High-Speed Rail – The First Three Years: Taking the Pulse of China's Emerging Program

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High-speed rail services have now been operating in China for three years. How are they performing? What has happened to the conventional services they parallel? What has been the impact on the airlines? Little comprehensive information has been published to date but a general picture is emerging in which high-speed rail, as in other countries, is competing strongly on short and medium-distance routes up to 1,000 km while air remains dominant over longer distances. Overall, however, diverted air passengers have not been a major source of high speed rail ridership. A larger source has been 'generated' trips: new trips by passengers who were induced to travel by the greater convenience of high speed service. Based on this evidence and the continuing strong growth in Chinese urban populations and incomes, we are cautiously optimistic about the long-term ridership (and hence economic viability) of the major trunk railways of the high-speed rail network in China. This optimism is tempered by the need to develop a sustainable financing mechanism in the short to medium term and to carefully weigh the costs and benefits of the peripheral extensions of the network.

THE NETWORK SO FAR

China began to operate network-wide 200 km/h services in April 2007 as part of what is known as the Sixth Speed-Up[1] but the first high-speed rail (HSR) service on a dedicated line was the Beijing – Tianjin service opened in August 2008 just prior to the Olympics. Since then, the network has grown to over 6,800 km, with a total of 16,000 km to be completed as part of the long range plan that runs to 2020 (Figure 1).

HSR CONSTRUCTION STANDARDS AND COSTS

The new HSR lines are of two general types: trunk lines, which are passenger-only lines designed to operate at a maximum speed of 350 km/h, and secondary mainlines and regional intercity lines designed with a maximum speed of 250 km/h, some of which are passenger-only and others which can also carry express freight such as container services.

Most lines have a large proportion of tunnel and viaduct (in hilly areas)[2] or elevated structure (in flatter areas)[3], the latter to conserve farmland and minimize severance. The construction cost naturally depends on the proportion of such tunnels and structures but typically ranges from RMB 80-120 million per km (US$13-20 million) excluding stations. Station costs naturally depend on their frequency and scale of construction but can add up to a further 30% for the shorter lines serving major cities.

HSR SERVICES AND FARES

The lines generally operate reasonably intensively, typically an hourly or half-hourly service between 7am and midnight (Table 1), normally with 8-car sets. The main exceptions

[1] A trial 200 km/h section was opened in 2002 between Qinhuangdao and Shenyang which was upgraded to 250 km/h in 2007. These 'speeded-up' services, together with the 250km/h and 350km/h HSR services, are collectively known as the CRH (China Railway High-speed) services.

[2] The 835 km of new construction for the Guiyang - Guangzhou railway has 54% of its length in tunnel and 29% on viaduct and bridges.

[3] The 357 km Shijuazhuang – Zhengzhou section of the Beijing – Guangzhou north-south trunk line has 69% of its length on viaduct and bridges.

Figure 1 Chinese High Speed Rail (HSR) Network as of February, 2012

are lines that have been opened in advance of adjacent sections of the network (such as Zhengzhou–Xian) and so are currently only providing service for local trips.

Table 1 Selected Service Patterns (as of July 2011)

Section	First dep	Last arr	Services /day(1)
Wuhan – Guangzhou	0700	2349	50
Zhengzhou – Xian	0800	2246	12
Changchun – Jilin	0656	2124	28
Beijing – Tianjin	0630	2333	76
Beijing – Shanghai	0700	2327	49
Wenzhou – Fuzhou	0734	2245	27

(1) Per direction; some lines also have services to/from intermediate points

In 2007, CRH services totalled about 40 million train-km per year, all on conventional 'speeded-up' lines. By 2011 this had increased to over 250 million train-km per year, of which 85% was on dedicated lines with a maximum speed of 250 km/h or more. This represents about a quarter of the total passenger train-km operated on the network.

There are national fare scales for the two speeds but in practice HSR fares vary slightly from line to line (Table 2).

