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Research paper

Development of Transport in Eastern Regions of Russia

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Abstract

This article considers the issues on forming the Russian transport system, and the impact of distance and climate on the transport development. Special attention is paid to the role of railway transport in the country's transport system, the state and development of rolling stock, and the development of track equipment. Considerable attention is paid to the development of transport and the railway network in the Far East and Siberia.

Keywords: *transport system of Russia, railway transport, development of railway transport, transport in eastern regions of Russia.*

1. Introduction

The transport system created in Russia in the XIXth-XXth centuries is unique by its length and latitude location [1, 15, 26, 27]. It is possible to say that such elements as the Trans-Siberian and Baikal-Amur railroads, the Murmansk-Saint Petersburg railway, and the Norilsk-Dudinka railway are undoubtedly contributions of the Russian engineering thought to the material culture of the mankind [7, 8, 31]. Roads in the Baikal-Amur Mainline construction zone, the Yakutsk-Magadan highway, motorways in Yakutia, the Kola Peninsula, Yamal, Chukotka and Kamchatka were built under extremely difficult conditions. It is possible to say that the transport system created in Russia is unique and it is an important element of the Eurasian transport system.

At the same time, its uniqueness does not indicate to the fact that the transport system of our country does not have internal contradictions in its development and has no problems when functioning. On the contrary, the Russian transport system develops under difficult conditions that are objective and subjective. It has considerable reserves for the growth, but cannot always use them [1, 2, 7, 26, 45] within the historically short time period of 5-10 years. Delay and nonimplementation of many projects create difficulties related not only to functioning of the transport system itself, but also to the development of the entire national economy of the country.

2. Methods

Methodologically this study is based on scientific methods. The authors applied the methods of economic analysis, comparative analysis, average values, as well as the tabular method, and the method of typological grouping.

3. Results

It is possible to indicate the following objective factors that complicate the operation process and further development of the transport system [1, 14]:

1. The spatial length of the Russian territory,
2. The need to build railways and highways in high latitudes, under permanent frost conditions, and
3. The meridional location of most rivers in the north of the country and in Siberia.

It is necessary to single out the following subjective factors that complicate the development of the country's transport network [1, 17, 22, 40]:

1. Permanent shortage of funds allocated for the development of transport,
2. Collapse of the country's economy in the 1990s that had the most negative impact on rail, inland waterways and maritime transport.

The transport is gradually overcoming the crisis consequences, but even today objective and subjective factors restrain its development.

Table 1 shows the current state of the Russian transport (Table 1).

Table 1: Main Indicators of Transport Operation [15]

No. Ser. No.	Indicator	Unit	2010	2015	2016
1	Exploitation length of railroads for general use	thous. km	86	86	86
2	Exploitation length of electrified railroads	thous. km	43	44	44
3	Length of hard-surface roads	thous. km	786	1,154	1,162
4	Length of internal waterways	thous. km	101	102	101
5	Freights transported by railway	mln. t	1,312	1,329	1,325
6	Freights transported by highway transportation	mln. t	5,236	5,041	5,138

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7	Railway turnover	bln. t-km	2,011	2,306	2,344
8	Highway turnover	bln. t-km	199	232	234

The data of the table show that in 2010-2016 the development of the transport system slowed down. Thus, the volume of the freights transported by railway increased by 0.99%, and the that of the goods transported by road decreased by 1.88%. It follows from the table [15] that railway remains the main means of transport in the country, although the volume of freights transported by road is constantly growing, but the role of railway in the freight turnover is more significant because this type of transport is used to transport freights for long distance [37], the freight turnover of railway increased [in 2010-2016] by 16.55%, which, if the railway network does not develop, inevitably causes the overloading of transport and results in the disruption of the traffic schedule and an increase in the number of accidents [9, 17, 18, 20].

The two most important elements of the transport system are the communication routes and vehicles [3, 12, 33, 44]. Table 2 shows the results of considering the issue on the development of the communication system in Russia in 2010-2016 (Table 2).

