IMPACT OF SETTLEMENTS ON DEVELOPMENT OF HSR IN EUROPEAN COUNTRIES

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ABSTRACT

The development of high-speed transport in European countries began more than 30 years ago and since then large HSR networks have been developed. And as the development of HSR in the territory of Russia is a topical issue now, it seems relevant to carry out analysis and to identify the laws governing the development of HSR in Europe in the context of searching for the most optimal schemes for development of high-speed transport in Russia.

In this paper, we analyze the structure of population distribution and its impact on development of HSR in France, Germany and Spain. On the basis of the analysis, a number of regularities have been revealed, which make it possible to explain many aspects of development and functioning of HSR by the features of population distribution.

Keywords: HSR, population distribution, transport network, transport network morphology, passenger transport in Europe.

Background. *Russia is embarking on development of high-speed railway transport – high-speed rail (HSR). The vastness of the territory of Russia, a significant uneven distribution of population, as well as the need to provide a one-time commissioning of lines of considerable length in any direction require a multicriteria assessment of feasibility and effectiveness of the chosen scheme for development of HSR in Russia. Since HSR is primarily designed for passenger transportation, such an assessment should take into account the structure of population distribution and its transport mobility.*

In many of the world's leading countries, the development of HSR has been going on for several decades. Therefore, it is important to analyze and evaluate these processes, to search for patterns and possible analogues for development of the Russian HSR network.

The topic of this work is focused on the main features of development of high-speed transport in European countries, primarily from the position of impact of resettlement features on development and functioning of HSR network. From this point of view, among the countries of Europe with HSR, Germany, France and Spain are the most suitable for meaningful analysis. These countries are quite large in area and population and have a highly developed economy (Table 1). In particular, Germany and France are among the world's technological leaders and occupy the fourth and sixth place in terms of GDP in the world (at the time of beginning of construction of HSR, they occupied the third and fourth place, respectively). The existence of significant economic and technological prerequisites made it possible to create, within a relatively short period of time, well-developed national HSR networks in these countries.

Among other large European countries, only Italy has a significant network of HSR. However, the structure of its network is largely determined by the specific form of its territory. The Italian network is a single line stretched along the Apennine peninsula, which makes it less interesting for our analysis. In the rest of Europe, HSR is not developed very much and is mainly intended for cross-border passenger transportation (for example, the lines linking London and Brussels to the French network of HSR), so the structure of population distribution in these countries does not have a significant impact on development of HSR.

It should be noted that studies devoted to the analysis of high-speed transport networks have not been carried out in practice, since, until recently, the object of research itself was not available. However, now there is an interest in studying the network aspect of development of HSR [1, 2].

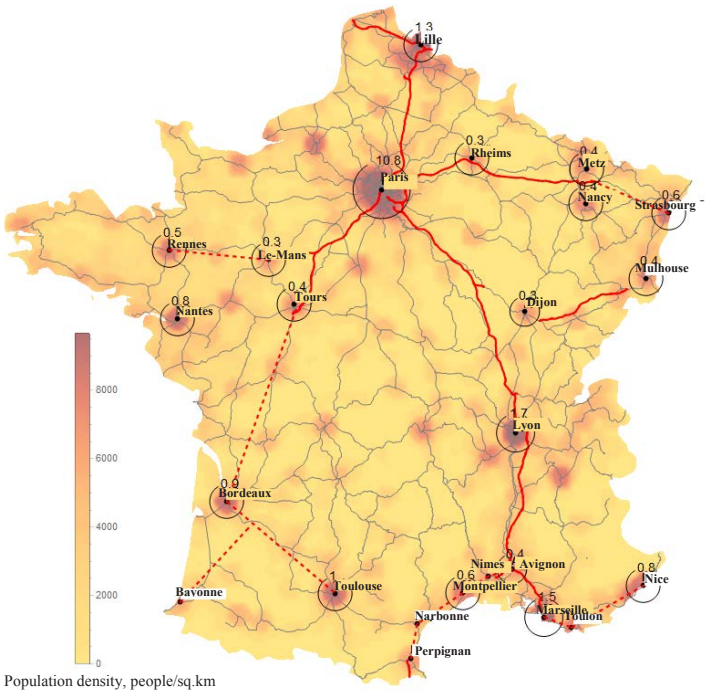
Since HSR is primarily designed for transportation of passengers (in Europe, significant freight transportation is carried out only for some HSR of Germany [3]), the spatial distribution of population is a key factor determining the development of HSR network. At the same time, it is necessary to keep in mind that most of the currently functioning HSRs are not self-supporting and require significant state support [4], and the economic feasibility of their construction is justified by indirect effects (economic, environmental and technological) [5, 6]. In addition, HSR is an important tool for regional development, as evidenced by the accelerated economic growth of cities included in HSR network [7]. Therefore, the impact of population settlement on development of HSR should not be considered only from the point of view of the demographic potential necessary for generation of economically profitable volumes of passenger transportation. To a much greater extent, the development of HSR in European countries is aimed at providing as many people as possible with

