COMPLEX SOLUTIONS FOR THE PROBLEMS OF INFRASTRUCTURE DEVELOPMENT AND TRANSPORTATION RESOURCES

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ABSTRACT

The paper presents an approach to justification of complex strategies for organization of rail transportation in conditions of limited investments, classification of operational reserves, methodological principles for integrated solution of the problems of development and use of infrastructure and transportation resources based on the variant technological modes of functioning of the railway network.

Keywords: railway infrastructure, transportation, limited investments, methodology, operational reserves, classification, transportation resources, variant technological modes.

Background. *The non-decreasing power shortage of the main directions and nodes of domestic railways is accompanied by a severe shortage of available investment resources. Development and actualization of the general scheme for development of the railway network [1], business plans for large complex investment projects, justification of investment in facilities, preparation of technical conditions for design of construction, reconstruction and junction of tracks of non-public use – at any of these stages, the question arises: what and in what order is to be refused, in order to minimize the loss of technological effect?*

The problem of determining the range of external and internal conditions under which the need and the minimum permissible efficiency of measures to develop the railway infrastructure remain is equally difficult. As it is known, incompleteness of information about the size and structure of traffic flows for the future concerns all types of traffic, and in the freight traffic – not only laden, but also empty car flows. For example, it is rather difficult to indicate what proportion of traffic will be carried out in the cars of individual rolling stock operators, which car fleet regulation system will be built by these operators. Therefore, monitoring algorithms and risk assessment (Pic. 1) should not only rely on the results of the study [2], but also ensure, on the one hand, the choice of solutions that do not lose their effectiveness with possible changes in the initial data, and on the other hand – contain logical conditions and computational procedures that reduce the probability of errors indicated in the diagram (see Pic. 1).

Objective. *The objective of the author is to consider complex solutions for the problems of infrastructure development and transportation resources.*

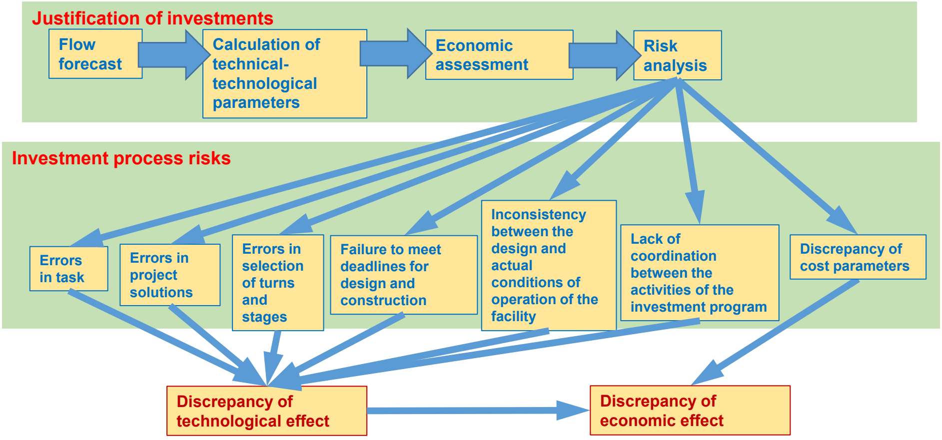
Methods. *The author uses general scientific and mathematical methods, comparative analysis, scientific description, evaluation approach.*

Results.

Transportation management strategies

The technological effect is evaluated primarily by the target indicators of integrated investment projects for development of railway infrastructure of JSC Russian Railways, which, as a rule, determine the achieved throughput and carrying capacity of sectors and destinations, route speed of passenger trains, section speed and weight norms of freight trains. Thus, the requirements for the parameters of the channels in the transport system are regulated (in the terminology proposed by professor P. A. Kozlov [3, 4]), but no requirements are set for characteristics of bunkers. In the terminology of railway transport, the characteristics of the channel are the capacity of stations, sections and in-junction runs, processing capacities of sorting complexes and cargo terminals; characteristics of the bunker – accumulative and regulating capacities of the road development. Underestimation of the properties and parameters of the bunker in the development of the railway network leads to results that are by no means abstract theoretical.

