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Research into Factors Influencing Traffic and Freight Capability of the International Transport Corridors in the Far East

V V Balenko¹, T N Kalikina¹, D S Serova¹

¹Department Organization of transport and safety in transport, Far Eastern State Transport University, Seryshevo st house 27 680021, Khabarovsk, Russia

E-mail: Victoria.balenko@yandex.ru

Abstract. This paper distinguishes major factors that restrain the growth of volumes of export freight turnover and considerably impede they work of transport corridors. The authors suggest measures aimed at decreasing the necessary train traffic capability and increase in freight capability at the expense of the incremental growth of train mass.

1. Introduction

The Russian Far East is very well placed from the point of view of the region's economic and geographic position within Russia and the Asian Pacific Region. It borders on such countries as China, Japan and the USA. The territory of the Far Eastern Federal District is crossed by the two major Russian railway mainlines: the Southern Latitudinal Railway (the Transsiberian Railway) and the Northern Latitudinal Railway (the Baikal-Amur Mainline), that have access to the major ports – Vanino, Nakhodka-Vostochnaya, and Vladivostok. One of the key projects aimed at the development of the Far Eastern Federal District (FEFD) is the creation of infrastructure for the efficient use of natural resources – the development of international transport corridors (ITC) [1].

Railways of the Far Eastern Region are the major link in the Euro-Asian transportation routing scheme, as they have access to non-freezing sea ports: Vanino, Sovetskaya Gavan', Vostochnyi, Nakhodka, Krabovaya, Posyet and others, as well as to border crossings: the Russian Federation – the People's Republic of China (Grodokovo-Suifenhe, Nizhneleninckoe-Tongjiang, Makhhalino-Hunchun) and the Russian Federation - the Democratic People's Republic of Korea (Khasan – Tumangang). The major share of the freight turnover (approximately 62%) passing through the international transport corridors in the Far East is made up of exports (coal - 67%, oil - 12%, timber - 10%, and others – 11%) [3], [5].

Nevertheless, even with the present day volumes of freight traffic the Far Eastern international transport corridors experience significant difficulties in operation caused by the following factors:

1. The Far Eastern Railway is a kind of quaziparallel transport system, i.e. a single well-developed direction of transportation prevails within the railway system and the stations are located far from each other;
2. The workloads of the majority of the entities involved in international transport corridors in the Far East are close to the critical maximum.



Therefore, the priority task for the Far Eastern international transport corridors under the conditions of increasing the volumes of export traffic is the development of cost-effective, economically expedient and technologically feasible sequence of measures for increasing the traffic capacity and in freight capacity.

2. Research rationale

A number of Russian and overseas researchers have long been studying the problems of increase in the traffic capacity and freight capacity. These problems are complex and cover a wide range of issues involving the reconstruction of permanent facilities and rolling stock, the modernization of transport operation and management procedures and improvement of the performance of engineering techniques.

A significant contribution to the development of research into traffic and freight capacities and their increase was made by: Sokovich V.A., Sotnikov I.B., Tikhonov K.K., Chernomordik G.I., Chernyugov A.D., Dmitriev V.A., Kochnev F.P., Makarochkin A.M., D'iakov Y.V., Maksimovich B.M., Lisitsin A.L., Shchit M.E., Mogila V.P., Kozlov V.E., Chernyshev M.A., Kashkin K.N., Gorinov A.V., Turbin I.V., Goncharuk S.M., Baturin A.P., El'kina L.V., Kozlov I.T., Shcheglovitov V.N. and other researchers [2],[4].

Their research fields can be tentatively divided into three groups.

The first group deals with research aimed at substantiating the efficiency of the stage-by-stage increase in traffic capacity and freight capacity of railway sections.

The second group deals with research in the efficiency of measures for the increase in traffic and the freight capacities of rail lines.

The third group deals with research into the influence of different factors on the traffic capacity and freight capacity of rail lines.

Nevertheless, despite the significant contribution of researchers, no optimal scheme exists for the introduction of measures aimed at the resolution of the problem of the utilized traffic capacity of the ITC.