Table 1

The main characteristics of Germany, France and Spain (2016). Compiled by the authors on the basis of data from the EU statistical service[1]

Country	Area, sq. km	Population, thousand people	Density of population, persons per sq. km	Length of HSR, km	GDP per capita, euro	Average monthly wage, euro
Germany	357021	82176	230	1475	38100	2620
France	547030	64847	119	2142	33300	2603
Spain	504782	46440	92	2938	24000	1829

[1] URL: http://ec.europa.eu/eurostat/data



Pic. 1. The network of HSR of France. Gray – railways, red – HSR with a speed of more than 250 km/h, dashed lines – under construction (planned) HSR. The population of cities with suburbs (zones surrounded by circles) is given in million people. Compiled by the authors on the basis of the data of the association «Eurogeographics»[1] and [9].

the opportunity to use this convenient, fast, safe and environmentally friendly mode of transport.

Analyzing the impact of population placement on HSR, it should be borne in mind that the natural market niche of high-speed transport is passenger transportation at a distance of 200–800 km (see, for example, [8]). At such distances, HSR is faster than any other modes of transport, while for distances of up to 200 km, motor transport is faster, and for distances greater than 800 km, an air transport is more suitable.

The article has the following structure. The first three paragraphs briefly review and analyze development of the infrastructure of HSR in France, Germany and Spain, the fourth paragraph is devoted to the dynamics of growth and cost of HSR, the fifth considers the organizational structure and rolling stock, the sixth analyzes the passenger turnover of HSR.

Objective. *The objective of the authors is to consider impact of population settlements on development of HSR in European countries.*

Methods. *The authors use general scientific methods, comparative analysis, evaluation approach, economic assessment method, graph construction.*

Results.

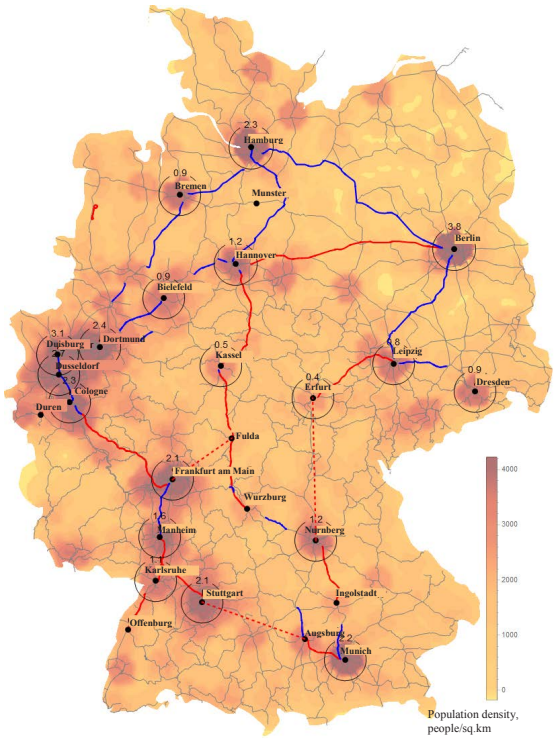
1. Infrastructure of HSR of France.

