INCIDENTS ON THE RAILWAY: ASSESSMENT OF CONSEQUENCES ELIMINATION

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ABSTRACT

A method for determining the calculated time of traffic opening and minimization of time costs, which is based on determination of the duration of time intervals «windows» to perform railway track repairs (rebuilding infrastructure after an incident) under the terms of the lowest costs of track works, taking into account overheads and costs of delays and trains' downtime was developed.

Keywords: railway, accident, disaster, elimination of consequences, emergency recovery work, reduced costs, interval in the traffic schedule, safety, risk level.

Background. *As incidents on the railway transport are considered the following cases: wrecks, accidents, derailment, failures of technical means [1].*

Development of effective options for railway track repair (recovery after an incident) with provision of a certain level of reliability and safety must be based on justification of economic factors affecting the duration of time intervals, further called «windows» [2].

Objective. *The objective of the authors is to consider a new method for determining calculated time of traffic opening and minimization of time costs in terms of «windows» for track repairs after the accidents.*

Methods. *The authors use general scientific and engineering methods, graph construction, assessment method.*

Results. *Methods of assessing the liquidation of consequences of the accident is designed to determine the calculated time of traffic opening and minimization of reduced time costs of repair of track and infrastructure.*

In accordance with existing guidelines as reduced time costs when choosing the duration of the «window» are considered the amount of non-recurring time costs of repair of track and railway infrastructure and loss of time in transportation process [3].

Reduced time costs (R_{cost}, h) can be expressed by the dependence:

$$R_{cost} = T_{tr} + C_{CX} + \alpha_{pot} \cdot P_D, \qquad (1)$$

where T_{tr} is time costs of transportation of emergency trains from the disposition area to the scene, and their return to the connecting station, hours;

C_{TE} is nonrecurring time costs in the «window» for performance of repair work on the track and infrastructure when eliminating consequences of the accident, hours;

P_D is loss of time caused by the delay of trains (additional stops and lay-over), schedule changes and changes in the routes in the period of the «window», and after its completion, hours;

α_{pot} is an empirical parameter obtained as a result of approximation of the results of generalization of time losses from delays, downtime, changes in traffic routes etc. of trains during the «window» and after its completion showing their change with increasing the duration of the «window».

Time costs associated with delivery of trucks and emergency trains to the place of work and back (T_{tr}), are calculated according to the formula:

$$T_{tr} = \sum_{n=1}^{N} n_{loc} \cdot t_{loc}, \qquad (2)$$

where n_{loc} is a number of locomotives involved in serving work trains according to the project of organization of works, pcs;

n...N is a number of work trains involved in the technology of eliminating consequences of the accident;

t_{loc} is time of locomotive's use, hours:

$$t_{loc} = 2\left(\frac{l_1}{v_1} + \frac{l_2}{v_2} + t_{base} + t_{st}\right), \qquad (3)$$

where l_1 is average range of run from the base to the scene and back, km;

l_2 is the same and back from the base to the depot of locomotive registry, km;

v_1 is average speed of work trains at the section (approximately v_1 = 30–40), km/h;

v_2 is the same of single moving locomotive (v_2 = 40–50), km/h;

t_{base} is duration of shunting operations at the base and waiting for a route (about 0,5), hours;

t_{st} is time of maneuvers and waiting for a «window» at the station, adjacent to the site of work, hours.

Instruction of JSC Russian Railways [4, 6] on the provision and use of «windows» for repair and construction works recommends: «The necessary period of time to perform the planned scope of work with the closing of haul ($t_{ок}$) should be determined by limiting car»:

$$t_w = L_f / V_{lead}, \qquad (4)$$

where L_f is field of operations in the «window», km; V_{lead} is pace of performance of a leading operation in repair of track or technological performance of a leading car, km/h.

The technological performance means output per unit of time, taking into account technological projected loss of time (to pass trains on an adjacent track, for laying polystyrene plates, replacement of geotextile rolls, overloading of weeds, overwinding of packet units, and so on), which is independent of the duration of the «window».

Output in the «window» will be:

$$L_f = t_w \cdot V_{lead}, \text{ km}. \qquad (5)$$

Analysis of the practice of the organization of «windows» shows that the construction and repair works are carried out in accordance with the processes requiring a fixed duration of «windows» (linear m/ h, km / day).

