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A Review of China's High-Speed Trains versus the US and UK's

This comprehensive review paper explores the impacts of China's leading position in developing high-speed trains compared to the US and UK. The study uses multiple research papers to present insights into the development of high-speed trains across Japan, France, Germany, and China as a role model and to draw lessons for countries that follow. The main findings have suggested that government support contributed significantly to the development of these countries' high-speed train networks. But in contrast, politics in Britain and the United States were divided and inconsistent, making the development of this transport industry problematic, overdelays, and uneconomical.
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Introduction

One of the best travel modes of road transportation designed for efficiency, energy conservation, security, and comfort is high-speed trains (HST) because they reduce significant travel time and e-mission compared to traditional railway transport. Many nations have recognized the social and economic benefits of HST and have been implementing this transportation industry for decades. For instance, Japan was the first Country to build HST technology successfully in 1964 with the Shinkansen S-0 model, which had a high speed of 210 km/h in the commercial operation of the rail train networks. France followed in 1981 with the TGV-PSE model that operates at 280 km/h, and Germany introduced the ICE-1 at 250 km/h in 1991 (Zhou & Shen, 2011). Although China developed its HST network decades after these countries, the country made significant progress by launching its first CRH1 HST operated at 200 km/h in 2007. Within two decades, by 2023, China had constructed the world's largest HST network, with operational mileage reaching 42,000 kilometers, and it operates at speeds up to 380 km/h (Hu et al., 2023). Additionally, China has collaborated with Germany to develop high-speed Maglev Trains (HSMT), resulting in the fastest HSMT in the world, designed to travel at 430 km/h, which connects Shanghai Pudong International Airport with Longyang Road Station. In July 2021, China announced a 600 km/h HSMT project in Qingdao with independent intellectual property rights, which is currently undergoing high-speed trials (Huang et al., 2024) and expanding its influence to export HST technology across Asia, Europe, and Africa via the Belt and Road Initiative (BRI) (Xia et al., 2024).

While China is showing itself as the leader of developing HSTs, similar projects in the US and UK have stalled due to many different factors (The Economist, 2024; Benson, 2024). The objectives of this paper are twofold. First, to examine China's approach to HST development that would become a global leader and practice that other nations such as the US and UK, can adapt to their HST infrastructure planning. Second, to answer whether China can set a precedent for independent technological advancement in future HST projects and potentially reduce reliance on foreign partnerships. To answer these questions, the paper synthesizes the existing literature and the current state of the art. It begins by describing the economic impacts, costs, and the development of the HST network across the world (section two). The focus then shifts to analyzing why HST projects in the US and UK have failed to build (section three). Section fourth introduces

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the practices of HST development from Japan, France, Germany, and China before conclusions and recommendations are drawn.

Economic Impact of High-Speed Trains

According to a study from The Economist in 2017, the economic benefits of HSTs are hard to measure precisely because traditional analyses focus on the financial performance of HST lines, plus indirect results such as reduced road congestion. However, HSTs are more than just a mode of transport. China wants to build a "high-speed rail economy", its own twist on the theory of urban agglomeration: the bigger the city, the wealthier and more productive its people tend to be. The idea is to cap the size of megacities but achieve the agglomeration effect with the help of HSTs connecting the megacities with their neighbouring regions. China reckons that the resulting network of large, but not oversized, cities will be easier to manage. In China's three major population centers, the areas around Beijing in the north, Shanghai in the east, and Guangzhou in the south, life and work have started to follow the expansion of the HST network. Trains were previously too infrequent, slow, and crowded to allow daily commutes. Now, these three megacities are developing commuter corridors as housing in satellite towns and cities is significantly more affordable for city workers. The same study also suggested that in outer cities like Kunshan, average home prices are about 70% less than in nearby Shanghai. However, the HST between the two cities takes only 19 minutes and costs a mere 25 yuan ($3.60). Moreover, Kunshan is just one of many options for those seeking to escape Shanghai's high costs. About 75 million people live within an hour of the city by HST.