The first country in Europe and the second in the world (after Japan), which began development of high-speed transport, was France. The first in Europe specialized HSR Paris–Lyon with a length of 410 km was opened here in 1981. The line began to enjoy considerable popularity and quickly became a significant competitor to conventional trains and aircraft. Therefore, after it HSR was built in the west, connecting Paris with the cities of Tour and Le Mans (1989), followed by the line Paris–Lille (1992), which connected the capital with the northern regions of France and was later continued to Brussels and London (through the Tunnel under the English Channel). Also in 1996, a line of 106 km was built, which, bypassing Paris, connected the northern and southern HSR. In the 2000s the formation of the radial structure of the French HSR network with the center in Paris continued. The line Paris–Lyon continued to Marseille (2001) and the first line of the Paris–Strasbourg line through Reims to Nancy and Metz (2007) and part of the line to Mulhouse (2011), which linked the French and German networks of HSR, were built.

Thus, it became possible to connect Paris with almost all major cities in the north, east and south of France. Therefore, the development of HSR network in the short term is connected with continuation of the western line to Bordeaux and Rennes (the opening of the lines is expected in 2017/2018) and construction of HSR along the Mediterranean coast, which will connect to the Spanish and Italian HSR (access to Barcelona and Genoa, respectively). In the long term, the lines Bordeaux–Toulouse and Bordeaux–Bayonne are planned, which will continue to the Spanish city of San Sebastian and thereby will link the Spanish and French networks of HSR along the coast of the Bay of Biscay. Note also that HSR built before 2007 is designed for a maximum speed of 300 km/h, and later lines allow traffic with speeds up to 320 km/h [3, 9].

The morphology of the French HSR network is due to the peculiarities of spatial distribution of population, which has a pronounced monocentric character. The center of France is the agglomeration «Big Paris» with

[1] URL: http://www.eurogeographics.org



Pic. 2. The network of HSR of Germany. Gray – conventional railways, blue – HSR with a speed of 250 km/h, red – HSR with a speed of more than 250 km/h, dashed lines – under construction (planned) HSR. The population of cities with suburbs (zones surrounded by circles) is given in million people. Compiled by the authors on the basis of the data of the association «Eurogeographics» and [9] (HSR Berlin–Munich was inaugurated in December 2017. – ed. note).

a population of 10,6 million people, while the population of the second largest city of Lyon is six times smaller. In addition to Lyon in France, there are only two cities with a population of more than 1 million people and six cities with a population of 0,5 to 1 million. This distribution of population makes it natural to form a radial network of HSR, which connects the regional centers with Paris. This is also facilitated by the fact that the distances between Paris and most of the cities of France are within the range of 200–800 km, which is favorable for HSR. For example, the distance by air from Paris to Marseilles is 660 km, to Lille – 204 km, to Bordeaux – 499 km.

2. Infrastructure of HSR of Germany

The appearance of a high-speed passenger traffic in Germany dates back to 1991, when Hannover–Würzburg HSR began operating with a length of 338 km (part of this line as Fulda–Würzburg section has been used since 1988). In the same year 1991, the Mannheim–Stuttgart line was commissioned, followed by the planned construction of Cologne–Frankfurt, but the 1990 unification of Germany made significant adjustments to the plans for development of high-speed transport. Since the capital of the united Germany was Berlin, the urgent construction of Hannover–Berlin HSR was completed, which ended in 1998, and work on Cologne–Frankfurt line was completed only in 2002. Along with the construction of new specialized lines for organization of high-speed traffic, some conventional lines have been modernized, the longest of which is Hamburg–Berlin line (2004). At the moment, several more lines with a total length of 368 km are being built in Germany. In particular, in December 2017 the railway Nuremberg–Erfurt was opened (183 km), which will significantly shorten the travel time on Berlin–Munich route. There are also works on HSR from Offenburg to Swiss Basel. In the long term, Frankfurt–Fulda line is planned, which will connect Stuttgart–Cologne and Hanover–Munich lines.

