Dedicated High Speed Rail Network in India: Issues in Development

By G Raghuram, Professor; and Prashanth D Udayakumar, Research Associate; Indian Institute of Management, Ahmedabad, India

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For the development of High Speed Rail (HSR) network in India, there are a variety of issues. Drawing from lessons in HSR experience internationally (which consists of Asia and Europe), this article examines issues with regards to route fixation, location of stations, choice of grade level, choice of technology partner and need for standards, choice of gauge and interoperability of trains beyond core networks, pricing, revenues and funding, and financial viability.

As of April 1, 2015, the total length of HSR networks in the world was 29,792 km. China (19,000 km), Spain (3,100 km), Japan (2,664 km), France (2,036 km), Turkey (1,420 km) and Germany (1,334 km) have more than 1000 km of operational HSR network length. Having proposed as many as nine high speed rail (HSR) routes through Railway Budgets, India is now looking at entering the global HSR club soon.

In December 2015, a *Business Line* article reported that India and Japan signed a memorandum of understanding (MoU) to set up a high-speed route of 506 km between Mumbai and Ahmedabad based on the Japanese Shinkansen technology, costing INR 976.36 billion. Japan would fund $12 billion (about INR 781 billion, providing for about 80% of the project cost) offering a concessional loan to India with a repayment period of 50 years including a moratorium of 15 years, at an interest rate of 0.1%.

Figure 1: 500 Series Shinkansen Bullet Train in Tokyo Metropolis (Reproduced with permission from https://doyouknowjapan.com/)

Issues with HSR in India

For the development of HSR network in India, there are a variety of issues. Drawing from lessons in HSR experience internationally (which consists of Asia and Europe), we examine issues with regards to route fixation, location of stations, choice of grade level, choice of technology partner and need for standards, choice of gauge and interoperability of trains beyond core networks, pricing, revenues and funding, and financial viability. This article is an abridged version of an IIMA working paper with the same title.

Proposed High Speed Rail Service between Ahmedabad and Mumbai: Highlights

1. *Distance between terminal stations: 506 km*
2. *Operating speed: 320 km/hour*
3. *Stations: Mumbai, Thane, Virar, Boisar, Vapi, Bilimora, Surat, Bharuch, Vadodara, Anand/Nadiad, Ahmedabad and Sabarmati*
4. *Duration of travel:*
    a. *Typical Rapid Train: 2:07 hours (Stops at Surat, Vadodara and Ahmedabad stations)*
    b. *Each-stop Train: 2:98 hours (Stops at all stations)*
5. *Project Cost: INR 980 billion (including escalation, interest during construction and import customs duties)*

Source: Joint Feasibility Study, JICA, 2015

1. Route Fixation (Origin, Destination and Intermediate Stations)

Route fixation would include selection of the first route, which should both be an economically viable demonstration route as well as fit into a larger network vision. A distance of about 500 km between two major cities spanning a corridor with good economic development was an attribute of the first route in many countries including Japan, France and Korea. Apart from identifying the origin and destination of the route, the intermediate stations would also need to be decided. Fewer stations would provide for a faster journey time, while traffic catchment and political considerations may result in larger number of stations. Amidst demand to include more stations en-route, a service model consisting of a mix of non-stop trains and trains with stops, as in China, Japan and Taiwan, may be worthy of consideration.

Competition for HSR would arise from air travel (for longer distances, say above 500 km), night travel by conventional rail (say between 500 to 1000 km) and road travel (for shorter distances, say below 200 km). Based on international experience, the sweet spot is often viewed in the 300 to 600 km distance, where there would be an edge over air due to lower access and egress times, and over road and conventional rail due to the possibility of same-day return. The 506 km Mumbai-Ahmedabad segment has been selected as the first route for HSR in India.

A second sweet spot, leveraging the preference for night travel, could be in the 1500-km-plus distance, where there could be high speed trains with sleeping services. Having night travel would conflict with the traditional concept of doing maintenance by night in the HSR. However, it may be possible to explore mid-day maintenance schedules, when there would be a slack in demand.

At a micro-level, given the route choice, the alignment choice needs to consider environmentally-sensitive regions and protected archaeological sites, apart from other reasons that may influence land acquisition.

