Analysis of reliability and sustainability of organizational and technical systems of railway transportation process

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Abstract. The increase in the throughput and processing capacity of railway stations in many cases is solved through organizational and technical measures, which makes it possible to solve this problem only partially, while limiting the possibility of increasing the volume of work in the future. Private funds should become investors in the creation of specialized points for bulk staging and preparation of station cars. Car owners and manufacturers, leasing companies, and rolling stock operators are interested in creating this type of stations. The layout of the stations specialized for the car staging should ensure the implementation of a complex of processing operations: reception, sorting, dispatch, technical inspection, all types of maintenance and repair. The article presents the dynamics of the throughput capacity of the East Siberian Railway. It analyzes the indicator under consideration with parallel and non-parallel schedules, which determined the main factors affecting the throughput capacity of railway stations and sections of the East-Siberian Railway and the degree of their significance. To determine the main technical reasons for reducing the throughput capacity of railway stations and improving the quality of use of the indicator in question, the Ishikawa diagram was constructed. It provides a systematic approach to determining the root causes of the problem under consideration based on data on the throughput capacity of railway stations in Russia in 2013-2015. The analysis of the Ishikawa diagram identified the main factors: mismatch in the level of development of the federal railway network; errors in the management of car fleets; excess of car fleets; non-uniform arrival of car traffic volumes; decrease in the quality of car fleet management; private car fleet growth.

1. Introduction
The possibility of the increase in the throughput and operational capacity indicators of railway stations and hubs is currently solved in most cases, primarily through organizational and technical measures that do not require significant financial investments. Reconstructive measures related to capital investments in the construction of new fixed assets, to the construction and technical equipment of the arrangement of structural units of the industry are generally not to be considered. This technical and economic approach solves the problem only for today, while limiting the possibility of increasing the volume of work and activities of most railway stations in the future.

In the face of strong and open opposition to the accelerated development of Russia by the West and economic stagnation, the creation of a modern transport infrastructure can give an additional impetus to the development of the country. This area will most likely stimulate the development of the real sector of the economy, small and medium-sized businesses and result in the development of new areas of residence. For stable and rapid development of the country, investments in the railway transport system should be made at a faster pace.
According to statistics, the current situation is such that at least 80% of railway stations in the trunk lines do not have the sufficient track arrangement [1-4]. The experience of other countries shows that it is necessary to strengthen the technical equipment of transport structural units during a decrease in freight traffic or until the time when the load on the equipment of the stations approaches a critical level [5-7].

The relevance of the problem under study consists in the excess of the rolling stock, which leads to an increase in the load on the railway transport system and to a decrease in the throughput capacity of railway stations and hubs. The problems of insufficient capacity of the public and private tracks in loading and unloading areas become exposed.

2. Throughput capacity and its research

The dynamics of the throughput capacity of the East Siberian Railway (hereinafter referred to as the ESR) by sections: Zaudinskiy – Ulan-Ude, Ulan-Ude – Mysovaya, Tulun – Nizhneudinsk, Tayshet – Yuryt is represented in Figs. 1 and 2.

The dynamics of the throughput capacity of railway hauls with the parallel and non-parallel schedule is represented in Tables 1 and 2, and also in Figures 1, 2, 3 and 4.

The analysis of Table 1 and Figure 1 allows concluding that the indicator in question with the parallel schedule in the out direction has an unstable dynamics in the studied areas. In 2014, no changes occurred in relation to the base at the sections. In 2015, compared with the previous one, the throughput capacity of the railway hauls increased only in two of four sections: in the Zaudinsky - Ulan-Ude section by 12.409% (or 17 trains) and in the Tulun – Nizhneudinsk section by 11.382% (or 14 trains), while in the other two sections the indicator decreased by 20.13% (or by 31 train).

Using the data listed in Table 1 and Fig. 2, we can conclude that in 2014 relative to 2013, the throughput capacity with a parallel traffic schedule in the “return” direction underwent a change only in the Ulan-Ude - Mysovaya section, namely, the indicator grew by 25.203% (or by 31 trains). In 2015,
compared with 2014, the throughput capacity at the three sections under consideration decreased: by 20.13\% (or 31 trains) at Zaudinsky - Ulan-Ude, by 11.039\% (or 17 trains) at Ulan-Ude - Mysovaya and Tulun - Nizhneudinsk. Despite this, the indicator grew by 11.382\% (or 14 trains) in the Taishet - Yurty section.

