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Assessment of Drivers and Deterrents of Development of High-Speed Passenger Railway Transportation

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ABSTRACT

Reduction in travel time is one of the eloquent trends in transport developments. It is consistent with the desire of leading transport companies to create conditions to increase traffic speeds.

The objective of the article is to analyse prospects and drivers for development of high-speed rail transportation as of a priority transport segment characterised by best safety rates and environmental friendliness as compared to other types of transportation.

The review of core parameters of HSR is suggested to show features of its global development.

Ecological friendliness, encouragement of labour and other mobility of people, of innovative technology development of railways and interconnected industries are most relevant as universal drivers of HSR development.

Constraints due to substantial investment needs, long payback period, necessity to implement additional side projects to develop interrelated transport infrastructure to obtain more tangible economic and social effects, to provide for sufficient passenger flow at the initial or further stages of HSR operation were considered as main deterrents.

The factors, their parameters, assessment of their priority ranking when making decisions on construction or development of HSR are determined in each country by transport development strategies, current economic conditions, and a set of other factors.

Keywords: *railways, HSR, speed transportation, HSR rolling stock.*

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INTRODUCTION

The growing mobility of the world population has a significant impact on development of the transportation network, engendering challenges such as increasing travel speed and growing comfort. Similar trends are observed on railways as well: during the period 2010–2019 passenger turnover increased by 927,1 billion passenger-kilometres (28,8 %) [1].

The increase in population mobility determines the need to modernise existing transport systems that supposes adoption of advanced developments and technologies, improvement of infrastructure facilities, integration of various systems to obtain a synergistic effect (development of multimodal transportation) [2]. The development and expansion of urban agglomerations, widespread urbanisation form the trends towards growing demand for development of the transport system.

The railway industry, in turn, is one of constituent parts of the entire transport industry, providing necessary and sufficient conditions for functioning of urban agglomerations. One of the priority trends in development of the railway network in the context of an increase in migration flows is development of high-speed railway passenger transportation.

In accordance with the definition of the International Union of Railways, a high-speed rail (hereinafter referred to as HSR) combines many different elements which constitute a «whole, integrated system». The most critical, from the point of view of HSR operation, elements [3] of this system are:

• an infrastructure (two types of infrastructure are distinguished):

a) new lines designed for speeds of 250 km/h and above;

b) upgraded existing lines for speeds of up to 200 or even 220 km/h;

• rolling stock, especially designed specifically for train sets;

• telecommunications;

• signalling, equipment, etc.

In the Russian Federation, traditionally, HSR means a specialised dedicated (purpose-built) railway line that ensures movement of trains at a speed of more than 250 km/h. The provision of passenger railway transportation services at a speed from 160 km/h to 220 (250) km/h corresponds to higher-speed[1] traffic. The mixed type of traffic is also widespread: high-speed trains operate on lines intended for conventional trains.

The mixed type of train traffic has the advantages associated with the absence of the need for a complete reshaping of a railway or construction of new tracks. However, operation of trains with different features, properties and responding to divers technical requirements on the same railway tracks leads to additional costs associated with the need for constant maintenance and repair [4], as well as gaps in the timetable associated with overlapping tracks for conventional trains during the passage of high-speed trains [5].

HSR development in the Russian Federation and in the world is determined by various factors. The *objective* of the article is to analyse prospects and drivers of development of HSR as of a priority transport segment owing better safety rates and environmental friendliness as compared with other types of transportation.

RESULTS

Drivers of Development

Improved environmental requirements

Tighter requirements towards CO_2 emissions encourage development of the whole railway industry: transportation by rail has a lower environmental footprint compared to civil aviation, water and road transport.

According to the information of the International Union of Railways [6], the advantages of railway transportation and, in particular, of HSR are determined by:

• land allotment for HSR is 2–3 times less than the area of highways;

• emissions of carbon dioxide per passenger-kilometer on railways is four times less than that of air transport, and 3,5 times less than that of cars;

• energy consumption of rolling stock per passenger is four times less than that of cars, and eight times less than that of aircraft.