The prefeasibility report, submitted by RITES along with French Systra and Italian Italferr in 2010, considered the route as Ahmedabad-Mumbai-Pune. The feasibility report submitted by Japan International Cooperation Agency (JICA) in 2015, dropped the Mumbai-Pune link on considerations of viability. Within the Mumbai-Ahmedabad segment, the proposed stations are Mumbai, Thane, Virar, Boisar, Vapi, Bilimora, Surat, Bharuch, Vadodara, Anand/Nadiad, Ahmedabad and Sabarmati with an average interstation distance of 46 km. In this route, the traffic from/to intermediate stations would be a primary demand since air would not be viable choice for them.

Given that the choice of the first segment has been made, an interesting question would be where the second segment should be. Should it be an extension of the first, just connected to the first or an independent economically strong segment? Each would have its own pros and cons in leveraging supply-side and/or demand-side synergies. Of course, whatever be the choice, it would help being part of a master plan.

2. Location of Stations

The HSR stations may be located either in (i) existing railway stations at city centres, (ii) newly built HSR stations at city centres (iii) existing railway stations at the periphery of cities, or (iv) newly built HSR stations at the periphery of cities. To maximise patronage, stations would have to be in the proximity of catchment area and have seamless intermodal connectivity to significant access/egress nodes of other transport modes like conventional rail, metro and bus. To minimise costs, stations would have to capitalise on existing railway stations and optimise land acquisition.

While options (i) and (ii) may be ideal choices form the point of view of the catchment, options (iii) and (iv) would cost lesser and pose fewer problems in terms of land acquisition. While options (i) and (iii) would naturally have good intermodal connectivity, options (ii) and (iv) would need connecting rail/metro/bus services from/to existing railway stations. A long-term advantage of locating at the periphery would be potential expansion of the city and decongestion of the central business district.

At the Mumbai end, option (ii) has been chosen with a proposed terminal at the Bandra-Kurla complex. However, issues have been raised by the Maharashtra government in terms of land utilisation vis-à-vis other competing uses in this high-growth financial district of Mumbai.

3. Ground Level versus Elevated versus Underground

Having a HSR at ground level versus elevated would mean lower cost but would require increased land acquisition and providing crossovers for roads and adequate protective fencing. Ground level divides geographies, putting a cost on those who need access from one side of the alignment to the other. Elevated has implications for aesthetics and dealing with existing structures. Underground has least issues related to land acquisition, road crossovers and fencing, and aesthetics. Existing structures could be an issue but they can be resolved. However, it is the most expensive of the three options. Across all the grade options, population densities, land values and topography will affect costs.

4. Choice of Technology Partner and Need for Standards

Given the state of research and development in India and no HSR experience, it would be essential to go with another country with credible HSR experience as a technology partner. For the first route, Japan has been selected as the partner country. The question now would be the choice for further routes, whether to go with another partner to have technological and commercial flexibility or to wait and watch until the first route stabilises. This would have to be a strategic decision, since it has implications for long-term development.

Standards, pertaining to the rolling stock like maximum operating speed and moving dimensions, and those pertaining to track infrastructure like axle loading, gauge width, power supply systems, and signaling and telecommunications, need to be finalised, again with a strategic perspective.

The maximum operating speed would depend on rolling stock technology, gradient and curve radius of the tracks, use of tilting technology and safety standards. Moving dimensions will have to take into account stability, gauge width and interfering infrastructure. This has implications on carrying capacity, platform structure and catenary structure.

There are different standards of axle loading between Japan and France, with the former taking advantage of lower axle loading with more axles per train, and the latter having a higher axle loading with fewer axles per train, making the train lighter. The former reduces the track cost whereas the latter the rolling stock cost. A ballastless track, though with a higher initial investment, has a lower maintenance requirement, thereby allowing more availability of the track for operations.

For HSR in India, it would be important to choose between the standard gauge (1435 mm) and the broad gauge (1676 mm), the latter being the conventional gauge in India. Most countries with HSR use the standard gauge, including those where this is not the conventional gauge, like Japan and Spain.

