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Innovations as Basis for Strengthening the Market Position of Railways

(example of the Russian cargo transportation market in the late 19th – early 20th centuries)

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ABSTRACT

The formation of a large-scale railway network in Russia by the end of the 19th century contributed to a significant acceleration of the country's socio-economic development, thanks notably to the increase in volumes, improved quality and efficiency of cargo transportation.

The objective of the study described in the article is to analyse the expansion of the scale of activity and strengthening of the position of Russian railways in the cargo transportation market in the late 19th – early 20th centuries and to identify the significance of the introduction of innovations in the industry using the methods of historical and statistical analysis, assessment of the innovativeness of rolling stock and technics and benchmarking.

The study revealed that the enhancement of the economic role of railways, including the growth of their share in the cargo transportation market in the period under review was determined by the synergy of the increase in the length of the railway network and its increasingly intensive use due to the innovation-focused development of the railway industry. Innovations covered all aspects of development of the country's railways: construction and maintenance of railway infrastructure, design of rolling stock and its operations management. In particular, the high dynamism of innovative improvement of design characteristics of cargo locomotives and wagons was confirmed by the growth of the corresponding innovation coefficients.

Innovation-focused development of Russian railways in the period under review allowed them to take leading positions in the national cargo transportation market and, as it is evidenced by the performed cross-country comparisons, to achieve world leadership as for several key production and economic indicators. This historical experience is very interesting in modern conditions, when railways prioritise innovations to solve long-term problems of effective positioning in the transport and logistics services market.

Keywords: transport system, railways, cargo transportation market, competitiveness, cargo transportation intensity, cargo transportation efficiency, innovation-focused development.

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INTRODUCTION

The approaching bicentennial of railways is a good incentive to deepen research into the history of railway transport, including railways' economic history. Russia was one of the first countries in the world (the seventh in a row [1]) to establish railway transportation – as early as in 1837, 12 years after the appearance of the first public railway and 7 years after steam-powered railways had been recognised as an effective and promising mode of transport [2; 3, P. 15]. Although the railway network in our country had developed at a slow pace for three decades after that, then, in the context of deep social reforms, institutional mechanisms were created that ensured a radical acceleration of railway construction [4–6]. The rate of commissioning of new railway lines increased sharply from 1868 [7, P. 35], and by the end of the 1870s, a large-scale railway network with a length of over 20 thousand km was created in the country, connecting the main regions of the European part of the country into a single economic space and contributing to acceleration of socio-economic development [8; 9].

In the 1890s, rates of railway construction were record in all the Russian history [10], and by the beginning of 20th century, Russia took second place in the world in terms of the length of the railway network [11]. At the same time, there was a qualitative improvement in railway technology and management of the transportation process, which, together with the positive impact of development of railway transport on the country's economy, was revealed in the works [1; 7–9; 12–15] and several others.

Nevertheless, many aspects of development of Russian railways in 19th – early 20th centuries require additional study and understanding.

The objective of the article is to analyse the expansion of the scale of activity and strengthening of the position of Russian railways in the cargo transportation market during the specified period and to reveal the significance of implementation of innovations in the industry as a tool for that. To achieve this objective of the study, *methods* of historical and statistical analysis were used, as well as assessment of the innovativeness of technical means and benchmarking.

RESULTS

Growing importance of railways in the Russian transport system

In the pre-railway era, the main modes of transport in Russia, as in other countries, were horse-drawn carriages and inland waterways. At the same time, the possibilities for transporting goods on dirt roads were limited due to the autumn and spring muddy seasons of bad roads. The time of limited travelling was, for example, four months a year in Kursk and Tula provinces, four to five months in Penza and Ryazan provinces, six months in Kostroma province, and lasted most of the year in Perm, Vologda, Arkhangelsk and a few other provinces [16, P. 129]. As the founder of the economics of railway transport [in Russia] A. I. Chuprov noted, «sometimes the roads were so bad that the cabbies, having unloaded the goods, quickly escaped», while delivery of goods on time «was a matter of sheer luck» [17, P. 13]. The duration of navigation on inland waterways was limited to the period from ice break-up (the final clearing of the waterway from ice) to freeze-up and was five to seven months a year [17; 18]. These transport constraints had an extremely negative impact on the economic and social development of the country. Nevertheless, waterways, which had a high carrying capacity during the navigation period, were considered the basis for trunk cargo transportation.

