Potential of the railways of the multimodal transport network of the Eastern Siberia and Far East of Russia

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Abstract. The article notes the urgency of the problem of the formation and development of the regional multimodal transport network of Eastern Siberia and the Far East of Russia as a set of multimodal transport corridors. The enlarged functional structure of the design methodology for the integrated development of a multimodal transport network is presented. Using this methodology, the authors formulated the problem of designing the development of a regional multimodal transport network in Eastern Siberia and the Far East of Russia, gave a description of the proposed version of its appearance and the possible throughput of existing and new railways in the region under study. The options for the possible carrying capacity of the railway links of the network presented in the article represent an assessment of the potential of multimodal transport corridors, which is used to determine the options for the required traffic volumes along the network facilities.

1. Introduction

The Transport Strategy of the Russian Federation for the period up to 2030 (enacted by Russian Federation government decree No. 1734-r on November 22, 2008) (hereinafter Strategy) defined the main task of the state in the transport industry, which should provide access to safe and high-quality transport services and turn the geographical features of Russia into its competitive advantage to increase the competitiveness of the national economy and the quality of life of the population.

A special place in the Strategy is occupied by Eastern Siberia and Far East of Russia.

These regions are located in the Asian part of Russia. From the west they are bounded by the Yenisei, from the north by the Arctic Ocean, from the east by the Pacific Ocean, in the south by the state border of Russia with China, Mongolia and North Korea. The territory of Eastern Siberia and the Far East has the richest reserves of natural resources of global importance and makes up more than half of Russia. The main transport routes of Russia pass through the following regions: the Trans-Siberian mainline (hereinafter – the Transsib), the Baikal-Amur Mainline (hereinafter - the BAM) and the Northern Sea Route (hereinafter – the NSR).

At the same time, Eastern Siberia and the Far East have an insufficient level of accessibility of transport services for the economy and the population, which is one of the main reasons hindering the development of these regions. Therefore, the Strategy sets the task of the priority development of the
transport infrastructure of Eastern Siberia and the Far East of Russia, primarily the Trans-Siberian and Baikal-Amur Mainlines, the Northern Sea Route, seaports, border crossings and approaches to them, which should ensure the development of production for production, processing and transportation of natural resources and implementation of the country's transit potential.

2. Materials and methods
The analysis of the works of scientists and specialists in the transport industry [1-20 and others], given in [21-25], showed the particular relevance of the problem of developing transport infrastructure to ensure multimodal transportation along international transport corridors and confirmed the need to develop a design methodology for the integrated development of a multimodal transport network (MTN) [21, 22] (hereinafter the methodology).

The methodology is a scientifically grounded tool for solving the strategic tasks of transport development in Russia, set in the Strategy. These tasks are very difficult due to their large size. Their solution is also significantly complicated by the unstable economic and international geopolitical situation.

In this regard, it can be concluded that there is a need for scientific and methodological support for the implementation of the tasks of the Strategy.

To reduce the dimension of Strategy tasks, the methodology proposes to form a multimodal transport network from objects of a single transport network (ETN) as a set of multimodal transport corridors (MTK).

The methodology was developed and outlined in [21-25]. Its enlarged functional structure is represented by the following stages:

1. The formulation problem of design the development of the MTN.
2. Formation of the MTN shape variants.
3. Formation a set of possible strategies for stage-by-stage changes in the appearance and power of the MTN objects.
4. Formation of an area of effective strategies for stage-by-stage changes in the appearance and power of the MTN.
5. Choosing the optimal solution from the field of effective strategies, taking into account the accepted restrictions.
6. Support for the implementation of the adopted strategy.

The authors applied the methodology to solve the problem of the formation and development of a regional multimodal transport network in Eastern Siberia and Far East of Russia (hereinafter - RMTN). The authors' attention to this region is due to the fact that:

- Siberia and Far East of Russia is considered in the Strategy as a territory of large-scale projects focused on the production, processing and transportation of the richest reserves of natural resources of global importance, the main share of which is hydrocarbons;
- main competitive advantages of the Russian transport system are: i) the shortest land routes between the countries of the Asia-Pacific region and Europe; ii) the presence of an extended sea coast.

