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Application of Digitalisation in Staffing Planning for Railway Infrastructure Maintenance


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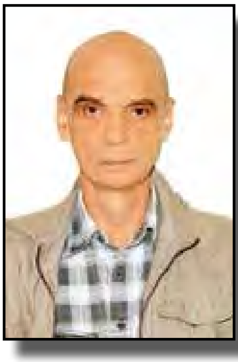
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ABSTRACT

Existing and suggested approaches to development of staffing plans regarding infrastructure maintenance are analysed from the point of view of ensuring interests of a railway infrastructure company, using example of JSC Russian Railways.

The existing methodology of planning workforce involved in maintenance of the railway infrastructure is based on the use of average values of parameters resulted from monitoring of the state of infrastructure structures, roadbed and track devices conducted monthly, as well as during autumn and spring continuous inspections and checks of the track. The received values of work to be performed only implicitly reflect the required number of workers, effective involvement in operation, and efficiency of each worker.

The modern trend towards digitalisation and cybernation of all processes, when organising maintenance of the track infrastructure, provides for maximum social adaptation of production processes to requests of owners, tasks of organisers and interests of performers. Staff planning based only on the volume of work to be performed does not allow digitalisation and social cybernation of an individual performer.

The syntagmatic component of such an algorithm is the monthly total worked time, which is determined by the actual engagement of each performer. The paradigmatic component of such models should be the same daily number of performers. The stage of preliminary assessment of application of the proposed algorithm for digitalisation and social cybernation of workforce planning supposed an increase in labour productivity, approximately by 20–25 %, an increase in quality of work and a more effective assessment of activities of each performer.

Keywords: railway, infrastructure monitoring, maintenance of railway infrastructure, digitalisation and cybernation of infrastructure maintenance, social adaptation of production processes, pattern, syntagmatic model.

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INTRODUCTION

The existing system of railway infrastructure maintenance is based on monitoring its condition and is carried out in the form of commission inspections, as well as by the use of assessment results by special technical diagnostic tools and equipment in accordance with the standards governing maintenance of tracks and infrastructure facilities[1] [1–5].

In JSC Russian Railways, the methodology of workforce planning regarding maintenance of the railway infrastructure is based on the use of average values of parameters of the infrastructure condition based on the results of monthly, as well as autumn and spring, continuous commission inspections and inspections of the track, infrastructure facilities, roadbed, and track devices[2].

The works performed by the teams of linear and operational sections for the coming month are planned by the road master together with foremen responsible for current maintenance of the track, roadbed and structures, considering the results of infrastructure monitoring. The developed schedules are approved by the head of the track division in the form of PU-74 schedule[3]. Development of the current PU-74 schedules considers the work performed during the previous month. When summarising the results of the work performed, the previous and completed current PU-74 schedules are considered.

Technical substantiated standards («TNK»[4] or «TNV»[5]), as well as other regulatory documents approved by the Central (CDI) or regional (DI) infrastructure directorates, branches of JSC Russian Railways, are the basic normative documents for calculating the standardised scope of work, the standardised number of employees and workers, the standardised duration of works.

The volumes of work obtained in this way can only implicitly reflect the number of workforce, involvement in operations, and efficiency of each employee.

MATERIALS AND METHODS

By the existing methodology[3], the planned tasks for performance of work are calculated according to the dependence (1):

$$N_{worked.hours} = \frac{V_{works} \times H_{TNK} \times K_t}{K_{measure}}, \quad (1)$$

where V_{works} is amount of work that is assumed based on the results of assessing the state of infrastructure elements by means of diagnostics (based on monitoring described above or on current control);

$N_{worked.\ hours}$ normalised time for work performance;

H_{TNK} is standard time to complete a unit of work (as stipulated in TNK or TNV);

K_t – coefficient of the temperature zone;

$K_{measure}$ – a unit of measurement for this work.

The production rate (N_{prod}) per work shift (8,2 hours) is determined by the formula (2):

$$N_{prod} = \frac{8,2}{N_{TNK} \times K_t} \times K_{measure}, \quad (2)$$

where N_{TNK} is time rate from TNK;

N_{prod} – production rate;

$K_{measure}$ – measurement units.

Time for travelling to the work site, for trains traffic and for the time used by signalmen to install necessary signs are determined according to actual data.

The volume of work performed in fact must coincide with the specified amount of work (for a working day, week, month).

The hours that were spent for work may be less than normalised time. Normalised hours must correspond to the work assignment.

The production rates per 1 hour and per 1 person are determined by dividing the measure rate established for this type of work by the time rate, and per shift – by multiplying the result by the duration of the shift.