Table 1. Throughput capacity of railway hauls with a parallel traffic schedule in the out direction.

| Section name          | Year 2013 | Year 2014 | Year 2015 |
|-----------------------|-----------|-----------|-----------|
|                       | out return| out return| deviation by 2013,\% | actual | deviation by 2013,\% | actual | deviation by 2014,\% | actual |
| Zaudinsky - Ulan-Ude  | 13 7      | 154 13 7  | 10 4 123 | 112.40 9 | 79.870 112.40 9 |
| Ulan-Ude - Mysovaya   | 15 4      | 123 15 4  | 10 3 125.20 | 111.38 2 | 79.870 88.961 79.870 88.961 |
| Tulun - Nizhneudinsk  | 12 3      | 154 12 3  | 10 3 137 11.38 2 | 88.961 11.38 2 |
| Taishet - Yurty       | 15 4      | 123 15 4  | 10 3 137 79.870 2 | 79.870 111.38 2 |

Table 2. Throughput capacity of railway hauls with a non-parallel traffic schedule.

| Section name          | Year 2013 | Year 2014 | Year 2015 |
|-----------------------|-----------|-----------|-----------|
|                       | out return| out return| deviation by 2013,\% | actual | deviation by 2013,\% | actual | deviation by 2014,\% | actual |
| Zaudinsky - Ulan-Ude  | 89 92     | 96 118    | 107.86 5 128.26 1 11 85 131.46 1 | 92.391 121.87 5 72.034 |
| Ulan-Ude - Mysovaya   | 10 4      | 106 106   | 96.154 6 123.25 93 105 89.423 122.09 3 93.000 99.057 |
| Tulun - Nizhneudinsk  | 58 77     | 60 96     | 103.44 8 124.67 99 104 170.69 0 135.06 5 |
| Taishet - Yurty       | 11 6      | 12 90     | 106.03 4 112.50 89 101 76.724 126.25 0 72.358 112.22 2 |

The analysis of Figure 3 shows that the throughput capacity of railway hauls with the non-parallel schedule in the out direction has been changing non-uniformly for three years. So in 2014, in relation to the base in the Zaudinsky - Ulan-Ude section, the indicator grew by 7.865\% (or 7 trains), as well as in the Tulun - Nizhneudinsk sections by 3.448\% (or 2 trains) and Taishet - Yurty by 6.034\% (or 7 trains). In 2015, compared with the previous one, the throughput capacity of the railway hauls increased only in two of four sections: in the Zaudinsky - Ulan-Ude section by 21.875\% (or 21 trains) and in the Tulun - Nizhneudinsk section by 65\% (or 39 trains). In sections such as Ulan-Ude – Mysovaya and Taishet – Yurty, the index decreased by 7\% (or 7 trains) and by 27.642\% (or 34 trains) respectively.
Figure 3. Throughput capacity of railway hauls with a non-parallel traffic schedule in the out direction.

Figure 4. Throughput capacity of railway hauls with a non-parallel traffic schedule in the return direction.

Having analyzed Table 2 and Figure 4, we can conclude that in 2014, in relation to the base, the throughput capacity of the railway hauls with the non-parallel schedule in the “return” direction increased in all sections: in the Zaudinsky – Ulan-Ude section by 28.261% (or 26 trains), Ulan-Ude - Mysovaya - 23.256% (or 20 trains), Tulun - Nizhneudinsk - 24.675% (or 19 trains), Taishet - Yurty - 6.034% (or 10 trains). In 2015, compared to 2014, in the Zaudinsky - Ulan-Ude and Ulan-Ude - Mysovaya sections, the indicator under consideration decreased by 27.966% (or 33 trains) and 0.943% (or 1 train), respectively. As for the rest of the sections, vice versa, the throughput capacity increased, namely, in the Tulun - Nizhneudinsk section by 8.333% (or 8 trains) and in the Taishet - Yurty section by 12.222% (or 11 trains).

Table 3 and Figures 5, 6 and 7 show the dynamics of the throughput capacity of the stations of the considered sections.