These factors determined the formulation of the problem of designing the development of the RMTN (the first stage of the methodology):

We form an RMTN and define effective strategies for a stage-by-stage changes in its appearance and power, ensuring:

1. advance development of transport infrastructure in the areas of export deliveries of goods, primarily the development of seaports and approaches to them;
2. realization of the country's transit potential.

At the second stage of the methodology, the RMTN shape variant was formed according to the set-theoretic representation in [21]:

$$MTN = \{MTK, E, C, H\},$$  \hspace{1cm} (1)

where $MTK$ is the set of multimodal transport corridors;
\[ MTK = \{ MTK_k \}, \quad k = 1,2,...,n_{mtk}, \]  
where \( E \) is the set of technological processes and events that occur on the MTN and affect its technical condition; \( C \) is the set of criteria that characterize the goals of MTN development in accordance with the scenario of socio-economic development of a country or region; \( H \) is the set of relations between \( MTK, E \) and \( C \).

The model of the multimodal transport corridor in [21] is represented by the set of subsets:
\[ MTK_k = \{ MTH_k, ZV_k \}, \quad k = 1,2,...,n_{mtk}, \]
where \( MTH_k \) is the subset of multimodal transport hub included in \( MTK_k \); \( MTH_k \in MTH \); \( MTH \) is the set of multimodal transport hub MTN; \( ZV_k \) is the subset of transport links included in \( MTK_k \); \( ZV_k \in ZV \); \( ZV \) is the set of unimodal and multimodal transport links MTN.

In [21, 27-34], the possible directions of \( MTK \) of the studied region were considered, the points of arose and terminated traffic flow and the territorial location of \( MTK \) were indicated, and the analysis of external and internal factors affecting the formation of RMTN shape variants was given. Using this information and the methods of forming the MTN shape [21], the authors obtained a variant of the RMTN shape as a set of the following \( MTK \) (Figure 1).

Multimodal transport corridors with access to the Trans-Siberian mainline:
1. \( MTK_1 \): Vladivostok multimodal transport hub (VMTH) – Transsib – Tayshet.
2. \( MTK_2 \): Ulan-Bator (Mongolia) – Naushki – Ulan-Ude – Transsib.
3. \( MTK_3 \): Manchuria (China) – Zabaikalsk– Karymskaya – Transsib.
4. \( MTK_4 \): Heihe (China) – Blagoveshchensk – Belogorsk – Transsib.
5. \( MTK_5 \): Tongjiang (China) – Nizhneleninskoe – Birobidzhan – Transsib.
6. \( MTK_6 \): Tumangan (NorthKorea) – Hasan (Russia) – Baranovsky – Transsib.

Multimodal transport corridors with access to the Baikal – Amur Mainline:
7. \( MTK_7 \): Vanino-Sovgavan multimodal transport hub (VSMTH) – Komsomolsk – BAM – Tayshet.
8. \( MTK_8 \): Hokkaido (Japan) – Sakhalin multimodal transport hub (SMTH) – Nysh – Selikhin – Komsomolsk – BAM – Tayshet.
9. \( MTK_9 \): VMTH – Selikhin – Komsomolsk – BAM – Tayshet.

Multimodal transport corridors from China with access to the seaports of the Far East and the Arctic zone of Russia:
10. \( MTK_{10} \): Suifenhe (China) – Grodekovo – VMTH (MTK «Primorye-1»).
11. \( MTK_{11} \): Hunchun (China) – Kamyshovaya – VMTH (MTK «Primorye 2»).
12. \( MTK_{12} \): Mohe (China) – Reinovo – Skvorodino – Tynda – Yakutsk – seaports Tiksi – NSW.
13. \( MTK_{13} \): Fuyuan (China) – Khabarovsk multimodal transport hub (HMTH) – seaports of Samarga.
14. \( MTK_{14} \): Fuyuan (China) – HMTH – seaports of Nikolaevsk on Amur.
15. \( MTK_{15} \): Mishan (China) – Tugiy Rog – Sibirtsevo – Novochuguevka – seaports Olga.

