Research of the Range of Location of Bases Track Machine Stations

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Abstract. The paper investigates the issues of rational placement of the main structural divisions of the repair complex of the track facilities of JSC «Russian Railways» - the production bases of track machine stations. An analysis of the current situation and the required development of production capacities and technical support of bases for the implementation of the program of track repairs along the railway network is presented.

1. Introduction

Track facilities is a multifunctional complex, the main task of which is to carry out all types of repair and maintenance of tracks and structures in order to ensure stable and safe operation of railways. The main structural subdivision of the track facilities repair complex are track machine stations (TMS). In the practice of design and construction of railways, there is the concept of "railway landfill", which is associated with the administrative division of the country.

At the same time, there are already known cases of the location of the bases of the track facilities on the border of the administrative zones. This creates certain difficulties in serving "foreign territory". In [1], the term "base service area" is proposed, abstracted from the administrative boundaries. It drew fair criticism - the concept of "area" traditionally has a biological and geographical character. In this paper, we propose the term "service ground for a link assembly (link disassembly, link repair) base" - this is a section of the railway network where overhaul, construction of new and dismantling of old tracks is provided by one production base (or several, different functionally, but interconnected production links).

Each production base of the TMS provides overhaul and reconstruction of the track on a certain section of the railway network - the service area. [2-7]. The issues of optimal placement and production capacity of the TMS bases are of particular relevance - the efficiency of the subsequent operation of the base depends on their solution.

Initially, the problem of optimal placement of the link-assembly production base was reduced to the transport and economic problem of determining the optimal distance of the links transportation [1,8-10].

This method does not correspond to the modern realities of the track economy for the following reasons: most of the main lines have been converted to a reinforced concrete base; the quality of links with reinforced concrete sleepers does not depend on the distance of the carriage; a number of changes have been made to the design of platforms for the transportation of links, which made the issue of quality loss during transportation of links with wooden sleepers irrelevant; practically nothing interferes with the redevelopment of the chain of link-assembly bases; currently, the process of intensification of
overhaul and reconstruction of the track is beginning, therefore, an increase in the production capacity of the network of bases.

The study of the polygon of the location of the bases of the track machine stations involves the choice of the objective function and the criterion for rationalizing the location and capacity of the production bases of the track machine stations. It became necessary to search for a new criterion and a new objective optimization function [7, 11-15].

The general optimization problem is decomposed into two - direct and inverse. The direct optimization problem is to determine the optimal distribution of the production bases of the TMS along the road network at a fixed productivity, which is taken as the productivity of the link-assembly technological lines that were mass-produced at the end of the last century.

In general, the actual production of the set "production base - track-laying train (PB-TT)" for the estimated time $T_{\Sigma}$, km,

$$Q_{T\Sigma} = \frac{T_p}{T_{p+T_{\Sigma}}(1-K_i)+\{(1-K_{tg})\}} \cdot Q_p,$$

where $Q_p$ is the estimated (without taking into account downtime) the production of the set for the time $T_{\Sigma}$, km; $T_p$ - time of clean work during $T_{\Sigma}$ (month, season); $K_i$ - the utilization rate of the set (characterizes the time of organizational downtime $T_{org}$) $K_i = 1 - \frac{T_{org}}{T_{\Sigma}}$; $K_{tg}$ - coefficient of technical availability (characterizes the downtime for technical reasons $T_{tech}$) $K_{tg} = 1 - \frac{T_{tech}}{T_{\Sigma}}$.

