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# The history of the emergence, development and improvement of high-speed railways: Technical, socio-economic and cultural aspects

**Abstract.** *The article deals with a comprehensive historical and analytical study of the formation and evolution of high-speed railway transport as one of the key technological and sociocultural transformations of modern society. The aim of the article is to reveal historical patterns of formation, technical evolution and socio-cultural significance of high-speed railway transport in a global context. The authors aim to show how the desire for speed became not only an engineering challenge, but also a driver of economic, urban and civilisational modernisation. An interdisciplinary approach combining historical-technical, comparative and socio-economic analysi has been used. Such a combination is justified by the essence of high-speed railways.*

*They are not just a transport technology, but a phenomenon that combines material engineering, state policy, the culture of speed, and human perceptions of space and time. For this reason, the logic of the study is not limited to a list of technical facts, but aims to show how an engineering idea gradually became a social reality. The source base includes peer-reviewed scientific publications, technical reports from railway companies, documents from international organisations, and contemporary research on the history of transport and engineering. The technical background of high-speed rail transport has been analysed since 19th-century railways to post-war projects of the mid-20th century, including Japan's Shinkansen system, France's TGV and Germany's ICE, as well as the subsequent development of a global high-speed railway network in China, Europe and other countries. The article combines technical, engineering, socio-economic, and cultural-civilisational approaches. It is shown that high-speed railway is not only an infrastructural phenomenon but also a social one, shaping mobility, urbanisation, regional integration, and environmental sustainability. The latest innovations of the 21st century: magnetic levitation, Hyperloop systems, and digitalisation, determining the transition to the era of energy-intelligent mobility have been considered separately. It has been concluded that the history of high-speed railway transport reflects the overall evolution of engineering thought, public policy and the culture of speed, which is transforming humanity's understanding of space, time and steady development.*

***Keywords**: high-speed raiwayl (HSR); transport modernisation; mobility; railway engineering; innovations; steady development*

## Introduction.

In a modern world where pace of life and mobility have become key indicators of social and economic growth, the development of high-speed railway communication is becoming important not only from an engineering perspective, but also in terms of culture and civilization (Strelko, Solovyova, Berdnychenko, Kyrychenko, & Solovyova, 2023; Strelko, Toropov, Horban, Hrushevska, & Bernatskyi, 2024). The idea of speeding up transportations by railway transport is the driving force behind infrastructure modernisation, technological progress and government policy. In this article we examine the history of emergence, evolution, and improvement of high-speed railways (HSR), focusing on technical and engineering aspects (materials, structures, traffic systems) and socio-economic factors (government policy, impact on urbanisation, mobility, and the economy).

The term HSR usually refers to railway lines designed for commercial passenger service at speeds significantly higher than traditional railway systems (generally over 200 km/h) and using specialised infrastructure or upgraded systems.

The engineering and technological innovations underpinning high-speed railways are not just about increasing speed. This is a complex: improvement of railway infrastructure (tracks, sleepers, stabilization), optimization of train aerodynamics, new materials for carriages and bridge as well as tunnel structures, power supply and automated traffic control systems. At the same time, these changes are associated with large-scale capital investments, government programmes, international technology transfers and a change in established mobility models: from 'travel = journey' to 'travel = a functional component of the economy and megaregion'. For instance, empirical studies of Chinese cities show that the opening of HSR lines contributes to the concentration of investments, talents and technologies in cities connected to the network – that is, the railway becomes a factor in innovative agglomeration.

In this regard, historical research into the development of high-speed railways has great potential: it allows us to trace how railway transport was transforming engineering thought, what technological barriers were overcome, how infrastructure implementation policy influenced regional development, and how perceptions of time, space and mobility changed. This article proposes two components of the approach: first, technical-engineering (technologies, materials, structures); second, socio-economic (public policy, urbanization, mobility, economic impact).

The historical understanding of HSR development was shaped relatively late – only when the phenomenon itself had already become a reality for several leading industrial countries. The first serious historical and technical studies appeared in the 1980s and 1990s and were focused primarily on the Japanese experience. Roderick A. Smith's study "*The Japanese Shinkansen: Catalyst for the Renaissance of Rail*" (2003), is considered to be a landmark work. In this publication Shinkansen appears not only as a technological breakthrough, but also as a socio-cultural experiment. Smith showed that Japanese high-speed railway model grew out of a combination of technical rationalism and national discipline – two traits that transformed transport into a symbol of modernity.

At the same time, another direction of historical research focused on comparative analysis was being formed in Europe. The publications by Javier Campos and Ginés de Rus, "Some Stylised Facts about High-Speed Railway: A Review of HSR Experiences Around the World" (2009), summarized decades of experience in various countries and offered a structured outline of the stages of HSR development. The authors traced patterns of funding, political support, and social effects, thus laying the groundwork for further economic and historical researches. Their analytical model was continued by Moshe Givoni (2006) and Roger Vickerman (2018), who emphasised that the history of HSR is primarily a history of institutional evolution: each state adapted the technology to its own political and cultural contexts.

In the 1990s, there appeared works that for the first time considered high-speed transport in the context of politics and public administration. The article by James A. Dunn Jr. and Anthony Perl, "Policy Networks and Industrial Revitalization: High Speed Rail Initiatives in France and Germany" (1994), showed that the *Train à Grande Vitesse (TGV)* and *InterCity Experimental (ICE)* projects were not only the product of engineering genius, but also of political compromises between the government, industry and society. Further researches have expanded the scope of analysis to the level of spatial planning, highlighting the impact of HSR on the formation of a 'new geography' of Europe.

Studies devoted to the Chinese experience play a particular role in contemporary historiography. The World Bank report China's High-Speed Rail Development (Lawrence, Bullock, & Liu, 2019) describes the phenomenal transformation of China's transport system over two decades and analyses this process as a socio-engineering experiment that combined centralized management, large-scale infrastructure and state ideology of modernization. Despite a large number of scientific publications, contemporary historiography of high-speed railways remains focused on several established topics, primarily the Japanese *Shinkansen*, French *TGV*, German *ICE*, and Chinese *Fuxing*. These models are rightly regarded as benchmarks for technical and managerial development, but this focus narrows the analytical field. Other national experiences remain in the shadows, as do issues of the interaction between speed, culture and social transformation, which are increasingly emerging in contemporary humanities studies.

For this reason, new researches seeking to integrate the technical, economic and cultural history of high-speed railways are becoming particularly relevant. Their task is not only to reconstruct the sequence of engineering decisions, but also to reveal the deeper meaning of this phenomenon as part of civilizational experience. Viewing high-speed rail through the prism of cultural dynamics, government policy and global socio-economic shifts allows us to overcome a narrow 'technological' vision and raise questions about the role of speed as a symbol of modernity, mobility and time.

In this context, the presented article is a timely attempt to critically summarize previous historical models, compare key paradigms of HSR development in different regions of the world, and trace how technical innovation is transformed into the social and cultural code of modernity. It is aimed not only at filling gaps in scientific descriptions, but also at expanding the boundaries of the history of technology itself in the direction of interdisciplinary analysis, where engineering, economics and culture are considered as components of a single process of high-speed transport evolution.

The aim of this article is to identify historical patterns in the formation, technical evolution and socio-cultural significance of high-speed rail transport in a global context. The authors attempted to show how the pursuit of speed has become not only an engineering challenge, but also a driver of economic, urban and civilizational modernization.

**Methodology.**

This study is based on a combination of several approaches that are not usually found in a single work: historical, technical, socio-economic and cultural. Such a combination is justified by the very nature of high-speed railways. They are not just a transport technology, but a phenomenon combining material engineering, state policy, the culture of speed, and human perceptions of space and time. That is why the logic of the study is not limited to a list of technical facts, but seeks to show how an engineering idea gradually became a social reality.

