

FACTORS OF CAPACITY OF TRANSPORT CORRIDORS OF THE FAR EAST

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ABSTRACT

The authors analyze the possibilities of the Far Eastern region for further development of international transport corridors, highlighting the discrepancy between the carrying capacity of sea and rail transport. The factors constraining growth of volumes of transportation of export cargoes by railroads and considerably complicating the work

of transport corridors are determined. A methodology for determining the efficiency of using parallel norms for the mass of freight trains and measures ensuring reduction in the required capacity of the transport infrastructure due to the phased progressive growth of the mass of freight trains are provided, if there are grounds to avoid additional costs.

Keywords: international transport corridor, seaport, railway, carrying capacity, required throughput, train mass, heavy traffic.

Background. Due to its geostrategic position and resource availability, the Far Eastern region has a certain potential for attracting capital and large commodity flows. One of the key projects in this regard is the creation of infrastructure conditions for the efficient use of natural resources and the development of international transport corridors (ITC) [1].

The railway in the Far Eastern Federal District (FEFD) is the main link in the Euro-Asian transportation sector, as it has access to ice-free seaports: Vanino, Sovetskaya Gavan, Vostochny, Nakhodka, Krabovaya, Posiet and others, as well as border crossings on the way to China (Grodekovo–Suifenhe, Nizhneleninsk–Tongjiang, Makhhalino–Hunchun) and North Korea (Hassan–Tumangan). The main share of freight flows (about 62 %) on the Far Eastern Railway is made up by the export of goods (coal – 67 %, oil – 12 %, timber – 10 %, others – 11 %).

In the near future, a significant increase in the volume of export traffic will be planned for the ports and border crossings of the Far Eastern Federal District. In addition, the construction of a modern sea coal terminal «Port Vera» (the declared volume of transshipment is 20 million tons), the port of Zarubino (the declared volume of transshipment is 80 million tons), the dry port in Hunchun (China) [1] is planned [2].

However, among the factors hampering development of the natural resource potential and the increase in the volume of export cargoes, there is such a serious one as the presence of infrastructure restrictions in the transport sector. The level of technical development of transport corridors in the railroad zone does not correspond to the carrying capacity of sea transport and the potential of the

region's mining enterprises. This means that increasing the carrying capacity of railway approaches to seaports and border crossings in the Far East, increasing the processing capabilities of stations and reloading complexes become a priority sectoral task.

Meanwhile, already now the load of transport infrastructure is about 83–92 % of the carrying capacity of ITC. At the same time over the past eight years there has been a systemic increase in the freight flow that follows to the countries of the Asia-Pacific region through the territory of the Far Eastern Federal District. That is, the load is close to the limit, and the emergence of infrastructure failures leads to the delays of trains from traffic, the introduction of conventional restrictions on loading, and many other difficulties in the work of the ITC [3]. In these circumstances, the local daily task, which is to achieve better controllability of the current transportation process, to reduce the deficit of carrying capacity on the railways of the region, comes to the fore, of course, in addition to global goals.

Objective. The objective of the authors is to factors of carrying capacity of transport corridors of the Far East of Russia.

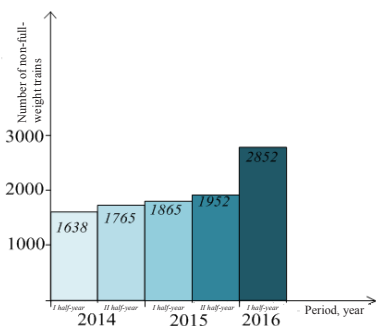
Methods. The authors use general scientific methods, mathematical calculations, evaluation approach, comparative analysis, graph construction.

Results. The analysis of the work of the Far Eastern Railway for 2014–2016 showed a significant number of non-full-weight and (or) incomplete trains following to the Far Eastern seaports. In 2014, the percentage of such trains from the total number was 13.8 %, in 2015 – 15 %, in the first half of 2016 – 22.1 %. In Pic. 1 it can be seen that in 2016 there was a significant increase in the number of non-full-weight and (or) incomplete trains in comparison with two previous years.

At the same time, according to data for 2015, on the approaches to ports and border crossings, the number of non-full-weight and incomplete trains reached 60 % of the carrying capacity of the infrastructure – Pic. 2.

The analysis revealed the main reasons for the non-full-weight and incompleteness of trains on the Far Eastern Railway:

1. Failure to complete the trains at one of the passing technical stations. This reason is due to the fact that 60 % of the freight flows in the direction of the Far East originate at the stations of the West Siberian and Krasnoyarsk Railways, where the weight norm of the trains is 6000 tons, which is less than the weighting standard established on the Far Eastern Railway. In addition, since the freight flow followed in



Pic. 1. The number of non-full-weight (incomplete) trains on the Far Eastern Railway.

the sending routes with a unified weighting norm of 6 000 tons, it was impossible to replenish the trains at passing technical stations, because it is forbidden to replenish the sending routes.