The ecological superiority of railway transport stimulates not only its overall development, but also contributes to acceleration of introduction of HSR in environmentally responsible countries.

[1] The original term in Russian can be translated literally as «fast» or «rapid». – *Translator's note*.

Implementation of the newest technology

The introduction of «end-to-end» digital technologies allows both the use of advanced developments in production of specialised trains and development of infrastructure facilities, for example, to use digital simulation systems [7], which optimise the processes of rolling stock operation through algorithms for processing big data, and intelligent systems operating on the principles of the industrial Internet, in the processes of monitoring the state of rolling stock and infrastructure facilities [8; 9].

Development of urban agglomerations

The expansion of urban areas allows for the transition from an increase in building density to development of suburban areas and formation of urban agglomerations. Such dynamics of urban development requires modernisation of the transport network, including improvement of suburban transportation and its connection to urban transport. On the contrary, the existing problems of territorial connectivity, the solution of which is identified as the priority of the scientific and technological development of the Russian Federation [10], negatively affect the conditions for development of human capital and formation of economic innovation clusters.

The development of HSR and of speed of intercity transportation constitute a certain safety margin for further development of the boundaries of urban areas, providing comfortable intercity connectivity and acting as a locomotive of development of multimodal transportation.

Development of non-energy economy

Global digitalisation of all sectors of the economy not only contributes to development of new technologies, but also creates conditions for their implementation. For instance, development of tourism and of the service-providing sector, as well as expansion of urban agglomerations, create a demand for more comfortable modes of transport, characterised, among other things, by higher speeds. The development of end-to-end digital technologies such as big data, artificial intelligence and robotics contributes to production and maintenance of the newest transport systems and provision of a decent level of customer service.

The development of a non-resource economy, stimulating competition in the labour market and redistribution of human resources between various sectors of the economy, acts as a transmission mechanism that immediately results in a significant increase in the volume of commuting and development of urban agglomerations.

Constraints

Despite the presence of important drivers, due to various socio-economic and technological reasons, mass construction and development of HSR is complicated by the presence of a number of barriers.

Long payback periods

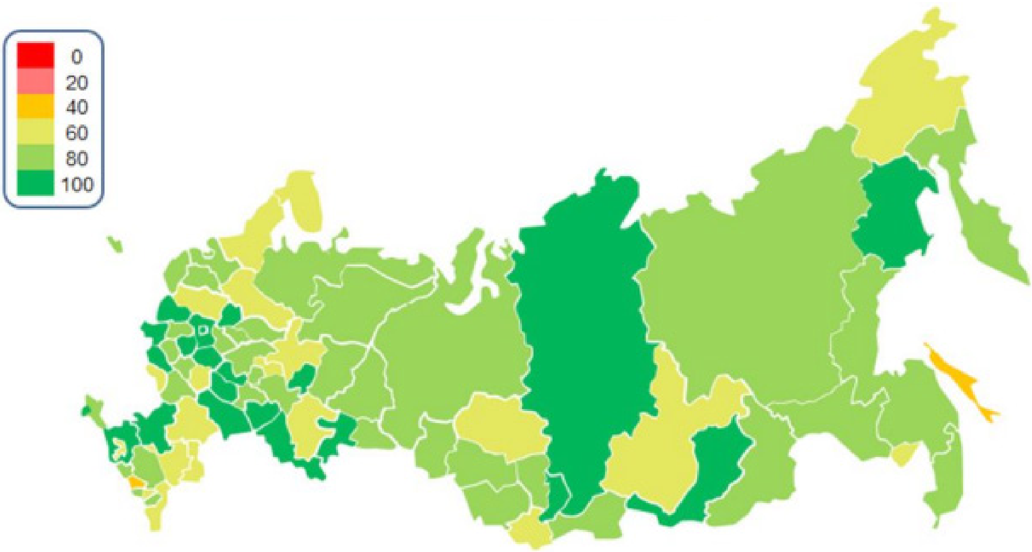
The implementation of HSR infrastructure projects is associated with high investment and capital costs associated, among other things, with the high cost of developing and implementing innovations, as well as with the need to invest significant funds in construction of new infrastructure or in modernisation of the existing one. Such projects can be carried out for 5–10 years, which implies the presence of various force majeure circumstances, comprising, for example, the need to implement previously unplanned solutions due to improvement of technological characteristics, development of fundamentally new technologies/solutions, or tightening of technical requirements.