In the current decade there have been severe consequences of the growth of freight car fleet in the changed principles of its operation. The phenomenon of technological deficiency of the car fleet in 2011–2013, when the overall availability of freight cars was growing, the reliability of supplying shippers' shipments fell, the difficulties with dispatch of cargo were growing – the result of the lack of harmonization of the infrastructure resources, the number of car fleet and traffic management methods. One of the reasons for this was, in particular, the transfer of a number of

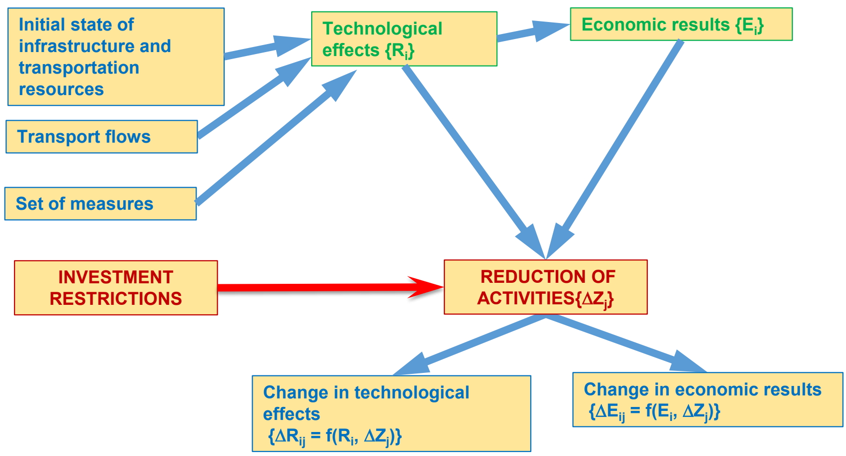


Pic. 1. Scheme for monitoring and assessing the risks of railway infrastructure development.

Table 1

Measures to compensate for the reduction of activities for development of railway infrastructure and transportation resources

Solution classes	Deteriorated indicators	Increased demand	Compensation measures
$\{\Delta n_{r.sec}\}$	$t_{wait.dep}$; K_{stops}; V_{sec}	Capacity of stations for unavailable trains and traction and energy resources due to a decrease in section speed	Parallel graph (S_1); switching of passenger and (or) freight trains to parallel runs (S_2); increase in weight and length of trains (S_3); reduction in passenger and suburban traffic (S_4)
$\{\Delta n_{r.st}\}$	t_{proc}; t_{tr}; t_l; n_3; K_{stops}; V_{sec}	Power of sections and traction resources for speeding up the export of trains	S_1; S_2; S_3; S_4; redistribution of sorting work (S_5); changing the scheme of traction service and warranty areas (S_6); increase in the level of traffic routing (S_7)
$\{\Delta N_{r.proc}\}$	t_{proc}; t_l; n_3; K_{stops}; V_{sec}	Capacity of stations for cars awaiting processing and cargo operations	S_5; S_7; depersonalization of the universal car fleet (S_8)
$\{\Delta E_{r.st}\}$	k; n_3; K_{stops}; V_{sec}	Processing capacity of the stations due to reduced transit flows of cars, capacity of sections and traction resources to speed up the export of trains	S_1; S_2; S_3; S_4; S_5; S_7; S_8
$\{\Delta M_{r.i}\}$	$t_{wait.dep}$; K_{stops}; V_{sec}	Capacity of stations for unavailable trains and power of sections due to the reduction in the weight of the train	S_2; S_4; S_5; S_7; S_8



Pic. 2. Reduction of activities under investment restrictions.

measures for the development of stations (including those envisaged by the scheme already mentioned [5]) to a later date.

In [6, 7] it was proved that in the range of excess filling of the capacity of the station track development, a part of the station tracks is excluded from the work of passing and processing the flows of trains and cars. At the same time, the resulting capacity of the railway infrastructure is significantly reduced relative to the passport values calculated in accordance with the instruction for calculating the available railroad capacity [8].