The analysis of Table 3 and Figure 6 showed that in 2014, compared to 2013 increased in two sections: Zaudinsky - Ulan-Ude - 4.673% (or by 5 trains), Taishet - Yurty - 46.269% (or by 31 trains), and in the Zaudinsky - Ulan-Ude and Ulan-Ude - Tulun sections, the indicator in question decreased by 28.205% (or 33 trains) and by 20% (or 21 trains) respectively. In 2015, compared to the previous one, in the Zaudinsky - Ulan-Ude section, the throughput capacity increased by 2.381% (or 2 trains), while in the remaining sections the indicator decreased: Ulan-Ude - Mysovaya – by 1.19% (or 1 train), Tulun – Nizhneudinsk – by 11.607% (or 13 trains), Taishet – Yurt – by 30.612% (or 30 trains).
The study of Table 3 and Figure 7 allowed concluding that in 2014, with respect to the base, the throughput capacity of stations in the Zaudinsky – Ulan-Ude and Tulun – Nizhneudinsk sections decreased by 16% (or 16 trains) and 5.333% (or 5 trains), respectively. Along with this, the indicator increased in two other sections: Ulan-Ude - Mysovaya - 3.70% (or by 3 trains), Taishet - Yurty - 37.736% (or by 20 trains). In 2015, in relation to 2014, the throughput capacity rate decreased in all sections: Zaudinsky - Ulan-Ude - 5.952% (or by 5 trains), Ulan-Ude - Mysovaya - 7.143% (or by 6 trains), Tulun - Nizhneudinsk - 32.394% (or by 46 trains), Taishet - Yurty - 21.92 % (or by 19 trains).

Table 3. Throughput capacity of railway hauls with a non-parallel traffic schedule.

| Section name        | Year 2013 | Year 2014 | Year 2015 |
|---------------------|-----------|-----------|-----------|
|                     | actual    | actual    | deviation by 2013,% | actual    | deviation by 2013,% | deviation by 2014,% |
|                     | out       | return    | out       | return    | out       | return    | out       | return    | out       | return    |
| Zaudinsky - Ulan-Ude| 117       | 100       | 84        | 84        | 71.795    | 84.000    | 86        | 79        | 73        | 79        | 102       | 94        |
|                     | 504       | 000       |
| Ulan-Ude - Mysovaya | 105       | 81        | 84        | 84        | 80.000    | 103.704   | 83        | 78        | 79        | 96        | 98        | 92        |
|                     | 048       | 296       |
| Tulun - Nizhneudinsk| 107       | 150       | 112       | 142       | 104.673   | 94.667    | 99        | 96        | 101       | 107       | 88        | 67        |
|                     | 523       | 000       |
| Taishet - Yurty     | 67        | 53        | 98        | 73        | 146.269   | 137.736   | 68        | 57        | 101       | 493       | 388       | 082       |
Traction power supply is the supply of electric energy to the electric rolling stock. To implement traction power supply in electric railways, electrical installations and devices are used, which include traction substations and traction networks belonging to either the railway or other transport or industrial enterprises. Table 4 and Figs. 8 and 9 show the dynamics of the throughput capacity of traction power supply devices.

The analysis of Table 4 and Figure 8 is indicative of the positive dynamics of the throughput capacity of traction power supply devices in the “out” direction for the duration of the entire period under consideration. So in 2014 compared to 2013, the indicator grew in the Zaudinsky - Ulan-Ude section by 34.043% (or 32 trains), Ulan-Ude - Mysovaya - 5.882% (or 7 trains), Tulun - Nizhneudinsk - 31.25% (or 20 trains), Taishet - Yurty - 13.83% (or 13 trains). In 2015, compared to the previous year, in the Zaudinsky - Ulan-Ude and Ulan-Ude - Mysovaya sections by 21.429% (or 27 trains), Tulun - Nizhneudinsk - by 34.524% (or 29 trains) and there were no changes in the Taishet - Yurty section.

Figure 7. Throughput capacity of traction power supply devices in the out direction.

Figure 8. Throughput capacity of traction power supply devices in the return direction.
Using the data in Table 4 and Figure 9, we can conclude that the throughput capacity of the traction power supply devices in the return direction tends to increase. For three years, the indicator in question increased in the Zaudinsky - Ulan-Ude section by 46.602% (or 148 trains), Ulan-Ude - Mysovaya - by 28.571% (or 37 trains), Tulun - Nizhneudinsk - by 77.273% (or 51 trains), Tayshet - Yurty - by 23.333% (or 21 trains).

Based on the obtained data on the throughput capacity of the locomotive depot and equipment devices, we can conclude that during the period under review there were no changes in the indicator values.

The analysis of the dynamics of changes in the indicator under study identified the main factors, affecting the throughput capacity of railway stations and sections of the ESR and the degree of their significance, a more detailed description of which is given below.

3. Main reasons for the throughput capacity reduction

When describing railway systems, it seems appropriate to use combinatorial structures and their determinant and stochastic estimates [8-12]. We will use a different approach [13-18].