Table 2 Economy HSR Fares (as of November 2011)

Section	Economy fare	
	RMB	RMB/km
350km/hr design speed [4]		
Wuhan – Guangzhou	465	0.48
Zhengzhou – Xian	230	0.46
Beijing – Tianjin	55	0.46
Beijing – Shanghai	555	0.42
250km/hr design speed		
Wenzhou – Fuzhou	91	0.31
Changchun – Jilin	32	0.29
Taiyuan – Beijing	149	0.29

For comparison, air fares are typically around RMB 0.70/km, with shorter trips a bit more expensive, and bus trips are about RMB 0.35/km, with sleeper buses slightly more expensive. The lower-speed lines are thus price-competitive with bus while the higher-speed lines are generally cheaper than air except where heavily discounted air fares are offered.[5]

EFFECTS ON CONVENTIONAL RAIL OPERATIONS

Service reductions on conventional lines paralleling new high speed services have in some case been extensive. In the case of the Wuhan – Guangzhou service, in 2007 there were 17 services daily to Guangzhou originating within the Wuhan – Guangzhou corridor (termed 'local' trains for the purposes of this discussion), with a further 42 trains from origins outside the corridor (termed 'through' trains for the purposes of this discussion)[6]. By 2009, these had increased to 23 trains and 47 trains respectively. The distinction is relevant as passengers wishing to travel relatively short distances (for example, from Changsha to Guangzhou) are generally less able to purchase a ticket on a 'through' train than a 'local' train[7]. Following the opening of the HSR line, local trains were reduced to only 6 services, with the through trains increased to 52 services (see table 3).

Table 3 Southbound conventional services into Guangzhou

Section	2007	2009	2011
'Local'			
Wuhan-Guangzhou	6	9	2
Changsha-Guangzhou	12	15	3
Shaoguan-Guangzhou	17	23	6
'Through'			
Wuhan-Guangzhou	21	24	25
Changsha-Guangzhou	25	30	31
Shaoguan-Guangzhou	42	47	52

Table 4 shows comparable figures for three other corridors, showing a general reduction in local trains and some adjustments to through trains in response to the additional capacity.

Table 4 Service changes – other corridors

Section	2007	2009	2011
'Local'			
Zhengzhou – Xian	4	6	0
Shijiazhuang -Taiyuan	1	4	4
Changchun – Jilin	0	6	2
'Through'			
Zhengzhou – Xian	63	58	57
Taiyuan – Beijing	11	9	23[8]
Changchun – Jilin	11	13	10

[4] On opening, the average operating speed of non-stop services on these lines reached as high as 90% of these design speeds. Operating speeds have recently been temporarily reduced by about 12–15 %, apparently to conserve energy and reduce vehicle maintenance costs.

[5] For reference, rail fares on conventional lines range from RMB 0.11/km for the slowest services to nearly RMB 0.30/km for the 200km/h services (almost equal to the cost per km on new 250km/h dedicated track).

[6] For example, a train originating in Beijing and terminating in Guangzhou would be classified as a 'through' train in this corridor, while a train originating in Wuhan (or Changsha, Shaoguan etc) and terminating in Guangzhou would be classified as 'local'.

[7] MOR's ticket quota system generally favors long distance travel at the expense of short-distance trips to maximize network utilization.

[8] Includes several long-distance trains (e.g. Beijing – Wulumuqi (Urumqi) and Beijing - Xian) rerouted to take advantage of the increased corridor capacity.

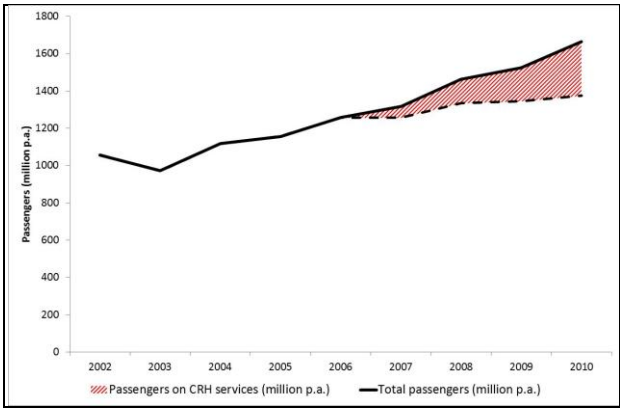
In some corridors, many of the conventional services removed have been overnight express trains. For example, between Changsha and Guangzhou in 2009, 12 'local' trains departed Changsha between 7 PM and midnight. With an 8 to 9 hour travel time, these overnight trains offered a mix of low cost and convenience since on-board hours could be spent sleeping. In 2011, after high speed opening, only 3 such trains departed during the same time period. The removal of these services has been reported in the media as a source of irritation among some passengers.

