

Planning the world's biggest high speed network

GROWTH China's railways are rapidly being transformed by a huge programme of new line construction that will see high speed trains running on a 32 000 km network by 2020.

Unprecedented in scale and scope, China's investment in high speed railways will bequeath the country no less than 13 000 route-km of high speed line by 2012. Over the following eight years another 5 000 route-km will be added, making China's the most extensive high speed rail network in the world.

The cost is huge, with the government pledging to spend 2 000bn yuan or US\$298bn at today's prices on high speed lines. The Beijing – Shanghai Passenger-Dedicated Line alone will cost the Ministry of Railways 221bn yuan, surpassing the Three Gorges dam to become the largest single engineering project in China.

This vast programme was preceded by detailed examination of high speed railways in other countries. In drawing up proposals for bringing high speed to China, the Ministry of Railways was able to draw on the experience gained from constructing new lines or upgrading existing routes in various countries such as Japan, France and Germany.

The result was a decision to build both new high speed lines and upgrade existing ones, with priority going to a programme of new Passenger-Dedicated Lines. The decision to choose both options reflects the country's transport needs and its geophysical structure. Occupying 9.6 million km², China is the world's third largest country. It is also the most populous, with 1.3 billion inhabitants. On the debit side, it has limited oil supplies and resource and environmental constraints.

In terms of administration, China consists of four autonomous cities, 27 provinces and autonomous regions, and two Special Administrative Regions (Table I). However,

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the population distribution is by no means even, with a much higher density in the east and southwest.

The political-economic axis lies in the east, where the most influential regions are Beijing, the Bohai Economic Region in the northern coastal area, the Yangtse River Delta in the central coastal region, and the Pearl River Delta in the south. Of particular note is a group of rapidly growing regions which include Changsha, Henan, Wuhan, the Chengdu-Chongqing cluster and the Strait West Coast cluster along the western shore of the Taiwan Strait [correct?]. The idea of the high speed network is to connect all these major centres together.

The 11th five-year plan

With centralised planning, all aspects of China's development are prepared by the Development & Reform Commission and enshrined in five-year plans. The country is currently in its 11th five-year plan period which draws to a conclusion this year.

The railway plan is part of the overall national development plan whose objective is to turn China into a middle-income country, but further work is needed to eliminate bottlenecks in the economy. Railways have an important role to play, and the current railway plan was developed from the previous five-year plan and from the medium and long term railway plan approved by the State Council in January 2004.

The government considers the development of rail transport of strategic importance because it offers high capacity, low average cost, minimal landtake and high standards of safety, as well as environmental and conservation benefits.

In 2005, the last year of the 10th

five-year plan, Chinese Railways handled 1.16 billion passenger trips representing 606 billion passenger-km. In the same year 2.69 billion tonnes of freight were carried, equivalent to 2 073 billion tonne-km. During the 10th plan, passenger-km grew by nearly 6% a year with tonne-km rising by nearly 8.6%.

The network also expanded, with 75 000 route-km reached by 2005. By that time one-third of the network was double track and 20 000 route-km had been electrified at 25 kV 50 Hz, a 35% increase over the five years.

In terms of railway technology, China had mastered operations at 160 km/h and had successfully integrated imported technology for construction of new lines and upgrading of older lines for speeds up to 200 km/h. On heavy haul coal routes trains were running with 25 tonne axleloads, and construction of the Qinghai – Tibet Railway confirmed the ability of Chinese engineers to build railways in high-altitude conditions with permafrost.

The backdrop to the 11th five-year plan included a forecast of annual economic growth of 7.5%, rapid urbanisation rising to 47%, continued industrialisation, further improvement in economic structures requiring higher levels of customer service, the need for conservation of resources and for a more environmentally-friendly society.

To keep pace with economic growth, the rail network needed not just to expand but to raise service standards to meet rising customer expectations. This led to the key objectives of the 11th five-year railway plan:

- improve the network for the medium and long term; this includes developing more efficient coal transport, providing better access to the hinterland from ports and border points, expanding to the west to promote development there, upgrading the established network in the central and eastern regions, developing container operations and constructing more transport hubs;
- modernise technology;
- ensure safety;
- reform the railway supply industry;
- improve the quality of staff.

Development blueprint

A major milestone in China's development of high speed railways was reached in January 2004, when the Medium to Long Term Railway

Network Plan was approved by the State Council.

This formed a blueprint for development of the network with the focus placed firmly on five key programmes:

- building the Xi-zhong Xi-heng grid with four vertical and four horizontal PDLs forming the basis of a national network;
- establishing inter-city passenger networks;
- improving the existing network through the so-called speed-up programme;
- developing the network to serve western China;
- building a railway along the West Coast with an option for a politically-sensitive link to Taiwan.

