculate the discount rate, we use a model that is a synthesis of a model (CAPM – *Capital Asset Pricing Model*) and a cumulative approach:

$$r=r_c+b\,(r_n-r_c), \quad (5)$$

where r_c – risk-free rate of return;

r_n – market rate;

b – risk coefficient, determined by the formula (6).

The advantage of the proposed method is that it combines the advantages of both models. A feature of the method is calculation of the risk coefficient *b*:

$$b=Cov(F_1, r): Var(r)\cdot b_1+Cov(F_2, r): Var(r)\cdot b_2+\dots + Cov(F_n, r): Var(r)\cdot b_n. \quad (6)$$

In addition, for a comprehensive assessment of innovative projects in railway transport [17], the need to take into account spatial relations was identified, which, in turn, requires the use of geoinformatics and digitalization methods [18; 19].

Discussion

At the stage of preliminary calculations (formula 7), a change in the number of maintenance personnel will allow for a reduction in operating costs.

Tentatively, on the scale of JSC Russian Railways network at LRL network, the salary fund savings can be obtained in the amount of about 180 ÷ 200 million rubles per year.

Saving the wage fund for Mikunsky IL will be about 1,2÷1,8 million rubles per year (formula 7):

$$E_{LRL}=H_{NORM}\cdot L_{SEC}\cdot Z_{YEAR}\cdot K_{CURR}, \text{ rub.}, \quad (7)$$

where E_{LRL} – economic efficiency of measures to optimize the costs and expenses of low-intensity sections of railway lines, rubles;

H_{NORM} – normalized number of track fitters needed for current maintenance of the first km of LRL track, determined in accordance with the «Standards for the number of workers employed in the current maintenance of the railway track», approved by the order of JSC Russian Railways No. 2667r dated December 26, 2016 and «Operational rates of material consumption for the current maintenance of the railway track», approved by the order of JSC Russian Railways dated April 15, 2015 No. 978r, person/km;

L_{SEC} – length of the track section under consideration, km;

Z_{YEAR} – average annual salary of a track fitter, rubles;

$K_{CURR}=\left(1\pm\sum_{i=1}^{n}\delta_{\text{COND}}\right)$ – coefficient reflecting the current level of the technical condition of this LRL section, modern features of its operation, modern organizational features of maintenance of the track and infrastructure and other features of operation of this section of LRL;

$\sum_{i=1}^{n}\delta_{\text{COND}}$ – percentage (unit fraction) of reduction (increase) in the number of maintenance personnel to perform maintenance of the track and infrastructure and other factors of operation of this LRL section;

i = 1, …, n – a list of various features of operation of LRL section, affecting the number of its maintenance personnel to perform maintenance of the track and infrastructure.

Conclusions. Organizational features of the infrastructure linear enterprises of the track division considered at the preliminary stage on the example of Mikunsky IL, allow us to conclude that similar structural units are expedient for optimizing management in the activities of linear enterprises of JSC Russian Railways.

In the future, it is necessary to carry out a technical and economic assessment of their activities in order to clarify the optimal boundaries of the service area for similar units, as well as to determine the number of production personnel and their personification for maintenance of the infrastructure of the railway track complex.

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