The prefeasibility report recommends an Indian broad gauge (1,676 mm) ballastless track system, and rolling stock with a 3,300 mm wide car body and 350 kmph operation speed. The study recommended a minimum horizontal curve radius of 6425 m. It recommended the almost universal 25 kV AC for traction and ERTMS Level 2 for signalling. Major manufacturers of HSR rolling stock like Siemens and Alstom had responded positively to the possibility of developing broad gauge rolling stock. The study also recommended standards that have a full level of technical and operational interoperability with the existing IR network. The feasibility report has, however, recommended standard gauge (1,435 mm) frame-type slab/ballast-less track system, and rolling stock of 3400 mm wide car body and a maximum of 320 kmph operation speed. The Japanese technology provides for a wider rolling stock, even while using the standard gauge which is narrower than the broad gauge.

With a poor safety record, the IR would need to take a big leap to a zero-fatality approach to safety in HSR. Earthquakes and natural disasters would call for well thought-out emergency plans, including restoration of power, track and other critical aspects of the HSR system.

5. Choice of Gauge and Interoperability of Trains beyond Core Networks

In many of the HSR countries, a significant amount of interoperability is enabled through easy transfer between the high speed and conventional trains at many of the stations having both systems, through well connected infrastructure, ticketing and signage.

Adopting the Indian broad gauge for HSR would ensure interoperability of the HSR rolling stock on conventional rail, potentially increasing the catchment for the HSR trains. This would of course raise the issue of whether conventional rolling stock should be permitted on the HSR route, especially if there is scope for increasing capacity utilisation.

Adopting standard gauge would provide more scope for sourcing of rolling stock, through easy acquisition from other countries. In this case, a gauge interchange system which changes the axle width, as in Spain, could help in interoperability. But speeds of trains are affected in those with variable axle technology. Separation of service types by providing dedicated rights of way can improve reliability and capacity.

While the prefeasibility report recommended broad gauge, the feasibility report recommended standard gauge. All countries, except Russia and Uzbekistan that operate on the Russian broad gauge (1,520 mm), use standard gauge.

The feasibility report also points to negative effect on quality of service and increase in rolling stock cost in the case of interoperability between HSR and conventional routes. Some of the mentioned reasons for the study to not choose broad gauge were that the maximum speed on broad gauge is 250 kmph compared to 350 kmph on standard gauge and that development of new rolling stock would be required for broad gauge.

6. Pricing, Service Levels, Revenues and Funding

It would be important to arrive at the optimal pricing keeping in view competitive modes, perceived value of the HSR service, and the ability and willingness-to-pay of different market segments.

HSR operators typically practice revenue-yield-maximisation techniques (e.g. Eurostar, SNCF) through price discrimination, with the possibility of increasing both commercial returns to the operator and benefits to users. Middle-of-the-day journey schedules (off-peak) can charge much lower fares, comparable with those of intercity bus, to induce greater shift from other transport modes and maximise revenue. Given that air travel would still be a tough competitor for the purely-tier-I O-D pairs, routes containing tier-II and tier-III cities with less penetration by air could be a big market.

Service levels are also important in maximizing revenues. Frequency of service is critical and needs to be high. It would be better to have more services with lower capacity than vice versa. Sitting comfort and value-added services including food, phone connectivity and Wi-Fi could discriminate on market segments. Non-fare box revenues through station-related real estate development and commercial services for the rail user would be necessary revenue additionality.

In case that the total revenues do not make the project viable, government subsidies may be required and tied with non-transport benefits, like technology percolation into other domains, economic development, game-changing sense of connectivity, and national pride due to cutting-edge infrastructure, that the project may bring in.

Given the analysis behind financial versus economic viability, the institutional structure may be under a public-private-partnership (PPP) mode or a government-owned engineering-procurement-contract (EPC) mode. Public funds, though limited in supply and cheaper when compared to private capital, have high opportunity cost due to potential use in socially more significant investments.

Apart from the bilateral financing option already being considered on the Mumbai-Ahmedabad pilot HSR route, supplier financing could also be an option. Further, there could be contribution of equity from state governments since economic benefits of HSR accrue to regional areas and tier-II cities. A hybrid project model having (i) EPC at low-interest bilateral funding for the construction phase, and (ii) Operate-Maintain-Transfer (OMT) during the operations phase, can be considered.

