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High-Speed Passenger Railway Transportation: Priority for Long-Term Development




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ABSTRACT

High-speed passenger railway transportation is one of the priorities of scientific and technological development for most of the leading world railway companies that have global plans for construction of new high-speed rail lines (HSR).

General review refers to plans of selected countries regarding construction of high-speed railways and the priority technologies/solutions required for the efficient provision of high-speed passenger services, as well as to costs and advantages associated with HSR construction. Besides, comparison of promising technology and adopted technical solutions is followed by assessment of their readiness level, and by features of HS trains operated by leading companies. Most important technologies comprise intelligent systems of autonomous train operation, remote traffic control, digital simulation of interaction of rolling stock and infrastructure, automated decision support systems, geospatial infrastructure monitoring, and real-time remote condition monitoring of rolling stock and infrastructure.

Conclusions drawn argue in favour of promising character of research in the field of breakthrough technology conducted by railways, possibilities for Russia to join the countries with most advanced high-speed rail passenger transportation.

Keywords: *railways, HSR, high-speed rolling stock, multimodal transportation, door-to-door transportation, priority technologies, UIC.*

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INTRODUCTION

One of the strategic priorities for long-term development of leading railway companies is provision of high-speed passenger transportation services. This direction is distinguished by companies on a par with development and implementation of digital solutions aimed, first, at increasing the level of comfort and optimising the cost structure. The development of high-speed transportation is focused directly on meeting consumer preferences associated with comfortable travel in the shortest possible time.

Given the increased demand of the population for door-to-door transport services, high-speed passenger transportation is the main category of transport, based on which a fundamental development of multimodal transportation is possible. According to the data of the International Union of Railways (UIC), the door-to-door travel time when using high-speed passenger transportation as the main means of transportation reaches 2 hours 55 minutes. The closest competitor is conventional railway transportation that accounts for 3 hours 40 minutes [1].

The development of this type of passenger transportation is on the agenda of most of the leading foreign railway companies: the total length of high-speed railways planned for construction was in 2019 of 40,5 thousand km [2; 3] (Table 1).

The UIC data as of the end of 2020 showed that 11,693 km of high-speed lines were under construction around the world. The high-speed network in commercial operation was 52,418 km long, out of which 39,674 km were in Asia, 10,766 km in Europe, 1,043 km in the Middle East, 735 km in North America and 200 km in Africa. With 35,740 km in operation, China represented more than 68 per cent of the world's high-speed rail network [4]. According to Marc Guigon, Passenger Director at the UIC, «in five to six years' time, the network will have grown by almost 25 per cent, but China will contribute only approximately 50 per cent to this extension» since the extension rate in PRC will slow down because the network is reaching its full deployment. Turkey, Spain, South Korea, and Switzerland are among the countries that are still completing their own network and/or extending it to reach the neighbouring countries. On-going projects are worth noticing: the Basque Y, which is a feat of infrastructure with more than 100 km of tunnels and 44 viaducts; the HS2 line in the UK, which will be the most expensive line per kilometre in the world; the Lyons–Torino tunnel (more than 50 km); the Californian link between Los Angeles and San Francisco. Several countries have recently completed the construction of HSR: Saudi Arabia (2018), Morocco (2018) and Denmark (2019). Several other new countries are eyeing the implementation of high-speed rail: Sweden, and more extensively Scandinavia, the Czech Republic, the Baltic countries, Russia, Egypt, South Africa, Australia, Canada, Brazil, Iran, Israel, Indonesia, Malaysia, and Singapore. The UIC passenger director particularly noticed vast countries which could extend the network in huge proportions, like the United States and Russia, as well as India has both the geographic and demographic potentials. An original initiative should be pointed out in Italy, with the first freight high-speed trains [4].

According to the data of new UIC Atlas High-Speed Rail 2021 prepared in early March 2021 [5] at the beginning of 2021 about 56,129 km of HSR were in commercial operation. Distribution of the length of HSR network in commercial operation by selected countries is shown in Pic. 2.

Table 1

Plans for HSR construction in selected countries as of 28.03.2019 (compiled based on [3])

Country	Under construction, km	Planned, km	Long-term planning, km
China	7207	1071	257
Japan	402	194	–
Korea	–	49	–
France	–	–	1725
Spain	904	1061	–
Germany	147	81	210
Italy	53	–	152

Table 2

Length of HSR network in commercial operation by countries [5]

Countries	HSR network length, km
China	38283
Spain	3487
Japan	3041
France	2735
Germany	1571
Finland	1120
Italy	921
Republic of Korea	893
Sweden	860
United States	735
Turkey	724
Saudi Arabia	449
Austria	254
Poland	224
Belgium	209
Morocco	186
Switzerland	178
United Kingdom	113
The Netherlands	90
Denmark	56

Distribution of the HSR in commercial operation, under construction, planned and long-term planned by continents is shown in Table 3.