Table 2: Main Indicators of Transport Operation [15]

No. Ser. No.	Indicator	Unit	2010	2015	2016
1	Exploitation length of railroads for general use	thous. km	86	86	86
2	Length of automobile roads, total	thous. km	1,004	1,643	1,659
3	Length of federal automobile roads	thous. km	50	52	52
4	Length of regional automobile roads	thous. km	450	474	472
5	Length of local automobile roads	thous. km	164	520	530
6	Length of main gas lines, total	thous. km	167	178	179
7	Length of main oil pipelines, total	thous. km	49	55	54
8	Length of internal waterways	thous. km	101	102	101
9	Length of internal waterways with the guaranteed track	thous. km	48	49	49

The table shows that Russia intensively constructs roads. For 2010-2016 the length of motorways increased by 655 thousand km [or by 65.23%]. At the same time it is necessary to note that the railway network in the country did not develop. This creates difficulties in the turnover of a wide range of goods, because the pipeline network [1, 15, 27] developing intensively allows transporting only gas, oil, and [limited oil products and coal]. In addition, pipelines are mainly export-oriented and, consequently, have little effect on the reproduction process in Russia. Our country has an extensive river network [5, 15] [the disadvantage of which is the meridional orientation of many large rivers of the North and Siberia] that is little used. The internal water transport has been suffering crisis since 1990. The country does not use the opportunities of coastal sea shipping [15, 27] that has great objective prospects for development, especially on the seas of the Pacific and the Arctic Oceans.

To summarize, the Russian transport system is developing, the state strives to overcome the permanent arrears in the construction of highways [1, 15, 14], the inadequate length of which suppressed the country's economic development during the entire 20th century. At the same time, insufficient attention to the development of railways causes overstrain in the operation of railways [4, 9, 15, 21, 23, 44], and the deterioration of the track and rolling stock. The decline of internal waterways and sea transport is wholly related to the economic breakdown in the 1990s, and the wish to get momentary benefit [8, 40] while shifting all costs to the consumer.

Table 3 shows the means of transport that are available in our country (Table 3).

Table 3: Means of Transport [15] (thous. units, as on the end of the year)

No. Ser. No.	Indicator	Unit	2010	2015	2016
1	Operating rail freight cars	thous. units	328	406	389
2	Commercial cars	thous. units	5,414	6,230	6,300
3	Sea freight transport and non-transport vessels	thous. units	2.70	2.70	2.68
4	River freight transport and non-transport vessels	thous. units	29.0	15.6	22.1

The means of transport that are available in the country are being currently reconstructed [13, 36, 39, 40, 43]. The rate of growth of trucks has decreased [which was characteristic for the early 2000s], the number of freight railroad cars has stabilized and even decreased somehow [21, 22, 25, 42]. The number of sea vessels is gradually being restored. The locomotive park is also being improved and reconstructed [9, 20, 31, 34, 37].

4. Discussion

Let us summarize the preliminary results. After the collapse of the Soviet Union, functioning of the country's transport system became more complicated. Internal waterways and partially sea transport almost stopped their activity. Railways are not developed. This creates problems related to functioning of the Russian transport system, which are supplemented by the lack of roads [highways and railways] or their extreme limitations in the eastern regions of the country and in the north [15].

Speaking about the transport operation in the eastern and northern regions of the country, it is necessary to emphasize the following: the territory to the Volga and the north of the Vologda Region is fully developed [in terms of transport]. Other Russian territories can be divided into:

1. Partially developed territories,
2. Territories that are not developed in terms of transport.

Of course, the territory of the Southern Ural, the South of the Middle Ural, Kuzbass, Tatarstan and Bashkortostan are developed in terms of transport, but the area of the eastern and northern regions of the country exceeds 12 mil. sq. km. On this territory of the country there is the Trans-Siberian Railway, the Baikal-Amur Mainline [the development of which has not yet been completed], the Saint Petersburg-Murmansk and Kotlas-Vorkuta railways. It is also necessary to mention such an important fact that a part of the Trans-Siberian Railway goes across Kazakhstan [16]. It is necessary to emphasize that in the eastern regions of the country the role of railway transport only increases due to the underdevelopment of road transport in these areas [14, 15], and destruction and difficult weather conditions for the operation of internal water and sea transport.

The data on the density of roads and railways in federal districts of Russia objectively show the state of transport in the eastern regions (Tables 4, 5).

