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High-speed railway. Effect of previous successful designers[1]

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ABSTRACT The paper examines the origins of scientific and engineering approaches to design and construction of public railways in the 19th century. The underdeveloped engineering and technologies of the time severely constrained the aspirations of designers and builders to reduce the length of the railway route. The high-speed railways (HSR) that began to be built in the 1960s were created in new engineering and technological conditions. The paper compares the characteristics of a number of railways built in the 19th century and high-speed railways of the 20th century. Some of the major railway lines built in the 19th century have high technical performance, such as a straight route. For example, the parameters of the 650 km long St. Petersburg–Moscow Railway[2] built in 1851 allowed for the arrangement of high-speed traffic (up to 250 km/h) after the reconstruction of its facilities without fundamentally altering the horizontal and vertical alignment.

KEYWORDS: route; railway vertical and horizontal alignments; route development ratio; high-speed railway; rail bypass; slope gradient; HSR; Sapsan EMU

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Доклад

Высокоскоростная железная дорога. Эффект работы предыдущих успешных проектировщиков[1]

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АННОТАЦИЯ Рассмотрено зарождение научно-инженерных подходов к проектированию и строительству железных дорог общего пользования в XIX в. Недостаточное развитие техники и технологии того времени накладывало серьезные ограничения на стремление проектировщиков и строителей сократить длину трассы железных дорог. Высокоскоростные железнодорожные магистрали (ВСМ), строительство которых началось в 1960-е гг., создавались в

[1] The full text of the report presented by the author in a condensed version at the 12th World Congress on High-Speed Rail in Beijing on July 8, 2025.
Полный текст доклада, прочитанного автором в сокращенном варианте 8 июля 2025 г. на XII всемирном конгрессе по высокоскоростному железнодорожному движению в Пекине.
[2] This was the name of the railway before September 8 [20], 1855. After the death of Emperor Nicholas I on February 18 [March 2], 1855, it was renamed Nikolaevskaya. On February 27, 1923, People's Commissar of Railways Felix Dzerzhinsky issued Order No. 1313 that renamed the Nikolaevskaya Railway into the October Railway. This is the only name of a railway in Russia, and one of the few in the world, that is not based on administrative division and/or a geographic location, toponym, or the name of a personality. The October Railway was named after the October Socialist Revolution in Russia that took place on October 25 [November 7 in the new style calendar], 1917. Dates up to January 31, 1918 are given according to the Julian calendar (known as the "old style"); the later dates are given in brackets according to the Gregorian calendar which was introduced in Russia on February 14, 1918 (the so-called "new style").

новых технико-технологических условиях. Приведены сравнительные характеристики ряда железных дорог, построенных в XIX в. и ВСМ XX в. Среди крупных железных дорог, сооруженных в XIX в., есть примеры магистралей с высокими техническими характеристиками, в частности, отличающихся прямолинейностью трассы. Так, параметры построенной в 1851 г. Петербурго-Московской железной дороги длиной 650 км позволили после проведенной реконструкции технических устройств, но без кардинального переустройства плана и профиля, организовать на ней высокоскоростное движение (до 250 км/ч).

КЛЮЧЕВЫЕ СЛОВА: трасса; продольный профиль и план железной дороги; коэффициент развития трассы; высокоскоростная железнодорожная магистраль; железнодорожный обход; крутизна уклона; ВСМ; «Сапсан»

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INTRODUCTION

The construction of railways on a broad scale in England and then in other countries is known to have started with the launch and subsequent successful operation of the Stockton and Darlington, the world's first public railway, on May 27, 1825. The implementation of the project was led by businessman Edward Pease (1767–1858) and outstanding engineer, "Father of Railways", George Stephenson (1781–1848). The success of the railway furthered with the construction of the first fully steam-powered railway between Manchester and Liverpool in 1830.

With the beginning of construction of the first railways in the world, the length of the rail line (the total distance of the main line) has been one of the major parameters, along with the route, vertical alignment, maximum gradient, and minimum horizontal and vertical curve radii. It is not just the length, but the length adjusted by the so-called "route development (elongation) ratio" taken to mean the ratio of the length of the main line to the geodetic line. For Russian railways, the development ratio is taken within the range of 1.1–1.25 for moderate conditions and is increased to 1.5 and higher for severe conditions [1]. The route development ratio is one of the criteria for assessing the quality of the design and survey work performed.

In the early to mid-19th century, when the first railways were built, the designers' efforts to shorten the length of the railway route, bringing it closer to the geodetic line, was strongly constrained by the state of the art in engineering and railway design and construction methods. Curved track sections, often sharp ones, appeared on the route due to the need to bypass natural obstacles, or, in some cases, the impossibility of building bridge or tunnel crossings over water bodies, hills or mountains, or because of excessive building costs. Besides, in the infancy of railway construction, the reduction of the route length was hampered by the low capacity of steam engines unable to overcome steep slopes in the terrain.

Because of all of the factors listed above, the route had to be extended (lengthened) by designing easy gradients with additional curved sections to bypass sharp rises on a hilly or mountainous terrain, which limited the speed of trains — one of the major railway performance parameters.

ERA OF HIGH-SPEED RAILWAYS

The construction of high-speed railways (HSR) in the second half of the 20th century took place in a different engineering and technology paradigm. Designed for travels at speeds exceeding 200–250 km/h, HSR have larger minimum horizontal curve radii — since the 1960s, their values have increased up to 7,000–10,000 m. It necessitated building intersections with other transport lines at different levels, and the number of man-made structures per unit of railway length has increased significantly. As a result, most HSRs built in the second half of the 20th century parallel to the existing railways are shorter than the latter.

For example, on the world's first HSRs Tokaido Shinkansen and Sanyo Shinkansen in Japan built in the 1960–1970s, the length of the line between Tokyo and Kobe stations is 548 km (*Fig. 1, 2*, *Table 1*), while the length of the railway built between the two in the 19th century is 589.5 km (41.5 km longer) [2].

Another example is the Direttissima (Direct Line), a high-speed rail route between Rome and Florence in Italy (built in 1977–1992), which is 238 km long, while the length of the **Linea Lenta** railway between the same cities built in 1871 is 372 km [3].