Another important impact of these service changes is freed-up freight capacity. For example, the 12 conventional passenger services removed from the Wuhan-Guangzhou line will leave capacity for approximately six additional freight services, providing important additional revenue generating capacity to the Ministry of Railways.

RIDERSHIP

Detailed official ridership figures for the HSR services generally are not available but indirect evidence suggests ridership is broadly favourable compared to international experience. In 2010, 290 million passengers (17% of the total carried in China) travelled on services operating at 200km/h (both on dedicated high speed lines and 'speeded-up' conventional lines as described above). The important contribution of these services to overall growth in rail passenger demand since 2006 is shown in Figure 2, where the incremental growth since 2007 is roughly equivalent to the volume currently carried on 200km/h plus services.

Figure 2 Rail passenger demand 2002-10



The first dedicated high speed line to open, from Beijing to Tianjin in 2008 with a relatively short length of 117km, is currently carrying about 25 million passengers per year. The line from Wuhan to Guangzhou (968 km) is carrying about 22 million passengers per year but most of these passengers do not travel the full length of the line. The average density of passenger traffic on this line is about 10 million passengers per year.[9]

The lowest ridership is probably found on the Zhengzhou – Xian and Nanchang – Jiujiang services; both are currently operating as isolated sections of future trunk lines (Figure 1 shows these existing lines and their place in the future network). As the rest of the network is completed, these lines will be able to provide service to a wider range of origins and destinations, helping to increase service frequency and ridership.

A key feature observed in HSR demand to date has been the high level of generated trips, i.e. trips made by those who have been induced to travel by the improved service levels (speed, frequency, reliability, and comfort) of HSR. In the

[9] The average density is derived by dividing the passenger-km by the length of the line in km. For the short Beijing-Tianjin line, where almost all traffic travels end to end, the density is approximately equal to the number of passengers, 25 million. For comparison, the Tokyo – Osaka line carried 141 million passengers in 2010, with an average density of 85 million. The corresponding figures for the Taiwan HSR are 37 million passengers with an average density of 22 million.

case of the Wuhan - Guangzhou line, in 2009 prior to the opening of the new high speed line, the corridor was carrying an estimated 45 million local rail passengers (i.e. those with both origins and destinations within the corridor). In 2010, the first full year of operation of the new HSR line, the estimated total travel on both the conventional and HSR lines was about 55 million, of which 20 million are travelling on HSR.[10, 11] Of these, about 1 million appear to have come from competing air services (see next section) and about 10 million have transferred from conventional rail services. A few have also transferred from bus and car. Based on these estimates, of the 20 million travelling on this HSR line each year, about 50% have transferred from conventional rail, about 5% have transferred from air and 45% have been either generated or transferred from bus and car, with the overwhelming majority of these being generated.

Put another way, for the Wuhan - Guangzhou rail corridor, about 25% of the conventional rail passengers have transferred to HSR while the overall rail market (conventional plus HSR) has increased by about 20%.

The Beijing to Tianjin service shows a similar pattern. Prior to 2008, about 8 million passengers travelled on the conventional rail service each year but this reduced by about 50 percent following the introduction of the HSR services. The bus service is also estimated to have lost about 1 million passengers to HSR. 25 million passengers per year are now using the new HSR line. On this basis, roughly 20 million passengers per year of the current demand either transferred from private vehicles (including minibus) or has been generated. As in Wuhan, the overwhelming majority of these have probably been generated trips. This suggests a conservatively estimated rate of generation of 65% or greater on this line, a dramatic indication of the latent demand for the type and quality of service being offered by HSR.

In the case of the line from Changchun to Jilin, a 111 km HSR line with a design speed of 250 km/hr, an estimated 4 million passengers per year previously travelled between the two cities on conventional rail services. The new high speed line, which opened in January 2011, is estimated to be carrying around 10 million passengers per year. Based on information from intercity bus operators, an estimated 2 million per year have transferred from bus service to the new HSR line. An estimated 1 million per year have transferred from local rail, leaving roughly 7 million per year of the HSR passengers who have either transferred from private vehicles or been generated, for an estimated generation rate of 40-50%.

Despite the high rates of generation noted above, patronage on some of the lines remains substantially below the opening-year forecasts developed in their respective feasibility studies.