The peculiarity of the German HSR network is that when driving on some specialized HSR, the trains pass part of the route along modernized or even ordinary lines. In addition, part of the German HSR is built in such a way that it is possible to carry out movement of freight trains. Most of Germany's specialized HSR are designed for maximum speeds of 250 km/h and 280 km/h, and modernized lines allow traffic with a top speed of 230 km/h [3, 9, 10].

Unlike France, the population of Germany is distributed throughout the country much more evenly. There are no agglomerations like «Big Paris», which not only has a population of 10,6 million people, but also has a very high density (Paris itself has a population density of about 22 thousand people per sq. km). Germany's largest city of Berlin has a population of 3,5 million people (4,5 million people with suburbs) and density of about 4000 thousand people per sq. km. Moreover, the large agglomeration Rhine–Ruhr (the cities of Dortmund, Duisburg, Dusseldorf, Essen, Cologne, etc.) has a total population of more than 10 million people, but its average population density is less than 2 thousand people per sq. km, and density of the central part of cities does not exceed 3 thousand people per sq. km. At the same time, Germany has much more cities than France with a population of more than 1 million people and from 0,5 to 1 million people.

Pic. 3. Network of HSR of Spain. Gray – conventional railways, blue – HSR with a speed of 250 km/h, red – HSR with a speed of more than 250 km/h, dashed lines – under construction (planned) HSR. The population of cities with suburbs (zones surrounded by circles) is given in million people. Compiled by the authors on the basis of the data of the association «Eurogeographics» and [9].

In Germany, the distances between major cities do not exceed the upper limit of the range 200–800 km, which is favorable for HSR: the distance from Hamburg to Munich by air is 612 km, and from Berlin to Duisburg – 471 km. However, unlike France, in Germany the distances between many large cities are less than 200 km, which makes high-speed transport less attractive compared to conventional suburban trains or buses.

Due to the polycentricity of population distribution, the logic of development of the German HSR network differs from the French one. Here the network develops so that each large city is connected to as many other major cities as possible via HSR via shortest way as possible. It can be noted that after commissioning of the lines under construction and planned (they are shown in dotted lines in Pic. 2) this task will be practically fulfilled (after these HSR, only the construction of Fulda–Erfurt line can have a significant additional effect).

3. Infrastructure of HSR of Spain

The construction of the national HSR network in Spain was started almost simultaneously with Germany. The first Spanish HSR connected Madrid with Seville in 1992. The opening of this line was timed to the Expo-92 exhibition in Seville. That is why the first HSR in Spain did not become the line to Barcelona, which would be more natural, given that Barcelona is the second largest city in Spain. After construction of the line to Seville more than a ten-year pause occurred and the next HSR Madrid–Lerida (the first part of the line to Barcelona) was commissioned only in 2003. However, after 2003, the rapid development of the Spanish HSR network began, which in terms of growth rates significantly outstripped France and Germany (Pic. 4). As a result, already in 2010 Spain bypassed these countries in the total length of HSR and by 2016 had about 3 000 km of HSR (second place in the world after China). In particular, in 2008 HSR Madrid–Barcelona, which by 2013 was continued along the Mediterranean coast to the French city of Perpignan, was completed. In addition, in 2010 Madrid–Valencia line was opened, and in 2013 construction of a branch from this line to Alicante was completed. Such intensive development of HSR network was the result of the plan for development of infrastructure and transport adopted in 2005, according to which Madrid should be connected via HSR with all the centers of the Spanish provinces. Now in Spain there are about 1000 km of HSR under construction, which should by 2022 connect Madrid with major cities in the north and north-west of the country.

Most of Spain's HSRs are new specialized lines, but there are also modernized conventional lines. The maximum speed of movement on specialized lines is 300 km/h, on the modernized – 250 km/h.