These circumstances negatively affect the increase in the estimate and in the required investments, which, in turn, determines the high level of the cost of travelling with high-speed railway for end users. The payback of such infrastructure projects depends directly on demand, which is determined by both the level of the population's payment capacity and the presence of significant economic ties between cities or regions. On the contrary, under the conditions of stagnation of the economy, a decrease in the number of business ties and a decrease in real incomes of the population, this barrier has a significant impact on the prospects for development of HSR.

Insufficient passenger turnover

The increase in migration flows, encouraging HSR development, is characterised by a relative impact, since the current level of passenger turnover is not sufficient in terms of the investment return on projects for construction of HSR.

In the Russian Federation, this situation is exacerbated by the presence of weak economic ties between regions, especially those lying



Pic. 1. Index of economic activity in the constituent entities of the Russian Federation in June 2021. (Source: Institute «Development Centre» of National Research University Higher School of Economics, official website. [Electronic resource]: https://www.hse.ru/data/2021/08/16/1410149399/ci_rea_2021–06.pdf. Last accessed 15.08.2021).

outside the central federal district. Economic activity in constituent entities of the Russian Federation is distributed extremely unevenly (Pic. 1).

Complexity of integration into already existed transport structures

The construction of HSR is fraught with various difficulties in the field of determining the optimal routes that allow reaching high speeds on the route, as well as in the field of integrating new dedicated lines into the established transport ecosystem of urban agglomerations, linking them with existing transport interchanges and stations.

Nevertheless, the impact of the above barriers is not critical, which is confirmed by the presence of existing and planned projects related to construction of HSR. The construction of HSR makes it possible to achieve such socio-economic effects as development of urban agglomerations, unloading of existing transport systems, stimulation of economic activity in regions and of tourism, and more even regional development of economic sectors. It is assumed that the greatest degree of attractiveness of high-speed railway transportation will be observed on routes with a length of up to 700–800 km. The transportation itself is safe and environmentally friendly [11].

The need for construction and development of HSR within the national transport system of Russia is explained through possible achievement of several socio-economic benefits, including:

• increased mobility of all groups of the population;

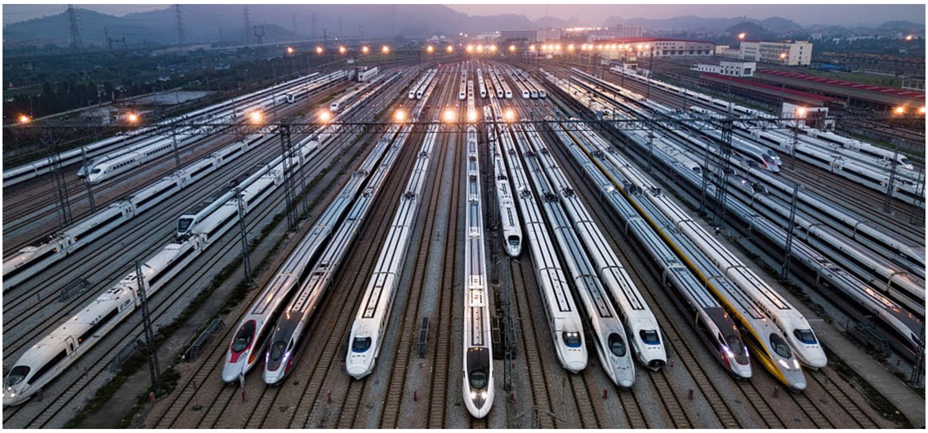
• increase in tourist flows within the country;

