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MASTER'S THESIS

**Analysis of the composition and condition of the Chinese railway
transport**

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Introduction

The research on the technological progress and construction progress of China's railway transportation is the basis of the research on the history of China's railway transportation. The perspective of technological history and construction history is the most basic meaning of the research on the history of China's railway transportation. The perspective of economic history is necessary for the research institute of the history of China's railway transportation.[1] China will gradually optimize and improve the layout of its road network, with advanced and applicable equipment, sustained and stable transport safety, modern and scientific operation management, improved innovation capacity, improved transport capacity and service quality, and significantly increased market competitiveness and international influence to meet the needs of completing the building of a moderately prosperous society in all respects.

Railway transportation is the product of the modern world economic development to a certain stage. The presence of the railway transportation and extension is beneficial to the formation of the regional division of the world economy, further promoting the development of world economy and speeding up the process of economic globalization. To explore technological progress and the construction progress of China's railway transportation is the basis of the study of the history of railway transportation in China. Technology history and construction history are the most basic meaning of the history of railway transportation in China. [2]The perspective of economic history is necessary for the research institute of the history

of railway transportation in China. This paper mainly aims at the types and historical development of China's railway transportation, and studies the future development of China's railway transportation as well as its role and influence in international trade.

1. Types of railways rolling stock and their technical and economic characteristics

1.1 Types of railway vehicles

Railway rolling stock can be divided into three categories according to their use: railway passenger car, railway wagon and special purpose vehicle.

Railway passenger and freight carriages can be divided into three categories: general buses, EMU passenger and freight carriages and high-speed EMU passenger and freight carriages.

Passenger transport vehicles are divided into several types as follows.[3][4]

— General buses: hard seat (YZ), soft seat (RZ), hard sleeper (YW) and soft sleeper (RW).

— EMU coaches: EMU trains (D), high-speed EMU trains (G) and Harmony EMU trains (C).

— Maglev Train (C).

Passenger service vehicles are divided into dining car (CA) and luggage car (XL).

— Goods vehicles can be divided into general goods vehicles and special goods vehicles.

— General purpose truck: open car (C), shed car (P) and flat car (N).

— Special truck: tank car (G), refrigerated car (B), ore car (K), cement car (U), live fish car (H), special car (T) and large cargo (D).

— Special purpose vehicle: postal vehicle (UZ), business vehicle (GW), health vehicle (WS), medical vehicle (YI), experimental vehicle (SY), maintenance vehicle

(EX) and education vehicle (WJ).

1.2 Technical characteristics

1. General buses and goods vehicles

The construction and maintenance cost are low; the investment is small; the capital risk is controllable. Low overall requirements on the railway system is suitable for construction in difficult areas. The speed of the train is slow and the energy consumption is relatively low. The average speed of the short-distance train is even worse than that of the car. [5]

The general speed train has less intelligent equipment, low level of railway system as well as low resistance to various safety risks, and the accident frequency is more than that of high-speed train. The construction of the railway center of gravity on the load is suitable for heavy freight lines. Not completely dependent on electric locomotives and power supply equipment, the railway center of gravity on the load can only use diesel locomotive.

The technology maturity and reliability is much higher than that of high-speed rail. It provides strong service to local county town passenger source. [6] The technology readiness level (TRL) approach, following planning experience in the PERT and CPM methods, gives the project director and project managers an opportunity to plan the development of a particular technology and take specific decisions regarding projects. [7] At the same speed and load, railway transportation is more energy efficient and environmentally friendly than road transportation, and has strong

continuity. These are the advantages that cannot be replaced by high-grade highways.

2. EMU passenger and freight carriages

The advantages of EMU buses, namely high-speed trains, include high speed, fuel economy, safety and reliability, and excellent service. So, from the very beginning, high-speed trains have shown great superiority. Compared with ordinary trains, the performance of high-speed trains is greatly improved.

Air resistance is the most important factor affecting the operation of high-speed trains. Therefore, high-speed train locomotives generally adopt streamlined headway shape (such as TGV: French high-speed electric locomotive), with smooth outer surface and glass windows flush with the outside to achieve the optimal aerodynamic pattern.

At high speed, make sure that the train has enough acceleration force. However, the adhesion coefficient decreases at high speed, so it is necessary to increase the axle load (power concentration) or the number of shafts (power dispersion).[8] Although the former cost is low, excessive axle load will increase the damage to the line.

Therefore, various countries adopt different degrees of power dispersion. For French bullet trains, the power is scattered. Mixed-current motor with smaller power is adopted. [9] The power of Series 0 is 185 kilowatts per shaft, and that of Series 100 is 230 kilowatts per shaft. TGV, ICE (ICE in Germany) is a way between the centralized and decentralized, each way setting 2 cars. TGV uses a high-power AC synchronous motor, with each shaft power charging 1.1 kilowatts. ICE uses an AC induction motor.

In order to achieve large deceleration, high-speed trains in various countries not only brake all moving axles, but also have brake devices installed on the slave axles. For example, Shinkansen trains are equipped with electric braking and disc braking system for all axles. [10] The TGV adopts electric braking combined with wheel tread braking on the moving shaft, while the slave shaft is only operated in disc shape. ICE adopts the combination of electric braking and disc braking on the shaft, and eddy current rail braking and electric braking on the slave shaft.

The sleeping berths of new type EMU train with sleeping cars are a longitudinal arrangement with two layers. [11] The interior and exterior photos of a sleeping car are shown as Figure 1. With this kind of train, a car can accommodate up to 60 berths, while a train can carry 880 passengers. So its transport capacity is higher than that of the first-class berth of an ordinary passenger train. Furthermore, the travel time and the ticket price of EMU train with sleeping cars are highly competitive too. The comparison among different kinds of passenger trains is shown in Figure 2. (a) Interior photos (b) Exterior photos Figure 1. Interior and exterior photos of a sleeping car.

Distance (km)	EMU train with sleeping cars	EMU train with speed of 300km/h	Ordinary passenger train
0	5	5	5
500	10	10	15
1000	15	15	25
1500	20	20	
2000	25	25	
2500			

(a) Comparison of travel time

Distance (km)	EMU train with sleeping cars Business seat	EMU train with speed of 300km/h First class seat	EMU train with speed of 300km/h Second class seat	EMU train with speed of 250km/h First class seat	EMU train with speed of 250km/h Second class seat	First class berth of ordinary passenger train	Second class berth of ordinary
500	3000	3500					
1000							
1500							
2000							
2500							

passenger train (b) Comparison of ticket price Figure 2. [11] [12]

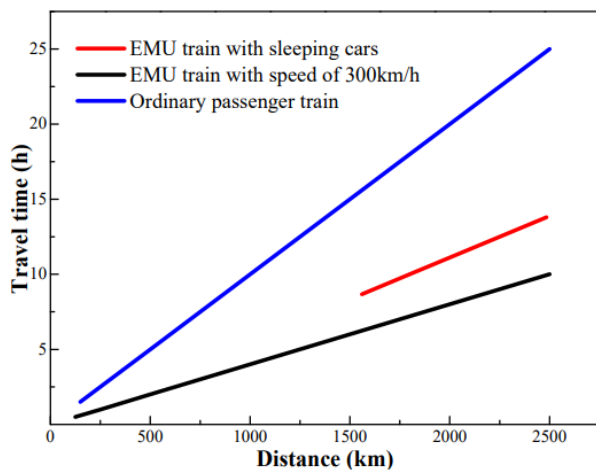


(1) Interior photos

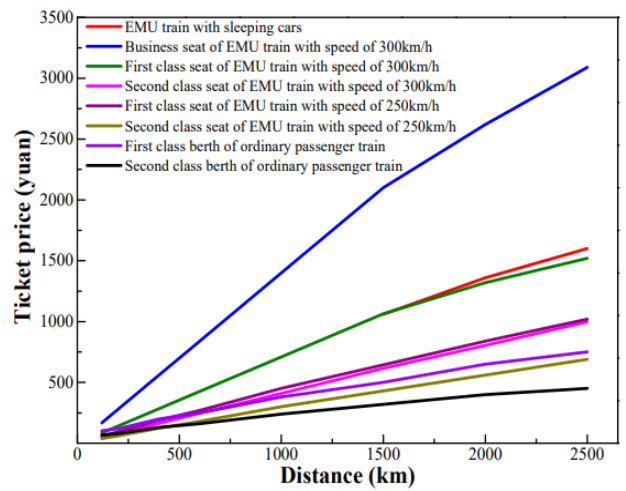


(2) Exterior photos

Figure 1. Interior and exterior photos of a sleeping car



(3) Comparison of travel time



(4) Comparison of ticket price

Figure2. Comparison among different kinds of trains

3. Maglev train

Maglev train (as shown in Figure 3) is mainly composed of three technical systems: suspension technology system, propulsion technology system and steering technology system. [12] Although propulsion system unrelated to magnetic force can be used, in most designs, the functions of these three parts are completed by magnetic force.

(1) Suspension technology system

The design of the suspension technology system can be divided into two directions, which are the normal type adopted by Germany and the superconducting type adopted by Japan. The suspension technology is developed into the electromagnetic levitation system (EMS) and electric levitation system (EDS).

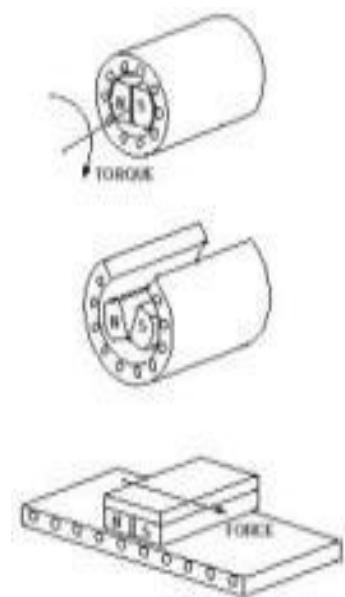


Figure 3. Maglev train

(a) EMS is a kind of suction suspension system, which is combined with the electromagnet on the locomotive and the ferromagnetic track on the guide rail to repel each other and produce suspension.

When the normal magnetic levitation train works, the electromagnetic repulsive force of the suspension and guide electromagnet under the vehicle is firstly adjusted, and the windings on both sides of the ground track react with the magnets to float the train.