Nevertheless, the world knows examples of railways built as early as the mid-19th century, their main design solutions still preserving their basic parameters even now, 150–170 years after: the route location, maximum gradient values, minimum curve radii, and others, allowing for accommodating traffic at speeds of 200–250 km/h after upgrading of certain

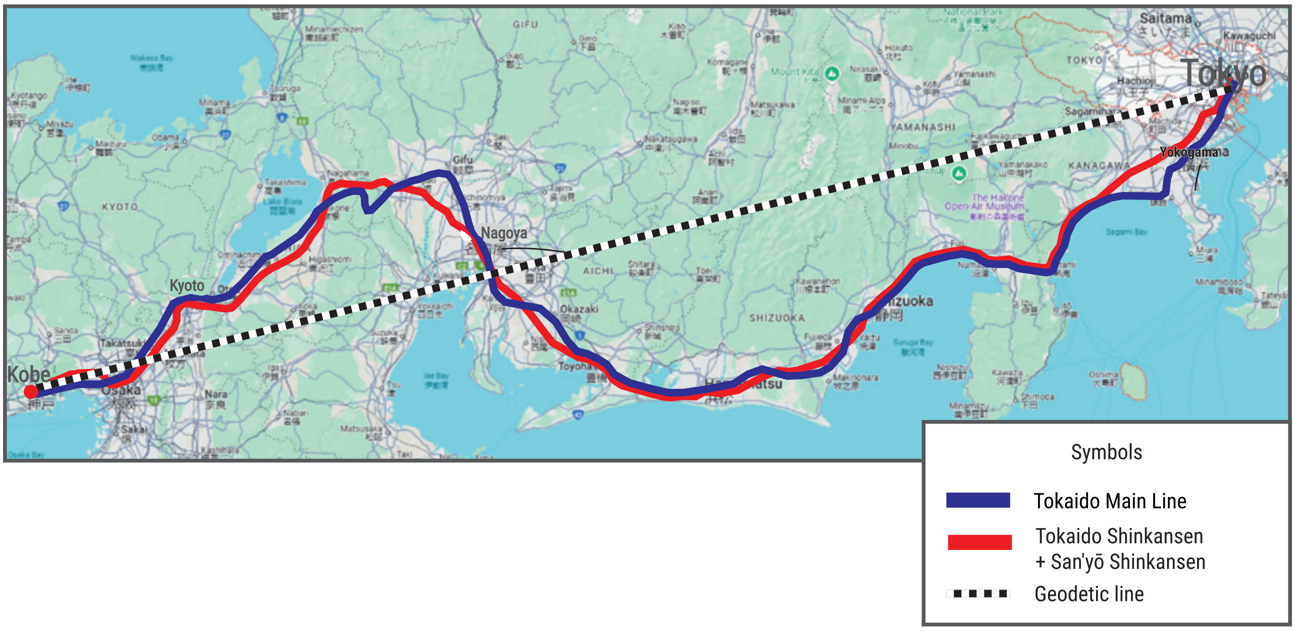

Fig. 1. Comparison ofthe route lengths of the Tokaido Shinkansen and Sanyo Shinkansen HSRs with the geodetic line

Table 1

Length of some railways and HSRs

Railway built before HSR ("Old") HSR	Opening year "Old"	Opening year HSR	Length, km / Route development ratio "Old"	Length, km / Route development ratio HSR	Geodetic length, km	Max. speed, km/h
Tokaido Main Line Tokyo–Kobe [2]	1872		589 ***1.3***		430	75
Tokaido Shinkansen HSR + Sanyo Shinkansen HSR: Tokyo–Kobe [3]		1964–1972		548 ***1.27***		285
Paris–Lyon (Paris–Marseille) [3]	1847		499,8 ***1.27*** ***862***		390.5	100
Paris–Lyon HSR (LGV Sud-Est) [3]		1981		425 ***1.08***		300
Rome–Florence (**Linea Lenta, LL**) [3]	1871		372 ***1.4***		232.3	100
Rome–Florence HSR (Direttissima, DD) [3]		1977–1992		238 ***1.02***		250
Madrid–Barcelona (Atocha Train Station) [3]	1882		699,7 ***1.39***		501.6	80
Madrid–Barcelona HSR (Chamartin Train Station) [3]		2008		620 ***1.23***		350
Beijing–Shanghai (old railway line) [3]	1896–1936–2005	2011	1451 ***1.36***		1060	160
Beijing–Shanghai [3]				1302 ***1.22***		380
St. Petersburg–Moscow (1851) [4]	1851				637.94	1851 – 50 2025 – 250
– 1851–1881			644.4 ***1.01***			
– 1881–2001			649 ***1.02***			
– 2001–present			644.4 ***1.01***			
Moscow–St. Petersburg HSR [5]		Design		679 ***1.07***		360

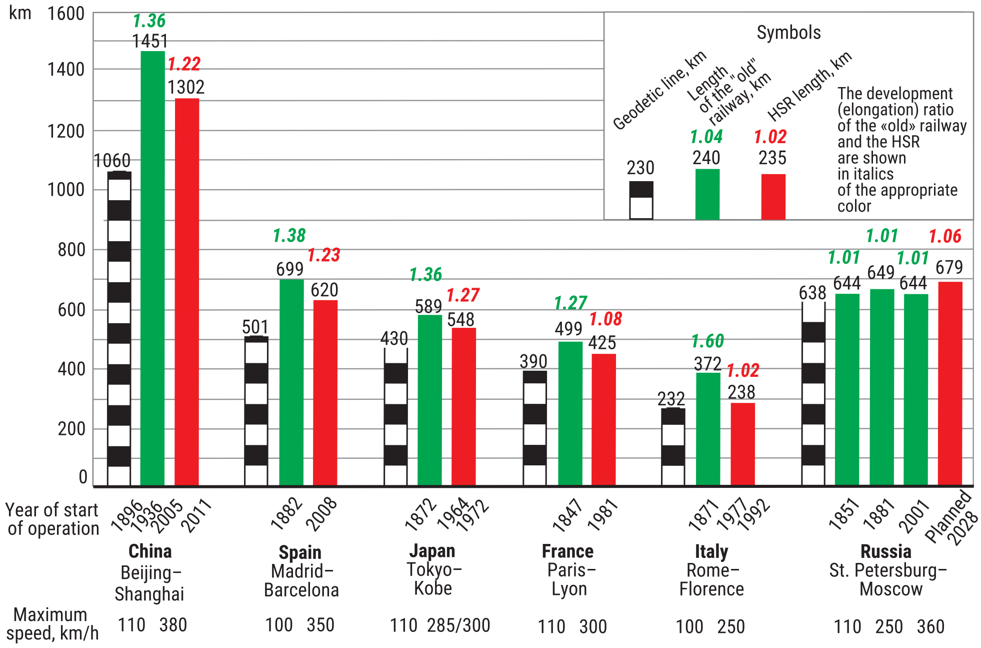

Fig. 2. Comparison of lengths of ordinary railways and HSR for a number of routes

infrastructure elements (without changing the basic design parameters).

One of these examples is Russia's first (and one of the world's first) long (more than 600 km) double-track railway line between St. Petersburg and Moscow which was put into operation in 1851.

The first 27-km long public railway between St. Petersburg and its suburban settlement Pavlovsk was built in Russia 14 years earlier. The line was built and put into operation by Austrian engineer Franz Anton von Gerstner. All the personnel, including designers, construction managers, as well as locomotive drivers and conductors, were foreigners invited to work in Russia.

However, just five years later, the design and construction of the first main railway line St. Petersburg–Moscow[3] was carried out by Russian engineers, the graduates of the first engineering institute in Russia: the Institute of the Corps of Transport Engineers (IKIPS) which was opened in 1809.