The spatial distribution of population in Spain has a structure close to that of France that is monocentric, but in Spain it is less pronounced. Although «Big Madrid» with a population of more than 6 million people is almost the same center as «Big Paris» (14 % of population in the former and 16 % in the latter), but among the Spanish cities there is a very large regional center which is Barcelona with a population of about 4 million people. However, Madrid is located in the heart of the country, and Barcelona is located almost on the border with France and because of its position cannot be the second center of the transport network. Therefore, it is quite natural to form a radial network of high-speed rail with a center in Madrid, which, in fact, was reflected in the above mentioned plan for development of infrastructure and transport.

The distances between Madrid and the regional centers are even more favorable for development of HSR radial network than in France: the distance from Madrid to Barcelona by air is 505 km, to Cadiz – 488 km, to Santiago de Compostela – 487 km. At the

Table 2

Comparison of population in HSR zone (2016). Compiled by the authors on the basis of data from the EU Statistical Service, the association «Eurogeographics» and [9]

Country	Population, thousand people	Density of population, people per sq. km	Population in HSR zone, thousand people	Population in HSR zone per 1 km of HSR, thousand people
Germany	82176	230	40134	27,1
France	64847	119	21986	10,3
Spain	46440	92	19947	6,8

same time, along the lines of HSR, departing from Madrid, there are more major cities than in France, which allows the network of HSR to be accessible to a larger percentage of the population of Spain.

Thus, three largest countries of Europe show a tendency to one of three types of configuration of HSR network – radial in France, complicated-closed in Germany, tree-radial in Spain. At the same time, the main traffic on these networks fit within the range of distances of 200–800 km, fits which high-speed rail transport leads the route speed.

4. Growth dynamics and cost of HSR

As of 2017, the process of creating national networks of HSR in France and Germany is almost complete, and in Spain it should be completed by 2022. Thus, despite the different conditions in these countries and the different lengths of the networks, it took about 30 years for each of them to build a HSR network connecting all major cities. Dynamics of growth of HSR networks of the countries under consideration is presented in Pic. 4.

At the same time, it should be noted that as of 2016, more than 40 million people live in the cities of Germany, connected by HSR network (50 % of the population), and in France and Spain, these figures are 22 million people (32 % of the population) and 20 million people (43 % of the population), respectively. After the completion of the construction of all planned HSR, this figure will increase to 25 million people (39 % of the population) for France and up to 26 million people (55 % of the population) for Spain. Thus, access to the HSR network in Germany is provided to a much larger number of residents than in France and Spain. Moreover, such an effect arises not only at the expense of a larger population and a higher density of population of Germany, but also because of the peculiarities of spatial distribution of population. This is indicated by the higher than in the other two countries, linear density of population in the zone of operation of HSR – the number of inhabitants in HSR zone per km of its operational length (Table 2).

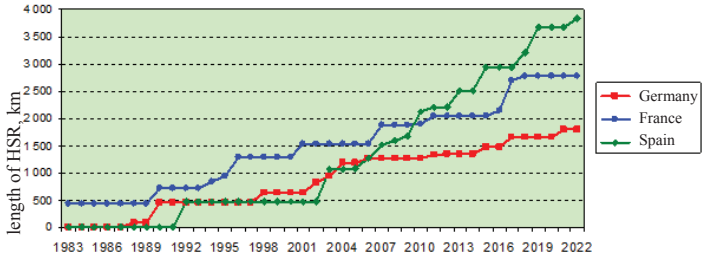
As can be seen from Table 2, the higher population in the German HSR zone cannot be explained by a higher population or density. The population of Germany is 1,27 times the population of France and 1,77 times the population of Spain (for density, the same coefficients are 1,93 and 2,5). At the same time, the population in HSR zone per 1 km of HSR in Germany is 2,63 times larger than in France and 4 times more than in Spain. That is, the differences in the population size in HSR zone per km of HSR are significantly higher than the differences in the number and density of population as a whole. Apparently, this effect is a consequence of polycentricity and uniformity of population of Germany.