3. Research

At present, the workload of the international transport corridors is about 83-92%. At the same time, the past 8 years have witnessed a systematic growth in freight traffic, bound for the Asian Pacific Region countries. This workload is close to the maximum and failures of infrastructure cause postponement of trains, the introduction of conventional restrictions on loading/unloading operations and impediments in the work of the whole ITC. The current task aimed at ensuring the stable functioning of the whole transport infrastructure of ITC, is to reduce the deficit of freight capacity [19], [8].

One of the major factors influencing the deficit of traffic and freight capacities is the presence of trains of incomplete weight and(or) of incomplete length that leads to a significant increase in the number of trains. Analysis of the work of the Far Eastern Railway in 2014-2017 showed a significant number of trains of incomplete weight and(or) of incomplete length proceeding to the Far Eastern ports. In 2014 the share of such trains out of the total number was 13.8%, in 2015 – 15%, in six months of 2016 – 22.1%. In 2016 the number of trains of incomplete weight and(or) of incomplete length increased significantly compared to the two previous years. In 2017 the tendency towards the increase in the number of such trains held true.

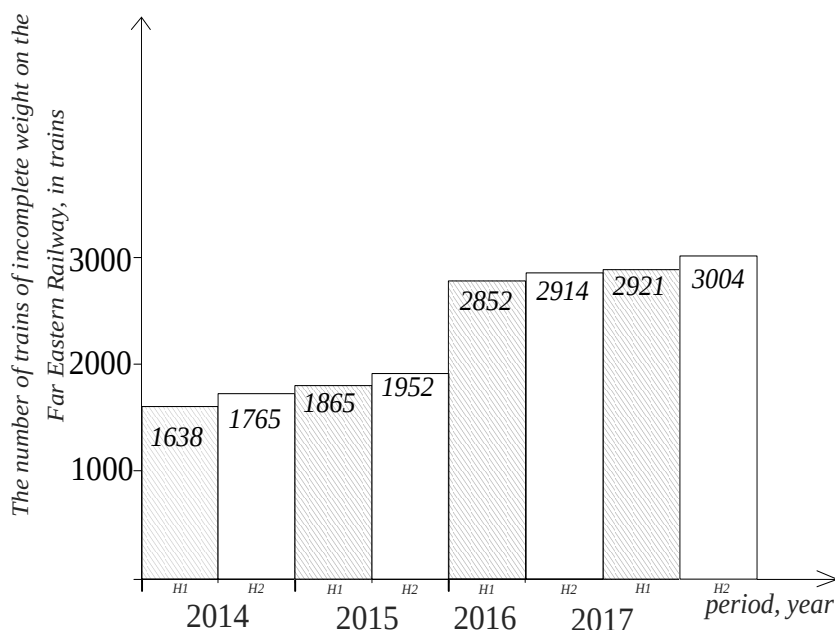


Figure 1. The number of trains of incomplete weight on the Far Eastern Railway.

At the same time, according to the data of 2017 the number of trains of incomplete weight and(or) of incomplete length on the approaches to ports and border crossings reaches 60% of their available traffic capacity.

We have distinguished the following major reasons for the presence of trains of incomplete weight and(or) of incomplete length on the Far Eastern Railway:

1. Trains are not replenished at trailing train stations. This situation has the following reason: 60% of freight flows bound to the Far East originates from the stations of the Western-Siberian and the Krasnoyarsk Railways, where the train load limit is 6,000 ton which is lower than the train load limit established for the Far Eastern Railway. This freight traffic follows sending routes with the standard weight limit of 6,000 ton therefore replenishment of trains on the route at trail train stations is impossible as it is prohibited.

2. A complicated track profile characterized by heavy gradients and excessive gradients. The most complicated sections on the traffic route Eastern Siberia – ports of the Far East: Taishet–Nizhneudinsk (8.5‰) and Bolshoi Lug – Andrianovskaya of the Eastern Siberian railway (17.4‰), Arhkara – Obluch'ye – Lagar (8.5‰) and Ussuriysk – Smolyaninovo – Nakhodka (27‰) of the Far Eastern Railway. The most complicated section within the whole operating domain is the section Ussuriysk–Smolyaninovo–Nakhodka running across the Sikhote-Alyn mountain range with three heavy excessive gradients up to 27 ‰ and a considerable number of curves of minor radius (170–210 m).