Within a historically short period of time, less than 10 years, graduates of this educational institution mastered the scientific basics and techniques of railway systems and railway construction, and developed advanced technologies for railway transport, one of the most important components of the industrial revolution, as applied to Russia's conditions.

Designing the St. Petersburg–Moscow railway involved making the first important scientific and technical decisions and determining the design parameters and principles for construction management and operation of the future main line. The process also included developing socio-economic and political criteria for decision-making in the field of emerging railway transport, in particular, such important ones as choosing directions of future railways.

According to historical records, the leaders of the project for construction of the St. Petersburg–Moscow Railway, engineers Pavel Melnikov and Nikolai Kraft were under moral and political pressure on the part of some ministers, other officials and business executives, who wanted to persuade them into building the line via Veliky Novgorod — the country's important historical, cultural and trade centre of the time located 190 km away from St. Petersburg (*Fig. 3*).

When St. Petersburg was founded as a new capital of Russia in 1703, a beaten trail via Veliky Novgorod

[3] This was the name of the railway before September 8 [20], 1855. After the death of Emperor Nicholas I on February 18 [March 2], 1855, it was renamed Nikolaevskaya. On February 27, 1923, People's Commissar of Railways Felix Dzerzhinsky issued Order No. 1313 that renamed the Nikolaevskaya Railway into the October Railway. This is the only name of a railway in Russia, and one of the few in the world, that is not based on administrative division and/or a geographic location, toponym, or the name of a personality. The October Railway was named after the October Socialist Revolution in Russia that took place on October 25 [November 7 in the new style calendar], 1917. Dates up to January 31, 1918 are given according to the Julian calendar (known as the "old style"); the later dates are given in brackets according to the Gregorian calendar which was introduced in Russia on February 14, 1918 (the so-called "new style").

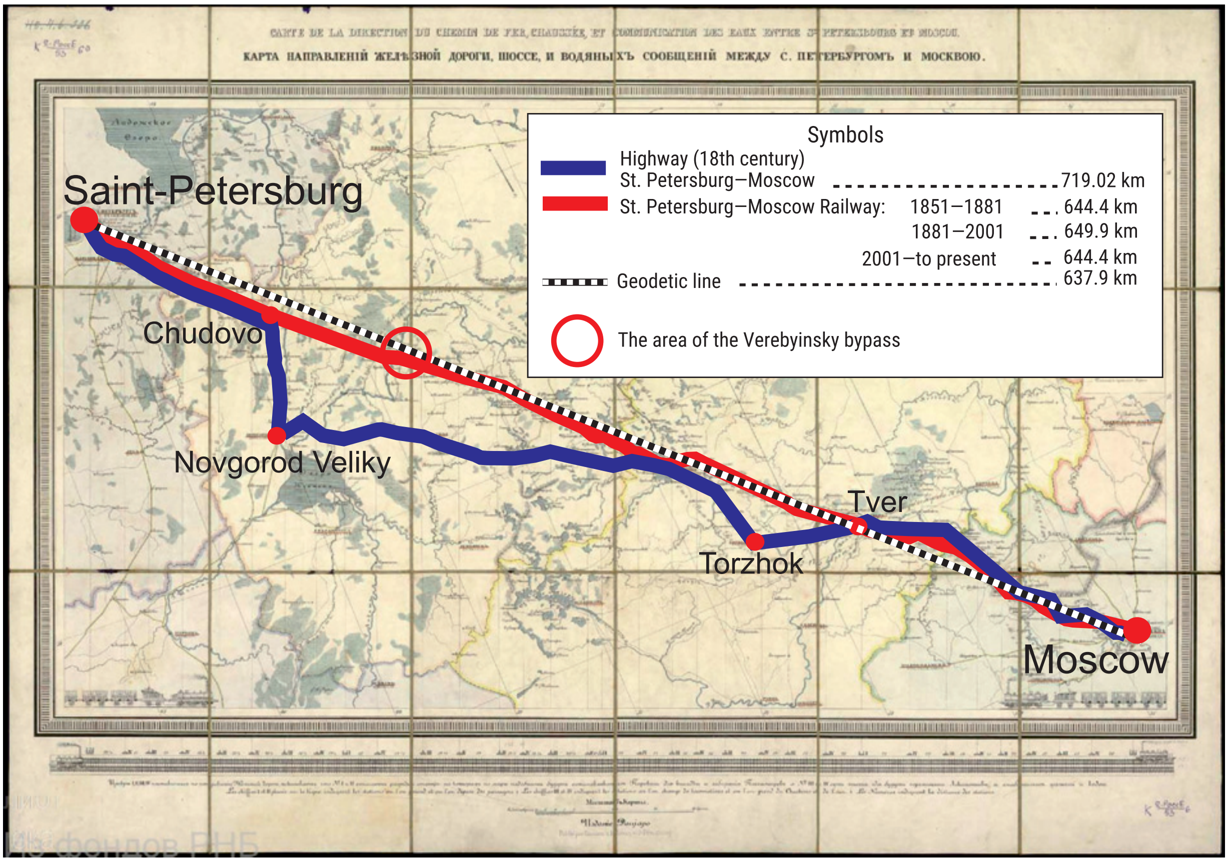

Fig. 3. Map of directions of railways, highways and water ways between St. Petersburg and Moscow
The map shows the line of the St. Petersburg–Moscow railway under construction. With supplements by Igor P. Kiselev[4] [6]

formed between the city and Moscow. By the early 19th century, after some construction work, the condition of the trail improved and it was turned into a 719 km long main road. Its route deviated from the shortest path and exceeded the geodetic line by more than 85 km (*Fig. 3*). The above mentioned influential political and economic establishment of the country lobbied the layout repeating the path of this very road when building the railway.

Pavel Melnikov and Nikolai Kraft stood up for building the railway line without going to Veliky Novgorod and were supported by Emperor Nicholas I who made the final strategic decision regarding the route of the future railway line to follow a direct path [7].

The length of the fully completed railway line which was put into operation on November 1 [13], 1851 was 644.4 km[5] [7], and the development ratio was 1.01, which is a great value for a railway. In general, the good quality of the design and construction of the St. Petersburg–Moscow line was, indeed, technically among the world's best results of the time, which was confirmed by its operation.

The St. Petersburg–Moscow Railway was put into operation in sections, on which regular services started in 1846. The technical parameters of the railway line were worked out and then implemented so thoroughly that further allowed fast increase of its capacity, increasing both the passenger and cargo traffic and travel speeds.

From the beginning, the railway line was built with two tracks of 5 ft (1,524 mm) gauge, which subsequently became the standard for the Russian Empire. Its vertical alignment contained balanced slopes in both freight-hauling (towards St. Petersburg) and passenger (towards Moscow) directions: 2.5 ‰ and 5 ‰, respectively. The line was distinguished by its straightness: it was 644.4 km long, which was just 7.4 km longer than the geometrically straight line by air. The minimum curve radius was 1,600 m on running lines, and 1,065 m at operation points. The embankments built on swamps were filled down to the mineral bed. The bridges on the line were built to the then best design proposed by transport engineer Dmitry Zhuravsky. The station buildings were built to standard designs [7].