Under the reaction of the guidance electromagnet and the track magnet at the lower part of the vehicle, the wheel and the track keep a certain lateral distance, so as to realize the non-contact support and non-contact guidance of the wheel and rail in the horizontal direction and vertical direction. [13]

The suspension gap between the vehicle and the running track is 10mm, which is guaranteed by a high precision electronic adjustment system. In addition, because levitation and steering are actually independent of the speed of the train, the train can still enter the levitation state even when it is stopped.

(b) (EDS) magnets are used on moving locomotives to generate an electric current in the rails. [14] As the gap between the locomotive and the guide rail decreases, the electromagnetic repulsion increases, which provides stable support and guidance for the locomotive.

However, a wheel-like device must be fitted to support the vehicle during “takeoff” and “landing,” since EDS cannot be suspended at speeds below about 55km/h. EDS system has been further developed under the technology of low

temperature superconductivity. [12][13] [14]

(c) The main characteristic of superconducting maglev train is the complete conductivity and diamagnetism of its superconducting elements at a relatively low temperature.

Superconducting magnets are composed of superconducting coils made of superconducting materials, which not only have zero resistance to current, but also can conduct powerful current that ordinary wires cannot compare at all. [15] This characteristic makes it possible to make electromagnets with small volume and strong power.

(d) Superconducting maglev vehicle superconducting magnet is mounted on the vehicle and induction power integration equipment, and train driving winding and suspension winding are installed in the ground on both sides of guide rail. Induction power integrates device on a vehicle by power integrated winding, induction power integrated superconducting magnet and superconducting magnet levitation guide of three parts.

When a three-phase alternating current is supplied to the driving windings on either side of the track at the speed and frequency of the vehicle, a moving electromagnetic field is generated, resulting in a magnetic wave on the rail.

At this time, the on-board superconducting magnets on the train receive a push synchronized with the moving magnetic field. [16] It is this push that pushes the train forward. Just like surfing, the surfer stands at the top of the wave and is propelled by the wave. Like surfers, superconducting maglev trains deal with the exact problem of navigating the pinnacle of a moving electromagnetic wave.

Therefore, a high-precision instrument is installed on the ground guide rail to detect the position of the vehicle, according to the information from the detector to adjust the three-phase alternating current supply mode, and accurately control the electromagnetic wave shape so that the train can run well.

(2). Propulsion technology system

Maglev train is driven by the principle of synchronous linear motor. The lower part of the vehicle supports the coil of the electromagnet, which acts like the excitation coil of a synchronous linear motor.

The three-phase moving magnetic field inside the ground track drives the winding to act as an armature, which acts like the long stator winding of the synchronous linear motor. It can be known from the working principle of the motor that when the armature coil as the stator has electricity, the rotor of the motor is driven to rotate by electromagnetic induction.

Similarly, when the substations arranged along the line provide three-phase FM/AM power to the drive winding inside the track, the load bearing system, together with the train, is pushed to move in a straight line as the “rotor” of the motor due to electromagnetic induction. Thus, in the suspension state, the train can fully realize non-contact traction and braking.

(3). Guidance technology system

The steering system is a lateral force that keeps the suspended locomotive moving in the direction of the guide rail. The necessary thrust, similar to the levitation force, can also be divided into gravitational and repulsive forces. The same electromagnet on the bottom plate of the locomotive can be used to power both the steering system

and the suspension system, or a separate steering system electromagnet can be used.

1.3 Economic characteristics

The railways require huge investments for purchase of land, laying of tracks, constructing railway stations and sheds, buying automobiles, etc. No single individual can afford to make all these investments. The economic characteristics of general speed trains and high speed train are as follows.

1. General buses and trucks

Advantages:

(a) Cost: A general speed train has a simple structure, mature technology and low requirements on railway system, so the cost of it is much lower than that of high speed train, which is suitable for construction in mountainous areas.

(b) Freight: Due to its slow speed, low energy consumption and easy maintenance, the operation cost and ticket price of a general speed train are much lower than those of high-speed trains.

(c) Stations: Due to the low speed of general speed trains and the low spacing requirement of stations, low-speed EMU trains can set up a large number of stations with high density along the railway to serve passengers in a wide range of areas. In addition, as most of the general railway lines are close to urban areas, it is sometimes faster and more convenient to take a general speed train than a high speed train.

(d) Loading capacity: The speed requirement of general speed trains is not high. High-power general speed locomotives can focus on improving torque and increasing

tension in the optimization design of transmission gear ratio. Therefore, general speed trains are suitable for large cargo transportation, and also for passenger trains with full passengers standing.

(e) Marshalling: A general speed trains generally adopt the traditional mode of a single locomotive pulling several trailers, so its marshalling is flexible, while a high-speed train usually adopt fixed marshalling.

Disadvantages:

(a) Speed: General speed trains are slow and inefficient in transportation. The average speed of short and medium distance trains is even lower than that of cars, which cannot fundamentally solve the Spring Festival transportation problem.

(b) Safety: A general speed train has less intelligent equipment, low level of railway system, and low resistance to various safety risks, and its accident frequency is higher than that of high-speed train.

(c) Tired: A common speed train has a simple body structure and simple internal facilities. Generally, it runs on slotted rails with small turning radius and is not as comfortable as a high speed train.

(d) Environment: Due to the cheap ticket prices and many stops of general express trains, it is inevitable that there will be low-quality passengers, so the overall health and public security environment of trains is not as good as that of EMU trains.

(e) Benefit: In the era of rapid development of material and spiritual civilization, general speed trains cannot generate sufficient and matching economic, scientific and technological, political and cultural benefits.

2. EMU buses

(1). Promoting the transformation from “urban development” to “industrial development”

The advantages of high-speed rail can let enterprise itself form a stronger industry consolidation requirement, so as to reduce the strength of local government management lead to the difficulty of industry consolidation coefficient. An inter-bank administrative areas and offshoring in the population also reduce the demand for urban development of local government, and the local government can make efforts on industry development. [17] As long as the government can timely provide corresponding policies to effectively avoid the emergence of “siphon effect,” high-speed rail network will certainly bring unprecedented development opportunities to the regional economy.

(2) Promoting industrial upgrading and transformation of regional economy

The opening of the high-speed rail quickly shortens the distance between two cities, which would lead to a large number of enterprises to reduce costs by keeping headquarters and R&D centers in the core city to form strong talent advantage and development advantage, and at the same time moving the production department to the city, along the service and manufacturing cluster formation, so as to drive the city’s economic development, regional economic industrial upgrading and transformation. [17]

(3) Promoting the industrial pattern reform of regional economy

Gao Tie netting constitutes the high-speed rail industry chain, including raw materials, spare parts, construction, machinery, supporting facilities, operations and logistics, as well as the follow-up service and so on of seven big links, which are associated with high iron industry of listed companies of more than 180, as well as the core enterprises of more than 62.[16][17] The industry is extremely complex, and many industries can get opportunities for development.

In addition to leading the development of various high-speed railway industries, the era of high-speed railway will inevitably promote the development of real estate, tourism, commerce, logistics, finance, entertainment and other related industries, and accelerate the transformation of industrial pattern of regional economy.

Of course, there are certain industries that are prone to decline because of the leapfrog development of high-speed rail, such as aviation. On the whole, however, high-speed rail can effectively narrow the economic gap between regions and bring the dawn of development to all relevant enterprises.

3. Maglev trains

High-speed maglev trains will meet the point-to-point transportation needs of China's big cities and have strategic significance in technology-driven and international competition. High-speed maglev trains will bring people more comfortable life and enjoyment, and high-speed and sustainable economic development.

A prototype of China's high-speed maglev test vehicle rolled off the production line in Qingdao, east China's Shandong Province, May 23rd, 2019. This marks a

major breakthrough in China's high-speed maglev technology. High-speed maglev trains can fill the travel speed gap between aviation and high-speed railway passenger transport, which has great technical and economic significance for improving the three-dimensional high-speed passenger transport network in China. On January 13th, 2021, the world's first high-temperature superconducting high-speed maglev engineering prototype vehicle and test line was independently developed, designed and manufactured by China. The production line was rolled off and put into operation in Chengdu on the 13th, with an expected operating speed of more than 600km/h.

The reasons why maglev technology has not taken off globally include the high cost of construction and operation and the difficulty of integrating it with existing transportation systems. However, in China, the necessity of high-speed maglev is reflected in point-to-point transportation, technological drive and strategic significance in the face of international high-speed traffic competition.

“Although China's railway network has a large scale of systems in operation and construction, its geographical breadth, large population, and the density of central and eastern cities make there a huge demand for point-to-point high-speed passenger transport with large capacity, such as from Beijing to Shanghai or Chengdu to Chongqing.” [18] Maglev technology is a point-to-point, high-capacity transportation technology that can be used as a useful complement to the existing high-speed and intercity railway network.

In terms of technological drive, magnetic levitation technology involves a variety of basic materials such as rare earth materials, permanent magnet materials and composite materials. The research and development of suspension technology is

helpful to promote the development of basic industry in China

2. Railway of China: past, present, future

2.1 Past railway of China

Railway construction in China began in the late Qing Dynasty. After the Qing government was defeated in the Sino-Japanese War of 1894–1895, the Eight-Power Allied Forces seized China's railway rights. During the railway building period of the Qing government (1876–1911), about 9,400 km of railways were built in China. Among them, imperialist direct construction and management accounted for about 41%; about 39% of imperialists were controlled by loans. China's state-owned railways, including the self-built Beijing-Zhangjiakou Railway and the Commercial Railway, and the redeemed Beijing-Han and Guangzhou-3 railways, accounted for only about 20% of the total.

After entering the Republic of China, the situation of China's railway remained unchanged under the circumstances of the decline of the country and the poverty of the people and successive wars. [19] During the period of railway construction by the Kuomintang government in Nanjing (1928–1948), about 13,000 km of railways were built on the Chinese mainland. By 1949, China counted 4,069 locomotives, each from more than 30 factories in nine countries, with as many as 198 locomotive models.