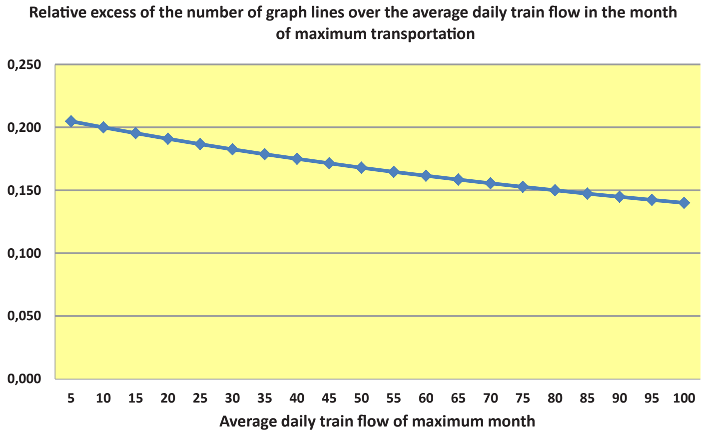
An approach to the rationale of integrated strategies for development of rail transport, including investment in infrastructure development, changing the number and structure of locomotive and car parks, improving the technology of traffic management (reducing the proportion of unproductive use of infrastructure capacity) was formulated methodologically [7].

Reduction of the activities of the investment program and their parameters $\{DZ_j\}$ under investment restrictions (Pic. 2), which minimizes the loss of technological effect

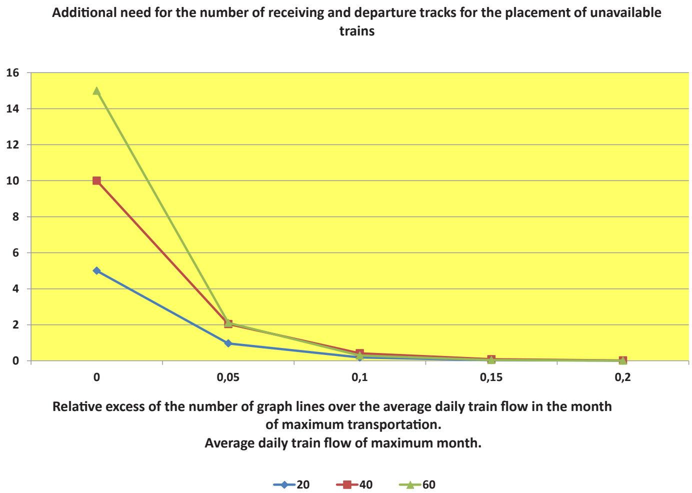
$\{DR_{ij} = f(R_i, DZ_j)\}$,

provides for the solutions of the following classes: reduction of the required capacity of sections on the hauls and (or) the traction power supply system $\{\Delta n_{r.sec}\}$; reduction of the required capacity of stations in parks, necks and connecting tracks $\{\Delta n_{r.st}\}$; reduction of the required processing capacity of the stations for sorting, freight and special devices $\{\Delta N_{r.proc}\}$; reduction of accumulative, regulating and service-technical [9] capacity of the track development of stations $\{\Delta E_{r.st}\}$; reduction of the required number of locomotive fleet and capacity of locomotive facilities $\{\Delta M_{r.i}\}$.

The solutions of each of these classes result in the deterioration of certain groups of indicators, the increase in the need for certain resource groups and the need



Pic. 3. Technically necessary excess of the estimated size of the freight traffic over the average daily size of the month of maximum freight traffic.



Pic. 4. Increase in the need for receiving departure tracks with a lack of traction and graph resources for the export of freight trains.

for certain technological compensation measures (Table 1), where $t_{wait.dep}$ is the waiting time for departure from the station, h; K_{stops} is the number of stops of freight trains on the section; V_{sec} is section speed of freight trains, km / h; t_{proc}, t_{tr}, t_l is the time spent at the station of cars, respectively, transit with processing, transit without processing and local, h; n_3 is the average daily number of trains delayed by the non-acceptance by the station; k is the number of train assignments.

The compensatory measures considered do not always lead to positive results. For example, a reduction in the required number and length of sorting tracks at a station in the calculation for future flows may cause the need to lay not less (if not more) number of tracks in the receiving parks of other stations and strengthen the humps, while slowing the progress of the car flows.

Classification of reserves

The excess of capacity over the average daily volume of work is determined by:

1) the required capacity of the railway infrastructure;

2) the given sizes of cargo and passenger traffic of the month of maximum transportation;

3) the required capacity for track development of railway stations and tracks of non-public use;

4) the available options for regulating car flows.