The Atlas comprised detailed data distributed by countries. To compare 2019 and 2021 data the Table 4 includes data on the countries previously indicated in Table 1 as well as on some other countries. The changed data are highlighted with grey background.

The UIC data on passenger turnover published in February 2021 [6] show steady growth trend (Table 5 shows data on selected countries).

The study has not set the purpose to analyse HSR project development in Russia since it requires detailed examination. According to some top managers of construction industry, as of 2020 the start of construction of HSR Moscow–St. Petersburg was planned in 2021. The section of the HSR exiting Moscow will have been built by 2024. The possibility to completely implement the project in 2027 was considered[1]. The speed of construction was estimated according to experts as 180 km per year[2].

The process of HSR construction is planned to be integrated with Moscow transportation hub and suburban rail lines [7]: the discussion agenda includes mutual interconnection with metro, surface urban transport, Moscow central ring, and intracity rail transportation system.

The objective f the study was general review of features of economic feasibility of construction of HSR lines, of priority technology/decisions necessary for provision of service of HSR transportation based on statistics data and content analysis of the documents.

[1] Construction of HSR line Moscow–St. Petersburg will start in 2021 [*Stroitelstvo vysokoskorostnoi magistrali Moskva–Sankt Peterburg nachnyotsia v 2021 godu*]. ITAR-TASS, 28.09.2020 [Electronic resource]: https://tass.ru/ekonomika/9570861. Last accessed 04.12.2020.

[2] The speed of construction of HSR in Russia should reach about 180 km per year [*Tempy stroitelstva VSM v Rossii dolzhny sostavit' do 180 km v god*]. News agency RZhD-partner.ru. [Electronic resource]: https://www.rzd-partner.ru/zhd-transport/news/tempy-stroitelstva-vsm-v-rossii-dolzhny-sostavit-do-180-km-god/. Last accessed 10.03.2021.

Table 3

HSR construction plans by continents as of March 2021 (based on [5])

Continent	In commercial operation, km	Under construction, km	Planned, km	Long-term planning, km
Europe	11819	2405	5713	3482
APR	42217	16515	7357	18320
Middle East	1173	3079	2146	1831
Africa	186	–	2010	2690
North America	735	563	1869	6044
Latin America	–	–	–	638

Table 4

Plans of HSR construction in selected countries as of March 2021 (compiled based on [5])

Country	Under construction, km	Planned, km	Long-term planning, km
PRC	14925	4361	7134
Japan	688	346	–
Korea	–	49	–
India	508		7479
France	–	–	1725*
Spain	1135	943	–
Germany	147	81	210
Italy	327	–	–
Australia			1749
Egypt		1370	300
Morocco			640
Canada			1523
United States	563	1659	4521
Iran	1336	117	1651
Turkey	1743	1944	

* including modernisation of HSR Paris–Lyon, and construction of detour of Lyon.

RESULTS

Economic feasibility of HSR construction

In world practice, the issue of economic feasibility of HSR construction is also quite «acute». However, according to the data of the International Union of Railways, provided there is a sufficient redistribution of passenger traffic from alternative transport categories (aviation and cars, buses), the benefits from HSR construction are sufficient for implementation of such infrastructure projects (Table 6).

It should be noted that construction and maintenance of HSR require significant investments. However, implementation of such an infrastructure project presupposes both direct economic effects (an increase in passenger traffic due to a reduction in passenger travel time) and indirect effects:

- Increased safety level.
- Increased level of highly qualified personnel and, accordingly, the growth of highly productive jobs (increasing the level of productivity).