On October 1st, 1949, after the founding of the People's Republic of China, 8,278 km of railways were repaired and restored. By the end of 1949, the total length of China's railways in operation had reached 21,810 km, with passenger and cargo

turnover of 31.441 billion ton-km. On June 18th, 1952, the first direct train between Manzhou and Guangzhou opened, covering a total distance of more than 4,600 km without obstruction. By the end of 1952, the length of China's railways in operation had increased to 22,876 km, and the conversion turnover of passenger and cargo had reached 80.224 billion ton-km.

After 1949, the rights to the railway were officially brought into state ownership and the Railway Ministry was founded to take charge. The railway construction developed according to the well scheduled plans and programming. The main lines were restored and connected and the construction work was done massively.

From 1876 to the end of 1948, there were about 14,602 miles (23,500 kilometers) of existing railways, but nearly half of them had been destroyed or damaged during the years of hostilities. Only 6,835 miles (11000 kilometers) were still in operation. Therefore, the first task for Chinese railway career was to restore the main lines and standardize their operation. By the end of 1949, Jinghan, Longhai, Zhegan, Nantongpu and Xianggui Railways were recovered, and nearly 5,143 miles (8,278 km) was open to traffic again.[20]

On July 1st, 1952, the Chengdu-Chongqing Railway, the first railway in New China, was successfully opened to traffic. In 1953, China started the first five-year development plan, and the enlargement of the railway network and production of trains, specifically steam trains were given priority. In June of 1953, Chengyu Railway (Chengdu – Chongqing) was completed and put into use, and was the first railway built since the founding of new China. After that, Tiancheng, Tianlan, Lanxin railways were accomplished one after another.

By end of 1957, the newly constructed rail lines amounted to 3,790 miles (6,100 kilometers) as part of the plan, which strengthened the links between China's interior and its east coast. It also consolidated communication with neighboring countries, such as Vietnam and Mongolia.

However, in 1958, the railway construction work was affected again and the railway operating order was disturbed gravely as a consequence of trying to achieve too much too soon. Sadly, this also resulted in an increased number of rail accidents. The major focus on coal and mineral freight disadvantaged the transportation of crops and light industrial products which had detrimental effects on the economy.

From 1961 to 1965, these problems were overcome, and the railway regained stable improvement and rectification. [21] In 1961, Baofeng (Baoji - Fengzhou) section of Baocheng Railway (Baoji -- Chengdu) was finished as the first electrified railway.

However, China railway suffered another disaster during the decade from 1966 to 1976. Several of the most important rail terminals were blocked, and the transport and freight suspended for a while. In 1968, the whole undertaking hit rock bottom.

From 1978, large resources were put into modernization of the network, and the disproportion in the railway development was readjusted. After long-term restoration and recovery, the development of the rail system maintained a good momentum. After the Third Plenary Session in 1978, the railway electrification process was accelerated greatly. Xiangyu, Shitai, Baolan and Chengyu lines were gradually

electrified. In just 24 years or so, China had constructed 41 electrified rail lines, with a total length of (11,567 miles) 18,615 km.

In September 1982, the Chinese government pointed out that “railway transportation has become an important factor restricting the development of the national economy,” and put forward the railway artery construction strategy of “fighting against Daqin in the north, attacking Hengguang in the south, and capturing East China in the middle.” [22]

In 2003, China’s railway operating mileage reached 91,000 km, and the total scale of the high-speed passenger transport network was proposed to reach more than 20,000 km.

On January 7th, 2004, the Chinese government has been clear about the Chinese railway network construction of medium and long-term goal: by 2020, the national railway mileage reached 100,000 km, the main busy trunk passenger line, FuXianLv and electrification rate reached 50% transport capacity to meet the national economic and social development needs, the main technical equipment at or near the international advanced level.

On January 12th, 2005, the large-scale construction of China’s railways began, with a total investment of more than 500 billion yuan.

On April 18th, 2007, China’s sixth railway speed increase was officially launched. CRH1, CRH2 and CRH5 bullet trains were put into operation on a large scale, with the train running at a speed of 200 km/h. Some sections of the Beijing-Harbin, Beijing-Guangzhou, Beijing-Shanghai and Jiaoji lines reached speeds of 250 km/h, ushering in the era of high-speed railway in China. In terms of freight, heavy-haul

freight trains with a capacity of 5,000 tons and a speed of 120 km/h will be run on the existing speed-enhanced trunk lines. Through the speed increase, China's railway passenger and cargo transport capacity has increased by 18% and 12% respectively.

During 2008 to present, China's railway capacity is persistently overtaken by demand. To meet the increasing demand, the authorities first increased the speed of trains to transport more passengers; then, high speed railways dedicated to high-speed trains were constructed.

Here are six speedups to support for operation of high-speed trains.[23]

(1)1997: The fast trains and overnight trains leaving in the evening and arriving in the morning were put into operation for the first time. The average speed of passenger trains was raised to 65 km/h (40.3 mph) from the previous 48 km/h (29.9 mph) of early 1993.

(2)1998: The top speed of fast trains was raised to 160 km/h (99 mph).

(3)2000: The faster railway network reached about 10,000km (6,200 mi).

(4) 2001: An additional 3,000km (1,850 mi) of railway were sped up.

(5)2004: Another 3,500 km (2,200 mi) of railway were sped up.

(6)2007: Intercity high-speed trains started to run along improved rail tracks. Their top speed reached 250 km/h (155 mph).

Although the speed had been greatly raised and numerous fast trains had been put into service, the rail capacity still could not meet the demand. To deal with this, the

plan of constructing a high speed railway network came into being, and the six nationwide China train speedups provided sound a technological foundation for the construction of high speed railways and operation of high speed trains. (See Figure 4)



Figure 4. High speed trains of China in 2008

On February 26th, 2008, the Ministry of Science and Technology of China and the Ministry of Railways signed the Cooperation Agreement on the Joint Action Plan for Independent Innovation of China's High-Speed Train. This will vigorously promote the development of Chinese standard EMUs. [24]Beijing-Tianjin intercity railway, China's first high-speed railway with independent intellectual property rights and international first-class level, was officially opened to traffic on August 1st.

On December 9th, 2009, the trial operation of Wuhan-Guangzhou high-speed railway was successful, and it was officially put into operation on December 26th. The highest operating speed is 394 miles per hour, and it takes 3 hours to travel from Wuhan to Guangzhou. The travel time between Wuhan and Guangzhou has been shortened from about 11 hours to about 3 hours. It only takes 1 hour for Wuhan to

Changsha and 2 hours for Changsha to Guangzhou. The Wuhan-Guangzhou high-speed railway has become the fastest and densest high-speed railway in the world. It is also China's first high-speed rail line running at 350 km/h. Since then, as the Qing-Shen passenger, the Beijing-Tianjin inter-city railway and passenger dedicated line, Wuhan-Guangzhou passenger dedicated line, Zheng west passenger railway, Hu-Ning inter-city railway and Shanghai-Hangzhou inter-city railway, a large number of at speeds of up to 200,250,300,350 km/h emu has been running, marks the level of China's railway existing railway-speed-increasing has firmly established itself as one of the worlds advanced levels.

On November 8th, 2012, the Chinese government pointed out the direction for the transformation of China's railway construction from "Made in China" to "Created in China." On December 1st, 2012, Harbin-Dalian high-speed railway, the world's first high-speed railway line located in the alpine region, was officially opened to traffic. The 921 km Harbin-Dalian high-speed railway connects the major cities of the three northeastern provinces and travels from Harbin to Dalian in just 4 hours and 40 minutes in winter. [22] [24]The "Chinese speed" of 200 km/h in winter in alpine regions has attracted the attention of the whole world.

At 6:31 on April 2nd, 2014, a 3,971 meter test train with a total length of 320 units and a full load of 30,000 tons of coal, pulled by 4 electric locomotives, started from Yuanshulin Station of North TongPu Line and reached Liucun South Station of Daqin Line safely and successfully at 18:56 on the same day after a journey of 738.4 km and 12 hours and 25 minutes. The 30,000-ton heavy-haul train operation test has been a complete success, achieving a jump in the traction weight of China's

heavy-haul railway trains from 20,000 tons to 30,000 tons, making China one of the few countries in the world that has mastered the 30,000-ton heavy-haul railway technology.[25]

China CNR CRH5A EMU trains loaded with the “China Creation” traction electric transmission system and network control system enter the final stage of the “5,000-km main line test” on November 25th, 2014. This is the first high-speed EMU in China to achieve full independent innovation of traction electric transmission system and network control system, which marks the transformation of China’s high-speed train core technology from “home-made” to “independent.”[22][25]

According to statistics, by December 2015, China’s total railway mileage had reached 121,000 km, ranking first in Asia and second in the world. Of these, 19,000 km are high-speed railways, ranking first in the world, and 53.5% and 61.8% of China’s railways are electrified. A high-speed railway network with high-speed railways as the backbone will be basically completed, with a total scale of more than 40,000 km.

Statistics from China’s Ministry of Transport show that by the end of 2018, China’s railway mileage in operation reached 131,000 km, with a railway network density of 136.0 km/10,000 km². During the year, 3.375 billion passengers were carried, of which 2.005 billion were carried by bullet trains. China’s railways transported 4.026 billion tons of cargo and handled 2.882.055 billion ton-km of cargo. A total of 802.8 billion yuan was invested in railway fixed assets.[25]

“Go global” strategy shows the world “China’s business card.”

In 2009, the Chinese government formally put forward the “going out” strategy of

high-speed rail, and initially set three strategic directions: Eurasia high-speed rail through Russia to Europe; the Central Line from Urumqi through Central Asia to Germany; and the Pan-Asian rail network that runs from Kunming to Southeast Asian countries all the way to Singapore.[26]

Then there is the China-Europe freight train, which has become a global sensation. The first China-Europe freight train (Chongqing-Duisburg) was successfully launched on March 19th, 2011. Starting from Tuanjie Village Station in Chongqing, the China-Europe Railway Express will depart from Alashankou in the Xinjiang Uygur Autonomous Region, passing through Kazakhstan, Russia, Belarus and Poland to Duisburg Station in Germany. The journey will take about 11,000 km and about 15 days. Since then, Chengdu, Zhengzhou, Wuhan, Suzhou, Guangzhou and other cities have also opened container trains to Europe. According to the statistics of the State Customs, by the end of June 2018, the total number of China-Europe freight trains had exceeded 9,000, transporting nearly 800,000 TEU of goods in 48 Chinese cities and reaching 42 cities in 14 European countries. The transport network covered major regions of the Eurasian continent.[22][23][26]

In August 2014, Thailand's ruling authorities approved a railway project linking China's Yunnan Province. The total cost of the project is about 741.4 billion baht (about 143 billion yuan). It is planned to build two high speed rail lines, namely Nong Khai-Matah (737 km in length with planned investment of 392.5 billion baht) and Chongkon-Pachi (655 km in length with planned investment of 348.8 billion baht).