2. A complex track profile, characterized by steep and protracted climbs. The most difficult areas in the direction of Eastern Siberia–ports of the Far East are: Taishet–Nizhneudinsk (8.5 %) and Bolshoy Lug–Andrianovskaya of the East Siberian Railway (17.4 %), Arkhara–Obluchye–Lagar (8.5 %) and Ussuriysk–Smolyaninovo–Nakhodka (27 %) of the Far Eastern Railway. The most difficult part of the whole range is the latter section, running through the Sikhote–Alinsky pass with three steep, prolonged ascents up to 27 % and having a large number of curves with a small radius (170–210 m).

To overcome steep ascents without stopping on the Ussuriysk–Smolyaninovo–Nakhodka site, and to increase its available carrying capacity, a new technology for train handling was introduced. Trains, assigned to the station of the Nakhodka junction, are formed at Khabarovsk-II station with a smaller weight norm of 5500 tons. Now the number of such trains is 40 % of their total number in this direction per day. The application of the new technology, on the one hand, increases the carrying capacity of the section, and on the other hand, is one of the main reasons for the non-full-weight of trains on the Far Eastern Railway.

The current measures to reduce the number of non-full-weight and incomplete trains on the Far Eastern Railway will slightly reduce the required carrying capacity – by 199,2 trains per year. Therefore, in order to solve the problem of capacity shortage, another option is suggested, which ensures a phased progressive growth of the train mass and the carrying capacity of the sections [4].

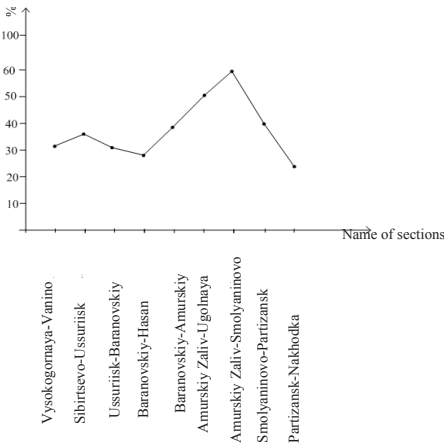
1. The use of parallel norms of the mass of freight trains on the main directions. This method, on the one hand, allows accelerating the movement of cargo flows, eliminating bottlenecks and reducing the load on railway stations connected with fracture of mass, and on the other hand, it increases the loading of the station of formation and loading of the station from the station of formation to the station of destination through an increase in the amount of traffic required.

A technique is proposed for determining the efficiency of using parallel norms for the mass of freight trains.

The choice of the station of formation of trains with a mass different from the unified one is carried out on the basis of the efficiency criterion (E_{par}), which depends on reducing the load of stations with a weight fracture and increasing the loading of the formation station and the station from the station of formation to the destination station:

$$E_{par} = \begin{cases} (\psi_{exs}^{v_j} - \psi_{par}^{v_j}) - (\psi_{par}^{v_1} - \psi_{exs}^{v_1}) \geq 0 \\ (\psi_{exs}^{v_j} - \psi_{par}^{v_j}) - (\psi_{par}^{v_1 - v_{k+1}} - \psi_{par}^{v_1 - v_{k+1}}) \rightarrow \max \\ -\psi_{exs}^{v_1 - v_{k+1}} \geq 0 \end{cases}, \quad (1)$$

where $\psi_{exs}^{v_1}$ is existing loading of the train formation station by a mass different from the unified (without the work on the formation of trains with parallel mass norms);



Pic. 2. The percentage of non-full-weight and incomplete trains from the required carrying capacity in some sections of the Far East Railway.

$\psi_{par}^{v_1}$ is loading of the train formation station by

a mass different from the unified (taking into account the work on the formation of trains with parallel mass norms);

$\psi_{exs}^{v_j}$ is existing station load with a fracture of mass;

$\psi_{par}^{v_j}$ is loading of the station with a fracture of

mass after introduction of parallel mass norms;

$\psi_{exs}^{v_1 - v_{k+1}}$ is the existing loading of the section

from the train formation station with a mass different from the unified to the destination station;

$\psi_{par}^{v_1 - v_{k+1}}$ is loading of the section from the train

formation station with a mass different from the unified one to the destination station when handling trains with parallel mass norms.