The article's source base covers a wide range of materials, from technical reports and statistical reference books to historical monographs and contemporary publications in peer-reviewed journals. Documents from Japan National Railways, SNCF, Deutsche Bahn, CRRC, as well as analytical reports from the World Bank, International Union of Railways (UIC), European Commission, International Energy Agency (IEA), etc. have been used. These materials were supplemented by the works of transport historians, in particular Wolmar (2010; 2012), Urry (2007) and Virilio (2006). All this made it possible to combine technical and humanitarian perspectives and regard HSR not only as a system of rails and wheels, but as part of contemporary history.

The logic of the analysis was consistent. First, we sought to recreate the context in which the very idea of speed emerged in the industrial age: what 'speed' meant to 19th-century society and why it became a measure of progress. Next, we examine the technical breakthroughs that made new types of trains possible, from Japan's *Shinkansen* to France's *TGV*. At the same time, we analyse not only the engineering level, but also the political and economic logic of the states that invested their national prestige in high-speed lines.

Methodologically, the study is based on the principle of historicism, therefore each technical solution has been considered in its specific temporal and political context. Technology never exists outside society, and railways are no exception. Another important principle is consistency: every change in the speed or design of a train is considered as part of a broader network of changes – energy, urban, cultural. In this sense, the history of HSR is not a line of technical progress, but a sophisticated network of interdependencies.

The Soviet experiments with the *CR3-1000* and *ER-200* electric trains are seen as attempts to catch up with Western technological trends within a different economic model.

The scientific value of this work lies not so much in the discovery of new facts as in the attempt to combine technical history with humanities. High-speed railway is considered here as a 'text' – a kind of message of the era, which tells how humanman overcomes space, changes his ideas about time and creates a new geography of movement around himself. Such an approach allows us to see the evolution of HSR not only in drawings and speed records, but in a deeper sense, as the history of human desire to move faster, more efficiently and more intelligently.

**Results and Discussion.**

***The Origins of High-Speed Transport (1830s–1930s).***

The beginning of the railway era in the 19th century laid the technical, engineering, and socio-economic foundations for the further development of high-speed transport technologies. As early as in 1825, on the First Journey of Locomotion No. 1 line between Shildon and Stockton, George Stephenson demonstrated the efficiency of steam locomotive transport as a key factor in industrialization. Although this event was not directly related to the concept of high speed, it opened up new opportunities for the technical hunt for speed.

It is estimated that in 1854, commercial trains' speeds were around 60 km/h, several times faster than the efficiency of the mail coach services of a decade earlier. Thus, the railway became not just a means of transport, but an infrastructural form that transformed perceptions of space and time, mobility and communication between cities.

In technical terms, this period was characterized by several key engineering innovations: improvements in steam traction, improvements in track layout and geometry, widespread introduction of steel rails instead of cast iron ones, increased length and width of sleepers, and improved installation accuracy. All this contributed to increased speed and reliability of transportations. Thus, from the mid-19th century onwards, we can talk about technological dynamics that would later become the foundation for formalizing the concept of "high-speed railways".

While commercial operation of high-speed passenger lines was still a long way off, the practice of setting speed records appeared at the turn of the 19th and 20th centuries. For example, according to *UIC*, speeds of about 100 km/h were achieved by 1850. The German project is particularly noteworthy: in 1901–1903, during tests of an experimental electric carriage (three-system three-phase current), speeds of over 200 km/h were achieved, including 210 km/h in October 1903. This experimental speed was a significant technical breakthrough, but at the same time it revealed a number of limitations: the weakness of the track, the instability of the carriages, the inadequacy of curved sections and the high cost of electrification. In this respect:

- increasing speed requires a significant increase in curve radii, improvement of bogies and suspension, and stabilisation of the track;
- economic feasibility was low because materials, installation, and electrification required large capital investments;
- infrastructure and operational requirements (power supply, cooling, ventilation, maintenance) were not yet adapted to high-speed systems.

This stage can truly be considered a 'preparatory' stage for the emergence of HSR: it conducted technical verification of speed limits and identified engineering challenges that were later resolved in the following decades.

In addition to simple traction and rail facilities, the first decades of the 20th century gave an impetus to the development of specific technologies aimed at increasing speed: optimization of rolling stock design (smooth contours, streamlined noses), use of lighter materials (aluminium or alloy steel structures), improvement of suspension and bogies, electrification of lines, etc.

Although these methods have not yet been systematically implemented on commercial HSR networks, they have significantly changed the engineering culture of railways. For example, the German experimental *Schienenzeppelin*, proclaimed as the '*Zeppelin on Rails*' (see Figure 1). This train promised to start a new era in travel (Howard, 2022). It had a lightweight aluminium body and an aircraft propeller engine, enabling the Schienenzeppelin to set a new speed record for railways on 21 June 1931, travelling at around 230 km/h on the Berlin-Hamburg line in Germany.

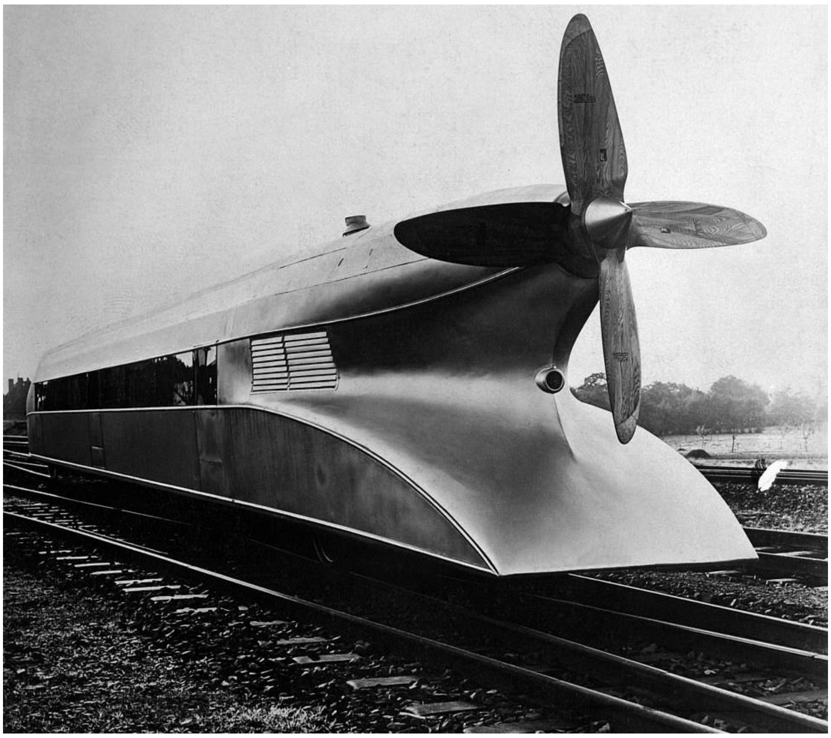

**Figure 1.** The train is seen on test rails in October 1930, when it achieved a speed of 93 miles per hour with 40 passengers on board (Howard, 2022).

*The Daily Mail* reported how it covered a distance of almost 290 kilometres in 1 hour and 44 minutes (Howard, 2022). The fastest train at the time could only cover this journey in three hours and 15 minutes. The record set by the *Zeppelin* ultimately lasted 23 years. Such experiments had a great impact: they showed that not only traction, but also design, streamlining, weight and air resistance become critical at high speeds. For the promising HSR, this meant: reduced weight, improved streamlining, a more rigid track, better suspension, and more precise balancing.

