

JUSTIFICATION OF THE TECHNICAL PARAMETERS OF THE RECONSTRUCTED RAILWAY

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Raising the speed of trains is one of the most important tasks of improving the operational work and development of railway transport. High-speed movement of passenger trains allows to reduce the time spent by the passenger on the trip and improve the quality of transport services. Thanks to these and other advantages over other modes of transport, high-speed traffic becomes an economical and ecological part of the global transport system [1].

Increase in speeds, while insuring safety and maintaining maximum facilities for passengers, might be accessed by using new rolling stock, strengthening track superstructure, and improving the design of a rail line [2].

When justifying design decisions on the choice of the most rational parameters for the reconstruction of railways for high-speed traffic, the need to take into account the incompleteness and unreliability of initial data on the conditions of construction and operation of the road is of great importance [3].

When determining the uncertainty factors, it should keep in mind that a railway line is a complex technical system located in various natural and technogenic conditions. These conditions affect the construction and operational performance of the railway, its bandwidth and carrying capacity. It should be studied during the project development process.

In order to switch to high-speed passenger train traffic in mixed freight and passenger traffic, taking into account the uncertainty of the initial information, it is necessary to consider using the methodology for justifying the technical parameters of the line reconstruction. For example, it was taken a section of a railway line located in the ninth transport corridor that runs through the territory of the Republic of Belarus. It has the following characteristics:

– *Main technical parameters*: guiding slope – 9%; section length – 100 km; useful length of receiving and sending tracks $l_{rs} = 850$ m; number of main railway tracks – 2 tracks; type of traction-electric AC ("Stadler", CHS4t, V180k); signals and interlockings device-auto-blocking; method of traffic organization (graph type) – batch; weight norm – $Q_{wn} = 3200$ tons'.

– *Dimensions of transport*: freight transportation – 25 million tkm / km per year; passenger traffic between 10 and 20 PPT / day.

As a result of the analysis of possible options for the operation of the railway after reconstruction, two uncertainty factors were established for high – speed passenger train traffic – the size of traffic and the value of the passenger-hour cost.

Three variants of the size of passenger traffic are accepted (n_{psi} in pairs of trains per day) and two variants of the cost of passenger-hour (e_{phj} in conventional units / passenger-hours):

$$n_{ps1}=10; n_{ps2}=15; n_{ps3}=20; e_{ph1}=4; e_{ph2}=8.$$

Thus, $3 \times 2 = 6$ variants of the calculation conditions are subject to analysis F_j :

$$n_{ps1} e_{ph1}, n_{ps1} e_{ph2}, n_{ps2} e_{ph1}, n_{ps2} e_{ph2}, n_{ps3} e_{ph1}, n_{ps3} e_{ph2}.$$

As a result of the analysis of the existing line technical condition and possible options for strengthening the line, the following design decisions were made E_i :

E_1 – construction of the third main track with its specialization for freight traffic with a partial-batch schedule;

E_2 – increasing the useful length of the receiving and sending tracks from 850 to 1050 meters, which will increase the weight rate of the train from 3200 to 4000 tons;

E_3 – use (purchase, production) of improved rolling stock that can realize higher speeds of passenger trains or increased weight of freight trains with minimal investment in track reconstruction.

As an optimality criterion, the minimum sum of the given construction and operating costs and the cost of the time spent by passengers on the road for the estimated year of operation is accepted:

$$S_{ch}=(K_{rec} + K_{rs} - K_{rs(ret)}) \cdot E \pm C_t + C'_{ph} \quad (1)$$

The one-time costs included in the criterion indicator include investments in railway reconstruction (K_{rec}) and the purchase of rolling stock (K_{rs}). The return cost is taken into account due to the release of used passenger cars and locomotives ($K_{rs(ret)}$). The discount rate (E) is taken equal to 0,1. The cost of time spent by passengers on the road (C'_{ph}) is determined.

The elements of the decision-making matrix e_{ij} (million c.u.) (table 1) are obtained as a result of calculations using the formula (1) for the accepted design solutions E_i ($i=\overline{1,3}$) under various design conditions F_j ($j=\overline{1,6}$).

Table 1 – The decision-making matrix in conditions of uncertainty

Design solution E_i	Settlement conditions F_j					
	$n_{ps} = 10$ PPT / day		$n_{ps} = 15$ PPT / day		$n_{ps} = 20$ PPT / day	
	$e_{ph}=3,3$ c.u.	$e_{ph}=6,6$ c.u.	$e_{ph}=3,3$ c.u.	$e_{ph}=6,6$ c.u.	$e_{ph}=3,3$ c.u.	$e_{ph}=6,6$ c.u.
E_1 – third track	107	112	128	130	134	136
E_2 – increasing the length of tracks	89	88	95	95	94	95
E_3 – new rolling stock	80	75	97	89	93	96

After the decision-making matrix is formed, the use of classical and derived criteria for decision-making under conditions of uncertainty is considered [4, 5].

According to the Wald criterion, the optimal solution will be E_3 – use of improved rolling stock, when using which the costs under any conditions will not exceed 97 million c.u. The options chosen in this way completely eliminate the risk. However, this advantage is worth some losses.

The idea of applying the Savage criterion is based on the transition from the decision-making matrix to the risk matrix. Elements of the risk matrix show the additional costs (losses) shown in relation to the most rational solution. The Savage criterion recommends E_3 as the optimal solution. At the same time, the amount of losses, even in the worst case, will not exceed 2,1 million c. u.

In some cases, when the probabilities p_j of F_j conditions are determined in some way (for example, based on statistical data or expert forecasts), the Bayes-Laplace criterion is applied. According to the Bayes-Laplace criterion, the E_3 solution will also be recommended as optimal.

The Hodge-Lehman criterion is based on the Bayes-Laplace criterion and the Wald criterion. The ν parameter is used to express the degree of confidence in the probability distribution used. If this confidence is high, the Bayes-Laplace criterion is emphasized, otherwise the Wald criterion is preferred. According to the Hodge-Lehman criterion, provided that all conditions are equally probable ($p_1 = p_2 = \dots = p_6 = 1/6$) and the degree of confidence $\nu = 0,4$, the optimal solution is E_2 – increasing the useful length of the receiving and sending tracks.

The Hurwitz criterion provides a solution that lies between the positions of extreme pessimism and extreme optimism. The weighting factor λ , which shows the degree of pessimism and takes values from 0 to 1. For $\lambda = 0,5$, a weighted average solution is obtained between the

points of view of the extreme optimist and the extreme pessimist. Applying the Hurwitz criterion for the parameter $\lambda = 0,4$, the optimal solution is E_2 .

Thus, the classical criteria of Wald, Bayes-Laplace and Savage recommended the use of improved rolling stock that can realize higher speeds of passenger trains or an increased weight of freight trains with minimal investment in track reconstruction. This will eliminate the risk of making the wrong decision.

References:

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