During the discussions about the possibility and necessity of building railways in Russia, which unfolded in the early 1830s, some supporters of their construction viewed railways as auxiliary transport arteries leading to the main shipping rivers along which domestic trade was carried out over long distances. Opponents of railway construction argued their position, among other things, by the fact that railway transport was inferior to cheaper water transportation of goods [19]. Thus, we can say that at that time there was a consensus regarding the leading role of inland water transport in implementation of trunk transportation of goods. However, as was the case of many breakthrough innovations both before and after the railways, their implementation not only refuted the arguments of sceptics, but also exceeded the expectations of their supporters. Already in the second half of the 1870s, railways carried almost 24 % more cargo than inland water transport, and their share subsequently grew steadily (Table 1).

Table 1

Distribution of trunk cargo transportation in Russia between railway and inland water transport in the late 19th – early 20th century

Years	Volume of cargo transportation, million tons			Share of railway transport, %
	Water transport	Railway transport	In total	
1876–1880 (on average)	13,956	17,248	31,204	55,3
1881–1885 (on average)	13,956	23,227	37,183	62,5
1886–1890 (on average)	16,626	29,50	46,126	64,0
1891–1895 (on average)	20,115	37,183	57,298	64,9
1896–1898 (on average)	27,584	49,943	77,527	64,4
1913	50,90	158,20	209,10	75,7

Source: compiled and calculated by the authors based on data [13; 18; 20].

Table 2

Changes in the coefficient of transportation* by rail of some important goods late 19th – early 20th centuries

Years	Goods		
	Bread (grain)	Coal	Oil
1882–1886 (on average)	0,163	…	…
1892–1896(on average)	0,221	0,643	0,196
1902–1906 (on average)	0,232	0,727	0,168
1913	0,221	0,782	0,473

Source: [1].
* [Ratio of goods transported to the volume of the total production of those goods].

Table 3

Distribution of transportation of main types of cargo between railway and inland water transport in the European part of Russia (according to data for 1898), %

Goods	Railway transport	Inland water transport
Main breads	69,4	30,6
Salt	61,5	38,5
Coal	98,6	1,4
Oil products	47,7	52,3
Forest building materials and firewood	31,1	68,9
Others	82,0	18,0
Total	64,9	35,1

Source: calculated by the authors based on data from the Appendix to the Statistical Digest of the Ministry of Railways. Issue 59. St. Petersburg, Department of Statistics and Cartography of the Ministry of Railways, 1900.

An ever-increasing share of the most important transport-intensive goods produced in the country were transported by rail (Table 2). At the same time, specialisation of transport modes emerged: coal, salt, and grain cargo were transported to a greater extent by rail, while timber building materials and firewood were transported by waterways (Table 3). From the point of view of the competitiveness of railways in the transport market and their role in the country's economy, it is important that at the end of the 19th century most of the «other» cargo (which included various types of finished products intended for both industrial and personal consumption) were already transported by rail. Subsequently, an accelerated growth in the railway transportation of many types of such goods continued. For example, in 1909–1913, compared to the period 1894–1900, the average annual volume of railway transportation of fresh fruits and berries increased by almost 2,6 times, fresh vegetables – by 3,8 times, iron, steel and cast iron – by 2,4 times, agricultural machinery – by 4,8 times [14, pp. 323–324].

The main advantages of rail transport were regularity and higher speed. At the same time, the estimate of the average usual speed of delivery of goods by rail over long distances of «300 versts[1] per day» [17, P. 13] cited by A. I. Chuprov and dating back to the 1870s seems overstated. However, at that time there was no necessary statistical base for such estimates. The