Technical prerequisites at the beginning of the development of high-speed railway transport were one component; socio-economic and institutional factors that shaped the demand for speed were no less important. In the 19th century, railways contributed to urbanization, the development of industrial centers, reduced delivery times for goods and passengers, and created new mobility opportunities.

Therefore, even in the pre-high-speed era, railways served to accelerate the economy, reduce distances between cities, and integrate markets. Industrial growth, population concentration in cities, and the need for a mobile workforce all created a strong incentive to reduce travel times. At the same time, governments and private railway companies were evaluating investments in the modernization of railway infrastructure, although not yet in a "high-speed" version.

International competitive dynamics should also be taken into account: countries that perceived railways as a symbol of modernity (e.g. France, Germany, Italy) were motivated to create faster routes as an analogue of industrial modernization and national prestige.

In the 1930s, there was a clearer transition to systems that can be considered the forerunners of modern high-speed railways. The *Fliegender Hamburger (Hamburg Flyer*) (Figure 2) was the first in a whole series of *Flying Trains* with which Deutsche Reichsbahn created an early high-speed rail network in the 1930s (DB Museum, n.d.). This made it an ancestor of today's *ICE*. The *Flying Trains* were diesel-electric railcars: a 12-cylinder Maybach diesel engine drove a generator, which in turn powered an electric motor. Engine and passenger seating were combined in the same coach – a principle that had proved unsuccessful with steam propulsion but was highly efficient with the new diesel engines. This made the train lighter and allowed higher speeds with lower energy consumption. In 1933, the *Fliegender Hamburger* express train between Hamburg and Berlin reached a speed of 160 km/h in regular service (Lambernd, 2024). This figure indicates that the engineering and institutional prerequisites were in place for the transition to speeds that had previously been considered fiction. However, full-scale operation of the HSR was not yet achievable: problems remained with infrastructure specialisation, safety, standardisation, capital investment and sustainable high-speed operation.

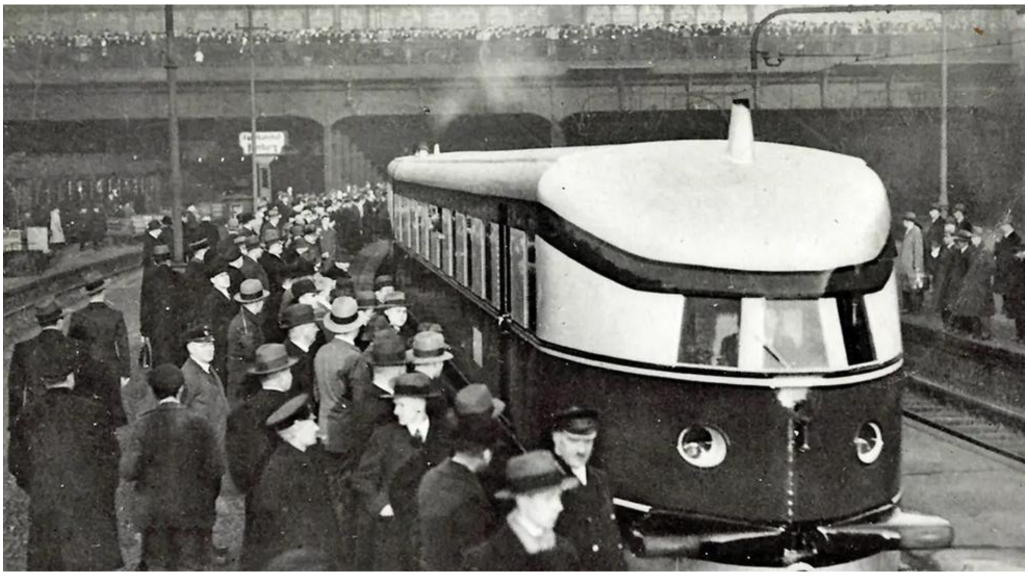

**Figure 2.** Fliegender Hamburger (Lambernd, 2024).

During this same period, experiments were conducted with electrification, lightweight rolling stock, aerodynamic designs, improved track quality, and control systems. Thus, it was the 1930s that formed the technical and social platform from which the HSR era would grow.

Thus, the period from 1830 to 1930 can be considered as the foundation for the further development of high-speed railway technology. Technological breakthroughs (from improvements in steam traction and track infrastructure to experiments with electrification, streamlining and materials) formed key technological elements. At the same time, socio-economic dynamics (urbanization, industrial development, population mobility, state modernization policy) created a demand for speed as an infrastructural value. It was at the turn of the 1930s that the formative phase began, from which the first systems closer to the concept of modern high-speed railways emerged.

***Formation of High-Speed Railway Concept (1945–1964).***

After the end of World War II, the global transport system found itself on the brink of change: infrastructure destruction, growing numbers of cars and air travel, urbanization, and accelerated economic growth. In this environment, the railway had to respond to new challenges: reducing travel time between cities, improving traffic reliability, and reducing operating costs.

In Western European countries and Japan, competition between different modes of transport was growing, putting pressure on railway administrations to modernize.

In engineering terms, this meant: increasing design speeds, switching to electrification, improving rolling stock and infrastructure designs (rails, sleepers, tracks with large curve radii), using lighter materials and streamlined shapes. According to the *UIC*, speeds of over 200 km/h were achieved in tests as early as the beginning of the 20th century, which in itself demonstrates technical feasibility, but did not mean commercial operation (International Union of Railways, n. d.). However, there were still significant barriers to the widespread introduction of such speeds, both technical and socio-economic.

After 1945, technological development of the railway system received a new impetus. European and Japanese engineers focused their attention on two areas: (a) adapting existing lines to higher speeds and (b) designing completely new routes and rolling stock focused on speed.

In Japan, for example, engineers from Japanese National Railways (JNR) studied Italian and French projects in the mid-1950s, attended electrical engineering conferences, and adopted the experience of alternating current switching for traction and track standardisation. This allows us to claim that the foundation of the modern HSR system was laid in the technical solutions of that period.

One of the important achievements was the improvement of the suspension and bogies: increased rigidity, stabilization of wave oscillations (“hunting oscillation”) at high speeds, improved rail connections, and all these engineering solutions were critical. For example, in France in the early 1950s, during tests of the *CC 7121* electric locomotive (Figure 3), a speed of 243 km/h was achieved on standard gauge track (Dumitru et al., 2024). This fact confirms that technological boundaries of motion have already been significantly shifted, but have not been adapted for mass operation yet.


**Figure 3.** *CC 7121* during the presentation of the Blue Ribbon, Paris-Gare de Lyon (Broncard, 1954).

Technical prerequisites required a political and institutional response, which became key in shaping the concept of HSR in the middle of the century. In Japan, the state, which suffered from oil dependency and the need for mobility (rapid movement of large passenger flows) between large megacities (the Tokyo-Osaka transport corridor), created a long-term programme for the development of high-speed railway transport. This policy included state funding, infrastructure standardization, and management models that allowed high-speed lines to be integrated into the overall network.

In Europe, as early as the late 1950s and early 1960s, the French, German and Italian governments began discussing national programmes to modernise rail transport as a means of competing with aviation and road transport, as well as a symbol of a modern state project (Cohen, 2014). For example, in France, Infrastructure Minister Edgard Pisani set a target in 1966 to reach a speed of 200 km/h on the Paris-Toulouse line. This meant not just engineering modernisation, but a state strategy aimed at changing mobility, economic planning and the symbolism of modernity.

The launch of high-speed systems required radical changes in infrastructure: the construction of new tracks with large curve radii, reinforced subgrades, special sleepers, straighter routes, bridges and tunnel structures that ensured high speeds without sacrificing safety. It should be noted that the use of conventional tracks with significant curves and very large gradients did not allow for a steady speed of 200 km/h or more.