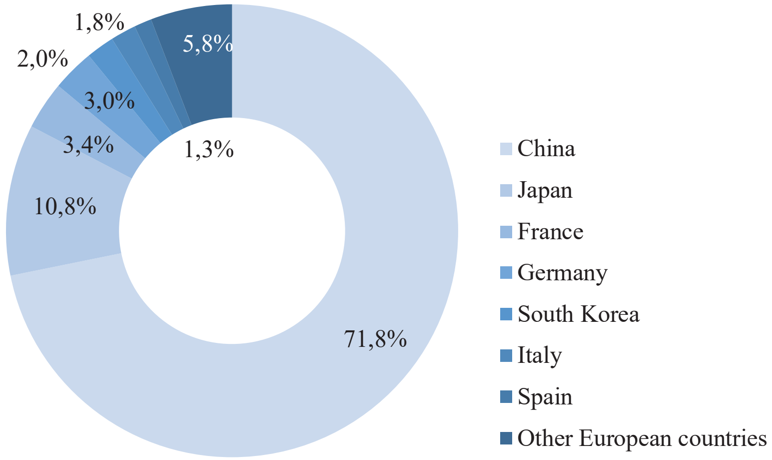
• ensuring complex synergistic interaction of various modes of transport in the field of passenger transportation.

Today, the Russian Federation is lagging behind foreign partners in development of high-speed railway transportation. According to the data of the International Union of Railways, China, Japan, France, Germany, South Korea, Italy, and Spain are the leading countries regarding HSR development in terms of total HSR passenger traffic (Pic. 2).

China is an absolute leader with the longest HSR lines in the world: as of the end of 2020, the total length of HSR in China was more than 38200 km [12], which is more than 2/3 of the total length of HSR in the world. China's investments in development of high-speed rail projects amounted to more than 110 billion US dollars. Pic. 3 shows a comparison of investments of several leading countries in development of HSR at the end of 2018.

China, France, and Germany are actively involved in the process of expanding national HSR systems, even despite the existing developed network of routes. Activity in the field of transport in France and Germany is guided by the current policy of the European Union to create a single pan-European transport network TEN-T, which includes highways and railways, inland waterways and airways [13].





Pic. 2. Leading countries in terms of HSR passenger traffic in 2019.
(Source: International Union of Railways, official website. [Electronic resource]: https://uic.org/statistics. Last accessed 10.08.2021).

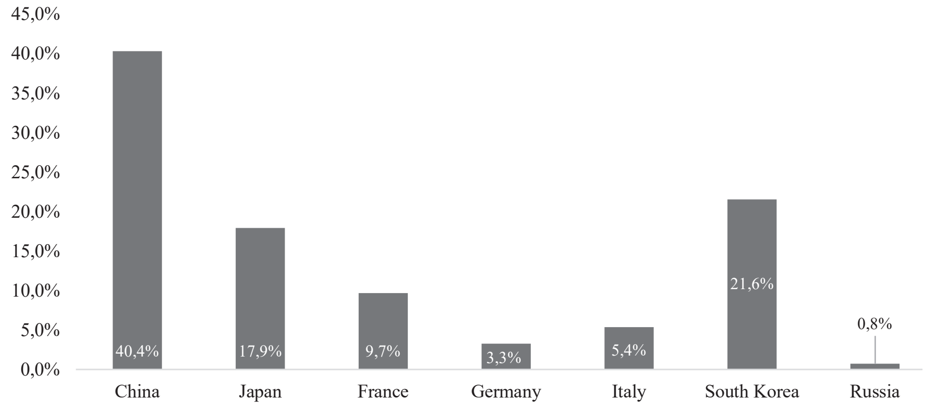
China's leadership is also observed in terms of the share of HSR in the total operating length of the railway network which is now of 40,4 % (Pic. 4).

The high share of HSR in the operational length of the railway network in China is reflected in the wide network of high-speed passenger railway transportation routes. The leaders in terms of the number of routes are China, Korea, and Germany (Table 1).

Despite the absolute leadership of China in terms of the total passenger traffic in highspeed passenger transportation, the largest share of HSR and high-speed passenger transportation in passenger traffic in 2019 was observed in Korea and France (Pic. 5).