The creation of the infrastructure necessary for organization of high-speed traffic requires considerable expenditure. As of 2015, the cost of building 1 km of new HSR in Europe is in the range of 15–40 million euros [11]. At the same time, the cost essentially depends on the country. For example, the cost of 1 km of HSR, built before 2006, is 15–28,8 million euros for Germany, 4,7–18,8 million euros for France and 7,8–20 million euros for Spain [6]. That is, German HSR is on average twice as expensive as French and Spanish ones. This is due to the fact that due to the high density and uniformity of the population, the landscape of Germany is saturated with a large number of artificial structures, which significantly complicates the diversion of land for HSR and requires construction of a large number of tunnels, bridges, aqueducts, etc.

Thus, the polycentricity and uniformity of distribution of population of Germany together with high population density and density lead to a significant increase in the value of HSR. On the other hand, the peculiarities of settlement of population of Germany allow, with a smaller length of HSR network, to provide access to a much larger number of inhabitants to it than in France and Spain. In this sense, the effectiveness of HSR in Germany is higher than in the other two countries.

5. Organization and rolling stock of HSR

Investments in HSR are paying off quite badly. In some sources (for example, in [4]) it is asserted that of all European HSR only Paris–Lyon line is profitable. Therefore, HSR does not represent a particular interest for private business and in European countries, the owners of the infrastructure of HSR and



Pic. 4. Growth of HSR length. Compiled by the authors on the basis of data [9].

Table 3

Organizational structure of HSR. Compiled by the authors on the basis of data [8] and the official website of Deutsche Bahn AG[1]

Country	Name of the network	Passenger transportation operator	Infrastructure owner	Sources of financing for HSR
Germany	ICE (Intercity-Express)	State company Deutsche Bahn AG (through the subsidiary DB Fernverkehr AG)	State company Deutsche Bahn AG (through the subsidiary company DB Netze)	Federal government, land governments, EU grants, borrowings in the stock market
France	TGV (Train à Grande Vitesse)	State company SNCF (Société Nationale des Chemins de fer Français)	State company RFF (Réseau Ferré de France)	Central government, EU grants, funds of local authorities and private companies
Spain	AVE (Alta Velocidad Española)	State company RENFE (Red Nacional de Ferrocarriles Españoles)	State company ADIF (Administrador de Infraestructuras Ferroviarias)	Central government, EU grants

[1] URL: http://www.deutschebahn.com/en/group/business_units/11957832/DB_Bahn_Long_Distance.html.

Table 4

Provision of HSR network with rolling stock (2016). Compiled by the authors on the basis of data [12]

Country	Number of trains	Number of trains per 100 km of HSR	Capacity of train, pass. seats	Total amount of pass. seats	Number of pass. seats per 1 km of HSR	Average capacity of a train, pass. seats
Germany	262	18	195–703	119868	81	454
France	495	23	350–558	223423	104	451
Spain	220	8	160–403	65707	22	299

high-speed transport operators are state-owned companies (see table 3). At the same time, the financing of construction of HSR is carried out by both national governments and the EU government in the framework of implementation of pan-European transport programs.

The rolling stock for HSR of the countries under consideration is produced by several companies and varies in cost and technical characteristics. In particular, Germany uses ICE1 (1991)[1], ICE2 (1996), ICE3 (2000) and ICE-T (2000) trains of the German company Siemens and the Canadian Bombardier. The maximum speed for ICE1 and ICE2 trains is 280 km/h, for ICE3 – 300 km/h, and ICE-T trains are designed for a top speed of 230 km/h. ICE1 trains have 12 cars, which accommodate 703 passenger seats. The other types of trains basically have 7–8 cars and 368–444 passenger seats, although there are trains with 4 cars, in which there are 195 passenger seats.

The rolling stock for HSR of France is produced by the French machine-building company Alstom. The main types of French high-speed trains currently used are TGV PSE (1981), TGV Atlantique (1989), TGV R seau (1993) and TGV Duplex (1996). Trains of the first two types have a maximum speed of 300 km/h, the rest – 320 km/h. Almost all French high-speed trains have 8 passenger cars. The only exception is TGV Atlantique, in which there are 10 cars with 480 passenger seats. A feature of TGV Duplex trains is that they use double-deck cars, which allows to significantly increasing the number of passengers without increasing the number of trains and the number of cars in one train. The capacity of TGV Duplex is 512 passengers, while the other trains with 8 cars can accommodate 375 passengers.