A new train handling technology was introduced in order to overcome heavy gradients without any stops on the section Ussuriysk–Smolyaninovo–Nakhodka and to increase the available traffic capacity. Trains destined to a station of Nakhodka rail junction, are formed at the station Khabarovsk II with a lower tonnage rating - 5,500 ton. At present the number of such trains is 40% of the total number of trains on this traffic route per day. On the one hand, application of this technology increases the traffic capacity of the section Ussuriysk – Smolyaninovo – Nakhodka, and on the other hand, this is one of the main reasons for the incomplete weight of trains on the sections of the international transport corridors in the Far East.

At present, a complex of measures for excluding incomplete weight trains and incomplete length trains on the sections of the international transport corridors in the Russian Far East will decrease the

required traffic capacity insignificantly – 199.2 trains less per year. Proceeding from this we suggest measures aimed at the decrease in the actual required traffic capacity [17].

We consider it expedient to perform activities step-by-step that ensure incremental increase in the train weight and freight capacity of railway sections [2].

1. Employment of multiple tonnage ratings for freight trains on major traffic routes. This method, on the one hand, allows a more rapid freight traffic, elimination of “bottlenecks” and workload reduction of the railway stations related with the transition of tonnage rating (further, weight transition stations); on the other hand, this method results in an increase in workload on railroad yards and loading of the section from the rail yard to the receiving station due to the increase in the required amounts of traffic [20, 7].

We suggest the following methodology for determining the efficiency of multiple freight trains tonnage ratings.

Railroad yards for trains of weight different from the uniform standard are chosen on the basis of the efficiency criterion (Z_{mtp1}) that depends on the reduction of workload at the weight transition stations and increase in the workload at railroad yards and sections from railroad yards to the receiving station [18]:

$$Z_{mtp1} = \begin{cases} (\psi_{exst}^{v_j} - \psi_{mtp1}^{v_j}) - (\psi_{mtp1}^{v_1} - \psi_{exst}^{v_1}) \geq 0 \\ (\psi_{exst}^{v_j} - \psi_{mtp1}^{v_j}) - (\psi_{mtp1}^{v_1 - v_{k+1}} - \psi_{exst}^{v_1 - v_{k+1}}) \geq 0 \end{cases} \rightarrow \max, \quad (1)$$

where $\psi_{exst}^{v_1}$ is the existing workload of the railroad yard for trains of weight different from the uniform standard (without the work of composing the train for trains with multiple tonnage ratings);

$\psi_{mtp1}^{v_1}$ is the workload of the railroad yard for trains of weight different from the uniform standard (taking into consideration the work for train composition for trains with multiple tonnage ratings);

$\psi_{exst}^{v_1}$ is the existing workload of the weight transition station;

$\psi_{mtp1}^{v_1}$ is the workload of the weight transition station after introduction of multiple tonnage ratings;

$\psi_{exst}^{v_1 - v_{k+1}}$ is the existing workload of the section from the railroad yard for trains of weight different from the standard to the receiving station;

$\psi_{mtp1}^{v_1 - v_{k+1}}$ is the workload of the section from the railroad yard for trains of weight different from the standard to the receiving station under handling trains with multiple tonnage ratings.

The following conditions must be held [13]:

- the composition of the train of weight different from the standard must be divisible by the capacities of the loading-unloading facilities at the receiving station, in cars;

$$m_{mtp1} : l_{useful}^{fcl}, \quad (2)$$

where l_{useful}^{fcl} is the useful length of the loading-unloading facilities at the receiving station, in cars;

m_{mtp1} is the composition of trains of weight different from the standard, in cars;

- counterpart between the lengths of tracks at railroad yards ($l_{useful}^{v_1}$), intervening interstations ($l_{useful}^{a_k}$), trailing stations ($l_{useful}^{v_j}$), receiving station ($l_{useful}^{v_{k+1}}$) length of train (l_{train}), in m:

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

where l_{car} is the average length of a car, in m;

l_{loco} is the length of locomotive, in m.