[4] https://expositions.nlr.ru/ve/RA4367/ot-parovoza-do-sapsana.
[5] The geodetic line is 637.9 km [2]; the difference is 6.4 km (about 1 %).

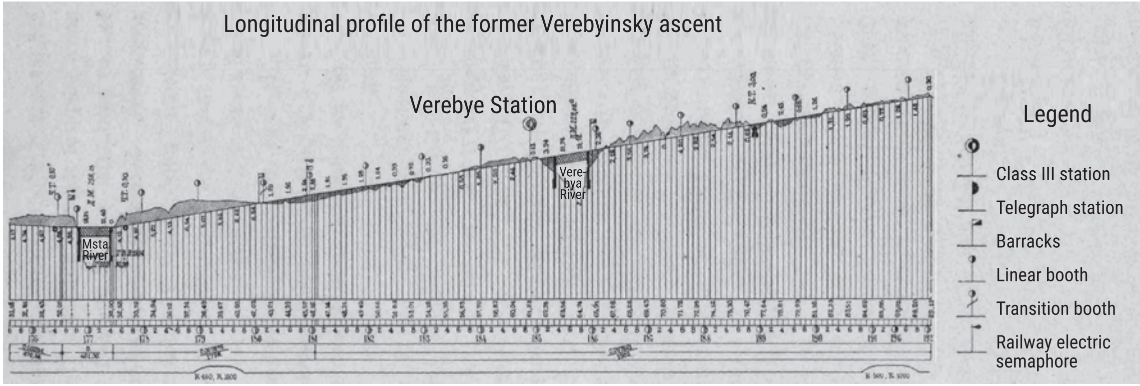

Fig. 4. Longitudinal profile of the former Verebyinsky ascent. 1851 [9, P. 116]

At the same time, problems began to show up when the operation of the St. Petersburg–Moscow Railway began. It revealed discrepancies between the levels of development of individual components of the whole transport system known as a railway. For example, the capacity of the steam locomotives used on the railway being, undoubtedly, among the world's best of the time, and the design of the brake systems on railway rolling stock did not meet the designed parameters and infrastructure elements which allowed for much higher travel speeds and train weights than the available rolling stock was able to provide.

The construction of the St. Petersburg–Moscow Railway was certainly a feat of a galaxy of brilliant transport engineers, railway managers, and operating staff who organized the train traffic on such a long rail line, as well as thousands of unknown builders and workers, including workers of the Alexandrovsky Plant.

It is important to note that the problems emerging with the commencement of the operation were successfully solved. The St. Petersburg–Moscow Railway has always been, and still remains, a technically advanced one in the Russian railway network, featuring the highest travel speeds. Enabling train speeds of up to 250 km/h, today it can be rightfully classified as a high-speed railway.

Following the desire to create a straight route between St. Petersburg and Moscow, with the length approaching the geodetic one, to ensure the highest possible speed and reduce the amount of construction (earthworks), and given the rising terrain from the bank of the Msta River, the designers made a long ascending grade for 15.5 km at the 177th–192nd verst (189–204 km) from St. Petersburg in the direction towards Moscow (*Fig. 4*). For this climb, the line's highest gradient of 7.8 ‰ was adopted, which is higher than the maximum gradient of 5 ‰ on the passenger direction of the railway as a whole [7].

On the long ascent, the railway line crossed a deep and wide ravine formed by the Verebya River. Based on the engineering and economic comparison of the options of building a bridge or a high embankment, it was decided to build a bridge across the ravine (*Fig. 5*).

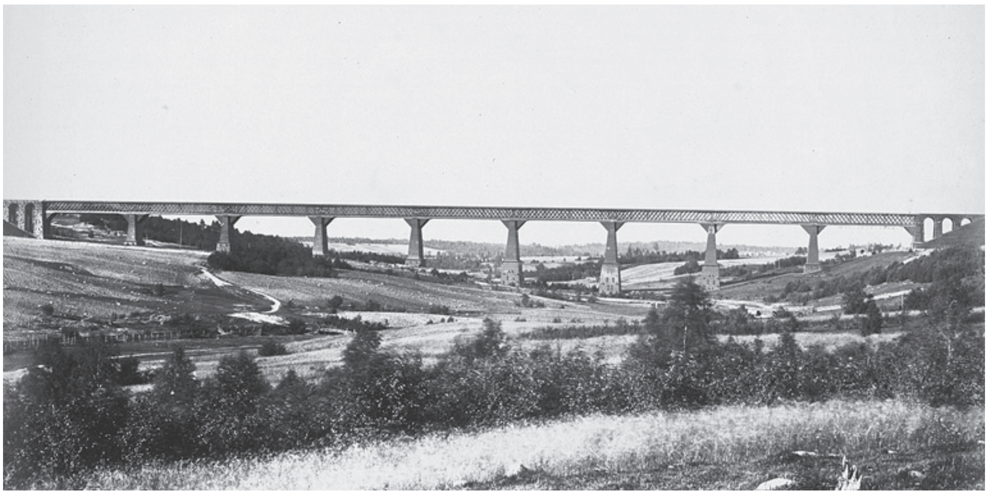

Fig. 5. Bridge across Verebyinsky Ravine. Postcard of the 19th century. Science and Technology Library of Emperor Alexander I St. Petersburg State Transport University (NTB PGUPS)

Pavel Melnikov assigned the project to Dmitry Zhuravsky, a graduate of the Institute of the Corps of Transport Engineers, young transport engineer, who subsequently became a prominent scientist in the field of bridge construction engineering.

Under the guidance of George Washington Whistler (*1800–1849*), an American engineer, the project's "engineering adviser", Dmitry Zhuravsky used a bridge truss designed by American engineer William Howe (*1803–1852*) and built from timber and steel tie rods (tension bars: metal strips or rods) [8].

At the instructions of Pavel Melnikov, Dmitry Zhuravsky re-tested the Howe truss theoretically, improved it and confirmed the correctness of his findings experimentally. He proved that the closer to abutments, the higher the load on verticals and diagonals, and proposed making truss elements of different thickness based on their location by reducing the cross-section of the tie rods closer to span centres. As a result, one of the first scientifically-based methods for the design of bridge trusses was proposed (1850). Whistler supported the proposals by Zhuravsky and they were used to build all bridges on the railway line [8].

Built in 1851, the Verebyinsky Bridge had nine spans with 49.7 m long wooden trusses resting on eight wooden abutments with a stone foundation and seven stone coastal arches 6.4 m each (*Fig. 5*). The height from the water to the level of the railway track was 50 m. The bridge was operated until 1881[6] [8]. Outstanding Russian bridge engineer Stanislav Kerbedz, who built the first permanent bridge across the Neva River in St. Petersburg in 1850 and the first bridge with trussed metal girders across the Luga River on the St. Petersburg–Warsaw Railway in 1856, emphasized, "Before Dmitry Ivanovich Zhuravsky, bridge construction was a mystery; after him it became an engineering science" [10]. In Russia, bridges built to the design improved by Zhuravsky are known as the Howe–Zhuravsky system.

