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The History of Development of Inland Transport Infrastructure: Technology and Economic Aspects. Part 2

Aleksey D. RAZUVAEV

Aleksey D. Razuvaev
Russian University of Transport, Moscow, Russia.
✉ *razuvaevalex@yandex.ru.*

ABSTRACT

The second part of the article (the first of which was published in the last issue of the journal) analyses the history of emergence of the rail track, as well as evolution of the railway-track substructure, including a review of the materials used for this.

A separate section is devoted to evolution of railways in Russia.

Brief conclusions are made regarding the importance of the historical and economic aspects of development of inland transport infrastructure.

The importance of considering this issue is quite high when conducting comprehensive research intended to get economic assessment and forecast the strategic development of transport infrastructure.

Keywords: land transport, railways, railway infrastructure, socio-economic development, economic history, historical analysis.

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Текст статьи на русском языке публикуется в первой части данного выпуска.

Emergence of a Rail Track and Evolution of its Substructure

The emergence of a rail track is a result of a natural evolutionary process associated with a human desire to move faster and safer, with the least energy consumption and with the ability to transport heavy cargo.

Professor K. Ya. Zagorskiy in [1, p. 10] wrote: «*Land transportation requires more significant and complex devices: here, in addition to rolling stock and driving force, it is necessary to create a track itself*».

The following factors became the main prerequisites for creation of a rail track (track along guides), which ultimately have a determining economic significance [2–5]:

• preventing the sinking of wheels of rolling stock (at the initial stages of track development of waggons and carts) into the ground;

• minimisation of friction forces, which means less need for the applied force (in case of metal wheels and rails).

The rail track design assumes the presence of guides: rails, runners, beds. Initially, in ancient times was the ancient Greek diolcus, a stone road for transporting ships across the Isthmus of Corinth. It was one of the prototypes of the rail track. In addition to dragging warships, merchant ships and goods were also moved along it on carts (which once again demonstrates the economic basis for creating such a way). Some other ancient Greek stone track roads had depressions of 50 mm and a track width along the outer edges of the depressions of 1600 mm [6]. Similar stone tracks, besides Greece, were found in the central part of the European continent and in America and are structurally similar.

The significant evolutionary leap in development of the rail track is attributed to 15th–16th centuries. During that period in the mines of Germany and neighbouring geographic regions, wood guides were used. Buggies, the wheels of which were equipped with ridges (flanges), moved along them.

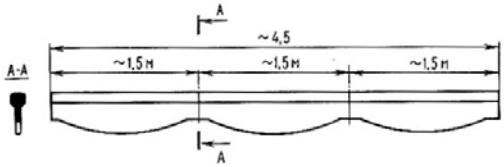
In some regions of England, wooden rail tracks for buggies have been known since the second half of 16th century, in 17th century they became widespread in mining areas[1] to transport coal in mines and deliver it to rivers and canals, the main transportation lines at that time, suitable for transporting bulk cargo[2] [7, p. 256]. The railway to transport coal on horse-drawn vehicles between the villages of Strelley and Wollaton near Nottingham, according to researchers, is

[1] History of railways in Great Britain. [Electronic resource]: https://www.sinfin.net/railways/railhist.html. Last accessed 11.06.2021.

[2] Coal Mining and Railways in the North East. [Electronic resource]: https://englandsnortheast.co.uk/coal-railways-north-east/. Last accessed 11.06.2021.

Pic. 1. Construction of the superstructure of the track "Cast iron wheel line". [Electronic resource]: https://umczdt.ru/news/demohtml/80.html. Last accessed 11.06.2021.

Pic. 2. Image of a wooden bench with an iron plate with a rim (corner rail). [Electronic resource]: http://www.rzd-expo.ru/history/history_of_railway_track/. Last accessed 11.06.2021.



Pic. 3. Profile view and section (A-A) of «wavy» rails. [Electronic resource]: http://railway-transport.ru/books/item/f00/s00/z0000020/st017.html. Last accessed 11.06.2021.

considered the first land-based railway made of wood[3].

On the territory of Russia in 1755 a narrow-gauge track with wooden rails was built at the mines of Altai, along which wooden waggons with a very original system of a leading cable moved. In 1788, at Aleksandrovsky plant in Petrozavodsk, the «Cast Iron Wheel Line» appeared, this was the first industrial railway in Russia: the main shops of the cannon plant were connected by a single transport line (Pic. 1).

After a long history of construction and operation of rail tracks in mines and at factories, that is, after the period of their exclusively industrial specialisation, horse-drawn passenger roads have become widespread. It is believed that the first such rail ways were built in 1801 in England between Wandsworth and Croydon and in 1807 in Wales (Swansea and Mumbles railroad) [8].

Due to the efforts of European (mainly English) engineers, the rail track, at an early stage of its development, went through the following evolutionary stages:

1) The original design of the longitudinal wooden planks was continually improved through perfectioning its geometric parameters and wea resistance. The beds themselves were reinforced with oak and then cast-iron strips (1738), and the supports were made of hard wood or stone.