- availability of operable locomotive fleet of train locomotives at the railroad yard (M_z^n) for their timely bringing up for train:

$$M_z^n \geq \frac{\theta_p^n}{60 \cdot I_{avg}}, \quad (4)$$

where θ_p^n is the calculated turnover of road locomotives;

I_{avg} is an average interval between freight trains.

On the Far Eastern railway this technology is being successfully employed on the section Khabarovsk II – Nakhodka. Handling 20% of trains (10 trains per day) on the section Khabarovsk II – Nakhodka with the weight of 5,500 tons (while the standard tonnage rating is 6,300 tons) decreases the workload of the limiting station of this traffic route Smolyaninovo from 0.95 to 0.70 due to handling these trains “under way”, at the same time the workload of station Khabarovsk II and the section Khabarovsk II - Nakhodka increases insignificantly – by 0.02, which corresponds to the efficiency criterion.

2. The rise in weight of freight trains. The Strategy for Developing Rail Transport in the Russian Federation up to 2030 plans for road service of freight trains with mass limit of 7,100 tons from Kuzbass coal mining region to the ports of the Russian Far East (Vanino, and Sovetskaya Gavan’). At present, the rise in weight of the freight trains proceeding to the Baikal-Amur Mainline is restricted by the useful length of the receiving-and-departure tracks at stations – the maximum weight of a freight train is 5,600 ton. This problem can be resolved by the use of innovation-based cars (with axial load of 23-27 ton/axis), which will increase the weight of freight trains without lengthening them [20].

A very important component of the present stage is also the **development of heavy haul**. The most expedient scenario of the development of heavy haul in the Russian Far East is the technology of distributed traction that allows a significant increase in the weight of trains and opens the prospect of handling growing freight flows within the shortest possible time. In the long run, the realization of these stages of gradual increase in the weight of freight trains will produce a considerable spare traffic capacity due to the increase in the ITC freight capacity.

Speaking of the increase in the weights of freight trains we should take into consideration the fact that train weights influence not only the railway sections but also all transport facilities, constituents of the transport corridors under consideration: railroad yards, trailing stations and receiving stations [16].

In order to implement the measures aimed at the gradual increase in weight of trains and their freight capacity, each transport facility that constitutes an international transport corridor must meet the following criteria [6]:

1. Railroad yard:

- availability of shipping to ports and border crossings that would be rhythmic and divisible by the composition of the train, in cars:

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

where $P_{day}^{v_1}$ is the daily volume of shipping to ports and border crossings, in cars;

m is the composition of train, in cars;

- track length ($l_{useful}^{v_1}$) corresponds to the train length (l_n), in m:

$$l_{useful}^{v_1} \geq l_n \text{ or } l_{useful}^{v_1} \geq m \cdot l_{car} + l_{loco} + 10, \quad (6)$$

where l_{car} is the average length of a railway car, in m;

l_{loco} is the length of locomotive, in m.

2. Sections: (the whole of station-to-station running line and intervening stations):

- the length of the receiving-departure tracks at the intervening stations ($l_{useful}^{a_k}$) corresponds to the length of the train, in m

$$l_{useful}^{a_k} \geq l_{train}, \quad (7)$$

- the number of receiving-departure tracks available is sufficient for the realization of the preliminary planned type of traffic (partially bunched):

$$\alpha_{bunch}, K = f N_{non}^{a_k}, \quad (8)$$

where α_{bunch} is the bunch coefficient;

K is the number of trains in 1 bunch of trains, in trains.

- on the electrified sections – the available spare capacity of the traction power supply system (S_{spare}):

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

where S - is the capacity of the traction power supply system;

$0,2 \cdot S$ is the value of the spare capacity of the system for traction power supply, that corresponds to the adopted reliability rate.

- on the boosting sections – availability of operable fleet of pusher locomotives (M_z^m):

$$M_z^m \geq \frac{\theta_p^m}{60 \cdot I_{sr}}, \quad (10)$$

where θ_p^m is the calculated turnover of pusher locomotives;

I_{sr} is an average interval between proceeding freight trains.

3. Trailing technical stations:

- The length of the receiving-departure tracks corresponds to the length of the train, in m:

$$l_{useful}^{v_j} \geq l_{train}, \quad (11)$$

- the availability of an operable locomotive fleet of train locomotives (M_z^n) for their timely substitution:

$$M_z^n \geq \frac{\theta_p^n}{60 \cdot I_{sr}}, \quad (12)$$

where θ_p^n is the calculated locomotive turn-over.