High-speed trains used on Spanish HSR are distinguished by a wide variety of types. This is due to the fact that during the first stages of the network development, Siemens and Alstom trains were used, and then the Spanish companies CAF (in cooperation with Alstom) and Talgo (in cooperation with Bombardier) began to produce their own trains. A little less than half of the trains have a maximum speed of 300 km/h or more, the rest – 250 km/h. As to the number of cars in the train and the number of passenger seats, there is a wide range of values. Trains have 3, 4, 8, 11, 12 cars and, accordingly, the number of passenger seats in the train varies from 160 to 403.

Data (partial) on the cost of rolling stock can be found in [4] and [11]. In particular, in [11] the average cost of a high-speed train for 350 seats is given. In 2015, it was 30–35 million euros or 90–100 thousand euros for a seat. [4] contains more detailed data on the cost of some types of trains as of 2011. According to these data, the most expensive trains are ICE1 (51 million USD or 81 thousand USD for a seat) and ICE2 (34 million USD or 92 thousand USD per seat). At the same time, TGV Duplex costs 27 million USD, or 53 thousand USD for a seat, and ICE-T – 20 million USD or 57 thousand USD for a seat.

General indicators of the number of high-speed trains in different countries are presented in Table 4. The largest fleet of trains is in France, both in terms of the absolute number of trains and passenger seats, and in terms of their number per unit length of HSR. At the same time, Spain, which has the longest HSR network, has significantly fewer trains. And the difference between Spain and the other two countries becomes especially noticeable when taking into account the length of HSR. In Spain, there are three times fewer trains and five times fewer passenger seats per km of HSR than in France. While Germany, which has the smallest length of HSR network, is

[1] Here and further in brackets the year of the beginning of manufacture of the given type of a train is specified.

Table 5

Passenger turnover on HSR, billion passenger-kilometers (in parentheses the share of HSR in the total passenger turnover in the railway transport is indicated). Compiled by the authors on the basis of data from the EU statistical service and [13]

Country	2010	2011	2012	2013	2014	2015
Germany	23,9 (29 %)	23,3 (26 %)	24,8 (26 %)	25,2 (28 %)	24,3 (27 %)	25,3 (28 %)
France	51,9	52,0	51,1 (56 %)	50,8 (56 %)	50,7 (57 %)	50,0 (55 %)
Spain	11,7 (52 %)	11,2 (49 %)	11,2 (50 %)	12,7 (53 %)	12,8 (51 %)	14,1 (54 %)

Table 6

Comparison of passenger turnover on HSR (2015). Compiled by the authors on the basis of the data of Tables 2 and 5

Country	Population, thousand people	Population in HSR zone, thousand people	Passenger turnover, billion passenger-kilometers	Passenger turnover of HSR per unit of population, km	Passenger turnover per capita in HSR zone, km
Germany	82176	40134	25,3	307,9	632,5
France	64847	21986	50	771,0	2272,7
Spain	46440	19947	14,1	303,6	705,0

Table 7

Changes in the structure of the passenger transportation market. Source [5]

Paris–Lyon	Before commissioning of HSR (1980)	After commissioning of HSR (1997)
Conventional rail transportation	40 %	3 %
Transportation on HSR	0 %	70 %
Air transportation	31 %	6 %
Madrid–Seville	Before commissioning of HSR (1991)	After commissioning of HSR (2002)
Conventional rail transportation	16 %	1 %
Transportation on HSR	0 %	61 %
Air transportation	40 %	8 %
Hamburg–Frankfurt	Before commissioning of HSR (1985)	After commissioning of HSR (2000)
Conventional rail transportation	23 %	3 %
Transportation on HSR	0 %	48 %
Air transportation	10 %	4 %

slightly inferior to France in relative terms. The smaller number of trains (passenger seats) and the lower average capacity of one train in Spain indicate that the intensity of passenger traffic in Spain is much less than in Germany and France.