Not only does HST make travel faster and convenient, but a report published in 2014 from the World Bank said the benefits of HSTs could substantially boost the productivity of businesses in China's coastal regions by an estimated 10% (Ollivier, 2014). Driven by this ambition to develop a high-speed rail economy, China had established the world's largest HST network by 2022, with nearly 40,500 kilometers of HST lines. Spain and Japan followed, each with over 3,000 kilometers. China is also at the forefront of HST expansion. In addition to its existing network, more than 13,000 kilometers of new HST lines are under construction. Completing these projects will increase the Chinese HST network by approximately 32% (Table 1).

Table 1. Length of High-Speed Trains Worldwide in 2022 by Country (kilometer)
(1. In operation: currently operating on High Speed Lines, 2. Under construction: Under construction or upgrade to support High Speed Lines, 3. Planned: Approved and funded lines that haven’t begun construction yet, 4. Long-term planning: Planned High Speed Lines that have been announced, but funding has not been approved as of yet).

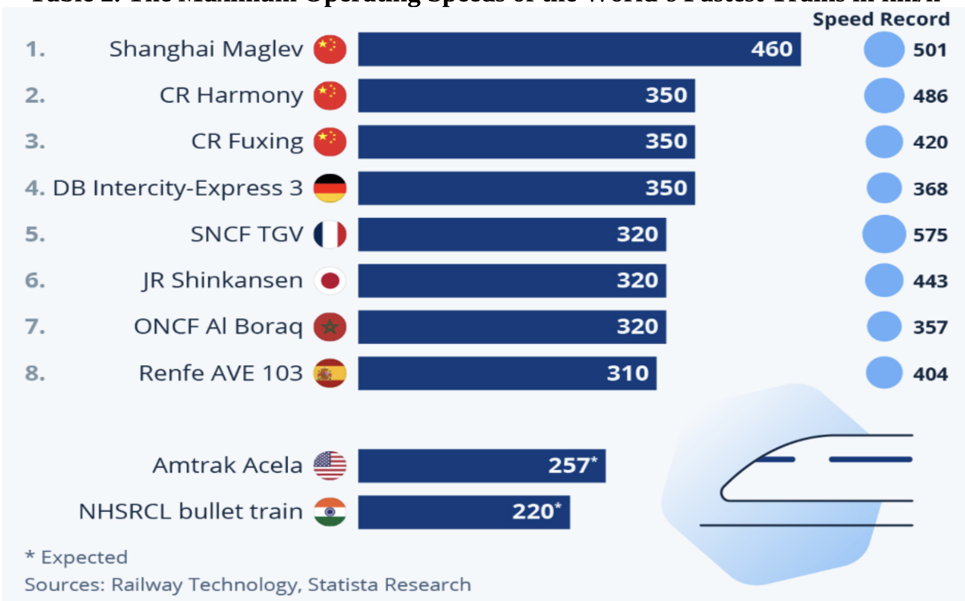
Country/Region	1. In operation	2. Under construction	3. Planned	4. Long-term planning	Total
CHINA	40,493	13,063	4,104	7,134	64,794
SPAIN	3,917	772	789	-	5,478
JAPAN	3,146	336	194	-	3,677
FRANCE	2,735	-	-	1,242	3,977
GERMANY	1,631	87	81	-	1,799
TURKEY	1,232	1,483	2,186	-	4,901
FINLAND	1,120	-	394	-	1,514
ITALY	921	327	-	-	1,248
KOREA	873	104	-	-	977
SWEDEN	860	54	208	1,082	2,204

USA	735	275	1,339	1,830	4,179
SAUDI ARABIA	449	-	-	-	449
AUSTRIA	254	281	71	-	606
POLAND	224	-	805	875	1,904

Source: International Union of railways, October 2023.

Data from Statista Research 2024 in Table 2 also shows China is a world leader in HST. While its regular long-distance trains reach maximum operating speeds of 350 km/h (217 mph), the world's fastest train currently is the Shanghai Maglev, which can operate at 460 km/h (286 mph) although, since 2021, it has operated at 300 km/h (186 mph) due to operational concerns. Germany, meanwhile, has matched China's regular high-speed rail prowess with its newest Intercity-Express 3. The ICE 3 and China Rail's Harmony and Fuxing trains beat the French TGV and Japanese Shinkansen, operating at 320 km/h (199 mph). This is the same speed that a lesser-known HST, Morocco's Al Boraq, is reaching in regular operation between Tangier and Kenitra on the Country's Northern coast (Statista Research, 2024).