The prefeasibility report of Ahmedabad-Mumbai-Pune HSR estimated 12 million passengers per annum in 2021, with pricing of INR 7.00 per km for first class and INR 4.50 per km for second class (75% of seats). The economic internal rate of return (EIRR) of the project on Pune-Mumbai-Ahmedabad route worked out to 12.8%. Findings by SNCF show a low internal rate of return of 2.4% over the life of the Mumbai-Ahmedabad HSR project, with recommendations of at least 50% of government funding and low fares for the route. This necessitates the need for Viability Gap Funding, if the project is implemented under PPP.

The feasibility report has estimated 17,900 passengers per day per direction in 2023 which translates to 13 million passengers per annum, and 31,700 passengers per day per direction in 2033 which translates to 23 million passengers per annum. The study also showed that the fare for HSR in China and Russia ranged from 0.08 to 0.14 USD (INR 4.47 to 7.82) per km. Of alternatives ranging from an average of 2A and 3A conventional rail fare to two times 1A conventional rail fare in India, the study found the 1.5 times 1A rail fare (about INR 6.52 per km) to be the revenue-maximising option. The EIRR of the Mumbai-Ahmedabad route worked out to 11.8%.

7. Financial Viability

One of the key viability concerns of HSR is the traffic generated, either due to shift from other modes, or due to induced travel because of better connectivity. In 2010-11, the modal share of passengers travelling in the Ahmedabad-Mumbai route, including Surat and Vadodara, by road (bus and car), conventional rail and air were 31.3% (15.7% and 15.6%), 66.0% and 2.7% respectively. According to T.S. Ramakrishnan, the annual traffic that the Mumbai-Ahmedabad HSR would attract by 2025-26 is expected to be about 99 million, including those travelling for part of the route, at a revenue-maximising fare of INR 5.00 per km.

Assuming that 20% (apart from the 80% Japanese funding at concessional rates) of the total cost of the Mumbai-Ahmedabad route would be funded by the Government of India (GoI) with an expected 8% annual return during the operational phase, the estimated daily financing costs for the route would be INR 106 million from when the repayment of the loan kicks in. We take this to be the 16th year (till when the Japanese loan has a moratorium), by when the ramp-up of traffic should have occurred. The project cost includes the ‘interest during construction’ for seven years. Over the remaining eight ramp-up years, we assume that there would be enough operating surplus to cover the interest payments. Subsequent to this, the GoI portion is treated as an equity with only interest due, but no principal repayment. Taking an average fare of INR 5.00 per km for the route with intermediate stops and for a scenario of 0.4 operating ratio, we arrive at a daily required ridership of 118,000 passengers (which translates to 43 million passengers annually). At an average of 1000 passengers per train, over 100 services per day (50 per direction) would be required.

The feasibility report estimates for 2033 with a train configuration of 10/16 cars (750/1200 seats) require 52 trains per day per direction. As of 2016, some of the high-traffic HSR routes like Paris-Lyon (409 km), Shanghai-Nanjing (311 km) and Tokyo-Shin Osaka (552 km), though being parts of bigger networks themselves, have more than 85, 300 and 330 trains respectively running every day.

Conclusions

The issues in developing a HSR network in India are complex. Given that India is a developing country, the primary concern is whether the funds for such a project could be better utilised in other domains, including in upgrading conventional rail. However, the Japanese funding to the tune of 80% of the project cost may not be available for other uses. The complexity of the project also arises due a variety of socio-economic implications like land acquisition, rehabilitation, and environmental concerns.

In spite of such complexity, there are many positive benefits and externalities of the HSR which would be useful in India's overall aspirational development. These externalities include technology percolation into other domains, economic development, game-changing sense of connectivity, and national pride due to cutting-edge infrastructure. In such a context, it is a good idea to begin and learn.

The Mumbai-Ahmedabad route is a good choice for the first route, since it connects India's first and seventh most populous cities, with significant economic development in the 500 km corridor between them. The demand of many tier-II cities along this route, which do not have air connection, is a significant part of the demand potential. In terms of future network growth, this segment can be part of further extension to Jaipur and Delhi.

The low cost Japanese financing has been a great catalyst. Though it is a tied funding with significant mandatory procurement from Japan, it cannot do much harm since Japan is at the cutting edge of HSR technology with over 50 years of experience.

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