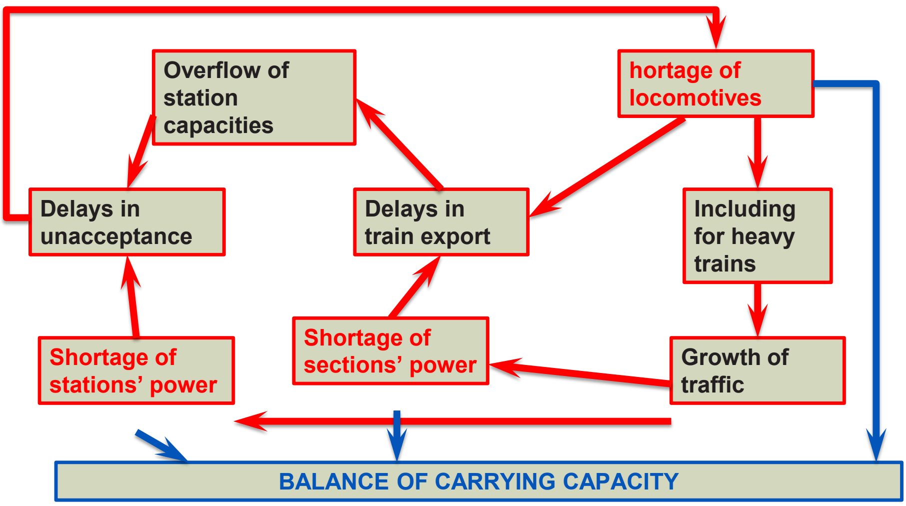
In the calculations and justifications, it is necessary to distinguish:

1) operational reserves (economically feasible excess of capacity over the average daily volume of work in the calculated year), which can be used to develop additional volume of transportation work;

2) the technically necessary share of the capacity of the infrastructure and transportation resources, which is used to ensure the reliability of the transportation process (compliance with the conditions for interaction of infrastructure elements, achieving specified technological effects, maintaining performance indicators within the acceptable range).

Operational reserves represent a reserve of capacity, formed when they are put into operation before the term for achieving the estimated traffic size, based on the need to reduce the overall operating and construction costs; while transport flows and unit costs in operation are less than the calculated value.

Technically necessary for the steady export of trains, the number of lines of freight trains in the traffic schedule, on which the need for locomotives and the indicators of the form CDL-13 should be calculated, and also to take the required throughput, is established by studies carried out using simulation and reliability theory. The relative excess of the estimated freight traffic over the average daily size of the month of maximum freight transportation varies practically in the range from 0,14 at 100 pairs of trains / days to 0,205 at five pairs of trains / days (Pic. 3). At the same time, a small number of unavailable trains during the maximum month will take place no longer than during two days, which is technologically feasible.



Pic. 5. Cyclical development of operational difficulties and balance of carrying capacity.

Ignoring these recommendations will cause chronic disturbances in the interaction of stations and sections of the railways. In the absence of reserve of schedules, the accumulation of unavailable trains at the nodes will require the addition of dozens of receivers in each direction (Pic. 4), make it impossible to deliver goods in a timely manner, and efficient use of rolling stock, energy resources and staff.

In operational conditions, operational difficulties develop cyclically (Pic. 5). At present, transition equations have been recorded and programmed, the solution of which allows modeling the development of difficulties and calculating the balance of the carrying capacity of railway ranges, proceeding from ensuring their maneuverability [7], that is, the unhampered advancement of train flows without delays in unacceptance by stations, external landfill sites, and without delay in the exchange of cars with non-public railway tracks.

The specified balance of carrying capacity should be determined by calculation on models of concrete polygons, allowing to calculate functions of distribution of technological time of delivery of cargoes and empty cars. Using distribution functions it is necessary to evaluate the reliability of fulfillment of legal (normative and contractual) delivery terms, which should be among the targets of investment projects and technological effects of the activities included in them.

Principles of an integrated solution

A comprehensive solution to the problem of development and use of the railway infrastructure and transportation resources should ensure in the conditions of current operation:

– sufficient invariance of sets of reconstructive measures to the conjunctural changes in traffic flows (cargo base, passenger flows, car fleet management system);

– opportunities for regulating car flows due to their redistribution between the elements of the railway infrastructure (use of parallel railway runs, redistribution of sorting work between stations, etc.).

This regulation will allow:

1) to maintain the necessary level of reliability of transport services during periods of repair and modernization of infrastructure, seasonal changes in passenger traffic and conditions of cargo operations;

2) to compensate the unevenness of traffic flows for individual correspondence and to reduce the overall need for space-time resources due to their interchangeability.

JSC Russian Railways carries out an integrated approach to repair and current maintenance of the infrastructure, providing for the transition from variant train schedules on sections and directions to the variant technological modes of operation of the railway network sites [7].