One reason for this is that many feasibility studies assumed a wholesale transfer of conventional rail passengers to HSR on opening. Few studies made a realistic allowance for HSR fares being much higher than fares on conventional rail (as described above), and many made a simple assumption that all existing conventional passengers would transfer to HSR. In fact, as mentioned above, using the Wuhan to Guangzhou line as an example, only an estimated 25 per cent have made the transfer. This transfer rate will, however, increase as incomes increase, providing a source of long-term growth for high speed rail ridership.

Another important reason for the discrepancy between forecast and actual ridership is that many feasibility studies assumed that the entire 2020 network would be in place by the opening year of any individual line. In practice, as shown in Figure 1, this final network configuration is still some years off for most corridors and demand will likely build up gradually as the network is

[10] The Wuhan-Guangzhou high speed line opened on December 26, 2009.

[11] Based on ridership growth trends in the corridor, the annual growth in demand would have been about 1.5 million trips in the absence of the new line.

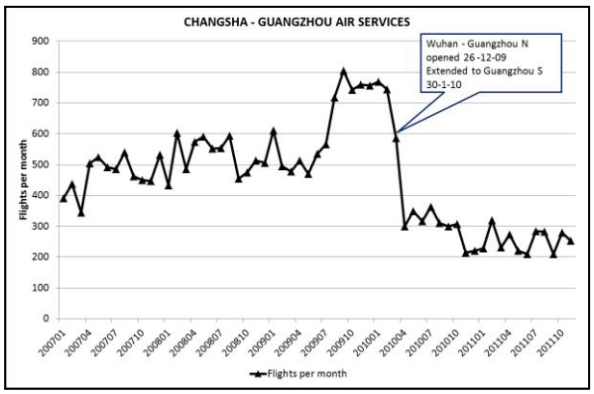
completed, making the 'ramp up' more marked than usual on these lines. For example, the feasibility study for the line from Zhengzhou to Xian estimated that local trips between origins and destinations within the corridor would represent just 20 percent of the total passenger-km on the line. The other 80 percent was represented by longer distance HSR trips – i.e. between destinations beyond either Zhengzhou or Xian – that are not yet possible with the current network configuration.

As the rest of the network is completed, travel between these other origin-destination pairs will become possible by high speed rail, supporting ridership growth on the Zhengzhou-Xian line. A similarly positive 'network effect' will be felt by other lines as the remaining pieces of the network enter into operation in the coming years.

IMPACT ON OTHER MODES

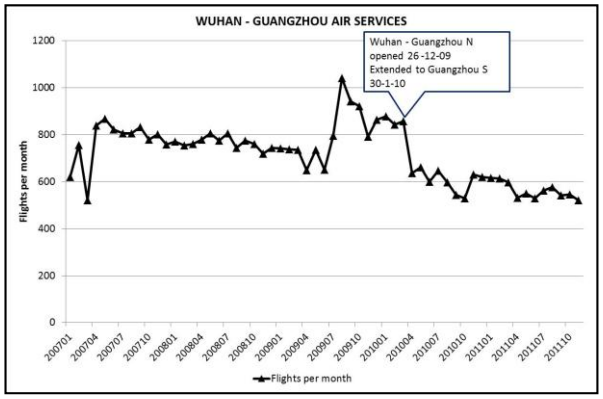
For distances up to approximately 500 km, HSR has had a strong impact on air demand. As has been widely reported, some short-distance air services have been completely withdrawn after an HSR line has opened; air routes from Zhengzhou to Xian and from Wuhan to Nanjing both survived only a few months after the opening of HSR. Figure 3 shows monthly air services (sum of both directions) between Changsha and Guangzhou, a distance of approximately 600km. Passenger demand has reduced from about 90,000 per month prior to the line opening to about 30,000 at the present time and services have reduced from 750 per month to 250 per month.

Figure 3 Changsha – Guangzhou air services



A similar pattern can be seen for the Wuhan – Guangzhou route (a distance of approximately 900km) (Figure 4), although in somewhat less dramatic fashion. Passenger demand has fallen by about one-half, from about 120,000/month to 60,000 per month, while flights have reduced from 900 per month to about 600 per month.