It is quite logical to propose as a criterion for the optimal limiting length of the arm of the paths of the service polygon of the production base $L_{po}$, km, but it is inconvenient in that it requires a large number of computations in the optimization process. It is advisable to separate from this criterion its variable part by options. Then the criterion for the optimal limiting leg length of the paths of the service polygon of the production base is the utilization rate of the PB-TT set

$$(K_{j})_{PB+TT} = (K_{j})_{PB-TT} + (K_{j})_{TT-PB} - (K_{j})_{PB-TT}(K_{j})_{TT-PB},$$

where $(K_{j})_j$ is the utilization factor characterizing the organizational downtime in the $j$ channel of technological interactions: $j = PB \rightarrow TT$ - downtime of the production base due to the fullness of the output warehouses; $j = TT \rightarrow PB$ - downtime of the track-laying train due to empty output warehouses of the production base. This criterion is easier to calculate than $Q_{T\Sigma}$. Optimization objective function - criterion maximization

$$Opt(L_{po}) = (K_{j})_{PB+TT} \rightarrow max,$$

and the optimum

$$\left(L_{po}\right)_{Opt} = max ((K_{j})_{PB+TT}).$$

The inverse problem is to adjust the optimal capacity of the production base with a limited transport capacity of the track-laying train and a fixed service area (based on the results of solving the previous problem). In general, the optimal base output, km,

$$Opt \left( Q_{T\Sigma} \right) = \min \left( (Q_{T\Sigma})_{plan}; (Q_{T\Sigma})_{TT} \right),$$

where $T_{\Sigma}$ is most convenient to take equal to the planned period, i.e., the season of track works; $(Q_{T\Sigma})_{plan}$ - production task for the season of the higher management level, km; $(Q_{T\Sigma})_{TT}$ - seasonal carrying capacity of the track-laying train, km. In the optimization problem, the second term of the set, km, is taken as a controllable factor, km,
where \( L_u \) average over the service range, the distance of transportation of links, km; \( \nu_{tp} \) average transport speed, km/h; \( q_{TT} \) is the season average load of the track-laying train, km of the track grid; \( q_{TT} = \frac{q_{TS}}{n_{mo}}; n_{mo} \) - number of technological windows per season; \( t_{to} \) - average time of the technological window, hours, \( t_{to} = \frac{q_{TT}}{P_{TT}} \); \( P_{TT} \) - productivity during the laying/dismantling of the track on the stretch, km/h; \( (K_r)_{TT} \) - coefficient of technical readiness TT; \( (K_i)_{TT\rightarrow PB} \) - the utilization factor characterizing the organizational downtime of TT in anticipation of the technological window. All members of the right side remain unchanged in comparison options, with the exception of \( (K_i)_{TT\rightarrow PB} \), which characterizes the organizational downtime of the track-laying train due to empty output warehouses of the production base. It is the criterion for the optimum production capacity of the base. Then the objective optimization function is the maximization of the criterion

\[
Opt(TT) = (K_i)_{TT\rightarrow PB} \rightarrow \max.,
\]

and the optimum

\[
(Q_{TT})_{opt} = \max ((K_i)_{TT\rightarrow PB}).
\]  

Taking into account the research method, the problem is related to the field of queuing systems (QS). In [5], the experience of solving QS problems by the analytical method - using systems of differential equations is generalized. With a certain convenience of this method - the solution is obtained "at the tip of the pen", it has certain disadvantages: input and output streams must be described by classical Poisson distributions; constraints on the length of "service chains"; structural constraints.

In work [1], a method for solving the QS problems in the field of technological support of track facilities by simulation modeling of predicted situations is presented and substantiated. This method requires powerful computer support (hundreds of thousands of calculations), but it is free from the disadvantages of the previous one - it can be used to simulate any situation from the field of QS. In this work, this research method is used as the main one [16-21].

2. Results and discussion

The main provisions of the simulation of objects and processes of link-assembly-disassembly-repair equipment.