Meanwhile, the first months of regular train traffic on the railway line in 1851 already showed that traveling on this long ascent (descent) was dangerous. Emergency situations repeatedly occurred due to the unreliable performance, alas, of the hand brakes installed in carriages, the best available at the time[7]. On the long descent on the way from Moscow, the train crews would sometimes be unable to stop the train and it would pass Mstinsky Most Station without stopping. To avoid accidents, the station master made sure that by the time the train arrived from Moscow, the previous train going towards St. Petersburg had already left for the 8-km long Mstinsky Most–Burga section in good time. Fortunately, those incidents did not have disastrous consequences.

On the other hand, when traveling towards Moscow with a full freight train, steam engines were not always able to surmount the long ascent. Trains had to be uncoupled into two parts at Burga station, and each was then delivered by a separate steam locomotive to Torbino station where they were recombined into a single train to proceed to Moscow.

On February 12, 1862, a freight train going from St. Petersburg to Moscow was uncoupled at Malaya Vishera station. The first half was delivered to Verebye station located on a slope towards St. Petersburg[8] and then *"uncoupled from the machine"*. Several carriages left at Verebye station went downhill on the running line towards St. Petersburg as they were poorly secured to the track (stove wood was placed under the wheels, as brake shoes had not yet been invented). They passed Mstinsky Most station and collided with a train pulled by locomotive No. 515, which was hauling the second part of the uncoupled train from Vyshny Volochok station. Six people died and several were injured. The incident was thoroughly investigated, resulting in studying the issue of placing stations on horizontal sections and of devices required to secure carriages uncoupled from locomotives [11].

In 1874, a routine inspection revealed an irreversible deterioration in the condition of the Verebyinsky Bridge that occurred over the 24 years of its operation. It was acknowledged that further operation of the Verebyinsky ascent, including the bridge, would be causing more and more difficulties. During the same period, it was decided to replace the originally built wooden bridges on the line with metal bridges in order to in-

[6] The successful completion of the Verebyinsky Bridge marked the beginning of Zhuravsky's scientific career and brought him fame as a bridge builder. He published several papers and a monograph On Howe Truss Bridges, making an outstanding contribution to construction science. In 1854, the above mentioned paper was submitted for a competition held by the St. Petersburg Academy of Sciences and was awarded the great Demidov Prize in 1855.

[7] Today, the description of the primitive design of manual carriage brakes used until the early 20th century in passenger services and until the 1920s in freight services is a revelation, even for many railway workers, let alone the general public. Thus, the St. Petersburg–Moscow Railway was the first to have one or two conductors (brakemen) onboard each passenger carriage who set the hand brake in motion by the signal (a locomotive whistle) given by the driver. In most designs, they rotated the chain wheel that pressed the wooden brake pads against the set of wheels. Cargo trains included several brake carriages (the number depended on the weight of the train) which had a vestibule where a conductor (brakeman) stayed throughout the journey and operated the brakes at the signal of the locomotive driver.

[8] Horizontal platforms for station tracks began to be built several years later.

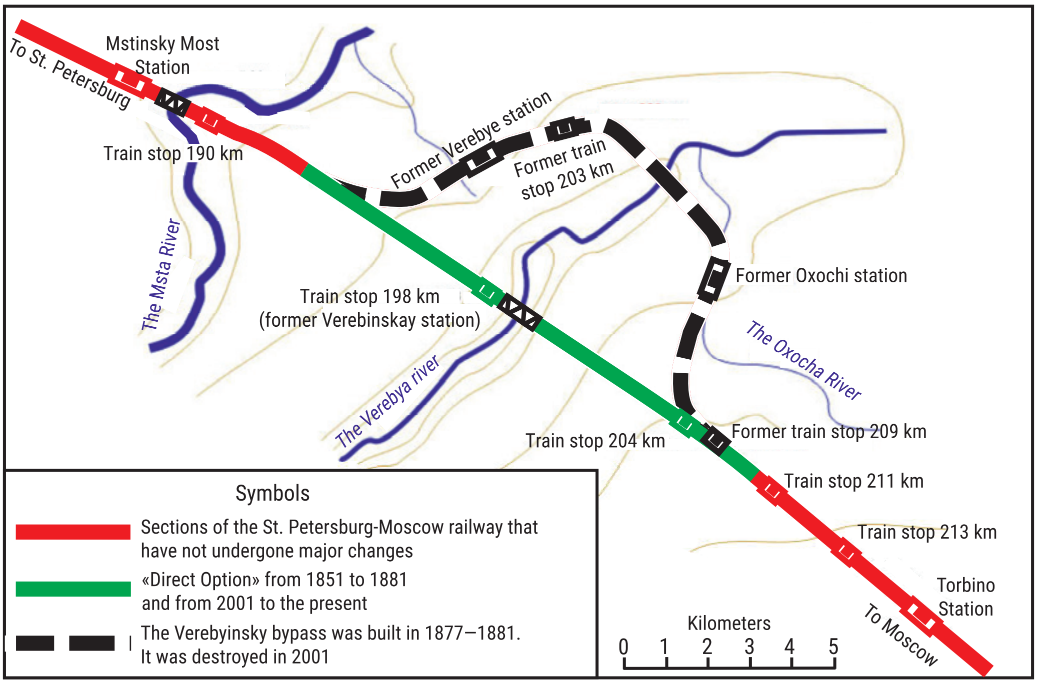

Fig. 6. Verebyinsky bypass scheme. Author: Alexander Fedosov (railway worker). 2008. With supplements by Igor P. Kiselev[9]

crease their load-bearing capacity and improve the carrying capacity of the railway.

The resulting decision provided for a radical solution of the problem of the Verebyinsky ascent and bridge by the comprehensive reconstruction of the railway section, including changes in the horizontal alignment and partial changes in the vertical alignment, which was carried out in 1877–1881.

The surveys carried out in the area of the Msta and Verebya Rivers discovered a good alternative involving building a bypass around the bottleneck with the maximum descents reduced to 6 ‰: the long ascent was divided into several shorter ascents with horizontal sections in between (*Fig. 6*). In 1878–1880, an embankment about 40 m high with a culvert of about 8 m in diameter was built for the Verebyinsky bypass at the crossing of the Verebye River (*Fig. 6*) [11]. The work to build the bypass, including construction of man-made structures, was superintended by Nikolai Belelyubsky, an outstanding bridge engineer, Professor of the Institute of Transport Engineers, who also led the design, survey and construction work for replacing the wooden bridges with metal ones [12]. The Verebyinsky bypass was opened on September 14 [26], 1881.

13 small bridges and 12 crossings were built on the bypass. A IV Class station, first named Novo-Verebyinskaya and later named (the former) Verebye station, and a halt station (later Oksochi station) near Oksochi settlement were opened.

