International Transport Forum

The Economics of Investment in High-Speed Rail

Roundtable Report

OECD

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Executive Summary

From its origin with the Tokaido Shinkansen in 1964, High-Speed Rail (HSR), defined here as new rail lines capable of operating speeds of 250 kilometres per hour or more, has grown relatively slowly over the last 50 years, with the World HSR network as of late 2013 standing at under 22 000 km. However, the network has been growing rapidly in recent years. With the first opening as recently as 2007, China has already an HSR network of almost 10 000 km. with a further 9 000 km under construction (out of a worldwide total of 14 000 km of line under construction).

Given the backdrop of an HSR investment boom, a roundtable was held in New Delhi in November 2013 with the aim of achieving a better understanding of the economics of HSR given the evidence that is emerging from both well established (e.g. France and Japan) and from new HSR (e.g. China) schemes.

At the outset it needs to be recognised that there is a range of HSR systems. It is important to distinguish between largely freestanding systems (such as the Shinkansen in Japan) and systems integrated with conventional rail networks. Integrated options may come in a number of forms, for example, HSR passenger services using classic rail tracks (such as the TGV in France), classic rail passenger services using HSR tracks (such as the AVE in Spain) or a complete mixing of classic and HSR services, including freight on HSR tracks (such as the ICE network in Germany). HSR may penetrate (or at least run close to) city centres using conventional tracks (as in France) or new tracks (as in Japan) or may instead predominantly serve edge of city locations (such as the mainly freestanding systems in China, Chinese Taipei and Korea).

The earliest HSR schemes, in Japan and France, principally tackled the inter-related issues of capacity (as separating fast trains from slow trains can enhance the capacity of rail infrastructure) and speed (with the requirement for rail to compete with air for the day return market on journeys of around 500 km), although promoting national champions in the rail supply industry was also an important factor. More recently factors such as journey time reliability (UK), economic development (China, Chinese Taipei), political integration/centralisation (Spain) and the environment (UK) have emerged as being important. The chosen HSR objectives will affect service design. Where the focus is on speed then the emphasis will be on non-stop services between major business centres around 500 km apart, although in exceptional circumstances there could be scope for night services at much greater distances. Where the emphasis is on other factors, there may be scope for more intermediate stops and for the development of long distance commuting markets.

In both the ex-ante appraisal and ex-post evaluation of HSR, cost-benefit analysis is the dominant methodological tool. Impact tables need to be carefully compiled to identify the relevant incidence groups (which is complicated where the rail industry is both vertically and horizontally separated) and the extent of fiscal and other transfers (particularly relating to changes in revenue, costs, land values and indirect taxation). If distributional issues are important (which they usually are for HSR given concerns that these are ‘elitist’ investments that might be something of ‘a rich man’s toy’) then the results should be presented in terms of market prices rather than resource costs, and the impacts on users segmented by income (or some proxy such as journey purpose).

Evidence from the UK on proposed HSR services, where analysis is based on market prices, suggests revenue may form 30% of gross benefits and rail user time savings (including from improved reliability) may be around 50% of gross benefits. Other important sources of benefit (around 10% each) can be related to reductions in rail overcrowding and wider economic benefits. Benefits from reduced road congestion and environmental betterment are relatively minor. These results are not inconsistent with the resource cost based analysis of HSR investments in Spain. Business travellers appear to be the main beneficiaries of HSR. As a result, key issues include the use of travel time by business users, their income levels and values of travel time savings, and the extent to which business travel will grow over time.

Sources of HSR traffic vary from scheme to scheme and according to the definition of what constitutes generated travel, but evidence from five existing HSR schemes in Europe suggests around 30% of HSR demand is abstracted from air, 30% from classic rail, 15% from road (predominantly car) and 25% is generated. In developing economies, where domestic air markets are not yet mature, abstraction from air will be lower and generation will be higher. For road, abstraction from car may be lower in developing economies but abstraction from bus and coach may be higher.

A feature of HSR is the high capital costs that are required to achieve the grade separation, curvature and gradient needed for high speeds. The costs will be higher where there are high population densities, high land values and unfavourable topography. Given the variety of locations and the types of systems, it is not surprising that these costs may vary from below EUR 10 million per route km (in China) to over EUR 100 million per km (in the UK, for the HS1 approaches to London). It is these high fixed costs that lead to expectation of economies of density – that average operating costs will reduce as usage of the HSR lines increases. Design operating speeds seem to be a key driver of capital costs. In China, increasing speeds from 250 to 350 kph appeared to lead to a near doubling of capital costs per route km.