Table 2. The Maximum Operating Speeds of the World's Fastest Trains in km/h



Source: Railway Technology, Statista Research

According to data compiled by Railway Technology in 2023, Spain's fastest train, Renfe's AVE 103, follows close behind with a maximum operating speed of 310 km/h (193 mph). For comparison, HSTs under construction and to be introduced in India and the United States won't reach these speeds. The US' new Acela trains entering service this year are expected to reach 257 km/h (160 mph), India is looking to construct trains with an operating speed of 220 km/h (137 mph).

For China's domestic economy, the current HST network accounts for 30% of total operating railways, or about 162,000 km of the national network. The percentage is expected to increase to 30% in 2024 from 20% last year. Despite international concerns about the network's debt and interest burden, China Railway reported a 2.7% increase in operating revenue in 2024 to 990.18 billion yuan, driven by both passenger and freight operations. The Country's railway system links 97% of Chinese cities with populations over 500,000. In 2024, it recorded 4.08 billion passenger trips, an increase of 10.8% yearly. The volume of cargo transported on the network in 2024 reached 3.99 billion tonnes, reflecting a 1.9% year-on-year increase and marking the eighth consecutive year of growth. While the operator did not disclose profit figures, it mentioned that profits reached a "record high" last year. By the end of 2024, its debt-to-asset ratio had declined to 63.8%, which is 1.7% points lower than the previous year. Looking ahead, China Railway has set ambitious goals for 2025, targeting a 2.6% rise in revenue to 1.016 trillion yuan, a 4.9% increase in passenger traffic to 4.28 billion trips, and a 1.1% rise in cargo shipments to reach 4.03 billion tonnes (SCMP, 2025).

The failure of building High-Speed Train projects in the US and UK

While China's HST technology has advanced considerably and a domestic industrial chain is emerging, Western countries, including the United States and parts of Europe, have faced budget overruns and delivery estimate challenges in expanding their HST networks. Constructing large projects like HST systems is inherently challenging, and neither the United States nor the United Kingdom is exempt from these difficulties. A study of 16,000 major projects, including large buildings, bridges, dams, power stations, rockets, railroads, information technology systems, and even the Olympic Games, uncovers significant issues in project management. Only 8.5% of these projects were completed on time and within budget, and just 0.5% were finished on schedule while delivering the expected benefits. In other words, 99.5% of large projects failed to meet their original promises (Flyvbjerg & Gardner, 2023).

For instance, the British government approved the HS2 project in Britain, intended to create a high-speed rail line connecting London and northern England capable of speeds up to 360 km/h, in 2012 with an estimated cost of £30.9 billion to £36 billion and a plan for operation by 2026 and full completion by 2033. The HS2 project underwent multiple delays and financial increases, leading to predicted expenditures reaching £110 billion. Operation of the HS2 project remains uncertain for 2041 despite starting delays in 2008. From financial excess to political debate, HS2 became a major dispute because different reevaluations by successive governments created conflicting viewpoints regarding the project. New governments have triggered project reassessments that created delays when assessing the advantages and disadvantages of continuing with HS2. Therefore, creating numerous unexpected technical obstacles because its execution requires extensive tunneling activities as well as bridge construction, along with land acquisition responsibilities. The project faced technical problems that needed extra resources for designs and plans with extended periods of resolution, which resulted in extra delays. Many British citizens continue to oppose HS2, questioning the stated benefits, including the shortened timeline and the economic growth opportunities that the project would bring. This strong opposition, now linked to the severe environmental consequences, funding costs and resource diversion, has prompted citizens to stage protests and campaign for policy changes that will affect both the decision and the timeline of the project (Benson, 2024).