The total length of the railway line, including the bypass, was increased by 5.3 km to reach 649.9 km. The new section had 44 % more curve sections, with curves of a smaller radius: 1,065 m (as at operation points) instead of 1,600 m adopted on running lines throughout the railway [7].

The presence of curves of a relatively small (compared to the rest of the St. Petersburg–Moscow line) radius on the new bypass theoretically limited the speed of trains, but in practical terms this was not significant. For a long period of operation, until the first decade of the 20th century, the maximum speed of passenger trains on the St. Petersburg–Moscow line did not exceed 90 km/h. Then, after 1914, the speed was reduced and was increased to 100 km/h in the mid-1950s only, then to 140 km/h in the 1960s, and to 160 km/h in the mid-1960s. [13] Thus, in practical terms, until the 1950s–1960s, the Verebyinsky bypass with its several curved track sections with a radius of 1,065 m did not limit the speed of trains, while after the bypass was complete, the total travel time between the end points increased by approximately 3 or 5 minutes.

The problem of speed limitations to 120–140 km/h on the bypass became relevant in the 1970s–1980s, when high-speed traffic (with a speed of up to 200 km/h) was introduced on the Leningrad–Moscow line [13].

In the early 2000s, as the economic and socio-political situation in Russia improved, it was considered reasonable to gradually introduce high-speed traffic and

[9] URL: https://dzen.ru/a/ZKaFtH729XQ00KjD.

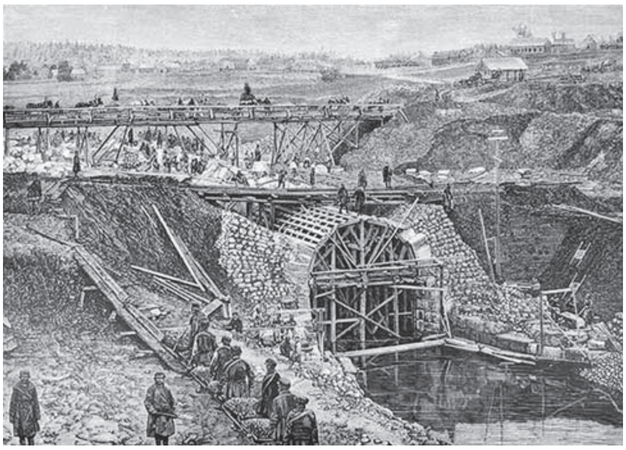

Fig. 7. Construction of a culvert on the Verebya River. 1878–1880. Central State Film, Photo and Audio Archives [11]

Fig. 8. Modern view of the embankment of the former railway bypass and culvert arch over the Verebya River. Photo by Dmitry Ratnikov. 2023[10]

Fig. 9. Construction of the new Verebyinsky Bridge. 2001. Photo by Mikhail Krivykh[11]

purchase foreign rolling stock for the operation on reconstructed lines. In the 2010s, the St. Petersburg–Moscow main line was modernized to accommodate traffic at speeds of up to 250 km/h. Specialists and scientists of Emperor Alexander I St. Petersburg State Transport University (PGUPS) were actively involved in the development of design documentation and scientific support. On a considerable part of the line, the track was rebuilt, including the expansion of the road bed subgrade, making it possible to partially straighten it; the track superstructure was reinforced; switch assemblies were replaced to allow for straight line operation at a speed of over 200 km/h.

The line's power supply system was considerably enhanced and partially redesigned using a new KS250 catenary suspension system developed with the active involvement of scientists at PGUPS [14]. The ICE 3 electric multiple-unit train produced by Siemens, Germany, was chosen by Russian specialists to run on the line. By the early 2000s, it had already proven itself well both in Germany and in Spain and China. A virtually new modification of ICE3, Velaro RUS (Sapsan), was created for the Russian 1,524 mm gauge with account of the clearance standards on Russian railways with the most active participation of the specialists of Russian Railways JSC.

As the line was prepared for accommodating high-speed traffic, practical discussion of the issue of straightening the route by excluding the Verebyinsky bypass started. In 2000, the Ministry of Transport of the Russian Federation decided to abandon the bypass and straighten the railway line along the route that existed before 1881 by building a new bridge across the Verebyinsky ravine (*Fig. 7*, *8*, *9*) [15].

In 2001, Mostostroy No. 6 OJSC, a subcontractor of the Baltic Construction Company, completed the construction of a two-track railway bridge crossing over the deep and wide valley of the Verebya River (more than 500 m long and up to 50 m high) for the straightened section at the Verebyinsky bypass on the St. Petersburg–Moscow Railway along the axis of the former wooden railway bridge. Bridge Construction Crews (specialized bridge construction units) No. 37 (St. Petersburg), No. 75 (Veliky Novgorod) and No. 61 (Vologda) of Mostostroy No. 6 OJSC took part in the construction of the bridge abutments [16].

A new double-track railway bridge for traffic at a speed of up to 250 km/h was designed by Giprotransput (a branch of Roszheldorproekt JSC, the state institute for the design of engineering works and industrial enterprises for track facilities and geological surveys) of the Ministry of Railways of the Russian Federation at a

[10] https://kanoner.com/pics/2023/12/verebynskyj-obhod-arka-vodopropusknoj-truby-nad-rekoj-verebe.jpg
[11] URL: https://news.novgorod.ru/articles/read/475.html

Fig. 10. New Verebyinsky Bridge with a running Sapsan train. 2001. Photo by Mikhail Krivykh[12]

slope of about 5 ‰ following the 9×55 metre scheme with metal split superstructures according to standard design 739/7 by Giprotransmost (the state design and survey institute for the design of bridges) for traveling on top of the precast reinforced concrete slabs of the ballast tank.

The steel and reinforced concrete split superstructures with 55 m spans built to standard design 739/7 of Giprotransmost had deck plate girders. The main 3.6 m girders consist of three blocks (17 + 21 + 17 m) [16].

The construction of the bridge involved driving and ramming about 2,000 metres of reinforced concrete piles; laying 11,000 metres of concrete and reinforced concrete masonry in the abutments; fabricating and installing 2,700 tonnes of metal structures for the superstructures; fabricating and installing 560 tonnes of metal formwork for the reinforced concrete slabs of the ballast tank; fabricating and installing 1,860 metres of reinforced concrete slab units; fabricating and installing more than 500 tonnes of auxiliary structures [16].

The new 536 m long and 53 m high bridge was opened for traffic on October 26, 2001. 17 km of the track superstructure of the former railway bypass and the Oksochi and Verebye stations located on it were dismantled by 2008. At the same time, the kilometre markers on the route from St. Petersburg to Moscow (and the sites of the distance markers colloquially known as “kilometre posts”) that had been determined after the completion of the Verebyinsky bypass in 1881 extending the line to 649.9 km were left unchanged. Thus, in the area of the former Verebyinsky bypass, the “205” kilometre post is followed by the “211” marker.