2) More surface of the bed was covered with cast iron, while later, rims were added to keep the wheels in the track (Pic. 2). In parallel with the flanges, there was a design that provided a groove on the rolling surface.

3) Cast-iron rails on the crossbars created a prototype of the rail track, setting also the standard gauge equal to 1435 mm (used in the Sheffield mines).

4) In 1820, John Birkinshaw succeeded in rolling an iron profile of rails which made it possible to increase the length of the rails by about four times. This became the beginning of creation of the railway in a literal sense. First, the rail was shaped into a beam of equal resistance in each span. Such «wavy» rails (Pic. 3) were laid on the first public steam-driven railways in England, but later due to the high cost of processing «wavy» rails, they were abandoned.

5) A further increase in bending resistance was achieved by thickening the rail at its bottom, which ultimately led to formation of the second head. Thus, in 1833, two-headed rails arose (Pic. 4).

6) The next step in development of rails is creation in 1835 by R. L. Stevens of a wide-bottom rail and improvement of a wide-bottom rail with a constant profile by the American C. Vignol (Pics. 5, 6) [4; 6].

In work [2], the following periodisation of development of track structures with an emphasis on rail construction is proposed:

• the middle of 16th century–1788 – creation of wooden planks and iron rails;

• 1789–1865 – appearance of cast-iron rails with a pronounced head and neck;

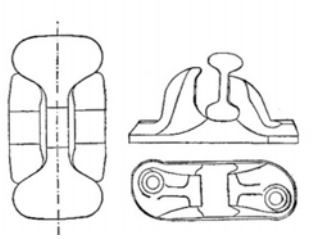
• 1866–1903 – creation of steel rails and selection of state-owned types of rails;

• 1903–1947 – standardisation of the chemical composition of the material and the geometry of the rail profile;

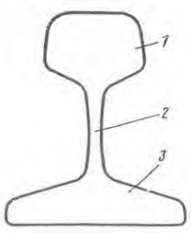
• 1947–beginning of 21st century – improvement of the modern design of rails and of their manufacturing technology.

Before the advent of railway transport, land roads hardly developed. The emergence and evolution of railways gave a powerful impetus to development of land infrastructure. Then the era of George Stephenson and the fundamental transformations in rail transport accelerated

[3] The Wollaton Wagonway of 1604. A Waggonway Research Circle Guide. [Electronic resource]: https://island-publishing.co.uk/WRC_mirror/woll_wag_leaflet_a4.pdf. Last accessed 11.06.2021.



Pic. 4. Sections of a double-headed rail. [Electronic resource]: https://www.1902encyclopedia.com/R/RAI/railway-27.html. Last accessed 11.06.2021.



Pic. 5. Cross-section of a wide-bottom rail: 1 – head; 2 – neck; 3 – outsole.

evolutionary processes. The practice of implementation of projects of land transport infrastructure spread over many countries, including, inter alia, due to a favourable entrepreneurial climate, developed in a number of countries, which was supported by the emerging socio-economic institutions of property and private initiative [9].

Evolution of Track Substructure Material

The stone track roads were replaced by longitudinal beds connected by transverse beams, later called sleepers (the Russian name for them «*shpala*» comes from the Dutch *spalk* – support). So, the tree for a long time took a leading position as a material for the manufacture of sleepers. Only in the middle of 20th century, reinforced concrete sleepers began to actively displace wooden sleepers.

It is possible to note the following main milestones of further evolution.

At the end of 19th century, in France, Italy, Germany, Hungary, Russia, the USA and some other countries, the first experiments were carried out to study the possibility of operating a reinforced concrete under-rail foundation.

In Russia on Ekaterininskaya railway, built in 1882–1904, a track was tested with a monolithic concrete slab and longitudinal metal benches.

In 1886, on the Trans-Caspian railway in Central Asia, to save money, the square castings made of asphalt concrete, laid diagonally under the rails were used [4].

In 1903, the first reinforced concrete sleepers in Russia were manufactured and tested in the laboratory of St. Petersburg Institute of Railways[4]. The main imperfection of the first structures of reinforced concrete sleepers was the absence of prestressing, which was eventually solved by installing and tensioning reinforcement inside the concrete sleepers.

In 1909, the Russian engineer N. E. Dolgov proposed a railway with a continuous monolithic reinforced concrete base for the first time and implemented it in various versions on the Dnieper Railway. Of the three versions of the structures he developed, a monolithic concrete slab was laid on the main site of the subgrade (in one of the options, a layer of crushed stone was preserved on the slab). The slabs covered the sides of the main site and formed drainage trays in the area of the ditches. Thus, the main site was completely protected from surface water penetration. The structures of N. E. Dolgov, laid in the track, had served from 22 to 40 years [10].