To determine the main actual reasons for reducing the capacity of railway stations [19-24] and improving the quality of use of the indicator in question, the Ishikawa diagram was constructed (Fig. 9). It provides a systematic approach to determining the main causes of the problem under consideration based on data on the capacity of railway stations in Russia in 2013-2015.

![Figure 9. Factors affecting the throughput capacity of railway stations.](image)

The following aspects are identified as the main reasons influencing the capacity of the ESR railway stations: mismatch in the level of development of the railway network (1); lack of promising centralized transportation planning (2); errors in the management of car fleets (3); insufficient available throughput capacity of the polygon network (4); insufficient processing ability of holding sidings (5); excess of car fleets (6); track possessions provided to perform the works on the track overhaul (7); non-uniform arrival of car traffic volumes (8); track profile (9); means for the movement of trains (10); norms of weight and length of trains (11); unpaired movement of trains (12); ratio of passenger and freight train speeds (13); the ratio of running, civil and section speeds (14); maximum permissible speed and its limitations (15); arrangement of intermediate color light signals (16); electrification of railways (17); signaling and communication (18); reduced quality of car fleet operation management (19); private car fleet growth (20); low quality and violation of technology for depot repair and overhaul of rolling stock (21); reduced quality of train inspection (22); high physical depreciation and aging of fixed assets (23); reduction in the number of employees (24); increase in warranty mileage of loaded and empty cars (25); train delay of more than 1 hour due to malfunction of the locomotive (26); failures in the operation of technical
means and equipment (27); poor track maintenance (28); inconsistency of actions of third parties and transport companies (29); low labor and technological discipline, insufficient professional level of personnel, poor knowledge of and non-compliance with regulatory documentation, omissions in the organization of preventive work (30).

The insufficient available throughput capacity of the main transportation directions and the low operating capacity of holding sidings, as well as the excess of car fleets are the consequences of a not very effective strategy for the development of railway transport after the collapse of the USSR. If at the time of the work of the State Planning Commission, rail transport developed in close coordination with the needs of the country's economy, then with the renouncing of centralized planning, especially during the period of a sharp decrease in freight traffic in 1991-1998, there was no strategic planning for the development of the transport network, especially railways. This led to a mismatch between the needs of the economy and the real situation.

Traditionally, the main way to increase the track-carrying capacities of polygons and directions is to increase the mass of the train. This approach has proven effective. For many years it has been widely used in practice. Such an operational indicator as locomotive performance is traditionally one of the main indicators of the operational work quality. Under the conditions of the general locomotive fleet, its significance is indisputable. However, in modern practice, interruptions in the regularity of operation pace of key stations often lead to stops in train traffic volumes [25–28], which leads to a decrease in local speed and locomotive productivity, while the fleet of locomotives sharply increases and, coincidently, there is a shortage of them at the locomotive shift points. The transition to the operation of the locomotive fleet in long circulation journeys seriously increases the price of errors in adjusting the locomotive fleet. The use of technology for handling empty trains with a length of 100 conditional wagons leads to the emergence of oddness. As a result, on the Trans-Siberian Railway there is traditionally an excess of circulation on the eastern borders and, vice versa, a lack of circulation on the western ones.

As the analysis of the Ishikawa diagram shows, from the perspective of the throughput capacity of railway stations, one of the main most significant factors can be distinguished: an excess of car fleets; errors in the management of car fleets; low level of development of the federal railway network; non-uniform arrival of car traffic volume; decrease in the quality of car fleet management; private car fleet growth.

Even a small excess of the rolling stock on private tracks, certain train oversupply in sections leads to disruption of interaction in operational work. Factors associated with congestion in traffic flows and certain oversupply of car fleets in sections and private railways, with the impossibility of sending trains from stations and (or) supplying arriving wagons to stations, as a rule, become the primary cause of the car oversupply at station track capacities.

Since 2009, there has been an increase in the share of the car fleet located on the railways of the Eastern polygon, which is associated with a redistribution of freight traffic. With the growth of the operating fleet located in the common infrastructure, the following main quality indicators deteriorate in the network railways: car turnover; downtime of transit (with and without the yard operation) and local cars; local speed; average daily mileage of locomotives; the number of “abandoned” trains and the train-hours of their delays [1, 29-31]. When establishing operator companies, the registration of the rolling stock was often carried out nominally, i.e. without checking the capacity of the home station layout.