Table 4: Density of Hard-Surface Roads for General Use by Federal Districts [1, 15] (as on the end of the year km., per 1,000 sq. km)

No. Ser. No.	Indicator	Unit	2010	2015	2016
1	Russian Federation	km	39	61	62
2	Central Federal District	km	232	349	355
3	North-West Federal District	km	45	61	62
4	Southern Federal District	km	132	227	229
5	North Caucasus Federal District	km	221	392	394
6	Privolzhye Federal District	km	150	226	227
7	Ural Federal District	km	23	39	40
8	Siberian Federal District	km	21	35	35
9	Far Eastern Federal District	km	6.1	9.5	9.5

Table 5: Density of Railways by Federal Districts [1, 15] per 1,000 sq. km of Territory (km)

Ser. No.	Federal District	2010	2015	2016
1	Russian Federation	50	50	50
2	Central Federal District	261	262	262
3	North-West Federal District	78	78	78
4	Southern Federal District	154	160	160
5	North Caucasus Federal District	124	123	123
6	Privolzhye Federal District	142	142	142
7	Ural Federal District	47	47	47
8	Siberian Federal District	28	28	29
9	Far Eastern Federal District	13	14	14

Let us analyze the data from the tables. The length and density of highways have increased in the country. For 2010-2016 the density of highways in Russia increased by 58.97%, while the density of railways remained unchanged. Cities and settlements of the Central, Southern, North Caucasian and Privolzhye federal districts have enough mainlines and roads. The territory of the North-West and Ural districts has less motor roads. The Far Eastern Federal District [15], which is the "face" of Russia in the Asia-Pacific region, has too few highways. Meanwhile, production, trade routes, financial and information centers are transferred to the shores of the Pacific Ocean [24, 26, 32, 41]. It is enough to look at the changes in the location of industry in the USA and Canada in order to make these conclusions – such states as California and Washington become new industrial, financial and information centers. The states located in the mountains also strive for the commodity exchange in the Pacific Ocean and develop rapidly. Alaska is intensively developed. Such provinces as British Columbia and Alberta have become a new production and financial center of Canada. The turnover of Chinese ports has achieved gigantic volumes [10]. The turnover of Japanese and South Korean ports is significant. The freight turnover of Russian ports of the Pacific basin is represented by the following indicators [as on 2017]: [11] Eastern – 69.2 mln. t., Vanino – 29.2 mln. t., Nakhodka – 24.2 mln. t., Prigorodnoe – 17.4 mln. t., Vladivostok – 16.9 mln. t., Posiet – up to 7.7 mln. t., and De-Kastri – up to 10.8 mln. t., making up 175.4 mln. t. The turnover of the largest ports of East Asian countries is much higher [as on 2014]: Shanghai – 678.4 mln. t., Singapore – 581.3 mln. t., Guanjou – 501.0 mln. t., Qingdao – 465.0 mln. t., Pusan –335.4 mln. t., and Nagoya – 207.6 mln. t.

It is quite clear that in order to adequately participate in the international division of labor that was formed in a dynamically developing Asia-Pacific region, our country needs to:

– Gradually develop the port economy, build new piers, put new container terminals into operation, increase capacities for the export of coal and oil [24, 26, 32, 41],

– Develop a land transport system, create new railways and highways in the eastern region, increase the traffic capacity of the existing highways, and increase the number of crossing points on the border with China and North Korea [26, 41],

– Build a bridge to the island of Sakhalin, build the Sakhalin-Hokkaido bridge [35],

– Develop transport logistics in Siberia and in the Far East, introduce a polygon control system in the railway transport of the Siberian and Far Eastern Region, increase the number of heavy trains weighing 6,000, 9,000 and 12,000 tons [6, 19, 30, 31, 39], and

– Bring the Baikal-Amur Mainline to its designed capacity [31].

To sum it up, today the Far Eastern region has an undeveloped infrastructure, the capacity of ports created in the Far East is lower than the trade turnover of the largest ocean ports of China, Korea and Japan [41]. The undeveloped network of railways and highways, as well as crossing points, high railway tariffs and conservative logistics schemes prevent a considerable increase in the Russian trade turnover with its eastern neighbors and the construction of the "East Asia-Western Europe railway bridge" [32, 41]. It is necessary to considerably expand the transit capacity of the Trans-Siberian and the Baikal-Amur Mainline, the South Yakut Railway [7, 26, 31, 41], to increase the traffic capacity of roads in the region, the Yakutsk-Magadan highway, and to extend the network of highways in the north of the Khabarovsk Territory and in the Magadan Region.