The transition to alternating current traction (e.g. 25 kV 50 Hz), the use of lightweight materials (aluminium alloys, multi-car train designs) and aerodynamic streamlines were also important. These technologies began to be intensively implemented during this period: their development and tests took place in the 1950s and 1960s as a preparation for the introduction of commercial HSR lines. An example of this is the work of the French railways on the *TGV 001* prototype in 1969–1970, which, although beyond the exact date of the middle of the century, is already a result of the efforts of this period.

The culmination of this stage was the launch of Japan's first commercial HSR line, the *Tōkaidō Shinkansen* (Tokyo–Osaka), in 1964. At the time of launch, its trains were running at speeds of around 210 km/h. This step was not only a technical milestone, but also a symbolic one: it effectively opened a new era of railway transport. For Japan, it was part of a strategy of 'economic miracle', megaregion mobility, infrastructure standardisation and building a national brand through technology. Thus, the middle of the 20th century can be considered the period when the HSR concept was transformed from an engineering possibility into a national transport strategy.

The launch of HSR had significant socio-economic consequences: reducing logistical and time barriers between cities, stimulating urbanisation and economic agglomeration, increasing the share of passenger transport by railway, and changing the model from "trip = journey" to "trip = everyday mobility". For example, studies show that the development of HSR facilitates the concentration of technology and talent in cities connected to new corridors. In addition, the modernisation of railway infrastructure has become part of many countries' national modernisation policies, as a symbol of progress and modernity. It is not only a transport project, but also a tool for economic development, labour mobility and the spread of innovation.

The period of the middle of the XX century was critical for the formation of the HSR concept: technical and engineering solutions (suspension, electrification, infrastructure, rolling stock) and state policy (plans, standardisation, financing) created the basis for the emergence of the first commercial line. At the same time, this stage outlined the socio-economic transformations that accompanied high-speed movement, changes in mobility, the creation of agglomerations, and new economic corridors.

***The Birth of the Shinkansen Era (1964–1980).***

After World War II, Japan faced the dilemma of upgrading its transport system. On the one hand, the traditional railway was overcrowded; for example, the Tokyo–Osaka line carried over 80 million passengers annually, and the journey time exceeded six hours. On the other hand, motor and air transport developed slowly due to limited space and energy dependence. With the rapid urbanisation of the 1950s, the Japanese government prioritised railways as the basis for creating a "high-speed transport corridor" that would be part of its economic growth strategy (Gubbins, 1989).

The *Shinkansen (新幹線 – 'New Main Line')* concept was born as an engineering and government project headed by Hideo Shima, head of the technical research department of Japanese National Railways. It was his technical vision of creating a completely new standard gauge of 1,435 mm (as opposed to the narrow 1,067 mm), specialised for speeds of over 200 km/h, that became the key breakthrough. This decision made it possible to get rid of the limitations of the old dimensions and curve radii, ensuring smoothness, stability and aerodynamic efficiency of movement.

The *Tōkaidō Shinkansen line* (515 km, Tokyo–Nagoya–Kyoto–Osaka) was opened on 1st October 1964 and became the world's first example of the systematic implementation of HSR technology (Nakanishi & Kurauchi, 2021). Its *Series 0 Shinkansen* trains (see Figure 4) reached speeds of 210 km/h, more than 30% faster than any commercial trains at the time.

**Figure 4.** The ribbon-cutting ceremony for the launch of the *Shinkansen* bullet train between Tokyo and the Shin-Osaka station on Oct. 1, 1964, in Tokyo. (Flippen, 2014).

The main technical features included: a special double-track line with increased curve radii (minimum 2,500 m), which reduced centrifugal loads; continuous welded rails, which eliminated shocks and vibrations; concrete sleepers and elastic fastenings, which ensured track stability; 25 kV 50 Hz AC electrification, which provided high traction power; aluminium-steel bodies with reduced air resistance; an automatic train control system, which prevented collisions (Mochizuki, 2011; Mindur L., Zamiar, & Mindur M., 2024).

All this turned Shinkansen into a unique technical ecosystem, where the train, track, signalling and control operated as a single integrated system. It was this ‘systemic approach’ (as opposed to the isolated improvement of individual components in Europe) that became the key to the success of the Japanese model (International Union of Railways, n. d.).

The Shinkansen project was not only an engineering phenomenon, but also a political one. It was financed (approximately 380 billion yen, or ≈1 billion USD at the exchange rate of that time) through a combination of the state budget, World Bank loans (approximately 80 million USD) and JNR bonds (Shima, 1994).The World Bank considered the project to be “a model of transport planning that integrates economic feasibility and technological innovation” (World Bank Report No. P-408). The political support of Prime Minister Hayato Ikeda (the initiator of the ‘Income Doubling Plan’) made the Shinkansen a part of a broader national modernisation strategy. Its launch in October 1964 coincided with the opening of the Tokyo Olympics, which strengthened its international resonance and emphasised the symbolic significance of speed as a sign of a new Japan (Wolmar, 2012).

During its first five years of operation, the Tōkaidō Shinkansen carried over 100 million passengers, and by 1980, over 1 billion (Okada, 1994). The project’s profitability increased so much that the capital investment was repaid in less than seven years. The main socio-economic outcomes: the formation of the “Tokai megalopolis” (a mixture of urbanised areas of Tokyo, Nagoya, Kyoto and Osaka); an increase in the share of domestic passenger railway transportations to 80%; the stimulation of regional integration and labour mobility; reduction of energy consumption by 30–40% compared to air transport.

In the 1970s, large-scale enhancements of rolling stock began: noise reduction, improved aerodynamics, transition to lighter designs and integrated traction systems (Figure 5). The development of the 100 series (1979) involved the application of aluminium bodies, air conditioning, reduced air resistance, and comfort for journeys over 250 km/h. At the same time, the network continued to expand: in 1975, the *Sanyō Shinkansen* line (Osaka–Fukuoka) was opened, and in the late 1970s, construction was started on new routes (Tōhoku, Jōetsu) (Smith, 2003; Takatsu, 2007; Nakanishi & Kurauchi, 2021).

**Figure 5.** Shinkansen bullet trains at a depot in Fukuoka in 1975 (Brasor & Tsubuku, 2014).

Japanese engineering thought shifted from "achieving speed" to "controlling speed": stability of movement, comfort, low noise levels, automated control systems – all this laid the technological foundation for the further development of global HSR systems (Figure 6).


**Figure 6.** The Shinkansen Lines (Nippon.com, 2025).

The success of the *Shinkansen* had a huge impact on other countries. France launched the *TGV* programme, relying on Japanese research into track stabilisation and electrification. Germany (*Deutsche Bundesbahn*) began developing experimental *InterCity Experimental* electric trains, which later led to the *ICE series* (Ebeling, 2005). Italy and Spain adapted the principles of control and technical monitoring. Thus, *Shinkansen* became a global standard – not only as a technology, but also as a concept of a "national infrastructure project aimed at maximum speed and safety". It was this Japanese experience that defined the further direction of development of European and Chinese HSR networks (International Union of Railways, n. d.).

The period from 1964 to 1980 became the turning point in the history of railway transport. *Shinkansen* incorporated engineering innovation, systematic planning, government policy and socio-economic effects into a single model. It was proved that speed and volume can coexist without affecting safety and stability if the system is built as a complex: infrastructure, energy, rolling stock, and management. From a technical point of view, it was the Japanese model that first created a true "high-speed ecosystem." From a socio-economic viewpoint, *Shinkansen* showed that transport could be a tool for national modernisation.

The Shinkansen became not just a technological project, but a symbol of the 20th century, combining engineering, economics and the culture of travel (Figure 7).