Since then, the Jakarta-Bandung high-speed railway, the China-Laos high-speed

railway, the Budapest-Belgrade railway and other overseas projects have been implemented. With the continuous progress of overseas projects such as the Malaysia-Singapore high-speed railway and the China-Thailand high-speed railway, China's "going global" strategy of high-speed rail has achieved its expected goals. By the end of 2017, 83% of countries and regions with railways in the world were using Chinese railway products, according to statistics from China's railway construction agency.

On January 1st, 2018, the commercial operation train of the Djibouti Railway, a standard gauge railway between Ethiopia and Djibouti, officially started operation. The railway, the first electrified railway in East Africa, is built with Chinese standards and equipment. With a total length of 751.7 km and a design speed of 120 km/h, the railway has a total investment of about 4 billion US dollars. It is the first whole-industry chain railway built by Chinese enterprises overseas to "go global."

On May 15th, 2018, the main construction of the Jakarta-Bandung high-speed railway project in Indonesia officially started.[27] The Jakarta-Bandung high-speed railway is a landmark project jointly promoted by China and Indonesia under the "One Belt And One Road" initiative. It is also the first order for China's high-speed railway to "go global."

Information from China's railway transport authorities shows that the "overseas territory" of China's high-speed railway has not only expanded to dozens of countries in Asia, Europe, Africa and the United States. On April 13th, 2019, the 22nd Mostar Expo was held at the International Exhibition Center in Mostar, Bosnia and Herzegovina. China Railway participated in the exhibition for the first time. Fuxing

train and China-Europe freight train made a wonderful appearance at the exhibition.

2.2 Present railway of China

In order to meet the increasing travel requirements of the people, China's railway authorities are constantly improving railway technology, but the improvement degree still cannot meet the transportation demand of the whole society. In 2007, for example, China railway freight volume could only meet 35% of freight demand. In major cities such as Beijing, Shanghai and Xi'an transportation capacity was more nervous. [28] In railway passenger aspects, it was equally hard to meet the needs of the people's travel, by providing room for 2.4 million passengers daily in average, compared with a National Day to send up to 3.4 million passengers. To this end, the Chinese government has increased the investment in railway construction, from the high-speed railway network, ordinary railway network and comprehensive transportation hub network to carrying out modernization planning.

1. The high-speed rail network

On the basis of the original planning of "four vertical and four horizontal" main framework, the high-speed railway should be increased to support passenger flow. The standard is suitable, and the necessary high-speed railway should be developed. At the same time, the existing railway should be fully utilized to form a high-speed railway network with "eight vertical and eight horizontal" main passageways as the framework, regional connecting lines and intercity railway as the supplement.

The construction standards of high-speed railway network have been clearly

divided. In principle, the new projects of high-speed railway main passageway planning shall adopt the speed standard of 250 km/h or above (which may be reduced in areas with complex topographical, geological and climatic conditions), and 350 km/h standard shall be adopted for railway lines with densely populated towns, relatively developed economy and running through mega-cities.[29] In principle, the regional railway connection line shall adopt the standard of 250 km/h or less. The principle of intercity railway is 200 km/h and below the standard.

Specific planning scheme includes: First, the construction of “eight vertical and eight horizontal” high-speed railway main channels should be completed. [30] The “eight longitudinal” channels are: Coastal Channel, Beijing-Shanghai Channel, Beijing-Hong Kong (Taiwan) Channel, Beijing-Harbin Channel, Hunan Channel, Beijing-Kunming Channel, Baoyin-Haikou Channel, and Lanzhou-West Channel. The “eight horizontal” channels are: Suiman Channel, Jinglan Channel, Qingyin Channel, Land Bridge Channel, Riverside Channel, Shanghai-Kunming Channel, Xiamen-Chongqing Channel, and Guangzhou-Kunming Channel. Second, regional railway links will be expanded. On the basis of the “eight vertical and eight horizontal” main passageways, the regional connecting lines of high-speed railway are planned to further improve the road network and expand the coverage of high-speed railway. [29][30] Third, intercity passenger railways will be developed. While giving priority to the use of high-speed and general speed railways to run intercity trains to serve intercity functions, China plans to build intercity passenger railways in urban agglomerations that support and lead the development of new urbanization, effectively connect large and medium-sized cities with central towns,

and serve commuter functions.

2.The general high-speed rail network

We will focus on expanding the coverage of road networks in the central and western regions, improving the network layout in the eastern region, improving the quality of existing road networks, and promoting connectivity in neighboring areas.



Figure 5. Railway map of China

Specific planning scheme includes: First, the formation of inter-regional fast large

capacity channel will be completed. It contains 12 cross-regional, multi-path, convenient large capacity inter-regional passageways. Second, the networks will face the “One Belt And One Road” international channel. We will promote connectivity between China and its neighbors in the northwest, southwest and northeast, improve supporting facilities at ports, and strengthen rear passageways at coastal ports. Third, we will promote poverty alleviation and land development of railways. [31] A number of planning projects have been put forward from three aspects: expanding the coverage of the road network, improving the passage into and out of Tibet and Xinjiang, and promoting the development and opening up of border areas. Fourth, we will strengthen the railway collection and distribution system. It is planned to build regional open railways and branch railways of open ports and garden areas, and improve the collection and distribution system.

The China train speed record is currently 486.1 km/h (302 mph) on existing track, 420 km/h (260 mph) on existing rail track for two pas trains and 605 km/h (375 mph) on test tracks, surpassing many countries in the world. [31]

Engineers are now working on maglev trains whose expected speed is 600 km/h (373 mph); high speed trains that can run in different countries with different gauges, different voltages, different environments and different signal control systems; and vacuum tube trains, also called super maglev which is said to be next phase in developing fast trains. (See Figure 6)

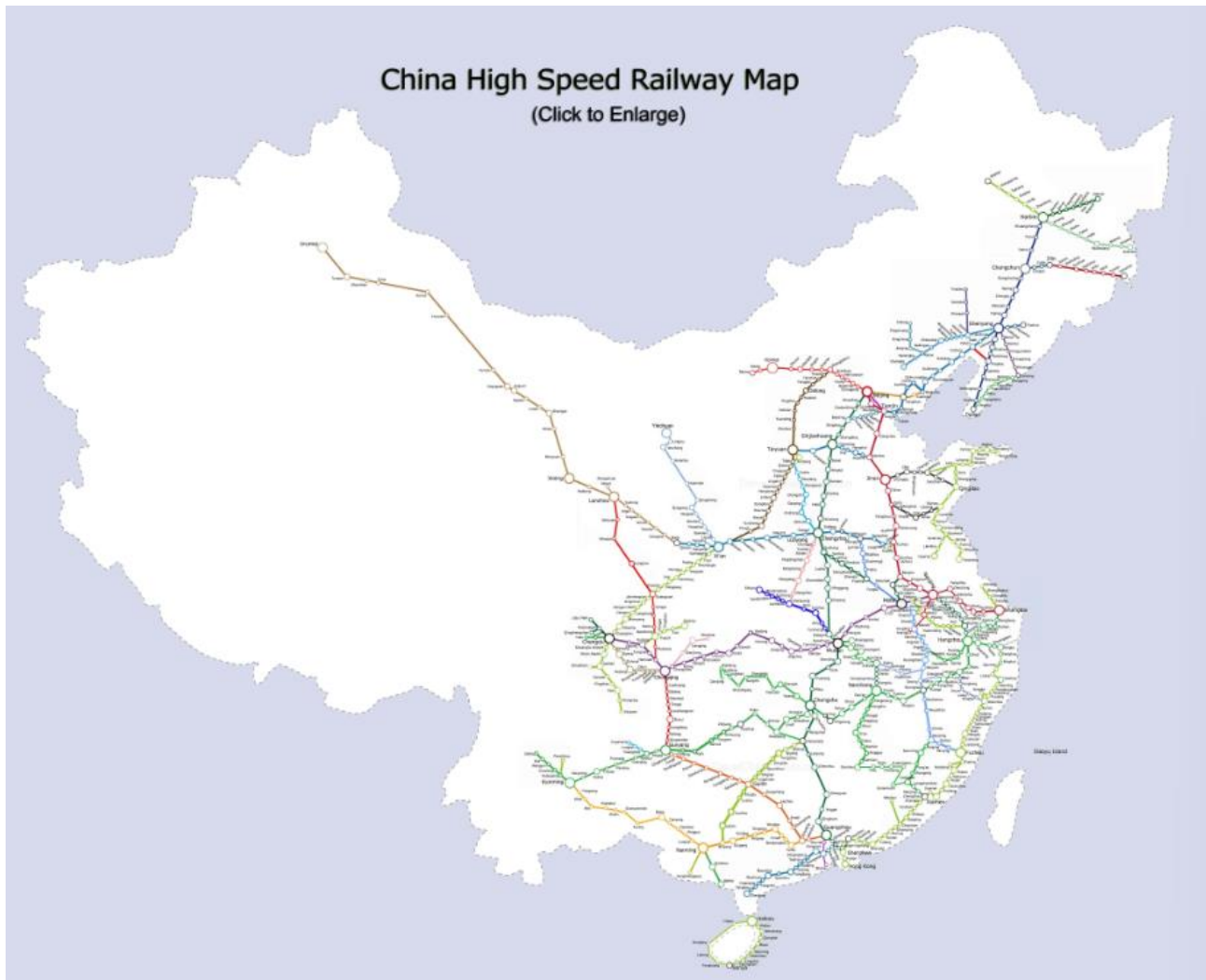


Figure 6. China High Speed Railway Network

China has world's largest high speed railway network as long as 40,000 km (24,855 mi) and capable of accommodating high speed trains running at 250 - 350 km/h (186 - 217 mph). The present high speed railway network mainly consists of four north-south and four east-west trunk railways. According to the long-term plan, the network will be extended to eight north-south and eight east-west high speed lines by 2030, with a total length of 45,000 km (27,960 mi).[31]

3. Integrated transportation hub

Hub is an important node of the railway network. In order to better play the overall efficiency of the railway network and support the point and line capacity, this planning and revision will further optimize the layout of railway passenger and freight hubs according to the principle of "inside the passenger and outside the cargo", and form a modern comprehensive transportation hub with complete system, integrated convenience and station and city integration. [32] To achieve "zero distance" passenger transfer, "seamless" logistics connection, transport services "integration."