As with capital costs, there is a high degree of variability in demand for HSR schemes, ranging from below 4 million passengers per annum (Madrid-Seville) to over 200 million passenger per annum (for the Tokaido and Sanyo Shinkansen). Much of this variation relates to urban spatial structure and the spatial distribution of population, but may also relate to fare levels (in relation to both income and to classic rail) and structure (with revenue yield approaches permitting higher load factors than a standardised fare scale), the location of HSR stations and to socio-cultural barriers to travel across national and sometimes regional borders. Most of these factors can be captured by gravity model formulations, whilst abstraction from (for example) air can explained by logistic curves (see Figure 1 in the main text for an example of a logistic curve) based on time (or preferably generalised cost) differences. A feature of many HSR markets is the long term growth in demand, with significant compound annual growth rates (in excess of 2% (Japan) and 8% (Korea)) found over protracted periods (27 years for Japan, 7 years for Korea), although some of this growth will be due to external factors, such as rising incomes and changes in economic structures.

Most HSR services have faced intermodal competition, with competition from low cost, no frills operators in the air, road and sea markets being an emerging feature. Intramodal competition has been less commonplace, either between classic rail and HSR or between alternative HSR services. An exception is Italy where head-on competition between Trenitalia and NTV appears to have led to a 30% reduction in fares, a 45% increase in service and a 30% increase in demand but it is not clear if this competition will be sustainable. High track access charges, which typically account for 25% to 45% of the revenue of HSR operators, can limit the amount of competition that can be sustained within the HSR market.

Two extreme positions on the use of economic analysis to assess HSR schemes may be observed, 'paralysis by analysis', typified recently by the UK and the US where despite a plethora of studies the amount of HSR service in operation is extremely limited, and 'build it and see' typified recently by China and Spain, where there have been large increases in the HSR network, with further extensions under construction. Related to this, a 'step by step' approach to developing an HSR network will permit the staged involvement of private sector funding, whereas a 'big bang' approach will entail a greater reliance on public debt.

A four stage test for HSR investments is suggested. First, does the HSR make a commercial return? If so, arguments concerning HSR being an elitist investment are redundant. Returns can be reinvested in other social projects or the project can be financed and operated by the private sector. However, there seem to be very few HSR schemes that have made a financial return that would pass a commercial benchmark, with the Tokaido Shinkansen (Tokyo-Osaka) and the TGV Sud-Est (Paris-Lyon) being possible exceptions. Of four recent openings in China studied, only one (Jinan-Qingdao) is covering financial costs. These commercial schemes have relatively high levels of first year usage (in excess of 20 million passengers per annum).

Second, does the HSR investment make a social return, based on rail transport benefits only? This is the basis of the social break-even approach developed by Gines de Rus, Chris Nash and colleagues, which postulates 9 million passengers per annum in the first year of operation as a typical break-even threshold. It appears that many, but by no means all, current HSR schemes may achieve this pass-mark. However, this approach is based on an assumption of a pass-mark BCR of 1. With constrained budgets, opportunity costs might mean that a BCR higher than 1 is required, with the UK focussing on 2 as a key threshold until recently, whilst Germany uses 3. This is a tougher test and as a result will require either higher demand levels or non-rail transport benefits.

This leads to a third test, does the HSR make a social return including quantified impacts on other transport systems (air and road) and wider economic benefits? These benefits have been important in establishing the case for HS2 in the UK. However, estimating these benefits requires modelling of the entire transport system (rather than just rail) and there remain great uncertainties as to the magnitude of wider economic benefits (particularly as a result of improved business-to-business connectivity) and the extent to which such benefits are additive.

Lastly, does HSR have social returns when qualitative wider benefits are taken into account? For example, the ex-post evaluations of Madrid-Seville and Madrid-Barcelona (both of which had initial usage levels of 5 million passengers per annum or less) have shown there to be negative social returns which are unlikely to be offset by wider economic benefits. Such, as yet, non-quantified benefits may include the role of HSR in nation building and as a spur to the development of indigenous technology and the modernisation of the economy.

A key metric is the level of passenger demand, with gravity model formulations providing a useful basis for high level strategic forecasts in advance of subsequent detailed modelling estimations. The application of these tests should be consistent and as rigorous for the last HSR investment in a particular nation-state as for the first. This suggests that HSR investments should be considered incrementally at a network level. The best lines should be identified and then the network evolution planned. It seems likely that line extensions can exhibit economies of scale/density, e.g. the extension of the TGV south of Lyon or of HS2 north of Birmingham. However, the development of brand new lines may rapidly exhibit diseconomies of scope. This in turn suggests a step-by-step approach to HSR investment may be more appropriate than a big bang.