According to the procedure used in railway transport until 1993, any enterprise that wanted to buy freight cars was under an obligation to build additional access roads, both at the loading station and at the unloading station. Now the total fleet is almost 1.1 million cars, but there are no staging tracks for them. It is the rejection of the previous rules that largely explains the current difficulties with the location of rolling stock on the tracks of the railway network stations. The excessive car fleet occupies thousands of kilometres of station tracks. According to various estimates, it is up to 4-5 thousand kilometres. Railway track congested by empty cars of the private fleet of most of the East-Siberian Railway stations interferes with operational work. Private tracks adjacent to the stations are not able to accommodate all
empty cars that have been freed from cargo or awaiting loading, so the bulk of unloaded cars are formed at loading and unloading stations [31-32].

4. Conclusion
In our opinion, to create specialized points for bulk staging and preparation of station cars is the main way to improve the quality of the polygon operational work in the conditions of excess fleet circulation and limitations on the railway network capacity. It is private funds that should invest in the creation of such points. Car owners and manufacturers, leasing companies, and rolling stock operators are interested in creating this type of stations. The layout of the stations specialized for the car staging should ensure the implementation of a complex of processing operations: reception, sorting, dispatch, technical inspection, all types of maintenance and repair.

References
[1] Zhelezov D V 2012 Establishment of stations specialized for bulk staging and preparation of cars as the primary way to improve the quality of polygon operational work under conditions of excess fleet circulation and capacity limitations The Bulletin of the Russian State University of Railway Transport 2 pp 142-150
[2] Vdovin K N, Feoktistov N A, Sinitskii E V, Gorlenko D A, Durov N A 2015 Production of high-manganese steel in arc furnaces. Part 1 Steel in Translation Vol. 45 10 pp 729-732
[3] Vdovin K N, Gorlenko D A, Feoktistov N A 2016 Characteristics of excess phase in cast high-manganese steel Steel in Translation Vol. 46 7 pp 484-488
[4] Vdovin K N, Feoktistov N A, Gorlenko D A 2016 The effect of the cast high-manganese steel primary structure on its properties Materials Science Forum Vol. 870 pp 339-344
[5] Spiess H, & Florian M 1989 Optimal strategies. A new assignment model for transit networks. Transportation Research Part B: Methodological, 23 B (2) 83-102
[6] Yolkin K S, Yolkin D K, Kolosov A D, Ivanov N A, Shtayger M G 2018 Technologies, which allow to reduce an impact of metal silicon production on the environment IOP Conference Series: Materials Science and Engineering 411 012028
[7] Kuzmin O V 2006 Combinatorial methods of modeling discrete distributions (Irkutsk: Irkut. unty Publ.) p 138
[8] Kuzmin O V, Orkina K P 2006 Building error-correcting codes using a Pascal-type triangle The Bulletin of the Buryat State University 13 pp 32-39
[9] Bulatov Y N, Kryukov A V, Suslov K V 2017 Multi-agent technologies for control of distributed generation plants in the isolated power systems Far East Journal of Electronics and Communications Vol. 17 5 pp 1197-1210
[10] Solodusha S, Suslov K, Gerasimov D 2016 Applicability of Volterra integral polynomials in the control systems of electric power facilities International Conference Stability and Oscillations of Nonlinear Control Systems (Pyatnitskiy's Conference) 7541227
[11] Suslov K V, Solonina N N, Smirnov A S 2011 Smart Grid: A new way of receiving primary information on electric power system state IEEE PES Innovative Smart Grid Technologies Conference Europe 6162654
[12] Kolosov A D, Gozbenko V E, Shtayger M G, Kargapol'tsev S K, Balanovskiy A E, Karlina A I, Sivtsov A V, Nebogin S A 2019 Comparative evaluation of austenite grain in high-strength rail steel during welding, thermal processing and plasma surface hardening IOP Conference Series: Materials Science and Engineering 560 012185
[13] Kargapol'tsev S K, Nachigin V A, Frolov V F 2013 Algorithmic support for the assessment of transportation process targets Modern technologies. System Analysis. Modeling 4 (40) pp 152-156
[14] Sivtsov A V, Sheshukov O Y, Tsymbalist M M, Nekrasov I V, Makhnutin A V, Egiazar'y an D K, Orlov P P 2019 Steel Semiproduct Melting Intensification in Electric Arc Furnaces Using Coordinated Control of Electric and Gas Conditions: II. On-Line Control of the State of the
Charge and Melt Zones in Electric Arc Furnaces Russian Metallurgy (Metally) 6 pp 565-569