After the above plan is realized, the long-term scale of railway network will reach about 200,000 kilometers, including about 45,000 kilometers of high-speed railway. The national railway network is fully connected with cities with a population of more than 200,000, and the high-speed railway network is basically connected with provincial capitals and other large and medium-sized cities with a population of more than 500,000, achieving a transportation circle of 1 to 4 hours between adjacent large and medium-sized cities and a transportation circle of 0.5 to 2 hours within city clusters.

Take Hangzhou West Hub as an example, Hangzhou West HSR Integrated Development is a transit-oriented development ("TOD") measuring over 10.7 million sq ft in total GFA. The development is strategically sited adjacent to the south square of the upcoming Hangzhou West HSR Station, poised to be a key transportation hub integrating railway, subway, rental vehicles and public transportation.

2.3 Future railway of China

China will gradually improve the layout of its road network, develop advanced and applicable equipment, ensure sustained and stable transport safety, conduct modern and scientific operations and management, continuously improve its innovation capacity, comprehensively improve its transport capacity and service quality, significantly increase its market competitiveness and international influence, and meet the needs of completing the building of a moderately prosperous society in all respects.

1. Road network construction

The length of China's railways in service has reached 150,000 km, of which 30,000 km are high-speed railways. The rate of track duplication and electrification has reached about 60% and 70%, respectively. A safe and efficient railway network with a reasonable layout, extensive coverage, and well-organized construction has been basically established.

High-speed rail expanded into a network. On the basis of the completion of the "four vertical and four horizontal" main framework, the construction of high-speed railways proceeded in an orderly way, the service scope of high-speed railways was further expanded, and a high-speed railway network was basically formed.

The trunk road network has been improved. The road network in the eastern part of the region continued to be optimized and improved, and the road network in the central and western parts of the region continued to expand. The links between the

western part and the eastern and central parts of the region were further expanded, with closer links within the region. The road network in the central and western regions reached about 90,000 km. We made orderly progress in the construction of foreign passageways, and made positive progress in railway connectivity with neighboring countries.

Intercity and suburban railways moved forward in an orderly manner. An intercity and suburban railway network will be formed in economically developed, densely populated and urban-populated areas, and other suitable areas will be laid out and constructed according to local conditions and their capabilities. The total railway capacity of intercity and suburban areas will reach about 2,000 km.

Integrated hub supporting connection has been established. A number of modern and efficient comprehensive transport hubs with complete facilities and equipment have been built, and about 3,000 km of feeder railways have been built. The efficiency of connecting railways with other modes of transport has improved significantly, and “zero-distance” passenger transfer and “seamless” freight transport have been basically achieved.

Beijing sees the investment as a way to stimulate demand in the wake of the Covid-19 pandemic and the continuing trade war with the US. It also wants to create a more integrated national market and distribute the benefits of economic growth more evenly across the country. At present, there are wide disparities in wealth between Chinese provinces, with the Beijing region averaging a nominal per capita income of more than \$20,000 compared with \$9,300 in the central province of Hubei

and \$4,500 in the remote northwestern province of Gansu.

The aim is to encourage the growth of regional hubs, thereby offering migrating rural workers an alternative to the relatively wealthy coastal provinces. All cities with a population greater than 200,000 will be on a rail line, and those with more than 500,000 people will have access to a service travelling at over 250km/h.

The year 2035 has additional significance, as it was the target date set by President Xi Jinping for China becoming "a modern socialist country". In the first half of 2020, China invested \$49bn in its rail network, an increase of 1.2% on the previous year. However, the scale of future spending will inevitably increase the sector's indebtedness.

More than \$1 trillion has been spent on rail lines since 2009, and China Railways' debt pile presently stands at around \$770bn. Most of China Railways' regional subsidiaries make heavy losses, according to this analysis. It reports that the least profitable operator, based in the southwestern city of Chengdu, suffered a \$1.8bn net loss in 2018, while those in the northern cities of Shenyang and Harbin each lost more than \$1.5bn in the same year.

This partly reflects the relatively low price of tickets – a second class fare between Beijing and Shanghai is presently \$80. It also reflects the fact that the domestic economy has yet to generate sufficient demand to make full use of its infrastructure. However, China appears willing to accept higher debt in view of the importance of maintaining demand in the economy.

China has increased its spending on road construction and maintenance. Official figures show a 13.8% jump in road building for the period from January 2021 and June 2021 compared to the same period for 2020 according to data provided by China's Ministry of Transport.[33]

Spending on road building for the January 2021 to June 2021 grew to US\$177.4 billion for China. Data from China's Ministry of Transport also reveals that truck haulage payloads increased by 29% to 18.48 billion tonnes for the January 2021 to June 2021 period, compared with the same period in 2020. The biggest increase in tonnages transported were in Hubei Province, a jump of 204.9%.

China plans to extend by 47% the total length of its national expressway system by 2035 to support regional economies, but the projects will only compound the massive debt incurred.

Expressways under the purview of the central government totaled 108,600 km at the end of 2019. Plans are to increase this to 160,000 km, according to the transport ministry.

Considering China had 150,000 km of expressways at the end of 2019, including those managed by local governments, the grand total is sure to exceed 200,000 km. The U.S. had about 98,000 km of expressways as of 2020, according to the Federal Highway Administration. The Chinese lead is expected to widen further.

When including all roads, China is gaining on global leader America. The

Chinese figure is seen rising from 5.01 million km at the end of 2019 to at least 6 million km in 2035, compared with 6.7 million km for the U.S. as of 2020.

An extended highway network would facilitate shipments of regional specialties to Beijing and Shanghai, while tourists and businesspeople would have an easier time visiting various regions from big cities. And highway construction creates jobs.

But expressways are a difficult business. Tolls and other revenue totaled 593.8 billion yuan (\$91 billion) in 2019, while total spending, including debt servicing and repairs, came to nearly 1.08 trillion yuan. One reason for the shortfall is that military and police vehicles can use expressways for free, while tolls are waived for all users during such extended holidays as the Lunar New Year. Debt servicing alone totals 840.9 billion yuan and exceeds toll revenue, so debt just continues to grow. In Guizhou Province, debt repayments are six times revenue. The situation is reminiscent of Japan, where highway operators ran into trouble over excessive debt.

For local governments, the priority is to create jobs and nurture related industries through highway construction. How much the completed roads will be used is of secondary importance. Expressway-related debt slightly exceeded 5.8 trillion yuan, or \$890 billion, at the end of 2019 -- equivalent to 5.9% of gross domestic product. While the central government's finances are still sound, social security expenses will grow sharply as the population grays. China's high-speed rail system has similar debt, so the twin liabilities of expressways and railroads are expected to weigh on the nation's coffers.[21][32][33]

2. Railway Transport services

The coverage is much wider. The national railway network basically covers cities with a permanent urban population of more than 200,000, and the high-speed railway network covers more than 80% of major cities.

Passenger travel is more convenient. The proportion of passenger transport carried by EMU trains reached 65%. 2~8 hours of connectivity between Beijing and most provincial capitals, 1~4 hours of fast connectivity between large and medium sized cities, and 0.5~2 hours of convenient commuting within major urban agglomerations have been achieved.

Transport of goods is more efficient. The freight transport capacity can basically meet the needs of trans-regional transport of energy, resources and other materials. The level of heavy-haul, efficient and specialized container transport has been significantly improved. A whole-process logistics service system featuring “door-to-door” and rapid delivery has taken shape. The proportion of multi-modal transport such as molten iron, railway and air transport has increased significantly.

Since July 12, 2011, the e-ticket system has been firstly adopted on Beijing–Tianjin Intercity Railway. Since December 23, 2011, all tickets can be bought at the official ticket website (12306.cn) except for trains due to depart in less than two hours. Debit card and credit cards with the China UnionPay icon, Alipay, and WeChat Pay are accepted.

3. Informatization construction

a. Passenger and cargo service network

Online ticket sales for passenger transport account for 80%, and online handling of freight services such as cargo acceptance, electronic payment and logistics tracking can be realized.

b. Intelligent transportation organization

The construction of a digital railway infrastructure framework that relies on railway geographic information platforms to serve railway construction, operation and management has been accelerated. The intelligent level of dispatching and command has been further improved, and the whole process of transportation and production has basically been informationized.[33]

c. Safety monitoring automation

The safety supervision information system, which integrates monitoring, monitoring and management, has been basically established to realize real-time monitoring and monitoring of production safety dynamic information and enhance the professional and automatic level of railway transportation safety monitoring.

We will build China into a modern railway country with higher standards, provide comprehensive services and guarantee for the development of a modern railway country, develop a modern railway industrial system with strong radiation functions, and build China into a world-class railway country with global competitiveness. For

main indicators of railway development sees table 1.

Table 1

Main indicators of railway development			
indicators	Closing date: 2020	Five-year value added	Annual Growth Rate (%)
Operating mileage (10,000 km)	15	2.9	4.8
Mileage of high-speed railways in operation (10,000 km)	3	1.1	11.6
Rewinding rate (%)	60	7	>2.0
Electrification rate (%)	70	9	>2.5
Passenger volume (100 million persons)	40	14.6	9.5
Cargo volume (tons)	37	3.4	2.0
National Railway Cargo Volume (Tons)	30	2.9	2.1
Passenger turnover (100 million person-kilometres)	16000	4040	6.0
Freight turnover (100 million ton-km)	25780	2030	1.7
National railway freight turnover (100 million ton-km)	23500	1902	1.8

Economic benefits brought by informatization refer to the net income created by using information products or services. The application of information on railway transportation can bring great economic benefits in different aspects.[34]

The achievement of railway informatization shortens the distance between passengers, consignors and railway. Passengers and consignors can not only know all kinds of services offered through railway interests, but also attain information they require such as the timetable, fare, consignment's status and its arrival time and so on. For the passenger transport, it solved the difficulty of buying tickets. Passengers can book or buy tickets, or apply for consigning the baggage through the Internet. The real-time train schedule, ticket price and dynamic travel time between stations published in the Internet are so convenient for travelers as to make their travel plans. After booking the ticket, passengers can get it anytime before their train. For the freight transport, consignors can enquire through e-commerce or EDI system, fill out a freightage application form, process the delegation, and then deal with the online payment system. [35] Whereas if the management means of transport information is backward, its resources cannot be fully used.