At present, the trend in production activities and in transport towards digitalisation and cybernation of all processes [6], when organising maintenance of the track infrastructure, provides for maximum social adaptation of production processes to requests of owners, tasks of organisers and interests of performers.

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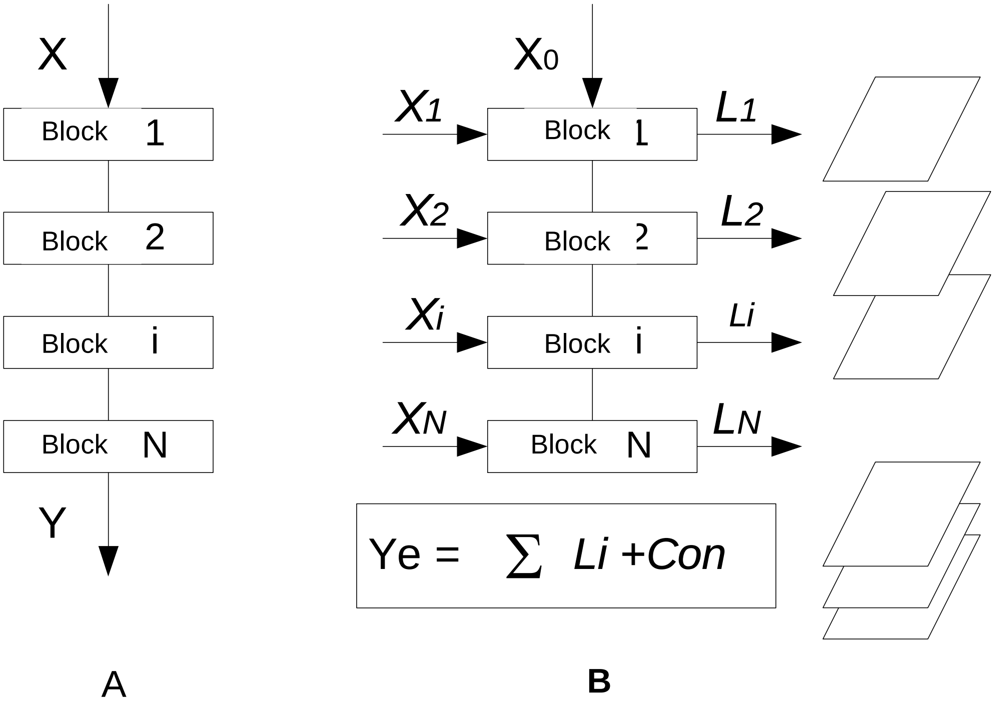
[1] Instructions on current maintenance of the railway track, approved by the order of JSC Russian Railways No. 2288r dated November 14, 2016.

[2] On comprehensive assessment of the state of the track (as amended by the order of JSC Russian Railways dated January 20, 2012, No. 72r.

[3] Journal of accounting of work on current maintenance and assessment of the state of the track and track devices (PU-74), approved by the order of JSC Russian Railways dated May 2, 2012, No. 857 r.

[4] Technical substantiated standards of time for work on current track maintenance (TNK). Department of tracks and structures of JSC Russian Railways. Moscow, 2009.

[5] Technical substantiated standards of time for work on current maintenance of the track (TNV) (as amended by the order of JSC Russian Railways dated 05.08.2015 No. 1976r) (7th edition, revised and supplemented) in 2 parts.



Pic. 1. Two types of decision-making models [9].

The existing practices of planning the production labour process of maintenance of the track infrastructure in terms of the volume of work performed does not allow digitalisation and social cybernation of an individual performer.

Social cybernetics is aimed at creating a theoretical basis for assessing and managing systems of cooperative distribution and accounting for activities of each performer [6]. It is based on identifying the share of participation of each performer in the overall production process while detailing the technology of working operations. The paradigm that social cybernetics uses in the analysis of any system is the basic law of social cybernetics. It says that all work teams go through six levels of social contracts for their subsystems:

- aggression ⇔ survival;
- bureaucracy ⇔ following the rules and regulations;
- competition ⇔ my gain – your loss;
- solution ⇔ disclosure of individual intentions;
- complementarity [7] ⇔ cooperation in common interests,
- freedom of choice (subsidiarity [8]) ⇔ the ability to manage own actions and self-control.

The transition through those six phases of relationships provides the basis for a social and cybernetic assessment of any evolutionary system, to which work teams can be attributed. Moreover, these phases manifest themselves in different ways in cybernetics systems of different orders.