[15] Sivtsov A V, Sheshukov O Y, Tsymbalist M M, Nekrasov I V, Makhnutin A V, Egiazar'y an D K, Orlov P P 2018 Steel Semiproduct Melting Intensification in Electric Arc Furnaces Using Coordinated Control of Electric and Gas Conditions: I. Heat Exchange and Structure of the Electric Arc Furnace Laboratory Russian Metallurgy (Metally) 12 pp 1108-1113

[16] Nekrasov I V, Sheshukov O Y, Metelkin A A, Sivtsov A V, Tsymbalist M M 2016 Slag conditions in electrosmelting: A review Steel in Translation Vol. 46 6 pp 435-442

[17] Sivtsov A V, Sheshukov O Y, Tsymbalist M M, Nekrasov I V, Egiazar'y an D K 2015 The Valve Effect of an Electric ARC and Problems in Controlling Electric-ARC Furnaces Metallurgist Vol. 59 5-6 pp 380-385

[18] Nekrasov I V, Sheshukov O Y, Metelkin A A, Sivtsov A V, Tsymbalist M M, Egiazar'y an D K 2015 Ensuring Consistent Foamability in Electric-Furnace Slags Metallurgist Vol. 59 3-4 pp 300-304

[19] Sheshukov O Y, Nekrasov I V, Sivtsov A V, Tsymbalist M M, Egiazar'y an D K, Metelkin A A 2014 Dynamic monitoring of slag oxidation and thickness in the ladle-furnace unit Steel in Translation Vol. 44 1 pp 43-46

[20] Abrosimov N V, Ageev A I, Adushkin V V, Akimov V A, et al. 2015 The security of Russia. Legal, socio-economic and scientific-technical aspects. Scientific foundations of technological safety Moscow

[21] Konstantinova M V, Balanovskiy A E, Gozbenko V E, Kargapoltsve S K, Karlina A I, Shtayer M G, Guseva E A, Kuznetsov B O 2019 Application of plasma surface quenching to reduce rail side wear IOP Conference Series: Materials Science and Engineering 560 012146

[22] Guseva E A, Kargapoltsve S K, Balanovskiy A E, Karlina A I, Shtayer M G, Gozbenko V E, Konstantinova M V, Sivtsov A V 2019 Comparative evaluation of corrosion resistance of wheel and rail steels in various media IOP Conference Series: Materials Science and Engineering 560 012181

[23] Grechneva M V, Balanovskiy A E, Gozbenko V E, Kargapoltsve S K, Karlina A I, Shtayer M G, Karlina Yu I, Govorkov A S 2019 IOP Conference Series: Materials Science and Engineering 560 012142

[24] Shtayer M G, Balanovskiy A E, Kargapoltsve S K, Gozbenko V E, Karlina A I, Karlina Yu I, Govorkov A S, Kuznetsov B O 2019 IOP Conference Series: Materials Science and Engineering 560 012190

[25] Kopylova T A, Mikhailov A Yu 2016 Evaluation of the functioning of intermodal nodes of urban passenger transport In the collection: Transport systems of Siberia. The development of the transport system as a catalyst for the growth of the state economy. The International scientific and practical conference pp 528-532

[26] Balanovskiy A E, Shtayer M G, Karlina A I, Kargapoltsve S K, Gozbenko V E, Karlina Yu I, Govorkov A S, Kuznetsov B O 2019 Surface hardening of structural steel by cathode spot of welding arc IOP Conference Series: Materials Science and Engineering 560 012138

[27] Gozbenko V E, Khomenko A P, Kargapoltsve S K, Minaev N V, Karlina A I 2017 Creating of the alternative lubricants and practice of their use International Journal of Applied Engineering Research Vol. 12 22 pp 12369-12372

[28] Chriqui C, Robilland P 1975 Common bus lines Transportation Science 9 pp 115-121

[29] Khomenko A P, Gozbenko V E, Kargapoltsve S K, Minaev N V, Karlina A I 2017 Comparative analysis of simulation results and test of the dynamics of the wheelset International Journal of Applied Engineering Research Vol. 12 23 pp 13773-13778

[30] Kargapoltsve S K, Khomenko A P, Gozbenko V E, Minaev N V, Karlina A I 2017 Development of new lubricants for reducing the wear of the elements of the path and running parts of rolling stock International Journal of Applied Engineering Research Vol. 12 22 pp 12362-12368

[31] Lebedeva O A, Kripak M N 2016 Modeling freight transportation in the transport network The
[32] Sazonov V N, Zagitov E D 2008 Russian Railways need modern effective solutions, not lightweight theories *World Railways* 4