The railway informatization can contribute to the informatization of business management, drive the innovation of technology, management and operation systems, and enhance the enterprise's competitiveness as well. It makes the policies and business models more scientific with informatization and completely realized the turning loss into gain. Since the interconnection, communication and information sharing during various departments at all levels, the system resources, such as information technology and network resources at home and abroad, can be used in

administration more scientifically. All departments and leaders of production and management can take forecast analysis and explore the proper development plans according to the market information and railway system' statues. That is to say, railway informatization enables the whole industry so scientific, orderly, reliable and safe that the railway maximizes its economic benefits.

Railway transport, as one of the most importation parts of the national economy, always keeps its leading position under the trend of informatization, which is decided by its own properties. Railway informatization not only is the objective need of railway transportation production, but can improve the labor productivity, extend transport markets, enhance the service quality for passengers and consignors, and promote the reform and innovation of the railway industry.

Nowadays, the research on economic benefits brought by railway informatization in our country is still at the stage of qualitative level. Its investment is more inefficient as well. While using the mathematic methods or some certain models to take the quantitative study can be more accurate, scientific and reasonable. This way of research also has a higher reference value in the practical application.

On the investment issue of informatization, spending too much will result in waste, while too little may restrict railway's development. As the consequence, there should be some evaluation indexes about this problem. This paper adds a variable into the production function method to further explore the quantitative analysis method of informatization investment.

3. China's railway in the international freight market

We will give full play to the overall competitive advantages of China's railway industry, strengthen railway exchanges and cooperation with other countries, speed up the "going global" of railways, promote the internationalization of China's railway standards, and build China-Europe Railway Express into a world-renowned logistics brand.

3.1 Promoting the "going global" of railways

We will make full use of both international and domestic markets and resources, actively promote China's all-round cooperation with foreign countries in technical consultation, construction, equipment manufacturing, transportation management, personnel training and technical standards, and promote the railway's "going global" development toward the high-end of the industrial chain and value chain. We will focus on key areas and projects, coordinate resource input, prioritize targeted policies, and strengthen policy support to achieve practical results. [36] We will foster railway equipment technologies, standards and service capabilities that meet the global market demand, and further enhance the internationalization of railway equipment.

For over two millennia, technology and politics have shaped trade across the Eurasian supercontinent. The compass and domesticated camels helped the "silk routes" emerge between 200 and 400 CE, and peaceful interactions between the Han and Hellenic empires allowed overland trade to flourish. A major shift occurred in the late fifteenth century, when the invention of large ocean-going vessels and new

navigation methods made maritime trade more competitive. Mercantilism and competition among Europe's colonial powers helped pull commerce to the coastlines. Since then, commerce between Asia and Europe has traveled primarily by sea.

Against this historical backdrop, new railway services between China and Europe have emerged rapidly. Just 10 years ago, regular direct freight services from China to Europe did not exist. Today, they connect roughly 35 Chinese cities with 34 European cities. Rail services are considerably cheaper than air and faster than sea, as Figure 1 illustrates, and could provide a compelling middle option for more goods in the coming years. Rail's share of cargo by value is already growing, increasing 144 percent during the first half of 2017, as compared to the same period in 2016. A study commissioned by the International Union of Railways estimates that China-Europe rail services could double their share of trade by volume over the next decade.

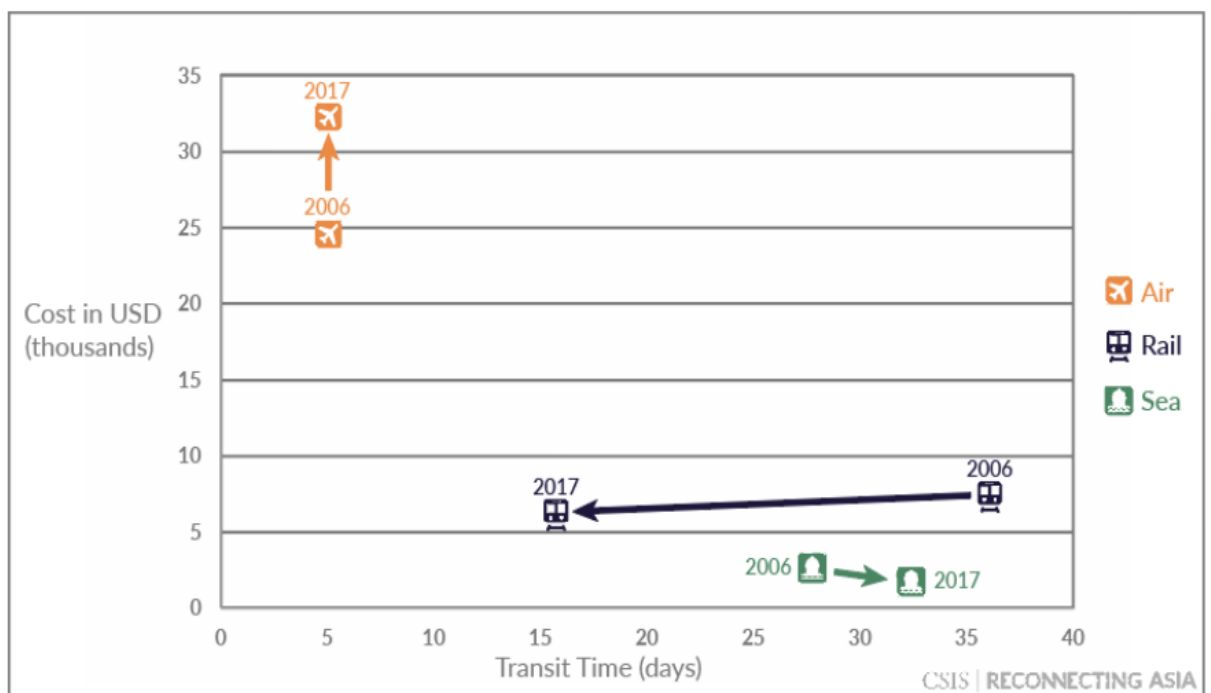


Figure 7. Shift in Transit Cost and Time (2006-2017)

Source: Xu Zhang, Eurasian Rail Freight in The One Belt One Road Era

China is the primary force behind these routes, and other countries have been eager to participate. Providing generous subsidies and state media promotion, China has made direct rail services a major feature of its Belt and Road Initiative (BRI), which aims to bind the world with Beijing through \$1 trillion of new infrastructure, trade agreements, and coordination across countless policy areas. [37] Even countries that have been reluctant to endorse the BRI have embraced these new routes. When a train from Yiwu, China, arrived in London, UK, in January 2017, The Telegraph called it “a new chapter in the history of the centuries-old trading route,” and The Guardian said it “heralds the dawn of a new commercial era.” In the past two years, historic firsts have been celebrated for trains arriving in France, Latvia, and Finland, among other countries.

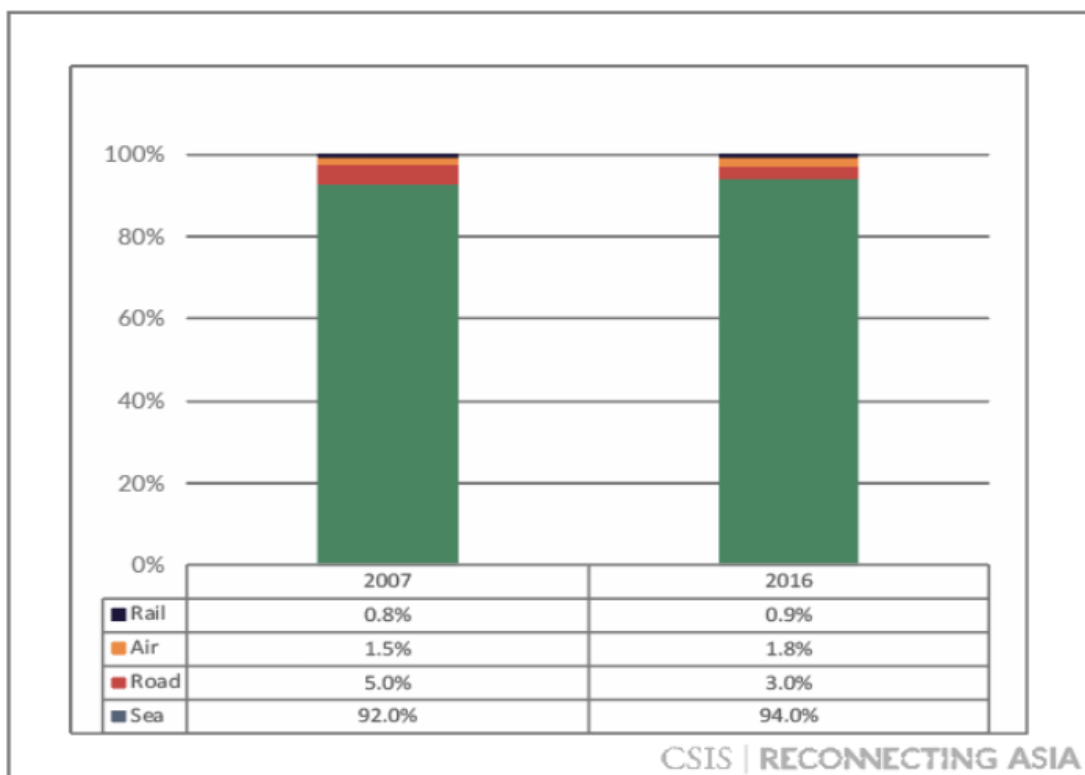


Figure 8. China-Europe Trade by Weight (2007-2016)

These new services have captured imaginations, but it remains to be seen how much trade they can capture. In 2016, rail carried just under 1 percent of trade between China and Europe by volume and just over 2 percent by value. As Figure 9 illustrates, maritime shipping remains dominant, carrying 94 percent of trade by weight and 64 percent by value in 2016. Compared to rail, air transport carried twice as much cargo by weight and more than 13 times by value in 2016. [36][37]These trends highlight the competitiveness of maritime shipping for low-value goods and the competitiveness of air shipping for high-value goods.