On the other side of the Atlantic, in 2008, California voters approved a rail service from Los Angeles to San Francisco that would take only 150 minutes, which is well below the typical driving time. The service was planned to be built within 20 years, at a cost of $40 billion. However, construction ran into trouble from the start; the timeline was repeatedly lengthened, and costs ballooned. The project's total cost forecast rapidly escalated to a staggering $100 billion, with an estimated completion date of only partial completion at the time of 2033, five years past the original date (Flyvbjerg & Gardner, 2023). However, recent expectations indicate that even if funds are granted, it would take another decade to complete the middle section. Despite receiving $3 billion in funds from the Biden administration in December 2023, a recent report from the Legislative Analyst's Office (LAO), a non-partisan fiscal adviser to California's legislature, estimated that even after the federal grant, the funding shortfall for the rail line is a whopping $80 billion, more than double the state's annual transport budget and there is no credible plan for raising that money (The Economist, 2024). Some analysts believe that the most important reason why HST has not yet taken off in the United States is a lack of sustained political support and momentum. The division of power between federal, state, and local governments in the United States often leads to inconsistent funding and opposition from politicians concerned about costs and benefits. Evaluation of public benefits along with air and road traffic displacement increases the complexity of this situation. The US government has allocated its resources primarily to road and highway development, which has resulted in substantial growth of the national road network. The emphasis placed on road infrastructure consumes financial resources and public attention, which would otherwise benefit HSTs (Jones, 2022).

Lesson from existing practices

Globally, four models of HST establishment can be identified: The Japanese model, the French model, the German model, and the Chinese model. All four have achieved significant results in practice, but each has distinct features and differences on the operational level. The following paragraphs discuss the four models to determine the lessons China can adopt to influence global standards and practices in this arena.

The Japanese model

Japan's HST network, often considered the world's first, began with the launch of the Shinkansen or "bullet train" in 1964. It was initially built and owned by the state and then privatized for operation. However, the state still owns most of the infrastructure. The primary motivation was to tackle Japan's overcrowded conventional railways and stimulate economic growth. Japan's HST technology was primarily a result of domestic innovation and research. The Japanese HST technology was developed without assistance from any foreign nation. The Shinkansen was created by Japanese engineers combined with domestic companies such as Kawasaki Heavy Industries and Hitachi in an effort free from major international involvement. The achievement of Japan stems from its robust engineering capabilities, government backing, and culture of technological innovation. Post-Japan, South Korea was the primary beneficiary of Japanese HST technology. A significant deal was signed in 2005 for Japan to assist South Korea in developing its own HST system (Tamaki, 2023).

The French model

France's HST network started the development of Train à Grande Vitesse (TGV) in 1981, with the main purpose of minimizing travel time between key cities in order to strengthen economic development. At the beginning, the state financed most of the costs of the first TGV line (Paris – Lyon). In addition, Alstom, one of France's leading transport multinational companies, which is also a major player in HST building infrastructure, was primarily responsible for TGV's expansion. Alstom undertook a substantial portion of TGV's infrastructure and train components fabrication and design, which also included the assembly (Sato, 2005).

The rest of the HST technology in France contained ingenious engineering efforts, including the design of trains, dedicated tracks, and complex signaling systems, which could then be relied on for exporting. Notably, France managed to achieve success with this model in the international arena. France, for instance, made an agreement for their HST network development with Taiwan back in 1986. Spain became a major recipient of French HST technology after it contracted Alstom to develop the LGV Est. These aren't the only countries to benefit from France's HST technology. Morocco, Saudi Arabia, and the United Arab Emirates have established partnerships between their local state-owned enterprises and Alstom and SNCF. France's success in HST also motivated several other European countries to adopt these practices (Alstom, 2024).

The German model

Germany's HST network was launched in 1991 with the Intercity-Express (ICE). Similar to France, its primary purpose was to minimize travel time between key cities to strengthen economic development. The development of the ICE system was primarily the work of Siemens, which specializes in technology and electrical engineering. Siemens played a crucial role in facilitating the design, construction, and provisioning of the components of the infrastructure and trains of the ICE system (Zhau et al, 2020).
After Germany, numerous other countries adopted Germany's HST technology. One notable example is China in 2004, when China entered into a contract with Germany, acquiring aid for the construction of the HST system. The collaboration between Germany and China laid the initial foundations for the development of China's HST network, which has since become the largest in the world (Huang et al., 2024).