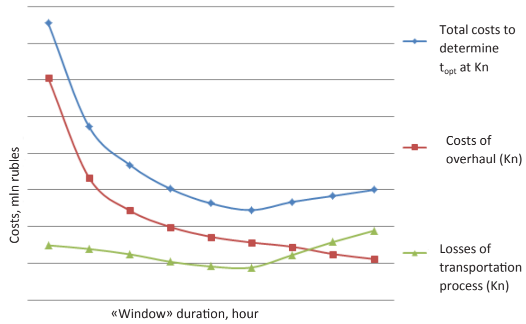
Time costs of track works and reconstruction of infrastructure (C_{ri}) in the elimination of consequences of the accident are determined either by using estimates of actual losses for the accident, or on the basis of costs of production technology, of corresponding typical production process, per unit of length, for example, 1 km:

$$C_{ri} = C_{cx} + C_i, \qquad (6)$$

where C_i is costs of recovery of infrastructure damaged in the accident.

Calculation of time spent on track works is carried out on the basis of costs of production technology, corresponding

Pic. 1. Determination of the optimal duration of the «window» when performing overhaul of the track using new materials (track recovery after an accident), taking into account the costs of related infrastructure departments.



typical production process per unit length (C_{te}, hours) and is determined by the dependence:

$$C_{te} = \frac{(T_{te} + \Delta T_b + \Delta T_{cut} + \Delta T_{plat} + \Delta T_{haul} + \Delta T_{swt} + \Delta T_{insjoint} + \Delta T_{checkp}) \cdot K_{at}}{L_{rcs}} + \rho_{fail} \cdot C_{FAIL}, \quad (7)$$

where T_{te} is average time costs to perform repair works to eliminate the consequences of the accident, similar to a corresponding set of technological operations of a typical technological process (or based on actual data of labor costs), hours;

L_{rcs} is reduced length of the calculated section, km;

K_{at} time cost adjustment coefficient (time cost adjustment coefficient on the operating conditions is determined by the relationship:

$$K_{at} = K_{rc} \times K_{bl} \times K_{‰} \times K_{Ci}, \quad (8)$$

where K_{rc} is coefficient of time (or labor costs) increase adjustment in carrying out repairs at the curved sections of the track;

K_{bl} is coefficient of time (or labor costs) adjustment depending on the distance of location of the parking base of emergency trains;

$K_{‰}$ is coefficient of time (or labor costs) adjustment depending on the slope of the longitudinal profile of the railway line);

ρ_{fail} is average probability of failure of technical means of track economy (average probability of risk) for the considered track section;

C_{FAIL} is statistically average time of failure of technical means of track economy for the considered track section, hours;

K_{Ci} is coefficient of time (or labor costs) adjustment on the congestion of the considered track section;

ΔT_b is additional time of works (or labor costs) within the high bank;

ΔT_{cut} is additional time of works (or labor costs) within the deep cut;

ΔT_{plat} is additional time of works (or labor costs) within the high or low platform;

ΔT_{haul} is additional time of works (or labor costs) within the haul;

ΔT_{swt} is additional time of works (or labor costs) for dismantling or laying of switch turnouts;

$\Delta C_{insjoint}$ is additional time of works (or labor costs) for dismantling of existing and arrangement of new insulated rail joint;

ΔT_{checkp} is additional time of works (or labor costs) for arrangement of new and dismantling of existing checkpoints on the haul within the repair section.

The cost of rebuilding infrastructure (C_i), damaged during the incident during additional works, such as reconstruction of contact network (C_{connet}), signaling and communications equipment (C_{sig}) and other related work, are provided by individual technological processes for production of repair and construction works.

$$C_i = C_{connet} + C_{sig}. \quad (9)$$

According to financial documents the costs are planned for restoring the damaged cars and locomotives, insurance payments as a result of damage to or loss of the goods transported, injuries or death of passengers.

When calculating the optimal duration of «windows» are taken into account the maximum delay of trains over the entire period of repair in the elimination of the consequences of the accident and the maximum output in the «window» with regard to implementation of the guaranteed volume of work [5].