Opportunities for effective implementation of such regimes should be incorporated into infrastructure development activities in the following areas:

– unification of weight and length of freight trains on parallel runs;

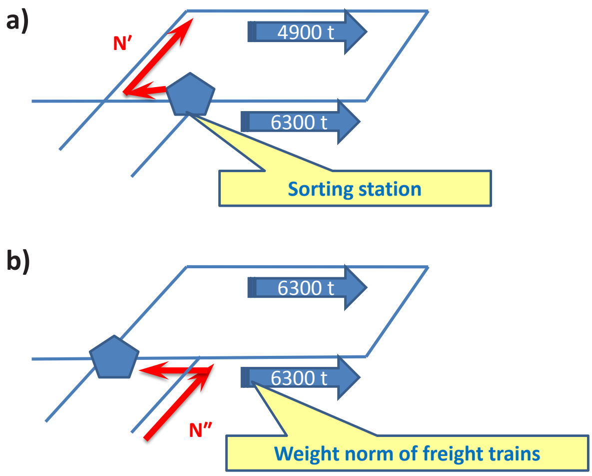
– location and development of marshalling yards, passenger (including passenger technical) stations, transport and logistics centers, car-linear and locomotive economies;

– concentration and (or) duplication of homogeneous operations in transport hubs;

– organization of preparation of empty cars and placement of cars not participating in the transportation process.

Not any topology of the railway network makes it possible to organize an effective interaction of railway junctions and directions. Let's consider two variants of placement of a sorting station and establishment of weight norms of freight trains on a railway range (Pic. 6).

The first variant (see Pic. 6a) provides for different directions in parallel runs different weight norms of 4900 and 6300 tons, as well as the concentration of sorting work with the placement of the sorting station at the node from which the car trains will follow with over-runs N'. This solution limits the possibilities of regulating the carload flows in the event of a change in the operational situation: the direction of the cars to the parallel run requires the organization of the fracture of the weights of the trains, and putting into effect effective design plan assignments at the marshalling yard will require either long idle times of the cars under accumulation or the direction of the cars to this station with additional reruns on the approaches. Thus, the development of possible operational difficulties can be eliminated by increasing the utilization of infrastructure, which can further complicate the situation.



Pic. 6. Variants of placement of the sorting station and weight norms of freight trains.

The second option (see Pic. 6b) provides on parallel directions a unified weighting norm of 6300 tons and the placement of a sorting station at the node in which the traffic flows will be sent with reruns of N″ < N′. Such a variant will require some increase in investments, but will allow efficient management of the car flows in a significant range of changes in working conditions, which, of course, will reduce direct production costs.

For the evaluation of the latter, each i -th variant technological mode $W(t_i)$ is characterized by a period of action of duration t_i with dates of beginning T_{0i} and completion T_i and with a set of parameters $\{W_1(t_i), W_2(t_i), W_3(t_i), W_4(t_i), W_5(t_i), W_6(t_i), W_7(t_i)\}$, where $W_j(t_i)$, $j = 1, ..., 7$ is the vector characterizing the j-th subsystem of the polygon operational technology.

The variables that make up the vector $W_1(t_i)$ characterize the technology of the organization of car flows operating on the polygon; $W_2(t_i)$ – parameters of intra-node (intra-station) technology; $W_3(t_i)$ – train schedule and train operation technology; $W_4(t_i)$ – traction service system; $W_5(t_i)$ – regulation of empty cars; $W_6(t_i)$ – technology for the operation of non-public tracks and other railway infrastructures; $W_7(t_i)$ – passenger and suburban traffic.

In this case, the variables $W_5(t_i)$, $W_6(t_i)$, $W_7(t_i)$ are located (in whole or in part) outside the zone of responsibility of JSC Russian Railways as the owner of the infrastructure and the guaranteeing carrier. Therefore, in a specific formulation, these variables act either as controllable variables in a multicriteria task or as a system of constraints in a single-objective problem.

Conclusion. *It should also be emphasized that the tasks of finding an effective set of parameters of a variant technological regime $W^*(t_i)$ should take into account the costs associated with the change of technological regimes (cost estimation of a set of possible technological changes), both in the case of fluctuations in the presented traffic flows of passenger and freight traffic, calendar periods of carrying out repair and construction works on specified directions.*

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