Figure 4 Wuhan – Guangzhou air services



However, this impact appears to die away quite quickly for distances over 1,000 km. The opening of the Beijing – Shanghai line (approximately 1,300 km) has had very limited impact on air travel between the two cities.

In contrast to longer routes where the chief competition in terms of travel speed and cost is air, the main competitors for shorter intercity routes are bus and private vehicles (car and minibus). Systematic volume data for both of these modes is unfortunately not often available but, based on evidence collected from bus service operators, they have often been hard-hit. The competing bus service along the Changchun

to Jilin route described above charges roughly the same fare as the new HSR line but offers a much lower quality of service, and has thus been all but eliminated; the service has reduced from a bus every 5-10 minutes to one or two buses a day, travelling via intermediate towns. The competing bus services along the Beijing to Tianjin route still maintain a significant price advantage over HSR (about half the HSR fare) but nonetheless have not been able to hold onto to their riders, having lost over half their patronage.

FINANCIAL PERFORMANCE

Very little information is publicly available on the financial performance of the HSR network. There seems little doubt, based on experience elsewhere and evidence collected in China, that most lines, except possibly isolated lines like Zhengzhou to Xian and Jiujiang to Nanchang, are covering their immediate cash costs (rolling stock and infrastructure operations and maintenance costs). The next important financial hurdle for any railway is its ability to cover its interest payments on debt, and it is likely that some of the better-performing services (with densities of 10-15 million passengers) are already doing that.

Of course, covering interest payments is not the same thing as making a profit, as depreciation on the capital investment is a substantial cost. However, most of the depreciation is for infrastructure with a very long life. Given the continuing growth of urban populations, incomes, and the overall network, ridership (and hence revenue) growth should continue to ramp up over time. If, in accounting terms, depreciation is deferred now, there should be ample time to close this gap over time for lines that are reasonably well performing.

The final financial threshold for a railway is its ability to repay the principal on its loan. Only a handful of HSR lines in the world have been able to reach this milestone. It seems likely that repayment of principal will ultimately need to be rescheduled in one way or another for all but the busiest Chinese lines. Conventional solutions to this issue include extending the tenor of the loans or sculpting debt repayments to better match the growth in demand over time. Other options include combining lines into a few large groups so that the main lines can support their feeder branches, or providing some funds from the conventional railway to reflect the benefit of the additional capacity which is being made available for them.

SUMMARY

It is now three years since the first high-speed rail line in China opened. The total volume carried is already larger than that on the French TGV services and is rivalling the volume on the Japanese Shinkansen services. It will continue to grow rapidly as the many lines under construction are completed and as urban incomes and population in China continue to rise.

Ultimately, the appropriate time frame to deliver final judgement on the program will be measured in decades, not years. However, evidence accumulated to date provides some key insights.

This evidence suggests that HSR can compete effectively with air at distances up to 1,000 kilometres but that it can gain only a limited share over longer distances. Over shorter distances, it seems able to take almost all the bus market as long as its stations are conveniently located. However, gains from both of these markets have been dwarfed by the size of the new, generated market for rail trips, representing passengers who had not travelled in the corridor before. We estimate approximately half or more of HSR passengers appear to be these new travellers.

This finding is significant, pointing to a large latent demand for the quality of service provided by HSR. These generated trips also suggest that businesses and individuals are already modifying

their behaviour to take advantage of this new mode of transportation, providing some preliminary evidence of the wider economic benefits to be provided by these lines in the long term. Based on these trends and the continuing strong growth in Chinese urban populations and incomes, we are cautiously optimistic about the long-term ridership (and hence economic viability) of the major trunk railways of the HSR program in China.

This optimism is tempered by some significant obstacles that will need to be overcome in the short to medium term. Little data is publicly available on the finances of the new lines but, based on experience elsewhere, even well-performing railways capable of covering their cash running costs and interest on their debt will almost certainly be unable to repay the principal without some long-term financing arrangements. Given the large scale of the HSR investment program, this issue will need to be addressed in the short term. The recent slowdown in construction activity may also provide an ideal opportunity to review the as yet unbuilt peripheral sections of the network, ensuring that they will not create an undue financial burden on the overall network.

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This note is part of the China Transport Note Series to share experience about the transformation of the Chinese transport sector. For comments, please contact John Scales (jscales@worldbank.org) or Gerald Ollivier (gollivier@worldbank.org), from the Beijing World Bank Office.