The blueprint was adjusted in 2008 after the global financial crisis. Instead of aiming to achieve a particular target line speed, the actual design speed would now be determined more on a case-by-case basis. At the same time, in an attempt to rejuvenate the economy and also as a way of addressing the rapidly rising oil price, approvals by the State Council for cities to build their own urban mass transit systems were accelerated.

Speed-up programme

In implementing the upgrading projects, Chinese Railways progressively increased line speeds on routes connecting its major hubs. Tracks were relaid and electrified and a new generation of EMUs was introduced.

The sixth phase of the speed-up programme was implemented in 2007 when many main lines such as those from Beijing to Harbin, Guangzhou, Shanghai and Kowloon, together with the Longhai line and the Jiaoji line, were all upgraded to permit line speeds of 200 to 250 km/h. In most cases the lines remained available for both passenger and freight trains.

China's first PDL was commissioned in time for the Olympic Games in August 2008, with trains linking Beijing and Tianjin at a speed of 350 km/h.

The planned inter-city networks mainly serve groups of cities with a high population in the same economic zone, for example within the Yangtse River Delta Region. These lines are usually less than 500 km in length, and in most cases speeds of 200 to 250 km/h are envisaged.

The provinces in the landlocked western region are comparatively backward. The blueprint calls for the

construction of 41 000 km of new railway to serve the major centres in Sichuan, Guangxi, Gansu, Shaanxi and Xinjiang provinces. In most cases the lines will cater for mixed traffic. They will need to be built through rugged terrain, posing serious engineering challenges; the rate of return on these projects is relatively low and the payback period on the investment is much longer.

National grid of high speed lines

The Xi-zhong Xi-heng network of four vertical (north-south) and four horizontal (east-west) high speed lines (Table II) forms the backbone for overall network development, with all eight built as PDLs. Totalling 12 728 route-km, this will be the biggest high speed rail network in the world, to be completed and commissioned in stages up to 2020.

The line with the highest economic and political profile is the long-planned PDL from Beijing to Shanghai. Connecting the political capital with China's commercial centre, it will serve important intermediate cities such as Tianjin, Jinan, the provincial capital of Shandong Province, Xuzhou, Bengbu and Nanjing. Construction is well in hand and tracklaying is advancing rapidly with a view to opening in 2012 [correct?].

At 2 260 km, the Beijing – Hong Kong route will be the world's longest high speed line. Linking the capital to the Hong Kong Special Administrative Region, the line passes through five provincial capitals: Shijiazhuang (Hebei), Zhengzhou (Henan), Wuhan (Hubei), Changsha (Hunan) and Guangzhou (Guangdong). It will also serve the Shenzhen Special Economic Zone.

The Beijing – Harbin line runs through Chengde and Shengyang, the provincial capital of Liaoning, to terminate in the provincial capital of Heilongjiang.

Also known as the Southeast Coastal Line, the Hangzhou – Fuzhou line connects the Yangtse River delta region with the southeast coastal area and the Pearl River delta. It runs through Hangzhou, the provincial capital of Zhejiang, Ningbo, Wenzhou, Xiamen and the Shenzhen Special Economic Zone.

The Xuzhou – Lanzhou line connects the northwest with eastern China, serving Xuzhou, Shengqiu, Zhengzhou (capital of Henan), Luoyang, Xian (capital of Shaanxi),

Boji and Lanzhou (capital of Gansu).

Connecting the east with the central region and the southwest, the 2 080 km Shanghai – Kunming line will offer services running at 300 to 350 km/h. The route serves four provincial capitals: Hangzhou (Zhejiang), Nanchang, (Jiangxi), Changsha, (Hunan), and Guiyang, (Guizhou).

The Tsingdao – Taiyuan line is somewhat shorter at 770 km, linking the east with the north via Jinan and Xijiazhang. Design speed is lower than the other routes at 200 to 250 km/h.

The Shanghai – Chengdu line joins the affluent east to the relatively less developed western part of China. With a length of 1 600 km, it passes through the difficult terrain of the Sichuan Basin and hence, with the exception of the Chengdu – Chongqing section which is designed for 350 km/h, the line is being built for trains to run at 200 to 250 km/h. The route passes through three provincial capitals: Nanjing, Hefei and Wuhan.

From Beijing, journey times to most of the provincial capitals will be dramatically shorter (Table III) once the network is completed by 2020. Together with the upgraded existing lines, it will form a high speed network totalling 32 000 route-km. By October 2010, there were nearly 3 000 km of route available for trains running at 200 km/h or more (Table IV).