The following conditions must be fulfilled:

- train composition with a mass other than the unified one must be a multiple of the capacity of the loading and unloading fronts at the destination station, car:

$$m_{par} \cdot l_{use}^{fr}, \quad (2)$$

where l_{use}^{fr} is useful length of loading and unloading fronts at the destination station, car, m_{par} is train composition with a mass different from the unified, car;

- correspondence of the lengths of the tracks at the station of formation ($l_{use}^{v_1}$), intermediate separate points ($l_{use}^{a_k}$), passing technical stations ($l_{use}^{v_j}$), station of destination ($l_{use}^{v_{k+1}}$) with the length of the train (l_t), m:

$$l_{use}^{v_1}, l_{use}^{a_k}, l_{use}^{v_j}, l_{use}^{v_{k+1}} \geq l_t \text{ or } l_{use}^{v_1}, l_{use}^{a_k}, l_{use}^{v_j}, l_{use}^{v_{k+1}} \geq m \cdot l_{car} + l_{loc} + 10, \quad (3)$$

where l_{car} – average car length, m , l_{loc} – locomotive length, m.



Table 1

Packet coefficient values

Track development of separate points restricting haul (including the main track)	Values of α_{pack} . For a schedule of					
	paired	unpaired in freight traffic with the coefficient of non-pairiness				
		0,9	0,8	0,7	0,6	0,5
$N_{\text{non}}^{a_{k-1}} = N_{\text{non}}^{a_k} = 4$	1	1	1	1	1	1
$N_{\text{non}}^{a_{k-1}} = N_{\text{non}}^{a_k} = 3$, or $N_{\text{non}}^{a_{k-1}} = 3, N_{\text{non}}^{a_k} = 4$	0,7	0,7	0,75	0,8	0,85	0,9
$N_{\text{non}}^{a_{k-1}} = 3, N_{\text{non}}^{a_k} = 2$	0,5	0,6	0,7	0,7	0,8	0,9
$N_{\text{non}}^{a_{k-1}} = N_{\text{non}}^{a_k} = 2$ provided that there are three tracks on the adjacent points: $N_{\text{non}}^{a_{k-2}} = N_{\text{non}}^{a_{k+1}} = 3$	0,4	0,6	0,7	0,8	0,8	0,9
$N_{\text{non}}^{a_{k-1}} = N_{\text{non}}^{a_k} = 2$	0,3	0,5	0,6	0,7	0,8	0,9

• availability of a fleet of serviceable train locomotives at the formation station (M_c') for their timely delivery for the train:

$$M_c' \geq \frac{\theta_c'}{60 \cdot I_{av}}, \quad (4)$$

where θ_c' is calculated turnover of train locomotives, I_{av} is average interval, with which freight train follow.

On the Far Eastern Railway this technology is already used on Khabarovsk-II–Nakhodka section. The handling of 20 % of trains (10 per day) with a mass of 5500 tons (with a standardized 6300 tons) reduces the loading in the direction to Smolyaninovo station, which is limiting on the direction of the station, from 0.95 to 0.70 due to the handling of trains «on run», while loading of the station Khabarovsk-II and the section Khabarovsk-II–Nakhodka increases insignificantly – by 0.02, which corresponds to the efficiency criterion.

2. Increase in the mass of freight trains.

The strategy for development of rail transport until 2030 presupposes the driving of freight trains with a maximum mass of 7 100 tons from the Kuzbass fields to the ports of the Far East (Vanino, Sovetskaya Gavan). At present, the increase in the mass of freight trains following the Baikal-Amur Main Line is hindered by the useful length of the station's receiving-departure tracks – the maximum freight train mass is 5600 tons. The solution to the problem is the use of innovative cars (axle load 23–27 t / axle), with which it is possible to increase the weight of freight trains without increasing the length.

At this stage, the development of heavy traffic is becoming an important component in the solution of this task. The most feasible scenario for this in the Far East is development of the technology of distributed traction, which makes it possible to significantly increase the mass of the train and open up prospects for growing cargo flows in the shortest possible time [5]. Ultimately, the implementation of plans for the progressive growth of the mass of freight trains will provide an opportunity to provide a significant reserve capacity by increasing the carrying capacity of ITC.

Speaking about the growth of the mass of freight trains, it is necessary to take into account the influence of this factor not only on railway sections, but also on all transport objects included in transport corridors:

loading stations, passing technical stations, unloading stations.

To implement measures that ensure progressive growth of the train mass and the carrying capacity, it is necessary, however, that each transport facility of the international transport corridor meet the following criteria.

1. Loading station:

• the possibility of a rhythmic and multiple of train of cargo shipment to the ports and border stations, car:

$$P_{\text{day}}^{v_1} : t, \quad (5)$$

where $P_{\text{day}}^{v_1}$ is daily volume of loading to the ports and border stations, car; t is train;

• correspondence of lengths of tracks ($l_{\text{use}}^{v_1}$) to the length of train (l_t), m:

$$l_{\text{use}}^{v_1} \geq l_t \text{ or } l_{\text{use}}^{v_1} \geq m \cdot l_{\text{car}} + l_{\text{loc}} + 10, \quad (6)$$

where l_{car} is average car length, m; l_{loc} is locomotive length, m.