Commercial operation of Sapsan trains on the Moscow–St. Petersburg line began on December 17, 2009. The operation was serviced by three pairs of trains per day. The route soon became very popular with passengers [13].

The creation a new specialized high-speed railway line between St. Petersburg and Moscow parallel to the railway opened in 1851 has been discussed since 1988, when the State Science and Technology Programme “High-speed Railway Transport”[13] was introduced.

Over the past years, the question has been considered at several levels. A feasibility study for the project was prepared; a relevant legal framework was developed; design and survey work and some detailed engineering activities started; and a pilot high-speed train Sokol was created. In a test trip on July 29, 2001, the train achieved the speed of 236 km/h, which was a record at the time for Russia; however, no large-scale production of the train was launched because of the economic situation.

The implementation of the project was set aside because of the complicated and contradictory socio-economic and political landscape in Russia in the late 1990s. The idea of high-speed railway traffic between the two largest cities, the two capitals of the Russian

[12] URL: https://news.novgorod.ru/articles/read/475.html
[13] The State Science and Technology Programme “High-Speed Environmentally Friendly Transport” was approved by Decree of the Council of Ministers of the USSR No. 1474 dated December 30, 1988 [17].

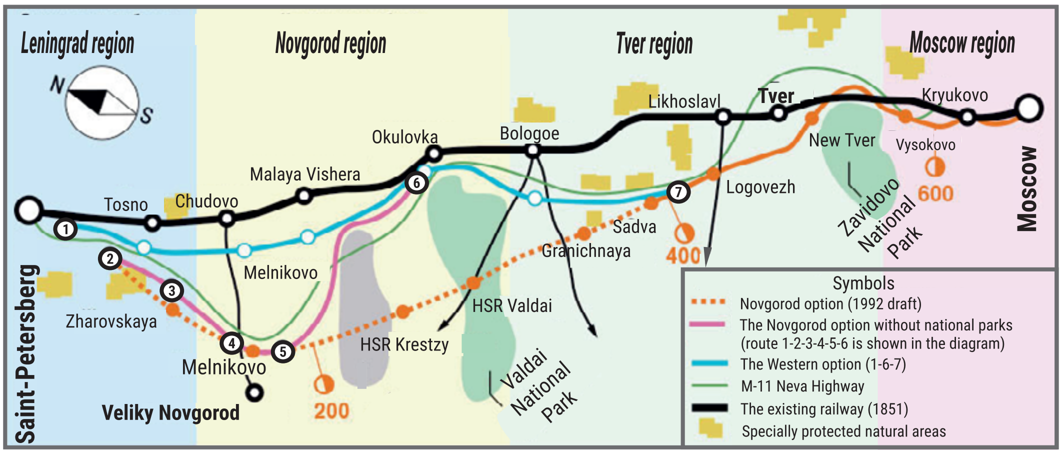

Fig. 11. Alternative routes of the Moscow–St. Petersburg HSR // Science and Transport, Annual Supplement to the *Transport of the Russian Federation Journal*. 2009. P. 10

Federation, was revisited at the end of the first decade of the 2000s.

On April 10, 2020, Russian President Vladimir Putin ordered to start designing the Moscow–St. Petersburg HSR. On September 29, 2021, the Moscow–St. Petersburg HSR was included in the Land-Use Planning Scheme of the Russian Federation for the Development of Federal (Railway, Air, Sea, and Inland Water) Transport and Federal Roads.

On August 17, 2023, President Vladimir Putin approved the National Project "Development of High-speed Railways" (HSR) and its first stage, the Moscow–St. Petersburg HSR Project [18]. Design and survey, engineering and preparation work for the creation of Russia's first HSR are underway.

More than 170 years after the launch of the St. Petersburg–Moscow Railway, the situation in its adjacent areas, populated localities, railway stations and the right-of-way along the railway line has changed drastically. Figuratively speaking, it has been "overgrown" with tracks, railway depots, station buildings, warehouses, and industrial facilities; lots of residential buildings have been built immediately adjacent to the railway and the grounds of stations; villages and towns have grown nearby.

The current attempts to lay the HSR route along the existing railway inevitably lead to considerable deviations from the longitudinal axis of its tracks. It is necessary to bypass railway station tracks and buildings in the right-of-way of the railway. Theoretically, it is possible to lay the new high-speed railway on the second level on continuous elevated structures with placing the supports near the existing tracks. But this increases construction costs significantly compared to the greenfield construction of a new railway. It will be necessary to build the elevated structures above the operational railway tracks with heavy traffic, "under the wheels of running trains" to put it figuratively.

In addition, various facilities where construction work is prohibited are located along the proposed line of the new HSR, such as, for example, dozens of specially protected natural areas (reserves), including one of the largest in Russia, the Valdai National Park. Many of these specially protected areas were identified and placed under protection (turned into reserves) in the 20th century and as such were not taken into account in the mid-19th century when the St. Petersburg–Moscow was built.

The design work on the St. Petersburg–Moscow HSR in the 1990s has shown that the new line's route will need to be moved away from the existing railway in order to bypass the emerging obstacles with the least losses and costs possible (*Fig. 11*). For example, the satisfactory alternative designed in the 1990s turned out to be 659.1 km long [19], i.e. 14.8 km longer than the existing railway line. The front-end engineering design in the 2020s (the so-called "Novgorod alternative" bypassing the specially protected natural areas) has shown that the length of the route will be about 679 km [5], because the situation along the railway has substantially changed over the past 30 years.

CONCLUSION

The parameters set for a number of railway lines built in the 19th century, such as vertical and horizontal alignments, route development ratio, minimum horizontal and vertical curve radii, still remain relevant in the 21st century. The St. Petersburg–Moscow Railway in Russia put into operation in 1851 is a compelling example. The modernization efforts completed during the period of its operation, including electrification and enhancement of its technical facilities, without affecting the basic parameters of the line allowed for launching high-speed traffic at speeds of up to 250 km/h with the use of modern rolling stock. At the same time, we can conclude that the construction of new high-speed railways in the world, both using the conventional “wheel/rail” method and the advanced magnetic suspension (maglev) technology, will face the phenomenon illustrated by the case of the St. Petersburg–Moscow Railway. It will be necessary to extend the railway route compared to the existing conventional railways and, in the future, even to high-speed railways built earlier. We need to revise the ideas about the quality criteria for design and survey activities that have been in place for nearly two centuries by taking into account the route development (elongation) ratio. We can confidently conclude that in many cases this ratio is worse for advanced high-speed railways than for the existing railways.

REFERENCES

1. Bogdanov A.I. *Surveying and designing railways*. Moscow. Yurait. 2025:104 p. URL: https://urait.ru/bcode/568584. (In Russ.).

2. *Construction and operation of the Nikolaev railway (1842–1851–1901): Brief historical essay. Compiled by the road administration*. St. Petersburg. Erlich Printing House. 1901:65. (In Russ.).

3. *History of railway transport in Russia*. In 3 volumes. Vol. 1: 1836–1917. Edited by E.Ya. Kraskovsky, M.M. Uzdin. St. Petersburg; Moscow. 1994:335. (In Russ.).