Operating costs time of transportation economy ($T_{tran.ec.}$), connected with the organization of handling of train flow during the «window» (t_w), are determined from the expression:

$$T_{tran.ec.} = (1+\xi)\cdot(\sum_{m=1}^{m} N_{fr}\cdot t_{fr} + \sum_{p=1}^{p} N_{pas}\cdot t_{\text{pas}} + n^{\text{fr}}_{\text{stop}}\cdot t^{fr}_{stop} + n^{\text{pas}}_{\text{stop}}\cdot t^{pas}_{stop} + n^{com}_{stop}\cdot t^{com}_{stop}), \quad (10)$$

where $\sum_{m=1}^{m} N_{\text{fr}}\cdot t_{\text{fr}}$; $\sum_{p=1}^{p} N_{pas}\cdot t_{\text{pas}}$ is total time of train delay en route, respectively, of freight and passenger, including commuter, train-hour;

$n^{\text{fr}}_{\text{stop}}, n^{\text{pas}}_{\text{stop}}, n^{\text{com}}_{\text{stop}}$ is total number of additional stops of freight, passenger and commuter trains, pcs;

$t^{fr}_{stop}, t^{pas}_{stop}, t^{com}_{stop}$ is time (duration) of one additional stop of freight, passenger or commuter train, hours;

ξ is accounting probability of occurrence of undesirable events or the occurrence of undesirable situations caused, for example, by overexposure of the «window» or other factors, which are classified as risk of additional time cost and reduction of income [7, 8].

Additional costs of train-hours are determined by the sum of the product of the number of trains delayed by the time of the «window». Data on the number of trains and their time delay in progress of each of them are accepted in accordance with the variation schedule of movement.

The increase in freight car turnover ($\Delta\vartheta_w$) because of the «window» is determined by the following relationship:

$$\Delta\vartheta_w = \frac{\Delta\sum_{n=1}^{n} N_{fr}\cdot t_{fr}\cdot m_{car}}{24\cdot U_{\text{car}}}, \text{ hours (days)}, \quad (11)$$

where m_{car} is a number of cars in a freight train, cars;

U_{car} is work of freight cars fleet (loading, unloading plus reception of laden cars), cars.

In connection with the growth of the freight car turnover because of the «window» is increasing the need for additional resources to ensure a given volume of traffic:

$$\Delta n_{car} = \Delta\vartheta_w \cdot U_{car} = \frac{\Delta\sum_{n=1}^{n} N_{fr} \cdot t_{fr} \cdot m_{car}}{24}, \text{ cars,} \qquad (12)$$

Additional demand for locomotives during the «window» is defined as:

$$\Delta M_{loc} = \frac{\gamma_{loc} \cdot \Delta n_{car}}{m_{car}}, \qquad (13)$$

where γ_{loc} is coefficient of need for locomotives per one pair of freight trains, taking into account the additional need for locomotive fleet to ensure uninterrupted movement of trains.

Reduction of locomotive performance ($\Delta\omega_{loc}$) in the «window» is fixed according to the dependence:

$$\Delta\omega_{loc} = \omega_{l\ pl} - \frac{\sum_{l=1}^{L} P_{loc\ net} \cdot L_{loc}}{\gamma_{net} \cdot (M_{p\ loc} + \Delta M_{loc})},$$

thous. t·km gross, (14)

where $\omega_{l\ pl}$ is planned average performance of train locomotive, thous. t·km gross;

$\sum_{l=1}^{L} P_{loc\ net} \cdot L_{loc}$ is volume of transportation by locomotives, thous. t·km net;

γ_{net} is coefficient of conversion of t·km net into t·km gross (approximately $\gamma_{net} = 0{,}67$);

$\Delta M_{p\ loc}$ is a planned number of locomotives.

The total dependence to assess the loss of the transport process:

$P_D = O_{CS} + (1+\psi) \cdot T_R$, rub, (15)

where T_R is time (duration) of possible losses of transportation process in the assessment of costs as a results of occurrence of an undesirable event or undesirable situation (risk), hours (days);

ψ is likelihood of an undesirable event or the occurrence of an undesirable situation (risk).

When determining the amount of the current cost of rail transport infrastructure consumables rates are used, depending on the spent brigade-hours of locomotive crews, locomotive-kilometers, locomotive-hours, cost of electricity and so on.

As an example, Pic. 1 shows the calculations of optimal duration of the «window» when performing overhaul of the track using new materials (track recovery after the incident), taking into account the costs of related infrastructure economies.

Conclusion. The above suggested methodology takes into account:

• determination of the minimum reduced costs for repairs, taking into account additional costs in the infrastructure and losses of the transportation process in the selection of «windows» duration for track operations;

• risks of additional costs and income reduction for the chosen mode of track operations that minimize losses during liquidation of consequences of the accident;

• costs of stopping train traffic caused by «windows», and compensation for the loss for their movement at the section (risk of decline in the share of income of a railway company, e.g. JSC Russian Railways);

• costs in the track economy when choosing the duration of «windows» for track works that minimize the loss of time.

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