In a number of countries, attempts to use large-block structures continued. These include the designs of B. I. Mushkatin (USSR, 1946), Laval beds (France, 1946), original reinforced concrete beds and shells (Czechoslovakia, 1958). The track was also laid on reinforced concrete block supports in the German Democratic Republic, Poland, the Federal Republic of Germany, England, Japan, and other countries.

The retrospective and development of the track substructure are considered in more detail in the works [5; 11; 12].

Brief Technical and Economic Analysis of Development of Railways in Russia

Since ancient times in our country, when moving heavy weights, wooden rails have been used, subsequently supplemented with metal plates. Then, in 19th century, cast iron became the main material for rails.

In 1769 near St. Petersburg a special linear-extended structure was built to transport the «Thunder-stone», which later became the pedestal of the monument to Peter I.

In 1805, when the exchange was founded in St. Petersburg, a cast-iron rail road was built to transport granite stones to the construction site.

[4] Reinforced concrete alternative. The first reinforced concrete sleepers // beteltrans.ru. [Electronic resource]: http://www.beteltrans.ru/history/history_783.html. Last accessed 01.09.2021.

Pic. 6. Wide-sole rail used on railways, respectively, on New South Wales Railway, Midland Great Western Railway, Great Western Railway. [Electronic resource]: https://www.1902encyclopedia.com/R/RAI/railway-27.html. Last accested 11.06.2021.

Pic. 7. Pig-iron horse-drawn road in Zmeinogorsk: 1 – model of the «chugunka»; 2 – a fragment of a cast-iron rail and a bogie wheel. Zmeinogorsk «chugunka» – progenitor of Russian railways // https://chuguntv.ru. [Electronic resource]: https://chuguntv.ru/zmeinogorskaya-chugunka-prarodite. Last accessed 11.06.2021.

Similar structures and specialised auxiliary tracks were arranged during the construction of dams and other hydraulic structures [13, p. 24; 16].

«In 1806, P. K. Frolov developed and submitted to the mining department a project of a railway from Zmeinogorsk mine to Korbalikhinsky silver smelting plant. In his project, he pointed out that annually to transport ore at a distance of up to 3 km on an ordinary road, 1078 souls are required, while by rail only two people and two horses are required, who during six summer months can transport «*the entire amount of ore for annual smelting*». The profitability of the railway seemed so obvious that in the same year the project was approved, the author started construction and put it into operation in 1809» (Pic. 7) [13, p. 25; 14, p. 293].

The first steam-powered railway in Russia was built in 1834 at the Demidovs' Nizhniy Tagil Metallurgical Plant. And the first industrial railways were the prototype of future public railway lines [13, pp. 25–27].

The railways gave advantages, then unattainable for other types of transportation: reduction in cost and a significant increase in speed of delivery of both goods and passengers.

For development of construction of railways in Russia it was very important to create relevant economic conditions. If their construction initially developed at a slow pace and by the mid-1860s, the total length of Russian railways was only about 3,5 thousand km, about 2 % of the world network, then after the state created conditions for attracting private capital (including foreign) on the basis of concessions, and development of the railway network in the country accelerated sharply [15;16]. K. Ya. Zagorsky noted the positive dynamics of construction of new railways in the 80s of 19th century for creation of new and development of the main branches of the national economy, the transition from extensive methods and forms of the national economy to the intensive methods of capitalist production [1, pp. 66–67; 18, pp. 162–163].

«At the end of 19th century, record rates of railway construction were achieved in Russia. In the period 1893–1900, the length of railways increased on average by almost 2,5 thousand km per year. Neither before nor after has the network developed so dynamically. On the eve of the First World War, its length was about 70 thousand km, and the density exceeded 4 km per 10 thousand inhabitants» [16, pp. 165–166].

The dynamics of railway construction in the USSR was not stable, although in terms of pace and state objectives the path of the Russian Empire continued.

At the present stage of development of railways in our country in addition to modernising old ones, it is necessary to lay new lines to economically promising regions and to connect agglomeration territories. At the same time, economically demanded scientific research and technical developments are needed for construction of high-speed railways and development of heavy-haul traffic.

CONCLUSION

The birth, evolution and development of transport, in particular of land (represented by railways) transport, is a significant economic achievement of the mankind [17].

Among the most important features, inherent in the infrastructure of land transport, from a historical and at the same time economic point of view, one can note the influence of institutions of private property on its development, state support for social significant projects, the historical continuity of the most significant historical routes («Silk Road», the way «from the Varangians to Greeks»), which determine the economic development of many regions, embodied in modern international transport corridors.

The materials of the article and the results of the conducted historical, technical, and economic analysis are the basis of one of the chapters of the monograph published during the period of preparation for printing of the second part of the journal publication [18].

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Information about the author:

Razuvaev, Aleksey D., *Ph.D. (Economics), Associate Professor at the Department of Economics of Transport Infrastructure and Construction Business Management of Russian University of Transport, Moscow, Russia, razuvaevalex@yandex.ru.*

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