4. Rakcheev E.N. *Dmitry Ivanovich Zhuravsky*, 1821–1891. Moscow. Nauka. 1984:240. (In Russ.).

5. *The most famous railway workers of Russia*. Compiled by T.L. Pashkova, V.A. Mikhailov. Moscow. Veche. 2005:316. (In Russ.).

6. Krivykh M. Verebyinsky Bridge: grandiose structures of the Novgorod region. *Novgorol.ru*. 01.22.2015. URL: https://news.novgorod.ru/articles/read/475.html. (In Russ.).

7. Kiselev I.P. Bridge to the Future // *Problems of Strength of Materials and Structures in Transport Construction: International Scientific and Practical Conference Dedicated to the 175th Anniversary of the Birth of Professor N.A. Belelyubsky, St. Petersburg, May 18–20, 2021*. St. Petersburg: Emperor Alexander I Petersburg State University of Railway Engineering, 2021:6-15. EDN MQYNMF. (In Russ.).

8. Valinsky O.S., Kiselev I.P. Scientific support for the design and construction of high-speed railway lines. Transport of the Russian Federation. Journal of science, practice, economics. 2024;1(110):11-28. EDN AKBQLP. (In Russ.).

9. Konovalova N., Kutsenina T., Retyunin A., Yurinov V. *From Estonia 200 to Sapsan*. St. Petersburg: OM-Express, 2023. 288 p. (In Russ.).

10. Turchenko V., Kharebov S. Verebinsky bypass (abandoned legend). *Semafor*. 2023. Issue 5. URL: https://semafor.narod.ru/5_2003/vereb.html. (In Russ.).

11. Shapiro L.B., Surovtsev A.B., Mukharev A.A. Bridge crossing over the Verebye River // JSC Institute Giprotransmost St. Petersburg. URL: https://gpsm.narod.ru/Projects/Verebye.htm. (In Russ.).

12. *High-speed rail transport. General course: Textbook for students of higher education institutions of railway transport:* I.P. Kiselev, L.S. Blazhko, M.Ya. Bryn [et al.]; edited by I.P. Kiselev. Moscow: Federal State Budgetary Institution of Continuing Professional Education “Educational and Methodological Center for Education in Railway Transport”. 2020:428 p. EDN MPVRST. (In Russ.).

13. Chronology of events. High-speed railway Two capitals. Concessionaire company for the project to build the high-speed railway Moscow – St. Petersburg. *High-speed railway. High-speed railway. Project of the President of the Russian Federation*. URL: https://xn---2--edd7ardtwel5cxd.xn--p1ai/#contacts. (In Russ.).

14. Alimov A.F. et al. *High-speed and high-speed rail transport: In the past, present and future: On the 150th anniversary of the St. Petersburg-Moscow railway*. 2003:447 p. EDN QNQGUX. (In Russ.).

15. Serebryakov D. What is known about the Moscow-St. Petersburg high-speed railway. *Information Telegraph Agency of Russia* (ITAR-TASS). 12.23.2024. URL: https://tass.ru/info/20230979. (In Russ.).

ЛИТЕРАТУРА

1. *Богданов А.И.* Изыскания и проектирование железных дорог : учебник для вузов. М.: Юрайт, 2025. 104 с. (Высшее образование). URL: https://urait.ru/bcode/568584.

2. Постройка и эксплуатация Николаевской железной дороги (1842 – 1851 – 1901 гг.): Краткий исторический очерк / Составлен управлением дороги. СПб.: Тип. Эрлихъ, 1901. 65 с.

3. История железнодорожного транспорта России. В 3 т. Т. 1: 1836–1917 / под ред. Е.Я. Красковского, М.М. Уздина. СПб.; М., 1994. 335 с.

4. *Ракчеев Е.Н.* Дмитрий Иванович Журавский, 1821–1891. М.: Наука, 1984. 240 с. : ил. (Научно-биографическая серия).

5. Самые знаменитые железнодорожники России / сост. Т.Л. Пашкова, В.А. Михайлов. М.: Вече, 2005. 316 с.: ил.

6. *Кривых М.* Веребьинский мост: грандиозные сооружения Новгородской области // Novgorol.ru. 22.01.2015. URL: https://news.novgorod.ru/articles/read/475.html.

7. *Киселев И.П.* Мост в будущее // Проблемы прочности материалов и конструкций в транспортном строительстве : Международная научно-практическая конференция, посвященная 175-летию со дня рождения профессора Н.А. Белелюбского, Санкт-Петербург, 18–20 мая 2021 года. Санкт-Петербург: Петербургский государственный университет путей сообщения Императора Александра I, 2021. С. 6–15. EDN MQYNMF.

8. *Валинский О.С., Киселев И.П.* Научное обеспечение проектирования и строительства высокоскоростных железно-

дорожных магистралей // Транспорт Российской Федерации. Журнал о науке, практике, экономике. 2024. № 1(110). С. 11–28. EDN AKBQLP.

9. *Коновалова Н., Куценина Т., Ретюнин А., Юринов В.* От ЭР200 до «Сапсана». СПб.: ОМ-Экспресс, 2023. 288 с.

10. *Турченко В., Харебов С.* Веребьнский обход (заброшенная легенда). Семафор. 2023. Вып. 5. URL: https://semafor.narod.ru/5_2003/vereb.html.

11. *Шапиро Л.Б., Суровцев А.Б., Мухарев А.А.* Мостовой переход через реку Веребьею // ОАО «Институт Гипротрансмост Санкт-Петербург». URL: https://gpsm.narod.ru/Projects/Verebye.htm.

12. Высокоскоростной железнодорожный транспорт. Общий курс: Учебное пособие для студентов вузов железнодорожного транспорта: в 2 т. / И.П. Киселев, Л.С. Блажко, М.Я. Брынь [и др.]; под ред. И.П. Киселева. Т. 1. 2-е изд., перераб. и доп. М.: Федеральное государственное бюджетное учреждение дополнительного профессионального образования «Учебно-методический центр по образованию на железнодорожном транспорте», 2020. 428 с. EDN MPVRST.

13. Хронология событий. ВСМ Две столицы. Компания концессионер проекта строительства высокоскоростной железнодорожной магистрали Москва – Санкт-Петербург // ВСМ. Высокоскоростная магистраль. Проект Президента РФ. URL: https://xn---2--edd7ardtwel5cxd.xn--p1ai/#contacts.

14. Скоростной и высокоскоростной железнодорожный транспорт : В прошлом, настоящем и будущем : К 150-летию железнодорож. магистрали Санкт-Петербург – Москва / А.Ф. Алимов [и др. [Б.м.], 2003. 447 с. EDN QNQGUX.

15. *Серебряков Д.* Что известно о ВСМ Москва – Санкт-Петербург // Информационное телеграфное агентство России (ИТАР-ТАСС), 23.12.2024. URL: https://tass.ru/info/20230979.

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