The sequential decision-making model is the simplest cybernetic model. It is built according to the principle (3):

$$(A \wedge B) \rightarrow P, \quad (3)$$

In expression (3), *A* is an event that affects object *B*, which leads to result *P*. Expression (3) is a classical expression of succession, in which the symbol → is called implication. An expression in parentheses is called a premise or antecedent. *P* is called a consequence or apodosis. Sequential logical actions and events are well tested with logical expressions. They form a logical sequence in the form of a set of expressions (3), which set logical chains of decision-making. Sequential actions and models are well modelled using graphs. Pic. 1 gives two types of decision-making models [9].

The direct algorithm is a sequential chain of actions, which are shown in Pic. 1a. In the diagram in Pic. 1a, the output of the current stage serves as the input to the next stage. Such models are called sequences because the inputs/outputs of the stages are consistent in them. However, interrupting a stage interrupts the entire chain. In this model, there is a single general rationality of actions.

RESULTS

A model of the above-mentioned type can be used in development of an algorithm for scheduling the scope of work regarding maintenance of the track infrastructure to eliminate the identified malfunctions by means of diagnostics. When modelling such a process, there is no relationship to specific performers. The digitalisation and cybernation of such processes consists in recording a planned or completed event, as well as the absence of such an event, in the form of a planned or completed one, which should have been based on the results of diagnostics.

Currently, the initial materials for development of such sequential models can be compiled from monitoring data using EK ASUI (single Corporate Automated Infrastructure Management System); KAS ANT (complex automated system of accounting, control of elimination of failures in the operation of technical means and analysis of their reliability); KASAT (integrated automated system for accounting, investigation and analysis of cases of technological violations) systems, commission inspections (autumn, spring, monthly, etc.), data from track measuring and defectoscope control devices and other materials evaluating the state of the infrastructure. The peculiarity of development of such a model for planning the scope of work for maintenance of infrastructure is that if any work operation is not performed in the chain of the sequential model the result is not achieved.

Pic. 1b shows a serial-parallel model of decision-making. This model focuses on producing results at every level of the decision-making stage, but with independent inputs for each stage. Such a stratified model is a collection of particular models in a general decision-making model. We can talk about syntagmatic models along horizontals (levels) and paradigmatic [10; 11] vertical models. In such models, there is one common result and a set of individual approaches.

These models include the labour force planning algorithm. The syntagmatic component of such an algorithm is the monthly total worked time, which is determined by the actual worked time of each performer. The paradigmatic component of such models should be the same daily number of workers.

Despite the variety of models, there are general rules and principles by which models of social cybernetics are formed. When generating models, the following rules apply:

- The area of interest is fixed as an information situation (A_1), in which management is planned to be carried out:
- In the information situation, conditions (A_2) are fixed, determined by a set of parameters or constraints.
- For the problem areas, known heuristics (A_3) are fixed in the form of patterns [12] or rules by which calculations can be performed.
- If a suitable model based on heuristics is not found, a new model is formed based on analytical studies (A_4).
- For the decision to be made, the conditions (A_5) of its correctness and admissibility are fixed.
- Criteria for evaluating the effectiveness of the solution are selected (A_6).
- Technology is applied (B) and the result is obtained (P).

This technique has a logical form (4):

$$(A_1 \wedge A_2 \wedge (A_3 \oplus A_4) \wedge B \rightarrow (P \wedge A_5) \rightarrow A_6. \quad (4)$$

There are many computational models that can be classified as structural objects, for example, the conceptual model [13], which is a theoretical prerequisite for building a computational model.