4. Receiving station:

- the length of the receiving-departure tracks corresponds to the length of the train, in m:

$$l_{pol}^{v_{k+1}} \geq l_{train}, \quad (13)$$

In addition, before launching the third stage we need to determine the share of heavy haul trains and the trains of increased weight within the whole volume of traffic. This value is influenced by both the planned traffic volume and technical capabilities of the whole transport infrastructure. [8, 9].

The increase in the number of such trains obviously leads to a reduction of the traffic volume. At the same time the average speed in a section increases due to the reduction of the number of stops for passenger trains overtaking and proceeding with caution, which in its turn results in a higher performance of the locomotives. [10, 14].

On the other hand, the organization of heavy haulage at constant volumes of traffic leads to an increase in the freight capacity of the traffic route. Fig. 2 presents the dynamics of the increase in the freight capacity under heavy haulage.

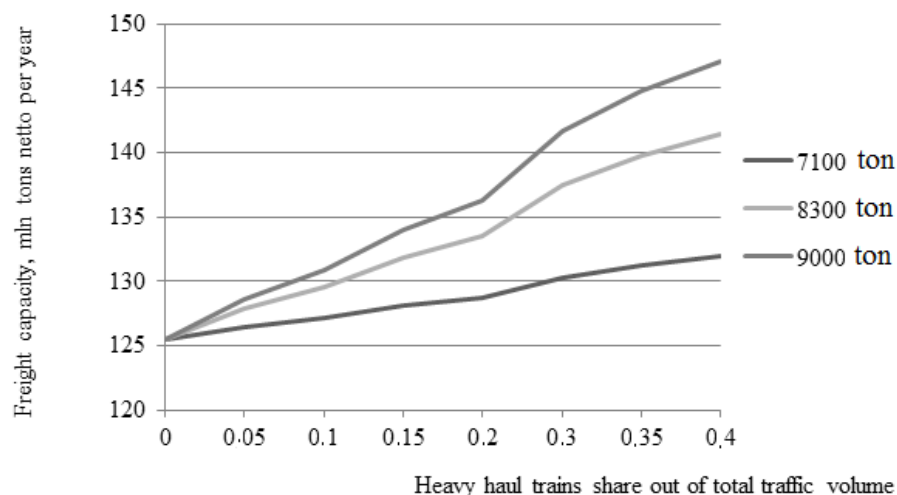


Figure 2. Dynamics of the increase in the freight capacity under heavy haulage.

While choosing measures for the gradual increase in the weight of trains and the freight capacity of sections the following aspects should be taken into consideration:

1. The freight capacity of a railway line after all the measures implemented must exceed the required volume of shipments:

$$G \geq U \quad (14);$$

2. The modernization period is the shortest possible:

$$T \rightarrow \min \quad (15);$$

3. The minimum sum of given expenditures:

$$Z = \sum_{t=0}^T K_t \cdot \alpha_t + \sum_{t=0}^T C_t \cdot \alpha_t \rightarrow \min, \quad (16)$$

where K_t , C_t are the corresponding capital investments and working expenditures at stage t ;

α_t is the cost discounting factor.

4. Conclusions

The development of the Russian Far East is closely connected with the development of the international transport corridors. At present, the workload of international transport corridors reaches 92% which testifies to the shortfall in traffic and freight capacities on the international transport corridors.

The authors have developed a methodology that determine the stages of accomplishing measures aimed at the gradual increase in the weights of trains and freight capacity of the railroad sections.

1. Introduction of multiple tonnage ratings of freight trains on the major traffic routes.
2. Increase in the weights of freight trains including development of heavy haul traffic.

Each stage must be started at the workload of ITC exceeding 65%. The system is capable of stable functioning with the workload up to 80%. Spare traffic capacity of 15% gives an opportunity to put the measures developed into operation in full.

Major advantage of the measures we suggest is that these measures allow the railways to avoid additional expenditures that they incurred with year-to-year planning. The measures we have developed are based on the demand to cope with the specified traffic volume which in the end causes cost reduction.

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