[1] 1 verst = 1 066,8 m

first surveys of speed of movement of goods transported in wagonload shipments on Russian railways were conducted in August-September 1907, 1910, 1911, 1912 along some specific routes [21, P. 59]. The average values of delivery speed on these routes fluctuated from 100 to 148 kilometres per day. A summary of the results of these surveys made it possible to determine that the average value of delivery speed for all of them was 141 km/day with an average transportation distance of 1103 km (which was more than twice the average network transportation distance of that period[2]). The obtained value of delivery speed, by modern standards, is small. However, it completely coincides with the average network value of the delivery speed of wagonload shipments in the corresponding distance range according to data for September 1949 (!)[3], when regular recording of speed and delivery times of goods was introduced. (The coincidence of the month of survey with the periods of the above-mentioned surveys is important, since the speed of cargo delivery varies significantly seasonally [22; 23]). Thus, the technological advantages of railways – all-season transportation, urgency of cargo delivery, high transit capacity – in combination with cheaper delivery over long distances [8; 17] determined the increase in their importance in the transport system of Russia and a growth of their share in the market of trunk cargo transportation. At the same time, local transportation over short distances (up to 25 km) remained more profitable to carry out by horse-drawn transport [16, P. 128]. Specialisation and interaction of various types of internal transport – railway, water and horse-drawn ones – allowed commodity owners to build the most profitable schemes for delivering their goods to various markets.

In the context of this study, it is important to note that since the end of the 19th century, railways have played a leading and increasingly significant role in the Russian cargo transportation market. It should be noted that the strengthening of the position of railways in the Russian cargo transportation market correlates with the acceleration of the country's economic development in the late 19th – early 20th centuries [15; 24]. This confirms a polemical nature of the conclusions of Nobel laureate Robert W. Fogel, who, based on the construction of a counterfactual model of 19th century's US economy, came to the conclusion that the absence of railways and the use of inland waterways instead would have slowed down economic development for only a few years [25; 26], and testifies to the validity of the opinion that Fogel's model did not fully consider the macroeconomic effects of development of the railway network, in particular, those associated with acceleration of cargo transportation [27]. There is every reason to believe that such impressive results in the leading economies of the world in that era, which are noted in modern macroeconomic studies, could be achieved only based on the development of railway transportation [11; 27; 28].

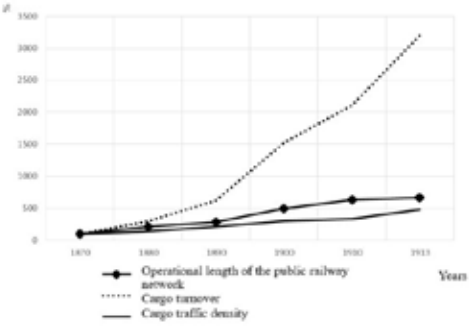
Growth in the scale and intensity of railway cargo transportation

The increase in the economic importance of railways and their share in the cargo transportation market was certainly associated with the development of the railway network, the length of which increased more than 6,6 times from 1870 to 1913, and as this growth occurred, more and more areas, settlements, and enterprises gained direct access to railways. However, while noting the growth in the length of railways, it is also necessary to pay attention to their increasingly intensive use. The density of cargo traffic, defined as the ratio of cargo turnover to the operational length of the network, grew slightly slower than the railway network itself (more than 4,8 times over the same period), which, in synergy with the growth of the network, made it possible to increase cargo turnover by almost 32 times (Pic. 1).

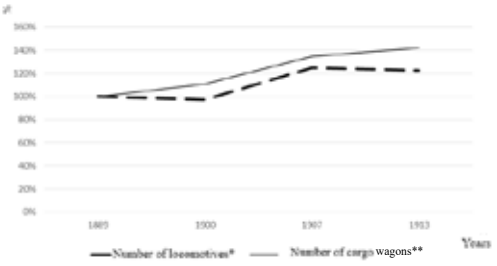
The growth in cargo traffic density was ensured, firstly, by increasing the saturation of the network with rolling stock (Pic. 2), which is evidence of an increase in the degree of implementation of the railways' capacity (in this case, the actual volumes of traffic could exceed the calculated ones [29, P. 102]) and the growth of their carrying capacity. The latter is also confirmed by the fact that the number of wagons and coaches grew faster than the number of locomotives. This means that the number of wagons with the train and its weight increased, and even with the same number of trains, it was possible to increase the volume of cargo transportation.

[2] This circumstance is significant, since with the increase in the distance of transportation, the speed of delivery of goods tends to increase [22].

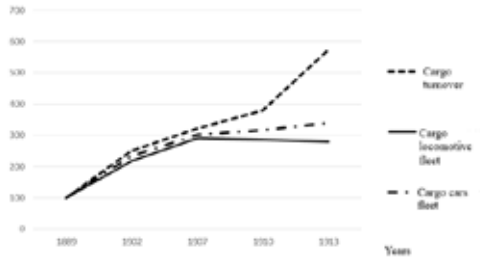
[3] Delivery duration and speed of cargo movement on railways in 1949–1953. Materials on railway transport statistics. Issue 267. Moscow, 1953, 232 p.