This version of the RMTN shape of the Russian Eastern Siberia and Far East allows us to combine the growth of production, processing and transportation of natural resources of global significance to seaports in the studied region and the realization of the country's transit potential.

According to the methodology, the next stage of designing an integrated RMTN development is the formation of a set of possible strategies for step-by-step changes in the shape and capacity of RMTN’s objects [21-23]. To do this, for the three scenario variants of the Strategy, it is necessary to assign estimated cases in accordance with [21]. In [24], a mathematical model for the formation of estimated cases is proposed. It allows you to take into account the influence of factors that generate uncertainty in the initial information, and determine possible variants for the required volumes of traffic on multimodal transport hubs of \( MTY_k \) and links \( ZV_k \) that are part of \( MTK_k \).
Each estimated case includes:
1. RMTN shape scheme that combines $MTY_k$ and $ZV_k$ of various modes of transport into $MTK_k$.
2. Existing and prospective variant for loading RMTN’s objects by years of the estimated period and directions of movement without taking into account traffic flows through the multimodal transport corridors.
3. Variant of required traffic volumes for each $MTK_k$ by years of the estimated period and directions of movement.
4. Possible volume of attracted investments and tariffs for transport services by year of the estimated period.

Variants of the required traffic volumes through the $MTK_k$ are dependent on scenarios of socio-economic development of the country, studied region and bordering countries, load of RMTN’s objects and potential of RMTN’s multimodal transport corridors.

Figure 1. The design scheme of the shape of RMTN of the Far East and the Arctic zone of Russia
The Strategy has developed three scenarios: inertia, energy and innovation, which take into account the probabilistic scenarios of socio-economic development of the Federal districts of Russia, the development of interregional economic relations and possible changes in the conjuncture of commodity and transport markets. In all scenarios, the tasks of advancing the development of transport infrastructure in the areas of export deliveries of goods and the implementation of the country's transit potential are set.

The Institute for Transport Economics and Development, based on three scenarios, evaluated the prospective volumes of cargo transportation on the Railways of the Siberian and far Eastern Federal districts of Russia and determined the load of objects of RMTN that the authors are studied.

According to the mathematical model for generating estimated cases for determining the variants of required volumes of traffic through $MTK_k$, the potential of RMTN’s multimodal transport corridors should be evaluated.

3. Results

The potential of $MTK$ of RMTN shape variant, proposed by the authors, is limited by the possible capacity of the: Railways of Russian Eastern Siberia and Far East (the two main railway mainlines – Transsib and BAM), railways to seaports and to land border crossings. The capacity of railways is characterized by capacity and carrying capacity and is determined depending on their main technical parameters: the number of main paths; the type of traction; the type of train schedule; the useful length of the receiving-sending station tracks; the weight of the train.

Railway RMTN’s links can be divided into four groups: 1) sections of the Transsib; 1) sections of the BAM and sections connecting Transsib and BAM; 3) sections of railway to seaports and to land border crossings; 4) new railway sections.

The links of the first group ($ZV_{1,2}$, $ZV_{2,16}$, $ZV_{16,14}$, $ZV_{14,22}$, $ZV_{22,42}$, $ZV_{42,30}$, $ZV_{30,31}$, $ZV_{31,39}$) are double-track electrified sections with a possible capacity of 132 pairs of trains per day.

The second group includes the link $ZV_{1,4}$ that includes a double-track electrified section and single-track sections with electric and diesel traction. The remaining links of the second group ($ZV_{6,28}$, $ZV_{28,97}$, $ZV_{97,29}$, $ZV_{14,6}$, $ZV_{30,28}$) are single-track sections with diesel traction. In the future, all links of the second group can be strengthened to double-track electrified railway lines with a possible capacity of up to 132 pairs of trains per day.