**Figure 7.** Crown prince Naruhito on board a *Shinkansen* bullet train in 1968 (Brasor & Tsubuku, 2014).

***The European High-Speed Era (1980–2000).***

Following the success of Japan's *Shinkansen* in the 1960s, European countries began to consider high-speed railway as a strategic tool for regional integration and engineering modernisation. In the early 1980s, the European railway sector was experiencing a crisis: aviation was actively conquering the market for medium distances (400–800 km), while road transport dominated in short trips. State-owned railway companies such as *SNCF* (France), *Deutsche Bundesbahn* (Germany), *FS* (Italy) and *RENFE* (Spain) needed a new technological response to achieve new heights of speed, comfort, schedule accuracy and economic efficiency.

It was at this time that the concept of the European HSR model was born, based on a combination of three principles:

1. integration into the existing railway network (unlike the isolated Japanese model);
2. state-private funding based on national budgets, the European Investment Bank and regional funds;
3. infrastructure compatibility between EU countries (unification of signalling standards, track gauge, traction systems).

The French *Train à Grande Vitesse* was the first European HSR system to enter into commercial operation. In 1981, the *Ligne à Grande Vitesse* (*LGV*) Sud-Est line (Paris–Lyon) was opened, where *TGV 001 series* trains operated at speeds of up to 260 km/h (International Union of Railways, n. d.; Lacôte, 2001). The *TGV* platform combined an aerodynamic body shape, 25 kV 50 Hz electric traction, continuous welded rails, reinforced suspension and a *TVM* (*Transmission Voie-Machine*) signalling system. A distinctive feature of the French approach was the use of a new high-speed track *LGV* compatible with traditional stations. This allowed to combine speed on highways with flexibility for access to city centres.

The success of the *TGV* was possible thanks to the political will of President Valéry Giscard d'Estaing and Prime Minister Raymond Barre, who supported the *SNCF* as a symbol of French technical leadership. During its first 10 years, the *TGV* carried over 100 million passengers, and from 1981 to 1990, its average speed increased to 300 km/h. Opening the *TGV Atlantique* (1989) and *TGV Nord* (1993) lines expanded services to Belgium, the Netherlands, and the United Kingdom via the Eurotunnel (International Union of Railways, n.d.). This had economic consequences. In particular, passenger traffic between Paris and Lyon increased by 65% during the first three years; tourism and business mobility were stimulated; and domestic air travel declined (some airlines were shut down). Thus, the *TGV* became not only a transport phenomenon, but also a social one: it linked the country into a single economic space and became a symbol of French technological nationalism (Perl, 2002).

In Germany, the *Deutsche Bundesbahn* engineering school developed the experimental *InterCity Experimental (ICE-V)* train in the 1970s, which broke the world record on 1 May 1988, reaching a speed of 406.9 km/h (Ebeling, 2005). This demonstrated the technical maturity of German engineering. Commercial operation of the *ICE 1* began in 1991 on the Hanover–Würzburg line. The *ICE* differed from the *TGV* in its modularity and multi-system capability: trains could operate under different types of electrification (15 kV 16.7 Hz AC / 25 kV 50 Hz AC) and automatically adapted to the signalling standards of other countries. The design featured lightweight steel alloys, soft swivel bogies, active suspension and a high level of safety. The German HSR model focused on integration with the regional network: *ICE* supplemented rather than replaced conventional trains. This enabled balanced regional development and decentralised mobility. The national strategy provided for co-financing of lands and the federal government. By 2000, the length of high-speed lines exceeded 1,100 km, and *ICE* became an integral part of Germany's transport policy (Perl, 2002; International Union of Railways, n. d.).

An Italian engineering school proposed an alternative solution, which involved increasing speed without building new tracks. The company *FIAT Ferroviaria* developed the *ETR Pendolino train* (1976), equipped with an active body tilt system that compensated for centrifugal force on curves and allowed the train to travel at speeds of 250 km/h on existing tracks (Lacôte, 2001).This technology was subsequently exported to Spain, the Czech Republic, Poland and Finland, and in the 1990s it was licensed by the company *Alstom. The Pendolino* solution had a strategic advantage for countries with difficult terrain and limited budgets: it demonstrated that the HSR effect could be achieved even on modernised old lines.

Spain became the next country to invest in HSR, opening the Madrid–Seville *AVE line* (1992) as part of the *Plan AVE 2000* national infrastructure development programme. The Spanish model combined French *TGV* technology with state funding and links to regional policy (Albalate & Bel, 2012).

In the United Kingdom, on the contrary, the development of HSR was slower. It was only in 1994 that the *Channel Tunnel Rail Link* (later *High Speed 1*) was opened, connecting London with the continent (Givoni, 2006). This was a key step towards the creation of a single European high-speed area.

At the same time, the *Trans-European Transport Networks* (*TEN-T*) initiative was launched in Europe to integrate national HSR systems into a single infrastructure network (European Commission, 1996). In the 1980s and 1990s, the main challenge was the compatibility of systems: different countries used different signalling standards (*TVM, LZB, ETCS*), traction voltage, dimensions and control languages. To solve this problem, in 1996 the EU initiated the development of a single standard, *ETCS* (*European Train Control System*), which became the basis for future integration (Lundström, Jäcker-Cüppers, & Hübner, 2003). From a technical point of view, it was during this period that new generations of rolling stock appeared: *TGV Atlantique* (1989) with speeds of up to 300 km/h; *ICE 2* (1996), which featured a modular design combining electric cars and locomotives; *Pendolino ETR 480* (1997), which had a fully digital tilting system. The introduction of these innovations allowed Europe to catch up with Japan and become the second centre of global HSR technology development.

High-speed railway became a key driver of urbanisation, tourism and economic integration. For example, after the launch of the *TGV Sud-Est*, 70% of business travel between Paris and Lyon shifted from air transport to the railways. In Germany, the *ICE* has contributed to the creation of a “knowledge corridor” between Munich, Nuremberg and Frankfurt, while in Spain, the *AVE* reduced the journey time between Madrid and Seville from 6 to 2 hours. Socially, HSR created a “space-time compression” effect by extending daily commuting zones to 200–300 km and forming “polycentric megaregions.” Economically, HSR strengthened the links between innovation hubs, universities and labour markets (Vickerman, 1997).

The period from 1980 to 2000 established Europe as the second global centre of HSR after Japan. The French *TGV* demonstrated the effectiveness of state technonationalism, the German *ICE* demonstrated engineering precision and integration, and the Italian *Pendolino* demonstrated innovative flexibility. Together, they formed the European school of high-speed transport, based on standardisation, energy efficiency and transport integration. The European HSR model became not only a technical project, but also a socio-economic one, demonstrating how infrastructure shapes the continent’s space and mobility.

***Soviet Experiments with High-Speed Travel.***

The idea of high-speed transport in the Soviet Union emerged independently of Japanese and European experiments, but within a different technical and political logic. Soviet science regarded high-speed trains not as a tool for market mobility, but as a manifestation of scientific and technological progress that demonstrated the “advantages of the socialist engineering school.” Since the 1960s, researchers into aerodynamics, rolling stock, and electrical systems for speeds exceeding 200 km/h have been started in the USSR. The development centres were the Central Research Institute of the Ministry of Railways, the All-Union Scientific Research Institute of Railway Transport (*VNIIZhT*), and factories in Riga, Kalinin, Kharkiv, and Leningrad.