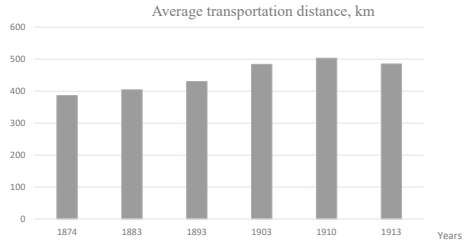
Pic. 1. Dynamics of development and use of the Russian railway network for cargo transportation in the late 19th – early 20th centuries (1870 = 100 %).
Source: calculated by the authors based on data from [7; 12; 18].



Pic. 2. Dynamics of saturation of the Russian railway network with rolling stock in the late 19th – early 20th century (1889 = 100 %).
** The share of passenger locomotives was 15–20 %.*
*** In 1907–1913 – including auxiliary ones.*
Source: calculated by the authors based on data [7; 18; 29].



Pic. 3. Comparison of the dynamics of cargo turnover and cargo rolling stock fleets on the Russian railway network (excluding local roads) in the late 19th – early 20th centuries.
Source: calculated by the authors based on data from [18; 29].



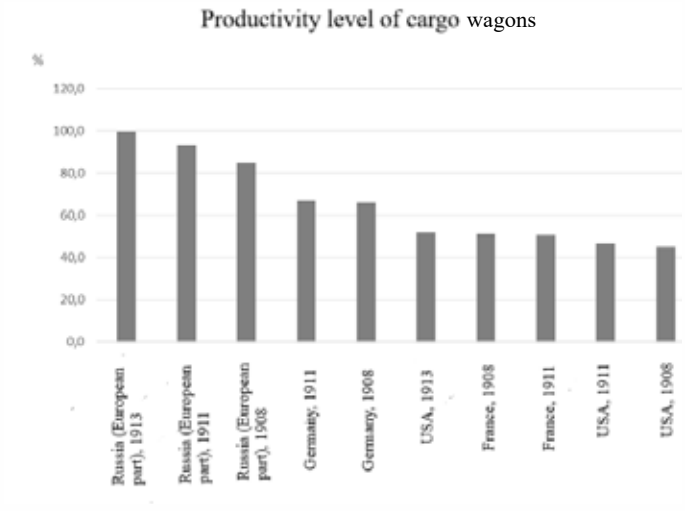
Pic. 4. Dynamics of change in average distance of cargo transportation on the Russian railway network in the late 19th – early 20th centuries.
Source: calculated by the authors based on data from [18; 29].

An even more vivid characteristic of the growth of railway carrying capacity is provided by a comparison of the dynamics of cargo turnover and the fleet of cargo rolling stock (Pic. 3). A faster growth of cargo turnover compared to the fleet of cargo wagons indicates an increase in the dynamic load and productivity of the wagon. And a faster growth of the fleet of cars compared to the fleet of steam locomotives, as already noted, indicates an increase in the average composition and weight of the train. Both factors together characterise the growth of the productivity of the use of steam locomotives and the carrying capacity of railways.

An important characteristic of the expansion of the geographical scale of railway cargo transportation is the fairly stable trend of increasing their average distance (Pic. 4), which intensified after, thanks to the construction of the Great Siberian Route – the Trans-Siberian Railway, the railway network stepped beyond the Urals and reached the Pacific Ocean [30; 31].

It should be noted that during the discussions on the options for organising transport links between Siberia and the Far East and the European part of the country, the alternative of railway and water transport was again revealed. Some scientists, in particular, A. I. Chuprov [32, P. 180], and government officials, in particular I. A. Vyshnegradsky [33, P. 54], who held the post of the Minister of Finance in 1887–1892, spoke against building a continuous rail route through the eastern regions of the country, but advocated only connecting river basins by rail, thus forming a rail-water link and reducing the required length of rail lines by more than half. Although less expensive, implementation of such a project would certainly not have ensured such regularity and speed of transportation, nor such carrying capacity, and would not have opened up such large-scale prospects for the long-term socio-economic development of Siberia and the Far East as creation of a continuous railway connection of the European part of the country to the Pacific Ocean, which was eventually implemented [30; 31].