It is necessary to develop the transport network in the Far East, however, it is not enough. Our country needs to expand railway construction to the east of the Volga River and in the north of the European part of Russia. According to the author, it is necessary to start designing the following railways:

– Nadym-Salekhard and Arkhangelsk-Pechora,

– Perm-Surgut, Nizhnevartovsk-Lesosibirsk,

– Lesosibirsk-Ust-Ilimsk, and

– To prolong the Baikal-Amur Mainline to Nikolaevsk-on-Amur, and make Nikolayevsk an export-oriented port.

Design and the further laying of the above mainlines will allow our country [and to be more exact, the country's transport system] to solve the following tasks:

– To improve the transport capabilities of the European north, the Northern Ural, the Lower Ob, which will create new opportunities to develop the Arctic,

– The construction of the Perm-Lesosibirsk highway will be the basis for creating the "northern copy" of the Trans-Siberian Railway, and the "western supporter" of the Baikal-Amur Mainline; in the long term, it is necessary to connect the Lesosibirsk-Ust-Ilimsk highway with the BAM and thus create a "Central Siberian Railway Corridor" that will allow trains from Perm [and, respectively, northwestern and central regions of Russia] to go to Nikolaevsk-on- Amur, passing the Trans-Siberian Railway.

The extension of seaports in the Far East, the increase in the capacity of the constructed railway and highway routes, the construction of new "northern" and "Central Siberian" roads will allow our economy to solve the following tasks:

– Russia will be friendly to a dynamically developing Asia-Pacific Region]; it will create all necessary prerequisites for the rapid development of the East of Russia and the country's economy as a whole,

– Real prerequisites will be created to create the "East Asia – Western Europe" transport bridge [28, 29, 38].

5. Conclusion

The results obtained during the study show that the railway transport is still the main type of transport in the modern Russia. For the last 30 years, the network of railways in the country has almost not been developed. The eastern and northern regions of the country are much worse equipped with the railway network than the central regions, the south and the Povolzhye. At the same time, the state has set new tasks to develop Siberia and the Far East. The offered projects need adequate transport, including railway support. To successfully develop the Asian part of the country, and to form a modern logistics complex in the Far East, it is necessary to develop a transport network in Siberia.

It is necessary to consistently develop the port economy, to put new container terminals into operation, to increase the capacities for the export of coal and oil, to develop the land transport system, to create new railways and highways in the eastern region, to build a bridge to the Sakhalin island, to build the Sakhalin-Hokkaido bridge, to develop transport logistics in Siberia and the Far East, to introduce a polygon control system in railway transport, and to bring the Baikal-Amur Mainline to its designed capacity. It is necessary to expand the railway construction eastward of the Volga and in the North of the European part of Russia, to start designing the following railway routes: Nadym-Salekhard and Arkhangelsk-Pechora, Perm-Surgut, Nizhnevartovsk-Lesosibirsk, Lesosibirsk-Ust-Ilimsk, to prolong the Baikal-Amur Mainline to Nikolaevsk-on-Amur, and to create real prerequisites for the construction of the "East Asia-Western Europe" transport bridge.

The task of the economic science is to add dynamism to the qualitative changes that are being already formed in the management of the transport system of the country, and primarily in its railway

transport. The development of logistics in transport, the introduction of new management methods, and the development of digital technologies will reduce the costs for the development of the transport system and will contribute to its qualitative improvement.

References

[1] Alexandrova N.B., Pisareva I.N. *Organizatsiya vagonopotokov* [Organization of car traffic volume]. SGuPSa Publishing House, Novosibirsk, (2017), 105 p.

[2] Barrow K. (2017) Eco Train explores new routes to sustainable traction. *International Railway Journal,* No. 3 (57), pp: 40-42.

[3] Briginshaw D. (2017) Plasser unveils bi- mode track machines. *International Railway Journal,* No. 7. pp: 18.

[4] CE transportation to end locomotive production on Erie. *International Railway Journal,* No. 9 (2017). pp: 8.

[5] Dedyukina N.V. (2017) *Otsenka riskov biznes-struktur promyshlenno-transportnogo kompleksa* [Assessing risks of business structures of the industrial and transportation complex]. Saint Petersburg, FGBOU HE PGUPS, 52 p.