Soviet experiments in the 1960s and 1970s were focused on creating laboratory electric trains to determine the limits of stability and safety at high speeds. In 1965, the *CR3-1000* train (based on the *ER-1* electric train) was tested on the Gorkyi Railway, reaching a speed of 185 km/h (VNIIZhT, 1966). In 1972, the Riga carriage works designed an experimental electric train, the *ER-200*, intended for speeds of 200–250 km/h (Figure 8). In 1973–1975, it set a record of 250 km/h on the Moscow–Leningrad section, exceeding the commercial performance of Europe at that time (VNIIZhT,1975). The main technical features of the *ER-200* are: aluminium car bodies with alloy frames; wheel sets with disc brakes; 3000 V DC power supply; aerodynamic shape of the main cars; regenerative braking system; improved noise insulation and comfortable interiors. These experiments did not become commercial, but laid the engineering foundation for subsequent developments and became direct analogues of the Japanese *Shinkansen 0*.

**Figure 8.** *ER-200 RVR* High speed train (Kirkland, 2019).

In the late 1970s and early 1980s, experiments with electromagnetic suspension and tube transport were carried out in the USSR. Projects of the Radio Technical Institute of the USSR Academy of Sciences envisaged the creation of magnetic levitation transport platforms moving in vacuum tubes at speeds of > 400 km/h. However, they remained at the experimental stage due to a lack of political priority and limitations of funding. Unlike in the West, where HSR was part of infrastructure mobility policy, in the USSR speed had ideological significance, namely, demonstrating technical might.

The researches of the *VNIIZhT* were financed through five-year plans and programmes of the USSR Transport Strategy. However, the lack of economic incentive (demand was planned rather than market-based), a shortage of currency to purchase components, and centralised management slowed down the introduction of HSR into serial production. Until the mid-1980s, the *ER-200* was operating on limited routes between Moscow and Leningrad, but due to track wear, energy costs, and service instability, the project was shut down in the 1990s (Westwood, 2001).

Soviet experiments show that the technical potential for high speeds has existed since the 1970s, but institutional, financial, and political factors determined the pace of its implementation. The USSR created a powerful engineering basis (*ER-200*, laboratory trains, magnetic levitation projects), but failed to transform it into a stable infrastructure due to its centralised economy.

***China and the Global Era of High Speeds (2000–2020).***

At the beginning of the 21st century, China became the main driving force in the field of high-speed railway transport. According to data from the International Union of Railways for 2024, in the last decade alone, China constructed a network with a length of 45,390 km, which is more than two-thirds of the global network with the length of 64,698 km. (Davenne, 2024, p. 5). The *Chinese High-Speed Railway* (*CHSR*) has become not only an engineering achievement, but also an element of the national strategy for economic development and spatial integration.

According to the *Medium- and Long-Term Railway Plan* (Zhou & Qiu, 2018), the Chinese government has set a goal of creating "eight vertical and eight horizontal railways (the so-called '8+8 network"') that will connect all metropolitan areas with a population of over 500,000 (Lawrence, Bullock, & Liu, 2019).

Such a scale is unique in the history of transport and was made possible by a combination of state planning, technology transfer and centralised funding. The reforms of the 1990s, initiated after the "*Reform and Opening-Up*" policy, created the conditions for large-scale infrastructure modernization (Wang, Strauss, & Zheng, 2021). After China's accession to the WTO (2001), the government decided to make high-speed transport a domestic market tool that stimulates consumption, employment, and technological independence.

The first HSR line was the *Qinhuangdao–Shenyang Passenger Line* (2003) – two-track electrified main line, allowing traffic up to 250 km/h (Tang & Sun, 2020). Later, in 2008, *Beijing–Tianjin Intercity* – was opened, the first full-fledged high-speed line designed for 350 km/h, which became the «technological testing ground» for the entire network). At the same time, the government approved funding through the State Railway Corporation (China Railway Corporation) and the Ministry of Finance. HSR infrastructure spendings from 2008 to 2020 exceeded $970 billion, equivalent to ≈ 1.2% of China's GDP each year (Lawrence, Bullock, & Liu, 2019).

In the early 2000s, China did not have its own high-speed technology, so it resorted to a licensed transfer model:

- *Siemens* (Germany) – platform *ICE 3* (*Velaro*);
- *Alstom* (France) – *TGV Duplex* technology;
- *Kawasaki Heavy Industries* (Japan) – *Shinkansen E2*;
- *Bombardier* (Canada) – *Regina X2000* (for tilting bodies).

Between 2004 and 2008, more than 100 agreements were concluded with these corporations in the amount of about 12 billion USD, with the condition of production localization at CSR and China CNR enterprises (Pepermans, 2020; Tang & Sun, 2020; Rui & Bruyaka, 2021).

Since 2011, China has introduced a fully localized *CRH380A* series (Tang & Sun, 2020; Yang, Qi, Li, & Wang, 2022), developed under license from the *Siemens Velaro*, but with improved aerodynamics, lighter bodies, and its own control systems (*CTCS-3*). In 2017, the production of the *Fuxing CR400AF/BF*, the first truly all-Chinese train designed for 400 km/h, was begun (CRRC Annual Report, 2018). The main technical features of the *Fuxing CR400AF/BF* were: a lightweight aluminum body, an aerodynamic "arrow" nose; a dynamic stabilization and noise reduction system; a GSM-R wireless communication system; and intelligent traction and braking control.

By 2020, China over 1,500 HSR railway junction had been in operation, with integration into urban metro networks and air transport. The track was standard (1,435 mm), concrete ballasted or slab track, which reduces vibration and maintenance costs (Watson, 2021; Zeng et al., 2022). The average design speed was 300–350 km/h, the minimum radius was up to 7,000 m. For safety, multi-level signaling systems *CTCS-2/3* (analogous to *ETCS*) are used.

The energy efficiency of *CHSR* is estimated to be 45–50% higher than that of air travel over the same distance (Lawrence, Bullock, & Liu, 2019). The system is supported through automated diagnostic centers that collect data in real time, a typical example of the transition to *Smart Rail 2.0.*

*China's HSR* has created a new geography of mobility. According to World Bank (Lawrence, Bullock, & Liu, 2019), 95% of China's population lives within a 50 km radius of the HSR station. Passenger traffic increased from 237 million (2009) to 2.3 billion (2019). In the 2010s, HSR provided ≈ 0.5% of GDP growth each year due to the agglomeration effect. Studies show that cities connected to HSR show 25–30% higher productivity, higher R&D investment and increased access to labor (Lawrence, Bullock, & Liu, 2019; Tang & Sun, 2020; Watson, 2021). Socially, HSR became a catalyst for second-level urbanization, namely, the emergence of accompanying cities around stations (HSR new towns), similar to the phenomenon of Japanese "economic corridors" (Miwa, Bhatt, & Kato, 2022).

China's "*One Belt strategy, One Road*" sees HSR as the infrastructural equivalent of «soft power», as a tool for diplomacy and export standards. China has become the second exporter of railway technology after France, and the company *CRRC* is the world's largest manufacturer of HSR rolling stock (Lawrence, Bullock, & Liu, 2019).

Despite the scale, the *Chinese HSR* has a number of challenges. Among which the most significant are the following: debt burden: the total debt of *China Railway Group* in 2020 exceeded 830 billion USD; uneven use: part of the lines in remote regions has an occupancy rate of < 50%; environmental consequences: electricity consumption and impact on land resources. However, in terms of efficiency, HSR remains the most environmentally friendly form of mass transport: $CO_2$ emissions per passenger kilometer are three times less than that of airplanes (International Energy Agency, 2019).

The Chinese era of HSR (2000–2020) marked a shift in the center of gravity of technological progress. China has demonstrated that in 20 years it is possible to create a large-scale, integrated, high-tech transport system that surpasses the historical counterparts of Europe and Japan. Three key lessons from the Chinese experience:

1.The synergy of state planning and technological localization ensures rapid scaling.

2.The integration of HSR into regional policy creates an economic effect of agglomerations.