During the construction of the Trans-Siberian Railway, several innovative solutions were implemented, from the mechanisation of earthworks, including the use of «multi-bucket excavators manufactured at the Putilov Plant»,



Pic. 5. Comparison of the level and dynamics of cargo wagon productivity (per unit of carrying capacity) of the world's leading railway systems at the beginning of the 20th century, %. Source: compiled by the authors based on data from [1].

as well as trucks [31, P. 199], to unique engineering solutions in the field of artificial structures [30; 34].

At the same time, the developments of Russian railways in the late 19th – early 20th centuries were innovation-focused, which deserves detailed consideration.

Innovative basis for increasing the intensity and efficiency of cargo railway transportation

A retrospective analysis of the main innovations in the field of railway transport shows that if in the 1830s and 1840s most of these innovations appeared in Great Britain, then starting from the 1850s more and more innovations were carried out in Russia [35, pp. 55–58]. Their implementation made it possible to use the infrastructure and rolling stock more intensively and economically, thereby increasing the supply of railway cargo transportation and strengthening the position of railways in this market.

The largest innovation in the field of cargo transportation management, which was not only technological but also institutional in nature, «was the original system of mutual use of cargo wagons» [1, P. 66], fully implemented in 1889 after more than 20 years of improving the interaction between distinct railways in the field of using cargo wagons [7, pp. 63–65]. Within the framework of this system, «the entire cargo wagon fleet of a single-gauge network can be provided for free common use by all railways, provided that:

1. The size of the cargo wagon fleet of each individual railway is constantly maintained.

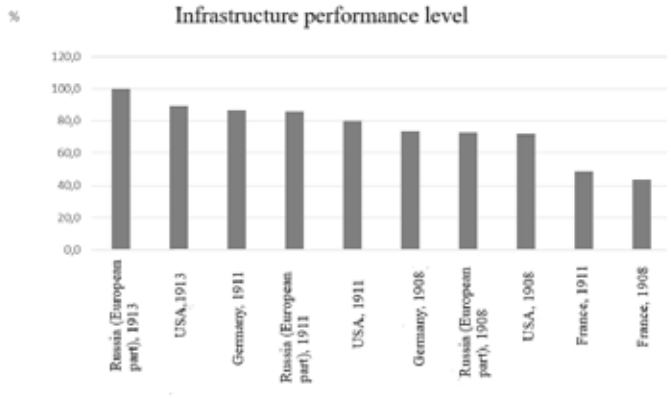
2. The established quality and condition of cargo wagons is constantly maintained» [1, P. 67].

The system of mutual use of cargo cars can be considered a prototype of a modern economy of shared use of resources [36–38]. The introduction of this system made it possible to implement non-reloading transportation between all Russian railways, thereby significantly accelerating and reducing the cost of transporting goods and ensuring, in synergy with other technical and technological innovations, a significantly more productive and progressively improving use of wagons compared to other railway systems. This is clearly seen from the data in Pic. 5, formed based on the benchmarking method, actively used in scientific research in the field of railway transport [39; 40].

The efficient use of cargo wagons contributed to the intensification of the use of infrastructure for cargo transportation (Pic. 6). The analysis of the data presented in Pics. 5 and 6, using the methodology proposed by Nobel laureate in economics Edmund Phelps [41], allows us to conclude that the Russian railways had a high level of dynamism, i.e. the desire and ability to innovate, at the beginning of the 20th century.

Innovations covered all aspects of the development of the country's railways.

In the track divisions, the most important innovations were associated with the transition to the use of steel rails, the use of heavier types



Pic. 6. Comparison of the level and dynamics of productivity of the use of railway infrastructure for cargo transportation (density of cargo transportation) of the leading railway systems of the world at the beginning of the 20th century, %.
Source: calculated by the authors based on data from [1].

of rails, the improvement of rail fastenings, the use of sleeper impregnation, and the improvement of the track maintenance and repair system [1; 42]. Some railways tested and applied innovative designs of under-rail foundations using concrete, asphalt concrete, and reinforced concrete [43; 44].

The rolling stock was improved. Due to several improving innovations, the power of steam locomotives increased, steam distribution was improved, boiler pressure and axle load increased. On this basis, opportunities opened for increasing the weight and speed of trains, as well as the cost-effectiveness of transportation. Modern methods for assessing the innovativeness of technics [45–47] make it possible, based on data from [48], to assess the dynamics of the growth of the innovativeness of freight steam locomotives produced in Russia in the late 19th – early 20th centuries (Table 4).