The polycentricity of distribution of population of Germany, the related branching of HSR network and the significant differences in the distances between large cities (many distances are considerably less than those favorable for HSR 200 km), apparently, substantially differ in the volumes and strengths of passenger traffic in different directions of HSR network. This, in turn, leads to the fact that high-speed trains running on different routes, significantly differ in speed and capacity.

Unlike German, French HSR are characterized by considerable uniformity. All French lines connect the periphery to the center and have few intermediate stations (there are no more than three large cities along each line), in addition, the distance to the center of the network is in general considerably higher than 200 km. Therefore, the rolling stock of French HSR is more homogeneous in speed and capacity. To a somewhat lesser extent, this also applies to Spanish HSR.

6. Passenger turnover on HSR

Indicators of passenger turnover on HSR are shown in Table 5. Here, attention is drawn to the fact that Spain has a passenger turnover significantly less than France and, even, Germany. However, in the structure of passenger transportation by rail, Spain and France occupy the same positions. In these countries, passenger turnover on HSR is more than half of all passenger transportation by rail, and in Germany only a quarter.

If we take into account the differences in population, the situation will be somewhat different. Table 6 shows the passenger turnover figures for HSR per capita (for the country as a whole and for the population in HSR zone), which by their meaning are indicators of mobility of population. According to these indicators, Germany and Spain occupy almost the same positions, while France is significantly ahead of them.

When analyzing the data presented in Tables 5 and 6, we will proceed from the assumption that the passenger turnover for all modes of transport is determined by the population size of the country and its income level, and the share of HSR in the overall passenger turnover is determined by the population distribution and the length of the structure network of HSR conditioned by this. This approach is simplistic, but it allows a meaningful interpretation of the available data.

In Germany, there are a higher population and a higher level of income than in Spain (Table 1). This

explains the fact that the passenger turnover on German railway transport is about four times higher than the passenger turnover on the railway transport in Spain. However, passenger turnover on HSR of Germany is only twice as high as in Spain. This is a consequence of the fact that in Germany HSR occupies a much smaller share of the passenger transportation market than in Spain. This, in turn, is due to the peculiarities of population distribution in these countries.

High rates of passenger turnover in France are due to the fact that on the one hand there is a large population and a high level of income (in comparison with Spain), and on the other hand, the peculiarities of population accommodation make high-speed transport extremely demanded and allow it to occupy a much larger part of the passenger transportation market, than in Germany.

A good illustration of the role played by HSR in different countries is the data on specific lines presented in Table 7. On the directions Paris–Lyon and Madrid–Seville high-speed transport is dominant. However, on Hamburg–Frankfurt direction, road passenger transportation occupies almost the same part of the market as HSR.

Conclusions. *The analysis of national high-speed transport systems of France, Germany and Spain, carried out above, allows us to conclude that population distribution has a great influence on development and functioning of HSR. In particular, such features of population distribution as population size and density, polycentricity and monocentricity, the degree of uniformity, the number of large cities and the distance between them directly affect the length and morphology of HSR network, its cost, coverage, rolling stock, passenger turnover and competitiveness of high-speed transport.*

From the point of view of possible analogies, the network of HSR of European countries, correlated with the peculiarities of resettlement in these countries, can be in its turn correlated, first of all, with the central regions of the European part of Russia, where the settlement conditions have some similarities with those in France and Spain. The formation of two or three priority directions originating from Moscow to the east and south (southeast), as well as Moscow–St. Petersburg direction, set the radial-tree type of HSR network with more significant distances between cities with a population of more than 1 million people than in considered countries. A special area is represented by cities of population of more than 1 million in the Urals (e.g. Yekaterinburg and Chelyabinsk). The distance between them is of 200 km and is the smallest in Russia. Given the European experience, smaller population density along the future lines of HSR and the long length of these lines in Russia, it should be assumed that the return on investment will go even longer. Therefore, determining the priority of construction of HSR, it is necessary to rely on the improved method, that is, the methodical justification apparatus extended by criteria and considered by indicators.

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