3.Infrastructure as a strategic «soft force» forms a new geopolitical architecture.

China has become the world standard "of mass high-speed transport", combining engineering complexity, efficiency and social impact. It is this model in the XXI century determines the further direction of global development of HSR technologies.

***Technological Innovations of the 21st Century: Maglev, Hyperloop, Environmental and Energy Efficiency.***

After two decades of dominance of classic high-speed systems, a new phase began at the beginning of the 21st century, which was aimed at finding technologies capable of exceeding the limits of rail contact and increasing energy efficiency. This stage is often called the "post-HSR era", in which research is aimed at magnetic levitation, vacuum transport and automated control systems. The main goal of this stage is to increase the speed over 500 km/h without losing stability, noise reduction and reducing energy consumption (International Energy Agency, 2019).

Magnetic levitation (in English. *Magnetic Levitation, or Maglev*) eliminates contact between the train and the track: the «car floats» on a magnetic field created by electromagnets or superconductors. This reduces friction to a minimum, allowing speeds of over 600 km/h to be reached. There are two main technologies: EMS (Electromagnetic Suspension), when electromagnets in carts attract the wagon to the guide (*Transrapid system*, Germany); EDS (Electrodynamic Suspension), when induction repulsion between superconducting magnets and the guide is used (*SCMaglev* system, Japan).

The first commercial example was the *Shanghai Maglev Train* (opened in 2004), a joint project between Siemens and Transrapid International connecting downtown Shanghai to Pudong Airport (30 km in 7 minutes, max. 431 km/h) (Singh et al., 2023; Gieras, 2025). Transrapid technology uses a linear synchronous motor and a real-time deviation stabilization system. Although the operation proved reliable, the project proved expensive: the construction cost was more than USD 1.2 billion (Baohua, Huang, & Shunping, 2008).

The Japanese response was *SCMaglev* (*Superconducting Maglev*), created by the *Central Japan Railway Company* (*JR Central*). During the 2015 tests, the *L0 Series* train reached a speed of 603 km/h, setting a world record (Mindur L., Zamiar, & Mindur M., 2024). A plan for a commercial line called *Chūō Shinkansen* (Tokyo – Nagoya – Osaka) is to start operations in 2030s and trains are to move at an average speed of 500 km/h.

The idea of vacuum pipe transport was proposed by Robert Hutchings Goddard in the 1910s, but received its modern implementation in 2013, when Elon Musk presented the *Hyperloop Alpha concept* (Musk, 2013). *Hyperloop* is a capsule that moves in a sealed tube with reduced pressure (≈100 Pa), using magnetic levitation or an air cushion, reaching speeds of 1000–1200 km/h. In 2020, *Virgin Hyperloop One* (USA) conducted the first test with passengers (Nevada Test Site) at a speed of 172 km/h. *Zeleros* (Spain) is developing a European version with a self-contained compressor and a grid-independent drive (Lluesma, Arguedas, Hoyas, Sánchez, & Vicén, 2021). *TransPod* (Canada) and *Hardt Hyperloop* (Netherlands) are developing a common standard for certification (*European Hyperloop Centre,* 2023). Although *Hyperloop* remains an experimental technology, its developers position the system as an evolutionary successor to HSR, with a potential rate three times that of current maglevs.

Modern HSR, *Maglev and Hyperloop* technologies are aimed not only at speed, but also at reducing the carbon footprint. According to the International Energy Agency (International Energy Agency, 2019), the average $CO_2$ emissions for HSR are: 14 g/pass-km for electric trains; 42 g/pass-km for aviation; 68 g/pass-km for cars. *Maglev systems* consume ≈20–25 kWh per 100 km/pass, which is 30% less than medium-range aircraft (International Energy Agency, 2019). *Hyperloop* will potentially be able to reduce energy consumption to 8–10 kWh/100 km/pass thanks to the vacuum environment. The environmental advantage of high-speed transport is becoming crucial in the context of the European Green Deal (2019) and Paris Agreement (2015) climate targets, which provide for a 90% reduction in transport emissions by 2050.

The current development of HSR is complemented by intelligent control systems that provide unmanned traffic, track monitoring, energy saving and passenger flow management. AI-driven Predictive Maintenance and IoT Sensors technologies are used in the networks of China, Japan and the EU. Using machine learning algorithms to manage traffic allows you to reduce energy consumption by up to 15 %. Thus, "smart rail" combines HSR with digital control systems, which creates a new quality of mobility – automated, environmentally friendly, efficient. The stage of the 21st century demonstrates that the technological evolution of rail transport is moving from mechanical improvement to an energy-intelligent system, where speed, efficiency and sustainability form a triune goal. *Maglev* and *Hyperloop* remain expensive experiments for now, but they indicate the direction of further development:

– reduction of physical limitations (contact, friction);
– full electrification and renewable energy;
– real-time digital transport management.

In the coming decades, the technological integration of magnetic levitation, vacuum tubes and artificial intelligence could create the third revolution in the history of high-speed transport – after the emergence of HSR (1960–1980) and its global expansion (2000–2020).

***Cultural and Civilizational Dimension of Speed.***

From the very beginning of the development of railway transport, speed was not only an engineering characteristic, but also a symbol of the era. In the 19th century, it meant "the mechanical overcoming of space", in the 20th century, "the mechanization of time", and in the 21st century, it became a metaphor for global interaction. Speed in the cultural dimension has become a reflection of how society perceives progress, risk and space (Virilio, 2006; Schivelbusch, 2014). HSR is not only a technology, but a form of social organization of time. It changed the perception of distance and mobility: traveling between cities ceased to be an event because it became part of everyday life.

In the 20th century, HSR became a "cultural icon" of modernism. The Japanese *Shinkansen* is a symbol of the "economic miracle"; the French *TGV* is a symbol of technonationalism; the German *ICE* is a symbol of engineering precision; the Chinese *Fuxing* is a sign of state power. As Urry (2007) notes, infrastructure shapes a "new sociality of mobility," where people measure the world not in kilometers but in minutes (Figure 9). Speed becomes cultural capital: countries demonstrate technological maturity through the speed of their trains. This creates the phenomenon of "railway aesthetics," through the architecture of stations, the design of trains, and public perceptions of comfort and the future.