The fleet of cargo wagons was also qualitatively improved on an innovative basis: increased payload and cargo capacity, reduced tare ratio, etc. [1; 49]. A significant increase in the level of innovation was typical for different types of wagons (Table 5), including wagons with increased payload capacity, which appeared at the beginning of the 20th century (Table 6).

An important component of the innovative development of rolling stock was the production and use of specialised cargo wagon. As early as 1862, refrigerated wagons for transportation of perishable goods appeared, in 1868 dump wagons appeared with a tipping body for bulk cargo, and in 1872 there appeared domestically produced tank wagons [42, pp. 89–90]. Other types of specialised wagons were also produced [1, P. 101]. By the beginning of the 20th century, the share of specialised wagons within the fleet exceeded 13 % (Pic. 7). Although it did not grow in subsequent years, moreover, the increase in the number of specialised wagons lagged behind the overall growth rate of the fleet, the fleet of specialised wagons made it possible to satisfy the growing demand for transportation of non-bulk cargo. At the same time, fundamentally new wagons appeared. For example, in 1910, the first isothermal wagon with mechanical cooling was built [49, P. 40]. In general, the specialisation of the fleet of wagons contributed to the strengthening of the positions of railways in the cargo transportation market.

It is important to note that the innovations were implemented by specific railways that were entities in the transport market and interested in increasing their efficiency and competitiveness [1, pp. 65–66, 94–96, 102]. If successful, their application was expanded to the entire network. A good example was the increase in the carrying capacity of a standard cargo wagon from 900 to 1000 poods[4] in 1907 on the South-Eastern Railways. Soon it began to be used on the Catherine's and Vladikavkaz Railways, and since 1910 it was approved by the Ministry of Railways for the entire railway network [1, P. 65].

The system of mutual use of cargo wagons, in turn, «grew» from agreements between neighbouring railways on the organisation of uninterrupted service and was finally implemented based on an network-wide agreement between all the railways [7, pp. 64–65]. At the same time, no «common fleet» of wagons based on its

[4] 1 pood – 16,38 kg.

Table 4

Increasing the level of innovation of Russian cargo locomotives in 19th – early 20th centuries

Steam locomotive series	Start of construction, year	Power, hp	Pressure in the boiler, atm.	Axle load, tf	Speed, km/h	Innovation coefficient
D	1845	140	8	11	15	1
G	1863	150	8	11	20	1,10
O^{p}	1897	400	11	12	50	2,16
O^{v}	1905	420	11	12	50	2,20
Sch	1906	550	14	14	65	2,82
E	1912	1000	12	16	65	3,61

Source: compiled and calculated by the authors based on data [48].

Table 5

Increasing the level of innovation of Russian cargo wagons in 19th – early 20th centuries

Type of a wagon	Type of wagon design (built by)	Start of construction, year	Specific load capacity, t/axle	Specific bearing capacity, m3/axle	Specific floor area, m2/axis	Tare coefficient	Innovation coefficient
Covered	Petersburg-Moscow railway	1846	2,05	9,775	4,9	0,95	1
	Peterburg- Warsaw railway	1860	4,1	23,1	8,9	0,73	1,87
	Petersburg-Moscow railway, rebuilt from four-axle to two-axle	1863	4,7	19,55	9,8	0,78	1,88
	Non-braking, of Kovrov workshops with trusses	1870	5	20,05	8,75	0,58	1,98
	Non-braking, of Kolomna plant	1879	6,25	18,1	7,9	0,52	2,08
	Normal 12,5 t, non-braking	1892	6,25	20,0	8,8	0,54	2,16
	Normal 16,5 t, non-braking	1911	8,25	19,5	8,8	0,43	2,50
Platforms	Petersburg-Moscow railway	1846	2,5	-	5,625	0,60	1
	Peterburg- Warsaw railway	1860	6,25	-	8,7	0,39	1,86
	Kolomna plant	1878	6,75	-	11,75	0,38	2,12
	Three-axle	1881	5,0	-	7,87	0,48	1,55
	Normal type, non-braking	1892	6,25	-	12,45	0,54	1,94
Gondola	For coal transportation with wooden body frame	1861	5,0	4,0	-	0,42	1
	For coal transportation with steel channels, non-braking	1880	6,25	10,0	-	0,48	1,54
Tanks	For transportation of oil, non-braking	1872	5,0	5,85	-	0,62	1
	For transportation of normal type oil, non-braking	1895	7,5	7,75	-	0,50	1,35
	For transportation of gasoline	1908	7,5	9,25	-	0,58	1,38

Source: compiled and calculated by the authors based on data [49].