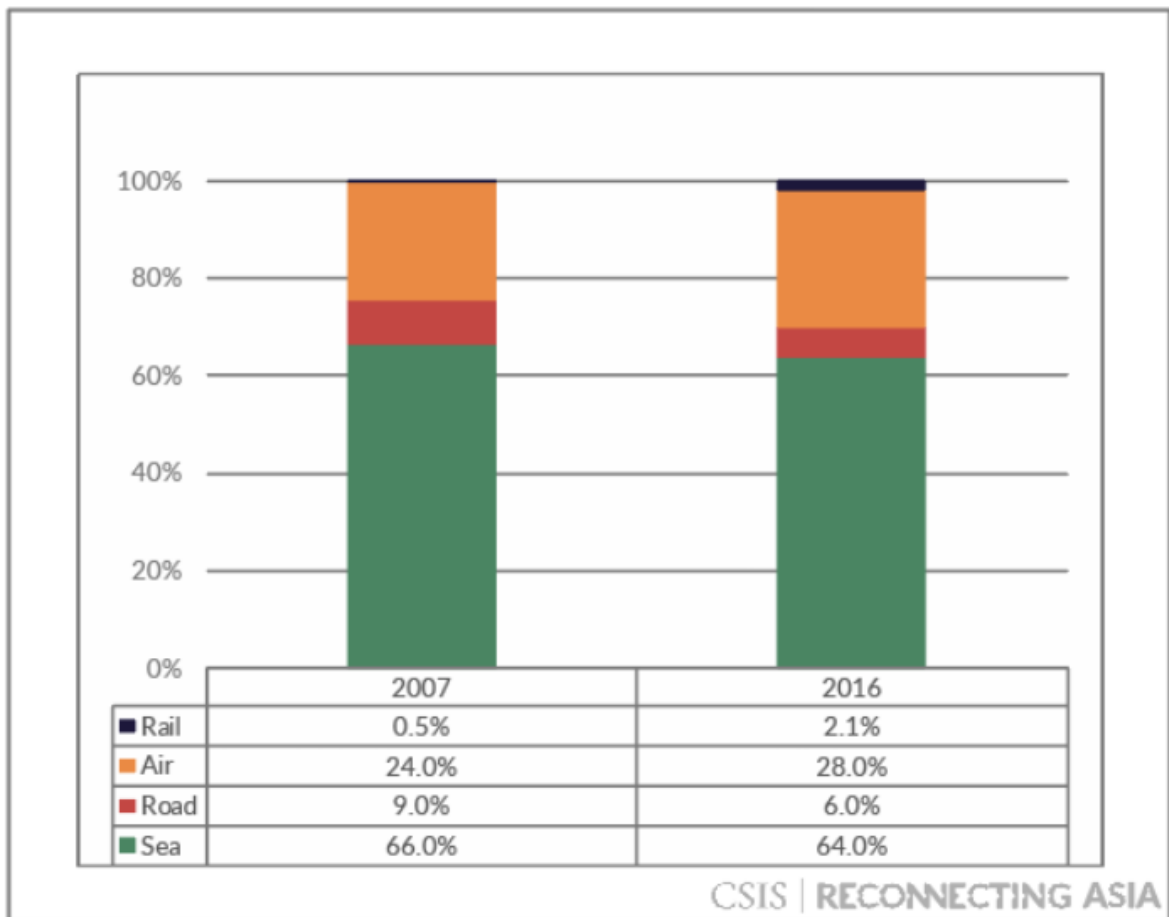


Figure 9. China-Europe Trade by Value (2007-2016)

Source: Eurostat, European Union, analysis performed by Infrastructure Economics Centre (CEI)

The rail services also face constraints to more dramatic growth. The future of Chinese subsidies is uncertain. A chronic trade imbalance between Europe and China means less demand for eastbound services and creates costs for repositioning empty containers. Other developments, including new airports in Asia and improvements to the European Union's rail network, could impact rail's competitiveness in the coming years.

The main challenge in squaring all these factors is that despite the attention they receive, there is little reliable and centralized information about these new services. Frequency of China-Europe rail services, cargo volume, cargo rates, and other basic information is hard to find, especially compared to maritime and air freight data. Many of these shortcomings stem from the newness of these routes, the complexity inherent in moving goods across many borders, and the resulting disaggregation of data. Data could improve in the coming years, but there are also incentives for obscuring the information. These trains carry not only commercial goods but also political ambitions. [38]

Drawing from interviews with 34 stakeholders, this report contributes to filling that gap in two parts. First, it examines the rise of China-Europe railway services and their drivers. China-Europe rail has grown not only in terms of origins and destinations but also in terms of cargo volume, cargo type, and overall competitiveness. Driving these trends are several political, technical, and technological factors, chief among them subsidies and improvements in logistics processes. Second, it considers these developments within a broader trade context

and identifies several challenges to future growth, including trade imbalances, capacity constraints, and the enduring strengths of maritime shipping.

Two views emerge from this analysis. The first is dramatic growth of the railways in recent years. These services are likely to continue growing in the coming years. Companies sourcing high-value, time-sensitive products or inputs from China should look seriously at whether some of their current supply chain should be shifted to rail. A narrow set of countries stand to benefit from leveraging their positions as transit hubs. China itself stands to benefit politically as well as commercially if these routes become sustainable. [39] The second view is more modest. In broader trade terms, these services are less game-changing than often advertised.



Figure 10. China-Europe Rail Routes and Frequency (2018)

Service frequency is increasing. Last year, there were an estimated 1,470 direct freight services from China to Europe and an estimated 730 services from Europe to China. As Figure 10 shows, several cities have multiple departures each day. In China, the most active hubs are often further inland. The closer origin and destination points are to the ocean, the stiffer competition they face from maritime shipping alternatives. Some recently announced routes are still in “trial” phases, and it is unclear whether they will become sustainable. But overall, there is a marked increase in service frequency compared to a few years ago.

The railways are also carrying a greater range of cargo, according to several stakeholders. Early services, as illustrated by the HP and Foxconn examples, often focused on laptops, cell phones, auto parts, and other high-value cargo. These products, particularly those produced in China’s inland provinces, are still the main candidates for rail transport because the higher cost for using rail can be offset by lower inventory costs. It is becoming easier to send perishable goods by rail thanks to “reefer,” or refrigerated, containers. [40] A niche market in shipping hazardous goods, including toxic materials to China, could add to eastbound freight in the coming years.

Rail has become more competitive in speed and cost, as Figure 8 showed in the previous section. When the American Chamber of Commerce compared China-Europe transport options in 2006, rail was not only more expensive but also slower than maritime shipping. As its yardstick for competitiveness, the analysis compared transport options for shipping a 40-foot container from Shanghai, China, to

Hamburg, Germany. In 2006, that journey took 36 days by rail. It now takes just 16 days. Cost has declined as well, but not as dramatically as transit time. If anything, the Shanghai-Hamburg comparison is conservative, since it uses two maritime shipping hubs as the origin and destination points. Rail could be even more competitive for origins and destinations further inland.

Cargo volume and value is rising. A key development is that some block trains have been replaced by more flexible offerings, including options to ship less-than-container loads, attracting smaller shippers. One major block train operator, Far East Land Bridge, reports shipping 37,000 40-foot equivalent units (FEUs) in 2017, up from 21,900 FEUs in 2016. The same company reported cargo value of more than \$160 million for 2017, a \$52 million jump from 2016. Putting aside the eastbound-westbound trade imbalance, which a later section considers, these figures are dramatic when compared to previous years. For example, during the first half of 2017, cargo value increased 144 percent compared to the same period in 2016. From almost nothing, China-Europe railways have emerged rapidly.

A mix of political, economic, and technical factors are driving these new services, the exact balance of which varies from route to route. As mentioned earlier, some services have run only once, entirely for promotional purposes. Others, particularly those further inland, offer a more competitive middle option between maritime and air freight. Overall, however, it is difficult to imagine these routes emerging as rapidly as they have in recent years without China putting its political and financial weight behind them.

Politically, China has used the announcement of new routes as evidence that the BRI is succeeding. For the most part, China's partners are happy to oblige. Foreign leaders readily promote the routes as symbols of deeper ties, regardless of their economic merits. They understand that the BRI is President Xi's signature foreign policy effort and hope that cooperating on a small, even symbolic project could open the door to broader cooperation and greater economic gains. Delegations from both countries often celebrate a train's first arrival. Chinese state media reports frequently on the new routes, often lumping together figures for routes between China and Central Asia with routes extending further to Europe.

China also provides generous subsidies for these routes, making their true economic viability more difficult to assess. According to reports, subsidies can range from \$1,000 to \$5,000 for each FEU, accounting for up to one-half the total cost.²⁰ One study that examined subsidies in 2014 found an even higher range, up to \$7,000 per container.²¹ The same study estimated that China's provincial governments collectively spent over \$300 million subsidizing China-Europe block trains during 2011 to 2016. That sum is modest when compared to the \$113 billion that China plans to spend on its railways in 2018.²²

To be sure, China is not the only subsidy provider, nor are shipping subsidies the only avenue for state support. The European Union and its members subsidize both railway infrastructure and operations. Some groups support these measures on social grounds, noting that rail is a more environmentally friendly form of transportation. But Europe's subsidies largely predate the emergence of China-Europe railway routes.

In contrast, China's financial and political support for these routes has coincided with their rise.

Several market-driven factors have helped as well. The relocation of Chinese manufacturing facilities further inland, driven in part by rising wages in coastal areas, has encouraged companies like HP to consider rail shipping. Maritime shipping has become slower, as ships "slow steam," reducing their speed to cut fuel costs. In aggregate, slow steaming also pushes down the total supply for maritime shipping, helping to stabilize shipping prices.²³ These developments have combined to make rail comparatively more attractive in speed and cost, even though maritime shipping retains an edge for most goods.