Chapter 1

Summary of discussions

John Preston[1]

This paper summarises a roundtable held in New Delhi, India, on the 18th and 19th December, 2013. This roundtable was convened to examine the key factors that drive the costs of High-Speed Rail (HSR) investment and review the economic benefits delivered by HSR services. This summary draws on a series of presentations made to the roundtable including an international review (Nash, 2013a) and national reviews from France (Crozet, 2013a), Japan (Kurosaki, 2013a), China (Wu, 2013a), Italy (Croccolo, 2013), the UK (Nash, 2013b) and Chinese Taipei (Chang, 2013). In addition, a series of presentations surveyed the prospects for HSR in India, including contributions from Singh, Pillai, Goyal, Raghuram and Pal (all 2013), whilst a presentation on Korea (Lee, 2012) and earlier work on HSR (Asian Institute of Transport Development, 2007) were tabled. The presentations and papers can be downloaded at http://www.internationaltransportforum.org/jtrc/RoundTables/2013-High-Speed-Rail/. This report is also informed by introductory remarks made by Montek Singh Ahluwalia of the Planning Commission of the Government of India, Mallikarjun Khan of the Indian Railways, and K.L. Thapar of the Asian Institute of Transport Development.

In the rest of this introductory section we will outline what is meant by HSR for the purposes of this roundtable and set out a very brief history. We will then in section 2 outline some of the key objectives of the roundtable. In section 3 we will consider the related issue of the key objectives for HSR investments. The kernel of this paper will focus on the cost and benefits of HSR (section 4), including consideration of demand impacts, costs, benefits and pricing and competition. The conditions for financial and social break-even will be considered in section 5 and funding issues examined in section 6. The Indian context will be considered in section 7, before some conclusions are drawn in section 8.

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1. Introduction

HSR services as we now know them originate with the Tokaido Shinkansen opened in 1964, followed by the Direttissima in Italy in 1977 and the TGV Sud-Est in France in 1981 (Nash, 2013a). Germany joined the HSR world in 1988 with the opening of the line between Fulda and Wurzberg, whilst Spain joined in 1992 with commencement of AVE services between Madrid and Seville. In Asia after Japan, HSR service commenced in Korea in 2004 and in Chinese Taipei and China in 2007. By November 2013, the UIC estimated that the World HSR network was 21 472 km, of which almost 7 400 km was in Europe and over 13 700 km was in Asia. China‘s rapid development has given it the largest national network at 9 867 km; followed by Japan (2 664 km), Spain (2 515 km),) and France (2 036 km)[1]. A further 13 964 km are under construction, led by China (9 081 km), Spain (1 308 km), Japan (779 km) and France (757 km), with Saudi Arabia (550 km) expected to join the HSR 'club' in 2015.

Although there is no single definition of HSR services, the most commonly cited is that used by the European Commission in Directive 96/48 (CEC, 1996). This defines HSR services as being provided on dedicated, new lines with the infrastructure capable of operating speeds of 250 kilometres per hour (kph) or more – often up to 350 kph. In addition, services capable of 200 kph or more on upgraded existing lines are classified as HSR. The roundtable focused on case studies of dedicated lines, whilst recognising the intermediate option of upgrading existing lines may be particularly pertinent in some countries.

Even where dedicated infrastructure is provided, it is important to distinguish between largely freestanding systems (such as the Shinkansen in Japan) and systems integrated with conventional rail networks. Integrated options may come in a number of forms, for example, HSR passenger services using classic rail tracks (such as the TGV in France), classic rail passenger services using HSR tracks (such as the AVE in Spain) or a complete mixing of classic and HSR services, including freight on HSR tracks (such as the ICE network in Germany) (see also Campos et al., 2009). The roundtable noted that the primary focus of HSR was to serve long distance business and leisure travel markets, with distances between major origin and destination pairs of at least 200 km and often much more (with 500 km being suggested as a typical distance)[2]. However, it was noted that where there was spare capacity, then regional commuting services (typically serving markets less than 200 km apart) may be important. For example, this is a feature of HS1 in the UK, where Kent commuter services are able to use the capacity not required by international services.