The Chinese model

Chinese leadership has adopted the traditional idiom "getting richer by building roads" to guide its infrastructure development through public financing and state loans (Jie, 2024). The leadership in China backs ongoing investment to support its goals of self-reliant technology development and economic power enhancement (The Economist, 2024). To build the world's most extensive HST network it achieved, China initially relied on technology imported from Europe and Japan and cooperated with global engineering firms like Bombardier, Alstom, and Mitsubishi to assemble the trains and train Chinese engineers. Expeditiously, Chinese engineers have developed extensive expertise, and Chinese domestic companies have emerged as global leaders in HST technology in the past decades. Nowadays, Chinese firms are pioneering innovations such as autonomous train operation, with the driverless "bullet trains" between Beijing and Zhangjiakou reaching 350 km/h speeds. In late 2020, Chinese state-owned firm CRRC, the largest global supplier of railway technology, unveiled a prototype for an HST capable of 400 km/h, equipped to operate in extreme temperatures and featuring gauge-changing technology for compatibility with wider tracks in Russia and Central Asia. This could facilitate direct train services from China to India and Pakistan through neighboring countries. The new 257-mile Laos-China Railway, set to enhance connectivity between southern China and Vientiane, reflects China's rail influence. Additional projects include a railway to Bangkok and beyond to Singapore. As CRRC shifts focus to international markets, rail infrastructure plays a crucial role in China's broader BRI, aiming to recreate a new Silk Road across Asia, Europe, and Africa (Jones, 2022).

Observation and recommendation

After conducting a comprehensive review, it appears that the common starting point of Japan, France, Germany, and China when building HSTs, is that for national governments to set out consistent policies and long-term investments that set clear goals and safeguard funding according to long-term plans, aimed at growing their economy, reducing travel time, connecting cities, and creating jobs. Japan, France, and Germany are the pioneers of HST technologies and have made the most of the intellectual resources from their nations' engineers and corporations. Subsequently, they took advantage of this success to promote the export of HST technology to other countries. Additionally, they also have a strong government behind them that funds HST projects.
Comparing China's HST development with other advanced HST countries reveals that, while all have achieved economies of scale and network effects, China's approach has been characterized by a more aggressive government role, larger-scale investments, and a greater emphasis on domestic innovation and indigenization (Jie, 2024). Furthermore, China's broad expansion of its HST network serves dual purposes of Chinese economic growth and societal requirements. As

stated in the literature review, the construction of HST infrastructure requires considerable spending, which generates economic activity by creating new jobs in the short term. In China's case, it has been one of the most powerful means to strengthen economic growth and stability. In addition, the construction and operation of these trains require maintenance and upgrades, which eternally generates demand (Zhao et al, 2020). In social aspects, HST responds to the problems of rapid urbanization and secondary cities' population agglomeration, as they become suburbs to megacities because of HSTs (Chen, 2012). These transport systems are more advanced compared to railroads and highways, saving considerable time when traveling from one city to another and making city-to-city movement more accessible. The system stimulates more business operations and tourism, thereby easing pressure on present-day transportation systems. The alternative mode of transportation represented by HST promotes environmental sustainability like air travel and private vehicles, thereby supporting Chinese aims to reduce carbon emissions (Zhang et al, 2023). In the view of this author, China has adopted foreign HST technology to jumpstart its development of its sovereign technology, but since then, it has made significant sovereign domestic innovations to leapfrog its former partners and current competitors. To strengthen its leadership in HST technology and reduce its current reliance on foreign technology, China should continue investing in R&D and human capital formation, encourage tech transfer from universities, research institutions, private sector involvement, and international collaborations, and implement policies that promote the diffusion of knowledge and technology spillovers. A favorable regulatory environment that supports domestic innovation and indigenization is also crucial. There is no denying that China has been investing heavily in this area, from the school level to research institutes and government investment. This has been demonstrated through the Made in China Initiative, which aims to not rely on developed countries in the West but instead to be self-sustaining (Wübbeke et al, 2016). Therefore, if China follows the business-as-usual scenario, with no changes in technology, economics, or policies, China could expect to maintain its current trajectory of technological advancement and market expansion. Under the Technological Leapfrog scenario, when China achieves significant breakthroughs in HST technology, it has the potential to set global standards and dominate the market. However, under a Policy Shift scenario, which is least likely to happen, if China adopts more protectionist policies such as restrictions or limits international trade, its global influence might be limited.