The accelerated pace of HSR development in China can be clearly traced due to current investment projects, as well as the clear scope for increasing the share of HSR passenger

Pic. 3. Analysis of investments in construction of HSR in 2018 per countries, bln US dollars.
(Source: Information agency RZD-Partner, official website. [Electronic resource]: http://www.rzd-partner.ru/zhd-transport/news/kitay-narashchivaet-investitsii-v-zheleznye-dorogi/. Last accessed 10.08.2021).



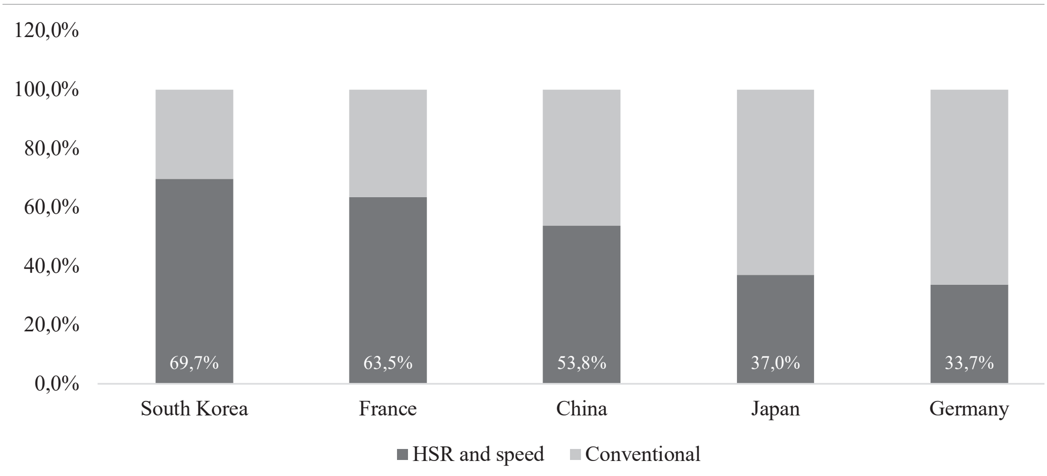
Pic. 4. The share of HSR in the total length of railway networks per countries.
(Source: International Union of Railways: official website. [Electronic resource]: https://uic-stats.uic.org/. Last accessed 10.08.2021) .

Table 1

Selected routes of high-speed railway transportation in some countries

Country	Routes
China Railway (China)	Beijing–Shanghai, Wuhan–Changsha–Guangzhou, Shanghai–Hangzhou, Shanghai–Nanjing, Beijing–Tianjin, Zhengzhou–Xian, Ningbo–Taizhou–Wenzhou, Wenzhou–Fuzhou, Shijiazhuang–Taiyuan, Fuzhou–Xiamenjin, Shijuang–Taiyuan, Fuzhou–Xiamen, Nanchang–Jiujiang, Hefei–Wuhan, Qingdao–Jinan, Hefei–Nanjing, Chengdu–Ganksian, Changchun–Jilin, Haikou–Sanya, Guangzhou–Zhuhai, Guangzhou–Xinhui
Renfe Operadora (Spain)	Madrid–Seville–Malaga, Madrid–Barcelona
Japan Railways (Japan)	Shin Osaka–Hakata, Tokyo–Niigata, Tokyo–Shin Osaka, Tokyo–Kanazawa, Tokyo–Shin Aomori–Shin Hakodate
SNCF (France)	Rennes–Paris, Calais–Paris, Strasbourg–Paris, Avignon–Lyon–Paris, Bordeaux–Tours–Paris
Deutsche Bahn (Germany)	Frankfurt–Hamburg, Frankfurt–Munich, Frankfurt–Cologne, Frankfurt–Stuttgart, Hamburg–Munich, Berlin–Hamburg, Berlin–Frankfurt, Berlin–Munich, Cologne–Berlin, Frankfurt–Aachen, Frankfurt–Brussels, Hamburg–Copenhagen, Cologne–Brussels, Frankfurt–Paris, Frankfurt–Basel, Frankfurt–Amsterdam, Nuremberg–Vienna
FS Italiane (Italy)	Naples–Bari, Palermo–Catania–Messina, Turin–Milan–Reggio Emilia–Bologna–Florence–Rome–Naples–Salerno, Venice–Padua–Bologna–Florence–Rome–Naples–Salerno, Udine–Venice–Padua–Vicenza–Verona–Brescia–Milan–Turin
Korail (South Korea)	Seoul–Dongdaegu, Dongdaegu–Busan, Osong (Cheongju)–Gnangju, Suseo (Seoul)–Pyeongtaek, Seoul–Gangneung