Table 6

Increasing the level of innovation of Russian cargo wagons with increased carrying capacity in 19th – early 20th centuries

Type of a wagon	Type of wagon design (built by)	Start of construction, year	Specific load capacity, t/axle	**Specific bearing capacity, m³/axle**	Load from the axle of the wheel set on the rail, kN	Tare coefficient of a non-braking car	Innovation coefficient
Covered	Moscow-Kazan railway, without bogies	1905	6,875	16,4	109	0,45	1
	South-West Railways	1906	9,375	25	138	0,48	1,27
	Central Asian railway	1909	9,375	19,5	144	0,55	1,21
	Catherine's Railway	1906	8,33	25	119	0,42	1,22
Platforms	Petersburg-Warsaw railway	1903	8,25	-	109	0,42	1
	Elongated	1908	8,25	-	125	0,51	0,99
Gondola	Coal	1908	7,5	9	130	0,40	1
	With metal body	1906	9,375	12,5	134	0,43	1,15
	Catherine's Railway	1906	8,33	10,7	113	0,36	1,06
Tanks	Vladikavkaz and Kazan railways	1895	6,25	7,25	97	0,54	1
	South-Eastern railways	1898	8,25	9,5	119	0,45	1,26

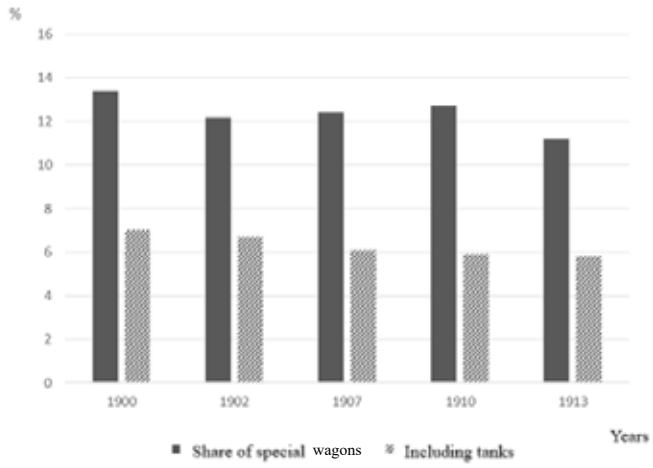
Source: compiled and calculated by the authors based on data [49].

centralisation was created, but mutual use of fleets belonging to specific railways was ensured. This experience is noteworthy in the context of modern discussions on the optimisation of cargo wagon fleet management [50].

Based on the innovation-focused development of Russian railways in the context of growing commodity production and the transportation market in the country, while pursuing a rational government economic policy [14; 51; 52], railway industry achieved high efficiency indices. By the beginning of the 20th century, in terms of return on invested capital, Russian railways ranked second among the leading railway systems in the world [12, P. 303], and in terms of the level of economic efficiency of current activities (according to the criterion of the minimum coefficient of operating costs) in 1913 they were at the top [53, P. 103].

CONCLUSION

The analysis of the development of railway transport in the late 19th – early 20th centuries, carried out using the Russian railway industry as an example, has shown that already in the first phase of the evolution of railway transport – the



Pic. 7. Changes in the level of specialisation of cargo wagons on the Russian railway network at the beginning of the 20th century.
Source: calculated by the authors based on data from [18].

phase of predominantly extensive development [27, P. 130], the intensification of railway activity was carried out on an innovative basis, which became the foundation for the development and growth of the industry's efficiency in the second phase of its evolution [27, pp. 131–133]. The innovation-focused development of Russian railways in the period under review, which was positively influenced by the multicentricity of development and implementation of innovative solutions, allowed them to take leading positions in the national cargo transportation market and achieve world leadership as for several key production and economic indicators.

This historical experience is very interesting in modern conditions, when railways are solving long-term problems of their effective positioning in the transport and logistics services market through creation of an innovative basis [54; 55].

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