China-Europe railways have also benefited from broader trade trends. During 2007–2016, trade between China and Europe grew 7.65 percent.²⁴ The EU is China's leading export destination,²⁵ and telecommunications equipment is China's largest export to the EU. Within the EU, Germany is China's largest trading partner and home to several of the most active China-Europe rail hubs. Looking ahead, Chinese exports of some rail-friendly goods to Europe, including high-tech products and automobile parts, are expected to grow faster during 2015–2019 than they did during 2012–2014.

Growing awareness could also be contributing to the growth of China-Europe rail services. Chinese state media claim that awareness of the BRI increased from 6 percent to 18 percent between 2014 and 2017 across a sample of 22 countries.²⁷

Promotion of these routes, while serving China's political objectives, also makes some commercial sense. Some outreach is necessary to market China-Europe rail as an alternative to other transport modes. After becoming aware, customers also need to be persuaded to make the switch. Similar tactics can be seen in the private sector, where Uber and other ride-sharing companies have subsidized transportation costs to attract customers.

Technical improvements to rail systems and customs processes have made railway services faster and feasible for a broader range of goods. China now has the second-longest railway network in the world. In some areas within China, the expansion of railway networks has outpaced the availability of commercial transport, temporarily increasing the competitiveness of rail. On China's border and beyond, some infrastructure investments have helped speed the movement of containers. For example, a relatively new dry port at Khorgos, on the China-Kazakh border, processes trains 20 hours faster than an older terminal on the same border. Temperature-controlled containers now allow for perishable goods to be shipped via rail, but the volumes are still modest. In February 2018, for example, China sent its first block train shipment of produce to Russia.

Customs and other "soft" infrastructure improvements have been equally important in recent years. A decade ago, prospective shippers had to coordinate arrangements with each country the railway crossed through. The additive costs of tariffs, permits, duplicative paperwork, mandatory inspections, and other requirements is a primary reason why the routes were barely used. Rail still requires

more paperwork than maritime shipping, but some requirements have been consolidated with common consignment notes. Logistics experts are now well-versed in navigating the remaining barriers and provide translation services for their customers to help expedite government approvals.

A basic challenge is that China-Europe trains carry a smaller amount of cargo compared to today's ships. As Figure 4 illustrates, a single block train can carry 12 times more than a single aircraft, but only 0.45 percent as much as today's largest ship. Obviously, taking on a significantly greater amount of trade will require many more train trips.

Meeting the International Union of Railways study's optimistic scenario of 371,000 FEU each year will require sending roughly 24 trains a day, a nearly five-fold increase over the 2016 level of 5 trains per day.

But capacity constraints could stand in the way of greater rail volumes. The main challenge is improving rail terminals, particularly those at change-of-gauge stations, and the rail system within Europe. Europe and China employ the standard 1,435-mm gauge, whereas Russia, Kazakhstan, and other former Soviet states use a 1,524-mm gauge. The difference in gauge means that no train travels the full length from China to Europe but rather containers are transferred from one train to another.

New rail infrastructure within China and transfer facilities on its border have helped alleviate pressure in Asia. As the principal entry point into the EU, the Polish and Belarusian border (Figure 11) is a key chokepoint.



Figure 11. Chokepoint at the Belarus/Poland border (2017)

These are also capacity challenges within the EU railway network. Most of Europe's rail system is significantly older than China's, and capacity constraints and modernization projects can create bottlenecks. In 2017, China-Europe trains experienced delays of up to six days.⁴³ The EU and its member states are making investments that will help alleviate bottlenecks, but these improvements will take time. The Trans-European Transport Network (TEN-T), a European Commission plan to improve transport, outlines actions up to 2030.⁴⁴ Meanwhile, even if these services remain faster overall than maritime shipping, customers value reliability. Delays remain a major risk for China-Europe trains, the main selling point for which is speed.

3.2 Create a China-Europe freight train logistics brand

We will implement the Brand Construction Plan of China-Europe Railway Trains, innovate the service mode of China-Europe Railway Trains, enhance the comprehensive service ability, build a world-famous logistics brand with international competitiveness and good reputation, and become an important platform to promote the construction of “One Belt And One Road.” We will improve the railway transport corridor between China and Europe, and plan to set up a number of freight train hub nodes in major inland cargo source areas, major railway hubs, major coastal ports, and border land ports. We will strengthen supply support and transportation organization, reduce logistics costs throughout the whole process, and facilitate customs clearance. We will basically form a comprehensive service system for China-Europe freight trains with reasonable layout, complete facilities, stable traffic volume, convenience, efficiency, safety and smooth traffic.

A China-Europe freight train left Ganzhou international land port in east China's Jiangxi Province for Budapest, Hungary on May 8, marking another achievement under the "dual-zone" cooperation agreement between China (Ganzhou) Cross-border E-commerce Comprehensive Pilot Zone and Hungary Central European Trade and Logistics Cooperation Zone, reported Chinanews.com.

Loaded with 50 40-foot containers, the train carries solar modules and mounting racks for the 80 MWp solar power plant project under construction by China National Machinery Import and Export Corporation (CMC) in Hungary's Buzsak.

3.3 Enhance the international influence of China's railway standards

China aims to raise its global competitiveness in the transport sector by setting up transport networks with wider coverage and higher speed, according to an official document.

The country will establish a comprehensive modern transport system by 2035, according to the document jointly released by the Communist Party of China Central Committee and the State Council.

The transport system will be composed of three networks: a high speed network of high-speed railways, expressways and civil aviation, an arterial network of low-speed railways, national highways and waterways, and oil and gas pipelines, and a basic network of provincial highways, rural highways, regional railways and general aviation, said Wang Zhiqing, a senior official with the Ministry of Transport.

China will build a domestic travel circle to limit commutes within cities to one hour and travel times to neighboring cities and major cities nationwide to two hours and three hours, respectively. [30][31][35]

Circles for speedy logistics will be completed to facilitate domestic goods delivery within one day, shipping to neighboring countries in two days and logistics to major cities worldwide in three days, according to the document.

The country will also promote intelligent transport with the support of big data, artificial intelligence, blockchain and supercomputing and adopt an environmentally

friendly model of development by saving energy and controlling pollution.

China's railway shall assign one institute to manage the internationalization of Chinese standards and define its responsibilities and working scope. Meanwhile, China's railway shall determine strategy for the internationalization of Chinese standards, decide the major direction or important field, carry out standardization-oriented research programs for its preponderant or prospective technologies, draw up the plan for intellectual property strategy of key technologies, and guide the internationalization of the Chinese railway technology standards. On the one hand, national and industrial standards are under the charge of the National Railway Administration (NRA), mainly concerning requirements on safety, basis, system, compatibility, and interoperability. On the other hand, China's railway formulates technology standards or normative technical documents to guarantee uniformity and compatibility of product, technology, equipment, and technique, if needed. Meanwhile, China's railway shall organize experts to systematically examine and complement the weak links of industrial technology standard system, complete the system and optimize it, accelerate the establishment and revision of key technology standards, perfect the technology standard system continuously, improve the advanced nature and economy of the standards, and enhance the competitiveness of the Chinese railway technology standards in international projects. Furthermore, China's railway shall strengthen the awareness and management of intellectual property, develop and hold more patents relating to the mainstream railway technologies in the future, push forward the patent obtaining process of independent technologies, actively promote the standardization of patents, develop the procedure

for “patented technology–standardized patent–international standard,” build up a standard system based on independent intellectual properties, and improve the competitiveness of Chinese railway products in global market.

China’s railway shall dedicate more efforts to fundamental and prospective technologies, and build up a good coordinated development system for technological innovation and technology standard. It shall also closely integrate the establishment and revision of standards with practices, such as R&D, test and application of technology and product, enhance the supports of research for standard development, strengthen testing and verification of key indicators of technology standards, transform advanced innovation results into technology standards quickly, use standards to popularize the application of new technologies and products, and drive industry upgrade and development.

China’s railway shall elevate the capabilities of independent innovation, establish and revise standards according to independent achievements and in combination with independent R&D, manufacture, application and maintenance of key technology and equipment.[36] [37] At the same time, it shall accelerate the development of the Chinese railway technology standard system based on independent technology. China’s railway shall leverage capital and policy, increase supports for the construction of test-used facilities and platforms, and provide conditions for inspection and test of independent innovative products. Besides, it shall promote the popularization and application of new independent technologies and equipment in national railways. It shall fully exert the conditions of railway construction and operation to actively provide conditions for tests of independent products on track

and on line, thus improving independent technologies and their standards unceasingly.

We will follow up the development trends of international railway standards, actively participate in the formulation and revision of strategies, standards and norms of international standardization organizations such as ISO/TC269, IEC/TC9 and UIC, carry out research and comparative analysis of Chinese and foreign standards, and actively transform international standards suitable for China's national conditions. We will accelerate the translation and publication of Chinese railway standards into foreign languages, and publicize and promote Chinese standards at various levels and in various ways in combination with overseas project contracting, export of major equipment and construction assistance. We will improve the intellectual property management system, improve the global distribution of intellectual property, and improve the level of intellectual property protection.

Conclusion

The continuous development of China's railway technology has promoted the upgrading of its industrial structure. The continuous improvement of China's high-speed railway technology can reduce the time of communication between regions, accelerate the frequency of communication between regions, and promote the speed of knowledge spilt. Therefore, it will promote the development of other industries and the continuous improvement of urban development level, as well as the upgrade of industrial structure. [35] The technological evolution of transportation infrastructure can accelerate the knowledge spillover between regions, reduce the variable production cost of technology in backward regions, promote the transfer of some technical services from developed regions to backward regions, improve the specialization level of backward regions, and optimize and upgrade the industrial structure. China's railway should not only upgrade its own industry, but also pay attention to the coordinated development of neighboring countries. [40] To this end, China's railway has opened "China-Europe Freight train" and "Central Asia freight train." Central Europe, central Asia, the opening of the trains to advocate fast and on time, safe and stable, green environmental protection way of freight between China and Europe and "neighborhood" all the way along the line between countries trade facilitation. It will become an important carrier to promote economic and trade exchanges between China and coastal countries and an important starting point for the construction of the Belt and Road.

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