[6] Dudyshko P., Kuzokhmetova E. (2017) Proyektirovaniye vysokoskorostnykh sovmeshchennykh avtomobilnykh i zheleznykh dorog [Designing high-speed combined roads and railroads]. *The world of Transport*, No. 3, pp: 152-159.

[7] *Finansovyye rezultaty upravleniya kachestvom transportnogo obsluzhivaniya* [Financial results of transport services quality management] // by edit Sokolov I. I., Lavrov I. M. Magnitogorsk, (2017).

[8] Fomina Z. A. (2017) *Elektrosnabzheniye zheleznykh dorog* [Electricity supply of railways]. M., 222 p.

[9] Goloskokov V. N. (2017) Poligonnyye tekhnologii otkryvayut novyye vozmozhnosti [Polygon technologies offer new opportunities]. *Railway Transport*, No. 6, pp: 17-20.

[10] Gruzooborot krupneyshikh mirovyh portov [Freight turnover of the world's largest ports]: https://en.wikipedia.org/wiki.

[11] Gruzooborot krupneyshikh portov Rossii [Freight turnover of the largest ports of Russia]: http://portnews.ru/news/251806/.

[12] Guo, R & Guo, J & Su, Y. (2017). Heuristic Rules of Multistage Optimization Algorithm for Wagon-flow Allocation in Marshaling Station. Tiedao Xuebao/Journal of the China Railway Society. No. 39 (6), pp: 7-9.

[13] Haag S., Eller M., Gratzfeld P. (2017) Metodical design of a vybrid propulsion for Short – distance railcars. *Elektrische Bahnen*. 115 No. 5, pp: 230-237.

[14] *Informatsionnoye obespecheniye gruzovykh perevozok* [Information support of freight traffic]. Rostov-on-Don, FGBOU IN RGUPS, 2017, 75 p.

[15] Kariakin V. I. (2017) Vektory innovatsiy [Vectors of innovation]. *Locomotive,* No. 2, pp: 6-10.

[16] Karta zh/d dorog Rossii [Map of the Russian railway]. http://www.tdesant.ru/info/item/194.

[17] Kompleksnaya sistema tekhnicheskogo obsluzhivaniya i remonta lokomotivov s primeneniyem innovatsionnykh tekhnologiy [Integrated system of maintenance and repair of locomotives by using innovative technologies]. *Railway Transport*, 2017, p. 30-36.

[18] Kondratova E.P. (2017) *Finansovo-ekonomicheskiye aspekty vosproizvodstva osnovnyh fondov zheleznodorozhnogo transporta* [Financial and economic aspects of reproducing fixed assets of railway transport]. Khabarovsk, DVGUPS Publishing House.

[19] Kozak V.N. (2017) *Obespecheniye gruzovykh perevozok na zheleznodorozhnom transporte* [Ensuring freight transportation by railway]. Rostov-on-Don, FGBOU HE RGUPS, 228 p.

[20] Levin D.Yu. (2017) *Ekspluatatsionnaya rabota zheleznykh dorog* [Operational work of railways]. M., INFRA-M, 232 p.

[21] Levin D.Yu. (2017) *Potrebnosti v perevozkakh i vozmozhnosti zheleznykh dorog* [Needs in transportation and railways possibilities]. M., INFRA-M, 247 p.

[22] Levin D.Yu. (2017) *Upravleniye ekspluatatsionnoy rabotoy na zheleznodorozhnom transporte* [Management of operational work in railway]. Rostov-on-Don, Feniks Publishing House, 542 p.

[23] *Logisticheskoye rukovodstvo zheleznodorozhnym transportom* [Logistics management of railway transport]. Kazan, Book Publishing House, 2017, 264 p.

[24] Macheret D., Macheret J. (2017) Problemy transportnogo obespecheniya severnykh regionov [Problems of transport security in the northern regions]. *The World of Transport*, No. 2. pp: 98-103.

[25] Maklygin N.V. (2017) 120 let v puti (Dalnevostochnaya zheleznaya doroga) [120 years on the road (Far Eastern Railway)]. *Railway Transport,* No. 9, pp: 4-9.