For the US: the history of HST development in the US demonstrates elements of public choice by examining how special interest groups affect governmental policy decisions, as seen in the case of the HST project in California, voted on by its residents. This public choice and lack of political momentum and support explain why extensive HST development in the US has not matched the levels seen in China, Japan or Europe. Moreover, the US infrastructure investment model promotes decentralization with important responsibilities assigned to state and local governments. Decentralization creates advantages but also results in funding and planning inconsistencies. The federal government cannot unilaterally order states to invest, so HST projects are often broken up or canceled, which makes the HST project implementation more difficult (The New York Times, 2025). Additionally, Americans rely on road and air travel; they demonstrate limited knowledge and travel experience with HST (CNN, 2023), which prevents them from understanding the benefits of HST compared to traditional roads and air travel. Therefore, the US government would need to dedicate substantial investment to public education campaigns that explain why alternative travel modes are essential and what advantages they provide. In addition, the US should also consider the Public-Private Partnership option for HST projects. This is a popular form that helps reduce pressure on the state budget, while also creating incentives for private businesses (Li et al, 2003).

For the UK: the HS2 network linking London with Birmingham, Manchester, and Leeds serves as an example for its delays and cost overruns are undeniable, despite many of the expectations, intentions and goals set out from the beginning, such as helping foster economy growth, generate employment opportunities in its construction phase, help develop the regions served by the project, and add to productivity by shortening inter-city travel time. Still, criticism of the additional expenses and delays is a problem in estimating the cost and benefit of HS2 (Benson, 2024). This is most troublesome because it puts the expectation that the benefits will outnumber the costs into question. In addition, an infrastructure project that consistently overruns its costs tends to limit funding available for other projects, resulting in lowered public trust in the ability of the government actually to improve its rail system. The suggested solutions are fourfold to resolve this problem. First, the UK government needs to provide investment capital or direct subsidies similar to China's state funding for the China Railway company in the early stages. Second, the UK may consider creating favorable conditions for private enterprises and guaranteeing bank loans for railway enterprises. If the project fails, the government must commit to paying a part of the debt, such as bank loans. Of course, if the policy is not attractive enough, it will also make investors wary because the private sector is reluctant to invest; after all, the capital recovery period is very long and difficult to calculate. Third, this is a factor based on option two, which is to reduce turnover tax for enterprises participating in HST development or support, and provide Minimum Revenue Guarantees for enterprises implementing HST. Finally, the UK should learn from China’s centralized political structure, promoting simplification of regulations and legal frameworks governing large infrastructure projects. This would reduce red tape and other bureaucratic hurdles. The UK could also develop strategic risk mitigation strategies by learning from China’s counter-risk management policies (Tang et al, 2007), which emphasize financial risk acceptance and rapid technological uptake, and set local standards to control safety and social risk, and then provide proactive solutions early in the disruption process to reduce cost overruns.

Conclusion

In conclusion, the development and export of HST technology have greatly benefited the economies of Japan, France, Germany, and especially China. The common HST model of these countries is inspired by strong government backing and a focus on domestic innovation to stimulate economic growth and counter unemployment. China is a country that adopted HST only in the past two decades but has surpassed its competitors to become a world leader in this field. To sustain its position of leadership in HST development, China should continue to invest, even if modestly, in research, technological transfer, and a friendly regulatory environment. In the US, the problem lies with the intersection of government blocking HST development, notwithstanding the favour for government investment in road and air travel. However, if the decision to build HST is voted by the public, the US would need to allocate consistent funds, policy between states and opposition governments, and alternatively promote Public-Private Partnership. In the UK, to address the concerns surrounding HS2's overrun costs and delays, the UK should simplify its regulatory processes for major infrastructure projects. Lastly, more relevant empirical studies about HS2 and the US’s California railway project are highly encouraged, as they will be needed and will assist in understanding the real impacts better.

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