2. Sections (set of hauls and intermediate separate points):

• Correspondence of the lengths of receiving-departure tracks of intermediate separate points ($l_{\text{use}}^{a_k}$) to the train length, m:

$$l_{\text{use}}^{a_k} \geq l_t, \quad (7)$$

• availability of a sufficient number of receiving-departure tracks for implementation of the planned type of schedule (partially-batch):

$$\alpha_{\text{pack}}, K = f(N^{a_k}), \quad (8)$$

where α_{pack} is packet coefficient;

K is a number of trains in 1 packet.

Values of packet coefficient for $K = 2$ are shown in Table 1.

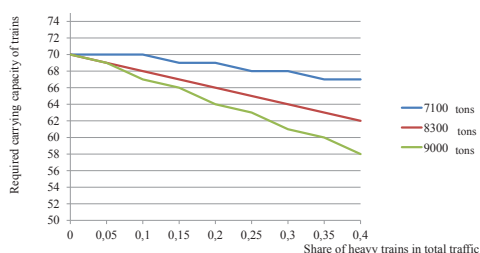
• on electrified sections – availability of a power reserve of traction power supply system (S_{res}):

$$0 < S_{\text{res}} \leq 0,2 \cdot S, \quad (9)$$

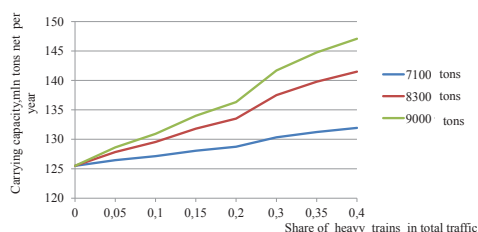
where S is power of traction power supply system; $0,2 \cdot S$ is value of the power reserve of traction power supply system, corresponding to the accepted standard of reliability.

• in the areas of pushing – the presence of a working locomotive fleet of pushers (M_c^p):

$$M_c^p \geq \frac{\theta_c^p}{60 \cdot I_{av}}, \quad (10)$$



Pic. 3. Dynamics of reduction of the required capacity in the organization of heavy traffic.



Pic. 4. Dynamics of increase in carrying capacity when organizing heavy traffic.

where θ_c^p – calculated turnover of locomotives-pushers;

I_{av} – average interval, with which freight trains follow.

3. Passing technical stations:

- Correspondence of lengths of receiving-departure tracks to the train length, m :

$$I_{use} \geq I_t. \quad (11)$$

- Presence of working reserve of train locomotives (M_c') for their timely rotation:

$$M_c' \geq \frac{\theta_c'}{60 \cdot I_{av}}, \quad (12)$$

where θ_c' –calculated turnover of train locomotives.

4. Destination station:

- Correspondence of lengths of receiving-departure tracks to train length, m :

$$I_{use} \geq I_t. \quad (13)$$

In addition, before implementation of the third stage, it is necessary to determine the share of heavy trains and trains of increased weight from the general dimensions of traffic. Not only the planned traffic volumes, but also the technical capabilities of the transport infrastructure have own impact here.

It is obvious that an increase in the number of such trains will lead to a reduction in traffic. So, for example, on the Trans-Siberian Railway, the average daily freight traffic is 70 pairs of trains, and the weight norm is 6300 tons. Accordingly, the carrying capacity of the direction is 125.5 million tons net per year (for freight even direction). Pic. 3 shows the dynamics of decreasing the required carrying capacity to provide transportation in the amount of 125.5 million tons net per year in the organization of heavy traffic.

Reducing the freight trains traffic will increase the speed of the section speed by reducing the number of stops under overtaking by passenger trains and following the yellow traffic signal, which in turn helps to increase the productivity of locomotives.

On the other hand, the organization of heavy traffic with constant dimensions of the process as a whole

leads to an increase in the carrying capacity of the direction. Pic. 4 shows the dynamics of its growth in this case.

Conclusions. The advantage of the proposed methods for reducing the carrying capacity deficit of ITC is that they are based on the need to master the assigned volumes of traffic, which avoids additional costs, as would be the case when improving activities are planned for years. In addition, the options considered are the foundation for development of infrastructure of international transport corridors and do not contradict the generally accepted strategy for development of rail transport. In the presented logic, the progressive growth in the mass of freight trains makes it possible to provide a significant reserve for the carrying capacity of the transport infrastructure by increasing the carrying capacity of the region's railways.

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