Table 5

Data on HSR passenger turnover (bln passenger/km) (based on [6]) as of 02.02.2021

Country	2010	2015	2017	2019
PRC (China State Railway Group Company)	46,3	386,3	577,6	774,7
Chinese Taipei (Taiwan High Speed Rail Corp.)	7,5	9,7	11,1	12,0
Japan (JR Group)	77,4	97,4	101,4	99,3
Republic of Korea (Korail)	11	15,1	14,9	16,0
France (SNCF Mobilit)	51,9	50,0	58,3	60
Germany (DB AG)	23,9	25,3	28,5	33,2
Spain (Renfe Operadora)	11,7	14,1	15,5	16,1
Italy (Trenitalia)	8,0	9,7	9,8	NA
Italy (NTV)	–	3,9	5,3	NA
Other companies	7,3	631,5	846,9	1029,4

Table 6

Costs and benefits in HSR construction (based on [1])

Stage	Costs	Benefits
Before construction	• Design studies. • Administrative procedures. • Acquisition of land. • *Construction of stations.* • *Construction of infrastructure.* • Testing and certification. • Environmental protection. • *CO_2 emissions from industrial plants.* • Purchase of rolling stock. • Construction of maintenance facilities. • CO_2 emissions from train and infrastructure construction. • Staff training.	• Increased employment (jobs created for infrastructure construction). • Increased employment (jobs created for train production). • Increased employment (jobs created for operating activities).
After construction	• Marketing and distribution of tickets. • Generation / purchase of energy. • Organization of transportation (including wages). • Provision of services to passengers. • Maintenance of infrastructure. • Maintenance of trains. • CO_2 emissions during line operation.	• Increasing the level of transport safety (reducing the volume of compensation payments). • *Reduction of costs for other categories of transport as a result of re-routing of the main traffic.* • *Reduction of CO_2 emissions from other transport categories as a result of re-routing of the main traffic.* • Time saved by passengers. • Increase in passenger traffic.

Positions with significant impact are italicized.

• Reduction of operative costs of related industries.

• Improvement of environmental situation due to reduction of CO_2 emissions.

HSR and the promising technology

The process of HSR construction, which is one of the links in the system of priorities for scientific and technological development of leading railway companies, very strongly correlates with development of new promising technologies and solutions, both in the field of transportation, and maintenance and repair. The most promising technologies and solutions that have a significant impact on HSR development are listed below:

• Intelligent systems for information and control support for autonomous train control and remote dispatch control systems.

• Digital simulation and construction of digital models of infrastructure facilities and rolling stock using satellite technologies and high-precision coordinate systems [8].

Table 7

Scale for assessing the level of readiness of technologies

TRL	Description of TRL
TRL1	Basic principles of technology studied and published
TRL2	Concept of technology and/or its application formulated
TRL3	Critical functions and/or characteristics are confirmed analytically and experimentally
TRL4	Component and/or prototype tested in a laboratory environment
TRL 5	Component and/or prototype tested in close to real environment
TRL6	System/subsystem model or prototype demonstrated in a close-to-real environment
TRL 7	The prototype of the system has been demonstrated under operating conditions
TRL8	Real system completed and qualified during testing and demonstration
TRL9	Real system confirmed by successful operation (goal achievement)

Source: National Standard of the Russian Federation: Technology Transfer. Methodological guidelines for assessing the level of maturity of technologies. GOST R 58048-2017 (came into force on 01.06.2018).

Table 8

The technology readiness level regarding tecnologies and solutions in the field of HSR in leading foreign railway companies

Technology/ solution in the field of HSR	TRL		
	Company	2017	2025 (forecast)
Intelligent systems for information and control support for autonomous train control and remote dispatch control systems	DB (Germany)	TRL9	TRL9
	FS Italiane (Italy)	TRL9	TRL9
	JR Group (Japan)	TRL9	TRL9
	SBB-CFF-FFS (Switzerland)	TRL9	TRL9
Digital modelling and construction of digital models of infrastructure and rolling stock using satellite technologies and high-precision coordinate systems	Network Rail (England)	TRL9	TRL9
	DB (Germany)	TRL9	TRL9
Simulation of interaction of rolling stock and high-speed traffic infrastructure to ensure energy efficiency and safety using «Big Data» processing algorithms	Deutsche Bahn	TRL9	TRL9
	FS Italiane (Italy)	TRL3	TRL5
	Network Rail (England)	TRL5	TRL7
	SBB-CFF-FFS (Switzerland)	TRL9	TRL9
	SNCF (France)	TRL9	TRL9
Automated systems to support management decisions and planning the technical maintenance of infrastructure and rolling stock	Deutsche Bahn	TRL9	TRL9
	NSB (Norway)	TRL8	TRL9
	BB (Austria)	TRL9	TRL9
Aerospace monitoring of infrastructure facilities of railway transport and adjacent territories (including for prevention of emergencies and using unmanned aerial vehicles (drones)	DB (Germany)	TRL9	TRL9
	Network Rail (England)	TRL9	TRL9
	SNCF (France)	TRL9	TRL9
Technologies for integrated operational monitoring of the condition of rolling stock and infrastructure in real time	DB (Germany)	TRL9	TRL9
	CR (China)	TRL9	TRL9
	JR Group (Japan)	TRL9	TRL9
	SBB-CFF-FFS (Switzerland)	TRL8	TRL9

Source: Based on official websites, press releases and annual reports of leading foreign railway companies.