In the third group, links ($ZV_{2,Na}$, $ZV_{16-Za}$, $ZV_{14-Re}$, $ZV_{22-Bl}$, $ZV_{42-Ni}$, $ZV_{31-TR}$, $ZV_{39-Ha}$) connect land border crossings to the Transsib, links $ZV_{39-Gt}$ and $ZV_{39-Ka}$ link land border crossings to the VMTH, and link $ZV_{31-33}$ is a continuation of the $MTK_{15}$. The technical condition of links $ZV_{16-Za}$ and $ZV_{39-Ka}$ can be strengthened to a double-track electrified section with a possible capacity of up to 132 pairs of trains per day. The remaining links can be strengthened to single-track electrified sections with a possible capacity depending on the railway line length: 10 km – up to 50 pairs of trains per day; 20 km – up to 40 pairs of trains per day. Link $ZV_{6,66}$ is a single-track section on autonomous traction with a possible capacity depending on the railway line length: 20 km – up to 28 pairs of trains per day; 30 km – up to 21 pairs of trains per day. Link $ZV_{6,66}$ is an element of corridor $MTK_{12}$, the continuation of which will provide access from the Mohe-Reinovo land border crossing to the Tiksi seaport of the Northern sea route.

The new links of the fourth group ($ZV_{66-81}$, $ZV_{97-88}$, $ZV_{88-Ny}$, $ZV_{30-98}$, $ZV_{98-99}$, $ZV_{98-97}$, $ZV_{39-33}$, $ZV_{33-98}$, $ZV_{33,95}$) will mainly pass through undeveloped territory, so it is advisable to consider them as single-track railway sections on autonomous traction with a possible capacity for the railway line length of the stages up to: 20 km – 28 pairs of trains per day; 30 km – 21 pairs of trains per day.

The options considered by the authors for the possible capacity of RMTN railways are summarized in table 1. They represent an assessment of the potential of the RMTN. Without this assessment, it is impossible to determine the variants of required traffic volumes through $MTK_k$ for different scenarios of socio-economic development and load of RMTN’s objects. Also without this assessment, it is impossible to assign the estimated cases for the formation of a set of possible strategies for stage-by-stage changes of shape and capacity of the RMTN’s objects.
Table 1. Potential of the railways of the multimodal transport network of the Eastern Siberia and Far East of Russia

| The links | The main technical parameters | Length of the limiting stages, km | A possible capacity, pairs of trains per day |
|-----------|-------------------------------|-----------------------------------|--------------------------------------------|
| ZV1-2, ZV2-16, ZV16-14, ZV14-22, ZV22-42, ZV42-30, ZV30-31, ZV31-39, ZV1-6, ZV6-28, ZV28-97, ZV97-29, ZV14-6, ZV30-28, ZV16-Za, ZV39-Ka | 2 main paths; electric traction; inter-train interval of 8 min | - | 132 |
| ZV2-Na, ZV14-Re, ZV22-Bl, ZV42-Na, ZV31-TR, ZV39-Ha, ZV39-Gr | 1 main path; electric traction; inter-train interval of 8 min | | |
| ZV6-66, ZV66-81, ZV97-88, ZV88-Ny, ZV30-98, ZV98-97, ZV98-33, ZV39-33, ZV33-98, ZV33-95 | 1 main path; autonomous traction; inter-train interval of 10 min | 10 | 50 |
| | | 20 | 40 |

4. Conclusion
To form a set of possible strategies for staged changes in the appearance and capacity of objects of a multimodal transport network, it is necessary to know their required capacity by years of the billing period [23]. For this purpose, based on the analysis of the scenarios of the socio-economic development of the country, the region under study and the neighboring states, the load of MTN facilities and the MTK potential for each estimated scheme of the appearance MTN, the options for the required freight and passenger traffic according to MTKk are determined and estimated cases are assigned [24].

Further, using the mathematical model of estimated cases, the required traffic volumes for multimodal transport hubs MTYk and links ZVik and the required capacity of MTN objects (railway stations, sections, port terminals, transshipment points from one type of transport to another, etc.) are calculated by the years of the calculation period [21, 24]. Comparing the required capacity of objects with the possible capacity, we assign a set of possible measures to change their technical condition and form possible strategies for stage-by-stage changes in their appearance and capacity [22, 23].

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