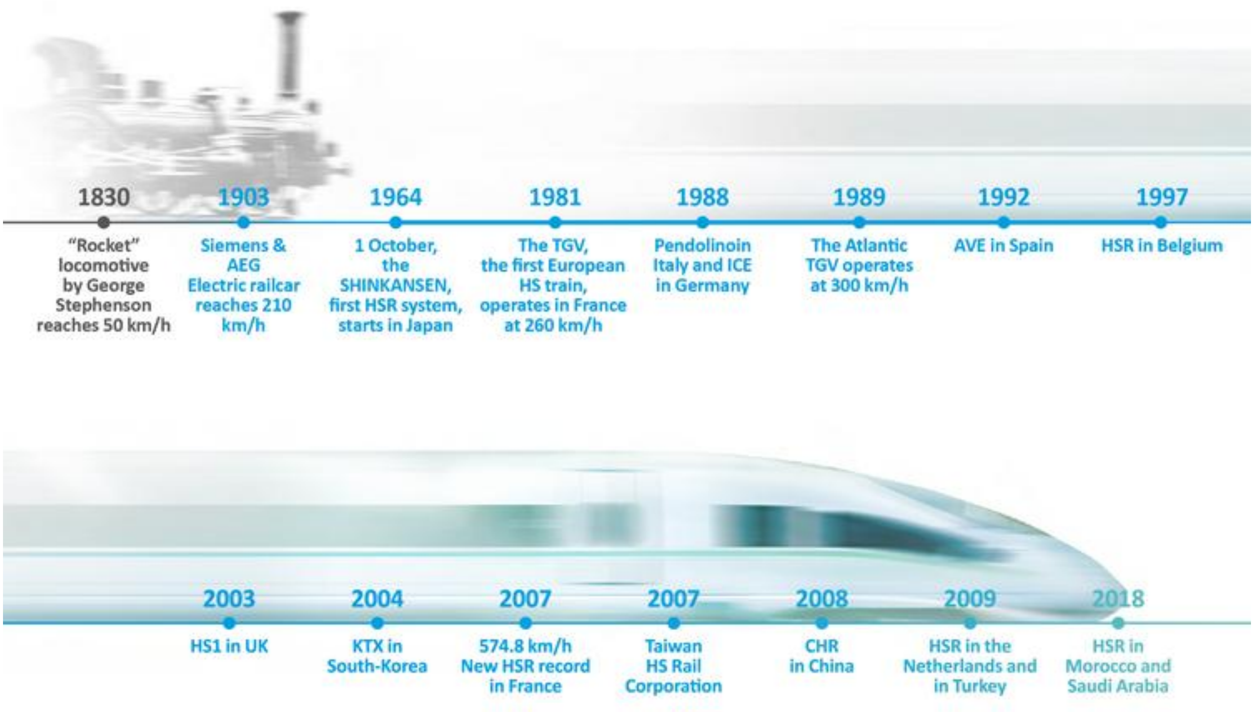


**Figure 9.** High-Speed Rail History (International Union of Railways, n.d.).

In a socio-economic sense, HSR has become a tool for shaping regional labor and knowledge markets. It reduces the space between cities, creating "megalopolises" and agglomerations of a new type (e.g. Tokyo–Osaka, Paris–Lyon, Madrid–Barcelona, Beijing–Shanghai). This phenomenon was called time–space compression – «space-time compression» (Harvey, 2008). At the same time, HSR contributed to the balancing of spatial disproportions. It became a catalyst for the development of secondary cities, which, thanks to convenient connections, received investments and new opportunities. In China, for example, HSR stimulates the growth of medium-sized cities (Suzhou, Zhengzhou), and in France it is the formation of «*TGV-towns*» (Reims, Le Mans).

In the 21st century speed enters a new dialogue with the concept of sustainable development (SDGs 9, 11, 13). HSR is positioned as one of the most environmentally friendly modes of transport: energy consumption per passenger kilometer is half that of aviation, and $CO_2$ emissions are three times lower (International Energy Agency, 2019). Modern researches consider the railway as a key component of the «green transformation», combining speed, mass and energy efficiency. The ethical dimension of speed, it is also an issue of accessibility: speed must serve not only as a privilege of large cities, but as an instrument of social cohesion. Therefore, the latest programs of the EU and China provide for the creation of HSR networks that cover peripheral regions, ensuring a balance between economic efficiency and justice.

High-speed railway, it's not just transportation, it's the language of engineering, reflecting the spirit of the times. Its architecture – is stations with glass and steel; its rhythm – is continuity of movement; its meaning – is overcoming the distance between the center and the periphery. Speed technology is becoming a form of culture that combines engineering, economics, and time philosophy. Thus, the idea of speed, born from technical experiments of the 19th century, went through the path to the global cultural code of the 21st century. The high-speed railway became a mirror of technical evolution and at the same time a projection of the human desire to overcome space and time. Its history — is the history of engineering, state will and the culture of modernity, which together form the face of modern civilization.

**Conclusions.**

The history of the development of HSR, it is at the same time the history of engineering evolution, public policy and changing ideas about space and time. Over the course of two centuries, humanity has transformed the railway from a means of transportation into a system that shapes the economic, social and cultural dynamics of civilization.

From steam locomotives of the 19th century to the *Shinkansen, TGV* and *Fuxing* electric trains, the development of the HSR was driven by the continuous search for a balance between speed, safety and efficiency. The key engineering milestones were:

– application of jointless track and automatic control system (Japan, 1960s);
– aerodynamic design and high-voltage electrification (France, 1980s);
– digital signaling *ETCS* and *CTCS* (Europe, China, 2000s);
– emergence of magnetic levitation and vacuum transport systems (XXI century).

HSR proved that transport infrastructure could be a tool for economic growth and regional integration. In Japan, *Shinkansen* stimulated the development of the Tokaido metropolis; in France, *TGV* became a factor of decentralization; in China, HSR created a network of urban agglomerations generating up to 0.5% of GDP each year. The economic effect of HSR is seen in the reduction of transport costs, increased labor productivity, the development of tourism, as well as in changes in the spatial structure of the country by creating "knowledge corridors" and new urban centres.

Speed in railway transport has turned into a cultural symbol of modernity. HSR embodies society's desire to overcome the limitations of space, and its architecture, design and rhythm of movement became part of the visual culture of the industrial age. The phenomenon of "space-time compression has changed the perception of distance, thanks to which a person began to think about geography in minutes, not kilometers.

In the 21st century, high-speed transport is entering the phase of energy-intelligent mobility: combining electrification with renewable energy sources; application of artificial intelligence for traffic control and maintenance; implementation of contactless systems (*Maglev, Hyperloop*). These trends shape the «third mobility revolution», in which the main thing is not so much to increase speed as to optimize time, energy and space.

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## Історія появи, розвитку та вдосконалення швидкісних залізниць: Технічні, соціально-економічні та культурні аспекти

***Анотація.*** *У статті представлено комплексне історико-аналітичне дослідження становлення та еволюції високошвидкісного залізничного транспорту як однієї з ключових технологічних і соціокультурних трансформацій модерного суспільства. Метою статті є виявлення історичних закономірностей формування, технічної еволюції та соціально-культурного значення високошвидкісного залізничного транспорту у глобальному контексті. Автори прагнуть показати, як прагнення до швидкості стало не лише інженерним викликом, а й рушієм економічної, урбаністичної та цивілізаційної модернізації. Застосовано міждисциплінарний підхід, що поєднує історико-технічний, порівняльний та соціально-економічний аналіз. Таке поєднання виправдане самою природою високошвидкісних залізниць. Вони не є лише транспортною технологією, це явище, що поєднує матеріальну інженерію, державну політику, культуру швидкості й людське уявлення про простір і час. Саме тому логіка дослідження не зводиться до переліку технічних фактів, а прагне показати, як інженерна ідея поступово перетворювалась на соціальну реальність. Джерельну базу становлять рецензовані наукові публікації, технічні звіти залізничних компаній, документи міжнародних організацій та сучасні дослідження з історії транспорту й інженерії. Проаналізовано технічні витоки швидкісного руху від залізниць XIX століття до післявоєнних проєктів середини XX ст., зокрема японської системи Shinkansen, французької TGV та німецької ICE, а також подальше розгортання глобальної мережі високошвидкісного залізничного транспорту у Китаї, Європі та інших країнах. Стаття поєднує* *техніко-інженерний, соціально-економічний і культурно-цивілізаційний підходи. Показано, що високошвидкісна залізниця виступає не лише інфраструктурним, а й соціальним феноменом, який формує мобільність, урбанізацію, регіональну інтеграцію та екологічну стійкість. Окремо розглянуто новітні інновації XXI ст. – магнітну левітацію, системи Hyperloop та цифровізацію, що визначають перехід до епохи енергоінтелектуальної мобільності. Зроблено висновок, що історія високошвидкісного залізничного транспорту є відображенням загальної еволюції інженерної думки, державної політики та культури швидкості, яка трансформує уявлення людства про простір, час і сталий розвиток.*

***Ключові слова:*** *високошвидкісна залізниця (HSR); транспортна модернізація; мобільність; залізнична інженерія; інновації; сталий розвиток*

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