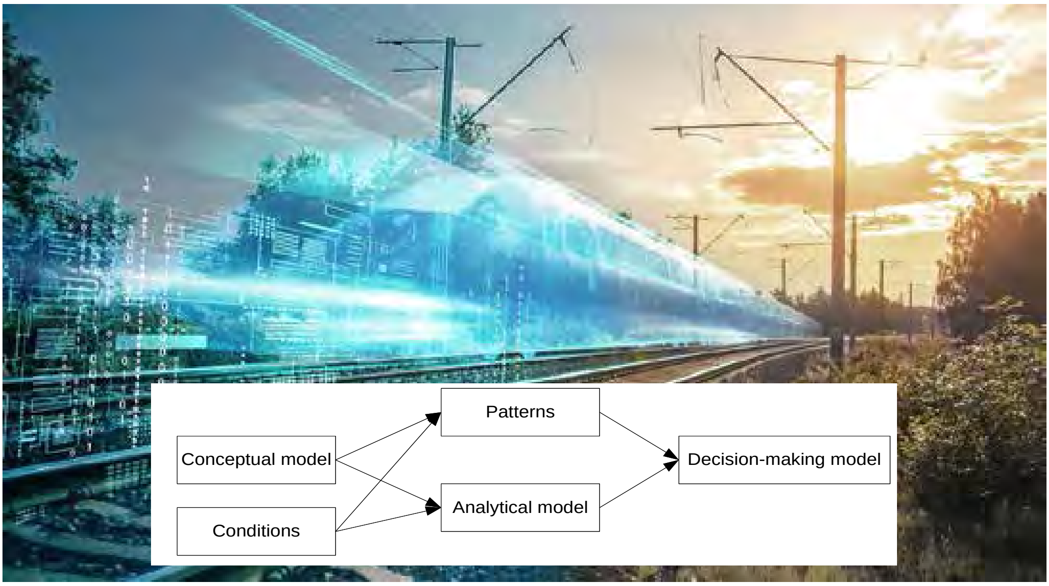
Pic. 2 is a diagram of construction of a decision-making model.

DISCUSSION OF THE RESULTS

As a strategic direction for digitalisation and social cybernation, planning of the workforce for maintenance of railway infrastructure is an addition to the existing methodology for setting planned targets for performance of work (dependence 1) by determining the number of performers to complete the task.

The basic regulation documents for calculating the standardised number of employees and the standardised duration of work are, for example, TNK[4] or TNV[5].

The algorithm for digitalisation and social cybernation of staff planning is that after establishment of planned targets for performance of work (dependence 1), the duration of work in working hours or working days is determined, as a quotient from dividing the planned volume of work by duration of the working day.



Pic. 2. Model building scheme [13].

Further, the planning process is carried out with the set number of workers, for example, according to TNK[4] or TNV[5].

When developing the «Schedule of execution of planned works» it is necessary to adhere to the following principle. At the beginning, the most labour-intensive work with the largest number of workers is distributed per working days. In case of incomplete workload of working days until the end of the month, the performers of this work are transferred to another job the next day (the «ladder» principle).

If the next work does not require involvement of all performers, those who performed the first job are transferred to the next jobs in parts. It should be borne in mind that the following works according to their technological features may require a certain stipulated number of workers, which is indicated in TNK[4] or TNV[5] for this work.

After completing formation of distribution of workers who have performed the first work for other works until the end of the month, it is possible to start distributing the remaining unallocated works. The distribution principle remains the same.

When forming list of workers intended for individually performed works, it is possible to attract several performers to speed up the performance. The situation of supplementing or reducing the number of teams, which are indicated in TNK[4] or TNV[5] for this work, is unacceptable.

To control the correct distribution of work and performers, it is recommended to keep records of performers regarding each working day.

When carrying out the operation of distributing working days for cases of incomplete working hours, several solutions may be considered [14; 15]. For example, redistribution of part-time working hours for travelling to the job location and back, for passage of trains and other losses of a production and technological nature. In this case, it is necessary to recalculate duration of working hours for the entire period of this work. This will lead to a decrease in duration of working days and a decrease in production, which must be considered when calculating the volume of work.

Another distribution option can be redistribution of excess time in the form of additional time to each working day as a factor in increasing labour productivity. This option is possible when the part-time job received by calculation is distributed within 30–40 % of the full working day.

After distribution of works and performers in accordance with the specified volumes and duration, a statement of the actual number of performers is drawn up.

The actual number of employees is one of the indicators that is used in the accounting system for the number of performers at a particular enterprise. In addition, such a calculation will help to analyse the work of the enterprise, identify shortcomings in the work of the team and provide opportunities for optimisation at a particular enterprise.

After drawing up a list of the actual number of performers, a list of the payroll of performers is drawn up.

The list number of performers of current maintenance of the track within the whole track division, which are based on materials of, for example TNK[4] or TNV[5], is determined by summing up the number of performers of each work, which is provided for by technology.

CONCLUSIONS

The research presented in the article is aimed at developing a mechanism for planning labour resources, their optimisation, rational distribution and control.

The algorithm for digitalisation and social cybernation of workforce planning allows keeping an operational record of each performer in accordance with the results of the work performed and occupation of performers according to the attendance number. Further development of the developed algorithm considers the process of automated operational accounting and control of staff planning, as well as of their performance in implementation of the assigned production tasks.

The stage of preliminary assessment of application of the proposed algorithm for digitalisation and social cybernation of staff planning supposes an increase in labour productivity, approximately by 20–25 %, an increase in quality of work and a more effective assessment of activities of each worker.

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