Link assembly, disassembly and repair technological complexes and lines, due to their high cost and long terms of design, manufacture, installation and commissioning, belong to technical objects for which a full-scale experiment, as a method of identifying the relationship of active and passive factors during design, verification of theoretical provisions and adopted design solutions, is economically ineffective. According to the criterion of minimizing costs, %/rub,

\[
E_i = \frac{C_i}{e_i}.
\]

\[
Opt(E_i) = | C_i \rightarrow \max; e_i \rightarrow \max |,
\]

where \( C_i \) is the reliability of the \( i \) method, %

\[
C_i = 100\% - [\Delta]_i.
\]

where \( [\Delta]_i \) - error of the \( i \) method, %; \( e_i \) - costs for the activities of the method, rubles. The most effective method is modeling, the reliability of the results of which meets the condition

\[
C_i \geq [C],
\]
where \([c]\) - the reliability allowed in the current design situation.

Geometrical parameters (size, surface roughness) of objects of technological impacts of link-assembly-disassembly-repair equipment - rails, sleepers, fastening elements - have a pronounced stochastic character. The interaction of these objects with each other, working organs and fields (vibrational, magnetic, gravitational) in technological processes is characterized by a large number of random factors with complex correlation interdependencies. Therefore, the most reliable method for modeling the interactions of objects in space in technological processes is imitation modeling.

The temporal characteristics of the interactions of the designed technological objects with counterparts have a clearly pronounced stochastic character. These interactions of objects are characterized by a large number of random factors with complex correlation interdependencies. Therefore, the most reliable method for modeling the technological processes of link-assembly-disassembly-repair equipment in time is imitation modeling.

The characteristics that fully and unambiguously represent a set of random parameters or a sequence of random events in a simulation model of an object or process are: the type of distribution specified by the probability density function, mathematical expectation, variance, a set of correlation coefficients with interrelated random variables (events).

A simulation model of a random value of a modeled parameter of a real object is a generated random number with the same statistical characteristics (statistical coefficient of similarity between the real and the model parameter \(k_{st} = 1\)).

A simulation model of a random event of a modeled process is a generated random event with the same statistical characteristics.

The causal relationships of the modeled object (process) between random values of individual parameters or random events and the results of the modeled technological process are presented in the simulation model by a computational algorithm that connects the sub-blocks of generating models of parameters (events) with the output model of results.

Statistical reliability is not possessed by a single simulated random value of a parameter or event, but by a set of similar parameters (events), the volume of which \(Q\) corresponds to the confidence volume of the sample \([Q]_{(\rho)}\) at a given confidence probability \([\rho]\) according to the Pirkos criterion

\[
Q_B \geq [Q]_{(\rho)} .
\]

Confidence probability

\[
(\rho) = 1 - \Delta_{ap} ,
\]

where \(\Delta_{ap}\) - permissible error of approximation to the optimal solution adopted for the current design step. A simulation model of an object or process of a link-assembly-disassembly-repair technique is a series of model experiments under constant conditions with the number of experiments corresponding to condition (13). Simulation results are not deterministic values, but statistical sequence analysis results.

The simulation model of interaction in the space of objects participating in the assembly-disassembly-repair technological process under certain characteristics of external conditions and internal properties of the simulated objects is a series of simulation model experiments under constant volume conditions \(Q_B\), the results of which are summarized in the form of statistical characteristics of the simulated interaction.

A simulation model of the functioning in time of an object of a link-assembly-disassembly-repair equipment as part of a technological infrastructure under certain characteristics of external conditions and internal properties of a modeled object is a series of simulation model experiments under constant volume conditions \(Q_B\), the results of which are summarized in the form of statistical characteristics of the modeled process [19-21].
3. Conclusion
In the proposed work, based on the analysis of the prospective volumes of laying and removing the rail and sleepers during track repairs and the existing technical equipment of the TMS production bases, the issues of the required development of the production capacities of the TMS bases are considered and resolved based on the method of simulation of objects and processes. Simulation modeling is carried out taking into account the data on the number, service life and residual resource of link assembly, disassembly and repair equipment as part of the implementation of the track repair program on the railway network for the period 2017–2021.

Issues are resolved using the regional principle of the location of the TMS bases for the entire service area of the Russian railway network - without looking at the borders of the railways - with the aim of their rational placement, specialization and phased technical equipment.

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