[26] *Nekotoryye aspekty upravleniya kachestvom transportnoy korporatsii (na primere OAO RZHD)* [Some aspects of managing quality of the transport corporation (through the example of JSC RZD)]: collective monograph. Pero, Moscow, (2017), 220 p.

[27] *Obobshcheniye mirovogo opyta tyazhelovesnogo dvizheniya* [Generalization of the world experience of heavy traffic]. Moscow, (2017).

[28] Osminin A.G., Sotnikov Ye.A. (2017) Osnovnyye faktory i usloviya perekhoda na poligonnuyu sistemu upravleniya [Main factors and terms and conditions for the transition to the polygon control system]. *Railway Transport*, No. 5, p.22-27.

[29] Perue Herbert (2017) China s giant weighs info the US market. *Trauways and Urban Transit*, 80 No. 951, pp: 96-99.

[30] Pikalin Yu.A., Rachek S.V., Semina O.V. (2016) Ekonomika i upravleniye modernizatsiyey podvizhnogo sostava na zheleznodorozhnom transporte [Economics and management of the modernization of railway rolling stock]. Yekaterinburg, 175 p.

[31] *Podvizhnoy sostav XXI v.: idei, trebovaniya, proyekty* [Rolling stock of the XXI century: ideas, requirements, projects]. Saint Petersburg, (2017).

[32] Pokrovskaya O.D. (2017) Klassifikatsiya obyektov zheleznodorozhnoy terminalno-skladskoy infrastruktury [Classification of railway terminal and warehouse infrastructure]. *Bulletin of UrGUPS*, No. 1, pp: 70-83.

[33] Pressure relief valve. Kelso Technologies Inc, La Groix Barry.

[34] Prokhorov V., Alyaba N. (2017) Razvitiye logisticheskikh tsentrov v stranakh Aziatsko-Tikhookeanskogo regiona [Development of logistics centers in the countries of the Asia-Pacific region]. *Logistics*. No. 7, pp: 26-29.

[35] Proyekt mosta na o. Sakhalin [Project of the bridge to Sakhalin]: https://en.wikipedia.org/wiki/.

[36] Shcherbak P.N. (2017) *Rekonstruktsiya i usileniye zheleznodorozhnoy infrastruktury* [Reconstruction and strengthening of the railway infrastructure]. Rostov-on-Don, 92 p.

[37] Simko J. F. (2006) *Swivel deck system for flatcar loading and unloading*. MPK B65g 67/04 (2006.01), B 61D47/00 (2006.01).

[38] Sinitsyna A., Delz S., Ko Levi Co. (2017) Iz Rossii v Kitay cherez Iran i Myanmu [From Russia to China through Iran and Myanmar]. *Logistics*, No. 4, pp: 32-36.

[39] Skachkov A.A. (2017) Kurs na povysheniye effektivnosti raboty (Zabaykalskaya zheleznaya doroga) [Course on increasing the efficiency of work (Trans-Baikal Railway)]. *Railway Transport*, No. 7, pp: 12-19.

[40] Smith K. (2017) Britain cancels major electrification projects. *International Railway Journal,* No. 9 , pp: 8.

[41] *Sovremennyye problemy sovershenstvovaniya raboty zheleznodorozhnogo transporta* [Modern problems of improving the work of railway transport]. Moscow, Russian University of Transport (MIIT), 2017, 216 p.

[42] Swedish government approves Malmo Lund four tracking. *International Railway Journal*, (2017), No. 1. pp: 62.

[43] Tsujie M., Yoshioka A., Mizutani Y., Terumichi Y. (2017) A study on the modeling for predicting worn profile of rail with multi-body dynamics and the verifying the validity. *Transactions of the JSME* (in Japanese), Vol. 83, Issue 854, pp. 17-00074.

[44] X.J. Zhao, J. Guo, H.Y. Wang, Z.F. Wen, Q.Y. Liu, G.T. Zhao, W.J. Wang (2016) Effects of decarburization on the wear resistance and damage mechanisms of rail steels subject to contact fatigue. *Wear*, Vol. 364-365, pp: 130-143.

[45] Zakharov A.O., Kulabukhov A.S., Rudnev V.S. & Kudelkin I. N. (2017) Perspektivnyy teplovoz dlya BAMa [Promising diesel locomotive for Baikal-Amur Mainline]. *Locomotive*, No. 4, pp: 42-43.