Sources: UIC and official annual reports of the respective railway companies.



Pic. 5. Distribution of countries by the share of HSR in the total passenger turnover in 2019, %. (Source: International Union of Railways: official website. [Electronic resource]: https://uic-stats.uic.org/. Last accessed 12.08.2021).

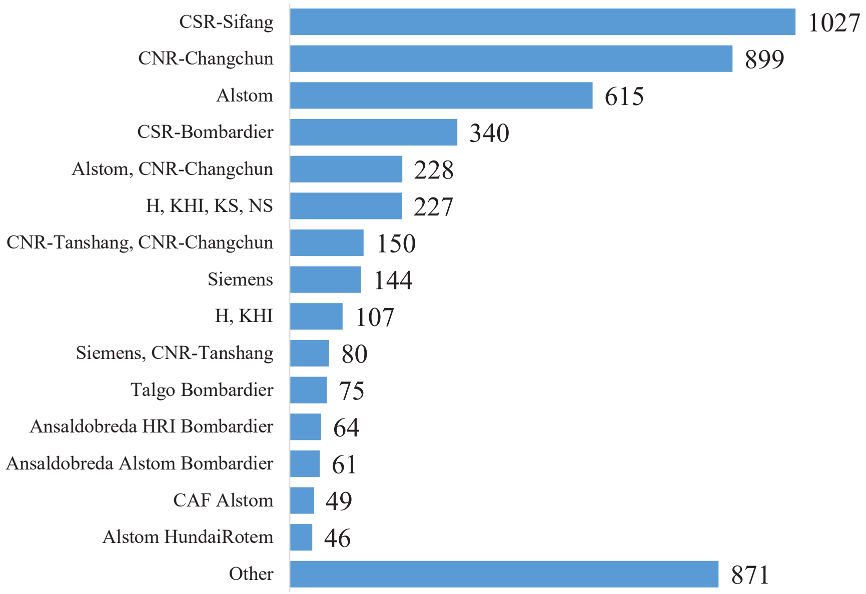
turnover in the total passenger turnover. The predominance of China in development of HSR is also observed in the production of specialised trains (Pic. 6).

One of the most common high-speed train models is CSR-Sifang. Other common models include CNR-Changchun, Alstom, and Bombardier.

The prevalence of Chinese manufacturers is explained by the increased demand associated with current and future projects of China regarding HSR development. France also plans to increase the number of high-speed passenger routes, focusing on decentralisation of Paris in the national HSR network and on increasing the share of regional HS infrastructure.

SHORT CONCLUSION

Development of HSR is determined by several universal drivers. They include ecological friendliness, encouragement of labour and other mobility of people, of innovative technology



Pic. 6. Ranking of manufacturers of high-speed rolling stock. Compiled based on the data source of the International Union of Railways: official website. [Electronic resource]: https://uic.org/IMG/pdf/202100801_high_speed_rolling_stock.pdf. Last accessed 12.08.2021.

development of railways and interconnected industries.

Deterrents and constraints to HSR development are due to substantial investment needs, long payback period, necessity to implement additional side projects to develop interrelated transport infrastructure to obtain more tangible economic and social effects, to provide for sufficient passenger flow at the initial or further stages of HSR operation. These factors, their parameters, assessment of their priority ranking when making decisions on construction or development of HSR are determined in each country by transport development strategies, current economic conditions, and a set of other factors.

In the Russian Federation, the need to develop HSR is considered as sufficiently high, and various plans for development of HSR are being discussed.

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