Table 9

Types of high-speed trains operated and planned for operation by leading foreign railway companies (based on [5])

Company	No. of train series	Number of trains	Planned number of additional trains	Max. design speed, km/h	Max. oper. speed, km/h	Manufacturer
China Railway (CR) (PRC)	27	2471	167	400	350	CSR-Bombardier, Kawasaki Heavy Industries, CSR-Sifang, Siemens, CNR-Tanshang, CNR-Changchun, Alstom, CSR-Puzhen Rolling Stock Co. Ltd., CRRC Tangshan, CRRC, CRRC–Changchun
Renfe Operadora (Spain)	15*	229	60	350	300	Alstom, Talgo-Bombardier, Siemens, CAF Alstom
JR Group: JWR, JRC, JRE, JRK, JRH (Japan)	27**	408***	59	320	320	Hitachi, Kawasaki Heavy Industries, Kinki Sharyo, Nippon Sharyo, Tokyu Car Corporation (J-TREC)
SNCF (France)	15	414****	–	320	320	Alstom
DB AG (Germany)	12	240*****	137	330	320	Siemens-Bombardier, Alstom
Trenitalia, NTV (Italy)	14	190******	103	400	300	Bombardier, Alstom, Alstom-Hitachi Rail Italy-Bombardier, Ansaldobreda, Ansaldobreda-Alstom-Bombardier, Siemens-Bombardier-Alstom, Siemens-Bombardier
Korail, SR (Republic of Korea)	4	97	–	330	300	Alstom, Hyundai Rotem

* Including 1 rolling stock series with expiring operation and 2 series to be operated very soon.

** Including series which are no more operated.

*** Some difference is possible due to original data format.

**** Without 66 trains jointly operated with SBB (Switzerland), Eurostar, Thalys.

***** Without 46 trains jointly operated with NS (the Netherlands), OBB (Austria), DSB (Denmark).

****** Without 31 trains jointly operated with SBB (Switzerland).

• Simulation modelling of interaction between rolling stock and high-speed traffic infrastructure to ensure energy efficiency and safety using algorithms for processing «Big Data» [9].

• Automated systems to support management decisions and planning of the technical maintenance of infrastructure and rolling stock [10].

• Geospatial monitoring of infrastructure facilities of railway transport and adjacent territories (including for prevention of emergencies and using unmanned aerial vehicles (drones) [11].

• Technologies for complex operational monitoring of the state of rolling stock and infrastructure in real time [8].

Most of the presented technologies and solutions are at the higher level of technology readiness (hereinafter – TRL) (Table 7) for most of the leading foreign railway companies (Table 8).

HSR rolling stock

Besides priority HSR-related technologies and solutions highlighted above, a fundamental element of organisation of high-speed passenger transportation is specialised rolling stock. The world leaders in terms of the number of types of high-speed trains operated are CR (China) and JR Group (Japan) (Table 9).

In the context of the maximum design and maximum operation speeds of trains in operation the absolute leadership belongs to China Railways (hereinafter – CR), significantly ahead of its closest competitors in all respects. The operated fleet of CR high-speed trains exceeds its closest competitor, JR Group, by 5 times.

CONCLUSIONS

Global plans regarding HSR construction around the world define this activity as one of the priorities. TRLs of most technologies and solutions required for high-quality and efficient provision of services for high-speed passenger railway transportation in the world are higher levels, which predetermines a high probability of further corporate development in this field.

Since number of companies operate rolling stock with maximum design speed of 400 km/h, we can draw a conclusion about the priority vector of scientific and technological development which is increasing train speed. Railways are active in research and development to further improve efficiency and speed, with Chinese and Japanese national railway companies leading the way in maglev and vacuum rolling stock technology.

The Russian Federation, within the framework of implementing its own HSR development policy, should rely on the best world practices and, using the accumulated significant scientific and technological capacity, and join the countries with the most developed high-speed rail passenger transportation.

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