Importing technology

The decision to import foreign technology was made after an assessment by the Ministry of Railways of domestic railway technology. This concluded that the general level of railway expertise was 20 years behind countries such as France, Germany or Japan.

On the other hand it was evident that economic growth called for a much higher level of service, which could not be met by using local technology. Even if research resources were poured into the industry, it would still have taken more than 10 years to develop the ability to meet current demand. Not only that, but continued growth would further widen the gap in expectations.

To break this deadlock, a 'market for technology' strategy was adopted. This was based on importing advanced technology, joint design and production, and eventual creation of a Chinese brand-name.

For example, to support the

operation of high speed trains, China needed to develop technology for the construction of ballastless track, a field dominated by suppliers in Japan and Germany. This was achieved by importing the technology and 'internalising' the techniques for domestic production. Four types are in use:

CRT I	Shinkansen	(Japan)
CRT II	Max Bögl	(Germany)
CRT II	Zublin	(Germany)
CRT II	Chinese version	

First high speed train tender

Similarly, the trains developed for high speed services are all referred to as CRH (China Railway High speed). The Chinese name for these trains is He Xie, which can be translated as Harmony or Concorde. The choice of name reflects humans being in harmony with nature by virtue of rail's ability to promote conservation and its environmental credentials. High speed is also a 'technically harmonious' product, with one train consisting of about 12 000 components and 145 subsystems. Production of a CRH train in China calls for the participation of over 120 enterprises from 12 provinces.

The invitation to tender for the first batch of high speed trains was made in June 2004. To be eligible, the bidder had to be a Chinese enterprise, but with the support of a foreign manufacturer with a proven track record in the design and manufacture of trains able to run at 200 km/h or more. The foreign company had to include provision for technology transfer, including the core technology. Firms that responded included Alstom from France, Siemens from Germany, Kawasaki from Japan and Bombardier from Canada.

The Ministry of Railways required the transfer of core technology such as system integration and traction components, including training and partnership in design, manufacture and quality control. For the programme to succeed, it was essential for Chinese engineers to be able to master the core technologies.

In 2008, in order to establish the domestic technology for high speed train production, the Ministry of Science & Technology and the Ministry of Railways consolidated resources from several universities and academic institutions: the Central Science Academy (Academia Sinica), Tsinghua University, Zhejiang University, Beijing Jiaotong University and Southwestern

Jiaotong University.

With this expertise in place, work began on developing China's own high speed trains. Studies embraced basic research, case studies and a range of scientific experiments. The key missions were to:

- 'assimilate and recreate' foreign technology to develop independently the core technology for production of trains able to run at 350 km/h and above;
- establish and improve on the independently developed technology with its own intellectual property rights so as to be competitive in the international market;
- create a chain of innovation and production linkages to make innovation self-sustaining;
- put the innovative technology into production and establish industrial partnerships so as to improve manufacturing capability within China.

The project involved funding to the tune of nearly 1bn yuan, representing the biggest research project ever undertaken by the Ministry of Science & Technology. It covered no fewer than 10 major fields of research and involved 25 top universities, 11 leading research institutions and 51 national laboratories. In terms of personnel, 68 fellows of the Academia Sinica are taking part in the programme, together with more than 500 professors, over 200 other researchers and more than 10 000 engineers and technicians.

The programme led to the development of four major series of CRH trains (Table V). More recently, work has progressed to include the CRH380 series, representing further development of the CRH2 and CRH3 families. The first CRH380A train entered trial service in September between Shanghai and Hangzhou. This train established a Chinese speed record of 416.6 km/h which China claims to be a world record speed for a production trainset.

Clear advantages

China meets all the requirements for high speed railways to be effective. It has a high and concentrated population, a growing economy with rising income, increasing urbanisation, low car ownership and unreliable air travel. All these factors make high speed railways very attractive.

The main criticism of the massive investment is the justification for such heavy spending. For example, there are concerns that the current

level of investment has outpaced economic development. The eight-line Xi-zhong Xi-heng network alone is costing US\$298bn, and it is inevitable that this will siphon funds away from other infrastructure. However, consideration of alternative ways of meeting demand, now and in the future, makes the case for high speed railways over investment in roads, domestic air travel or conventional railways.

When measured against current and future economic trends, high speed rail responds well. There seems little doubt that economic growth will continue, albeit not necessarily at the same pace as in the last three decades. So the demand for domestic travel will rise significantly, and with economic growth comes an enhanced propensity to travel. If it can be afforded, there is a need to build infrastructure ahead of demand, bearing in mind that all transport infrastructure investments entails a long lead time, whether in roads or airports.

High speed rail is also more reliable and more environmentally friendly than building more roads, which encourages the use of cars. Similar considerations apply to air travel. Rail is less dependent on fossil fuels, making it the preferred mode for the future.

The future lies with exports

Having now mastered the various technologies required for high speed railways, including the building of specialised trackforms and the manufacture of rolling stock, China now has the basis for an industry in its own right and the potential to develop future exports.


Governor Arnold Schwarzenegger recently visited Shanghai to seek Chinese support for the high speed railway project in California. That may lie some way in the future, but during a state visit to Turkey in October this year, a Chinese delegation signed an agreement with the Turkish government to build part of the high speed link between Ankara and Istanbul. In the course of time, China will not only be the biggest investor in high speed passenger rail, it will also become the biggest exporter of high speed rail technology. 

Table I. Population of Chinese cities and provinces in [20??]

Province	Population million	Capital	Population million
Hebei	69.9	Shijiazhuang	9.6
Shanxi	34.1	Taiyuan	3.4
Liaoning	43.2	Shenyang	7.4
Jilin	27.3	Changchun	7.5
Heilongjiang	38.3	Harbin	9.9
Jiangsu	76.8	Nanjing	7.7
Zhejiang	51.2	Hangzhou	8.0
Anhui	61.4	Hefei	4.9
Fujian	36.0	Fuzhou	6.8
Jiangxi	44.0	Nanchang	4.5
Shandong	94.2	Jinan	6.0
Henan	94.3	Zhengzhou	7.4
Hubei	57.1	Wuhan	9.0
Hunan	63.8	Changsha	6.6
Guangdong	95.4	Guangzhou	10.3
Hainan	8.5	Haikou	1.8
Sichuan	81.4	Chengdu	11.1
Guizhou	37.9	Guiyang	3.6
Yunnan	45.4	Kunming	6.2
Shaanxi	37.6	Xian	8.3
Gansu	26.3	Lanzhou	3.2
Qinghai	5.5	Xining	2.1
Autonomous Regions			
Inner Mongolia	24.1	Huhehaote	4.0
Guangxi	48.2	Nanning	6.5
Ningxia	6.2	Yinchuan	1.5
Xinjiang	21.3	Urumqi	2.3
Tibet	2.9	Lhasa	0.4
Independent cities			
Beijing	16.9		
Shanghai	18.9		
Tianjin	11.8		
Chongqing	28.4		
Special Administrative Regions			
Hong Kong	7.0	-	-
Macao	0.5	-	-

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Table II. The Xi-zhong Xi-heng network

Line	Length km	Speed km/h
North-South		
Beijing – Shanghai	1 318	350
Beijing – Hong Kong	2 260	350 [check]
Beijing – Harbin	1 700	350
Hangzhou – Fuzhou	1 600	350 [check]
East-West		
Xuzhou – Lanzhou	1 400	350
Shanghai – Kunming	2 080	300 to 350
Tsingdao – Taiyuan	770	200 to 250
Shanghai – Chengdu	1 600	200 to 350

Table III. Target journey time to provincial capitals from Beijing

Within 1 h	Tianjin, Shijiazhuang, Tangshan
Within 2 h	Zhangzhou, Jinan, Shengyang
3 to 4 h	Nanjing, Hefei, Dalian
5 to 6 h	Shanghai, Hangzhou
7 to 8 h	Nanchang, Changsha, Chongqing
8 to 9 h	Guangzhou, Fuzhou, Shenzhen
Within 10 h	Hong Kong

Table IV. Routes available for speeds of 200 km/h or more in October 2010

Line	Average speed km/h
Qinhuangdao – Shenyang (part of Beijing – Harbin)	200
Beijing – Tianjin	230
Ningbo – Taizhou – Wenzhou	220
Wenzhou – Fuzhou	210
Wuchang – Guangzhou	310
Zhangzhou – Xian	310
Fuzhou – Xiamen	200

Classification of lines by speed

Whereas the UIC defines a new high speed line as a railway with trains running at over 250 km/h, or at 200 km/h on an upgraded line, in China lines are graded in five speed categories:

Normal speed	100 to 120 km/h
Medium speed	120 to 160 km/h
Fast speed	160 to 200 km/h
High speed	200 to 400 km/h
Super high speed	400 km/h or more

Table V. Types of CRH train

Type	Chinese manufacturer	Original technology
CRH1	Sifang (Qingdao)	Bombardier Regina
CRH2	CSR Sifang	Kawasaki Series E2
CRH3	CNR Tangshan	Siemens Velaro
CRH5	CNR Changchun	Alstom Pendolino
CRH380	CSR Sifang	CRH2C, CRH3C