Another important distinction with respect to HSR services is the extent to which stations are located near city centres versus edge of city location. The dilemma of where to site stations goes back to the first HSR line, the Tokaido Shinkansen, opened in 1964 with Shin Osaka station some 3 km from the more central Osaka station. Off centre stations may assist in the expansion of the Central Business District and establishment of new business districts – a feature of both Lyon Part-Dieu and Euralille in France. Most HSR lines have attempted to gain access to the central areas of the major cities served, but with out of town stations serving smaller intermediate locations. Examples in France include Aix, Avignon, Belfort-Montbéliard, Besançon, Le Creusot, Macon-Loché and Valence. This reduces the cost of providing service to towns of 100 000 population or less. In France, such towns typically have a service of only three trains per day, increasing to five where there is a population of 200 000 and to ten or more for larger settlements (Crozet, 2013b). However, there are also systems that focus on edge of city locations – a feature of the systems in China, Chinese Taipei and Korea.

Another important issue identified by the roundtable, that should be dealt with up-front, relates to the approaches to planning HSR investments, with a contrast at the extremes between those systems where there was relatively little ex-ante analysis (characterised as a 'build it and see' approach, and believed to be typical of China and Spain) and those systems that have not yet been built which might be characterised as having had too much analysis ('paralysis by analysis'), perhaps the case of both the UK and the US (see Preston, 2012, and Perl, 2012). In part, this may reflect differences between the planning regimes in countries with common law codes, such as the UK, the US and India, and civil law codes, such as continental Europe. What constitutes the optimal amount of analysis, both ex-ante and ex-post, is of more than academic interest. With respect to ex-ante analysis, it might be expected that, at least up to a point, greater expenditure on analytical studies will lead to more accurate forecasts and hence lead to more robust decisions as to whether and when to invest in HSR and to help determine the optimal combinations of infrastructure, services and prices. However, there will come a point where more sophisticated approaches may involve more measurement error, which reduces the benefits from reduced specification error (Alonso, 1968). The roundtable seemed to concur that there may be a happy medium between the two approaches to ex-ante analysis highlighted above, but also noted that the ex-post evaluation of HSR is particularly limited, with the exception of France, and that such evaluation may be particularly important in improving the planning cycle.

2. Objectives

Given the above, the primary aim of the roundtable was to achieve a better understanding of the economics of HSR. This in turn leads to a number of secondary objectives. First, to determine what HSR is for. What is it good at? What is it irrelevant for? These issues will be considered in section 3.

Secondly, there are a series of objectives related to determining the costs and benefits of HSR, considered in section 4, and the financial and social break-even points, considered in section 5. Have some lines been profitable – showing a commercial return on investment? If so, under what conditions is this possible/likely? Where not possible, which non-commercial lines show a social return? What conditions need to be fulfilled? Which lines have proved a net loss in terms of socio-economic welfare, and are there as yet unquantified benefits that might offset these losses? Does competition (such as the current head-on competition between HSR services in Italy) change the outlook for costs and benefits?

Thirdly, as well as issues concerning economic efficiency, there are important issues concerning equity – the distributional effects of HSR investments. HSR has sometimes been criticised as 'a rich man's toy' – but who benefits from public support for HSR?

Lastly, the wider context needs to be considered by examining the rationale for spending public money on HSR instead of other transport investments, including investments in conventional rail, roads and airports. There is also the issue of very large transport investments such as HSR competing against investments in, for example, education, health care and housing. This was perceived to be particularly important in a developing country context.

3. The role of high-speed rail

HSR has multiple objectives (see Table 1.1), although the dominant rationale has been the perceived twin benefits of speed and capacity, which are inter-related attributes. Capacity and speed (to assist in competition with air) were the main drivers behind the development of the original HSR, the Tokaido Shinkansen. With average operating speeds (as opposed to top operating speeds) of around 250 kph, HSR can bring settlements 500 km apart within two hours of each other and hence within scope for return travel within a day. Moreover, it means that rail can compete with air for city centre to city centre travel over such distances and beyond e.g. Paris-Marseille (over 750 km) – indicative of a three hours journey time threshold. However, this rationale has been criticised. Crozet (2013b) highlights the concept of effective speed, associated with, amongst others, Illich (1974). This modifies speed to take into account the cost of speed in terms of the fare per km divided by the average hourly wage rate.[3] This indicates that ultra-fast but also ultra-expensive transport, such as Concorde, has a very low effective speed and as a result experienced commercial difficulties. It is conceivable that HSR could exhibit similar features where fares are based on full cost recovery and where hourly wage rates are low. The other main criticism of speed is that, given a constant travel time budget (which is itself contentious,) the resultant time savings will be dissipated in terms of longer journeys rather than more economic activity (Metz, 2008). A counter-argument is that higher speeds and longer journeys will permit better matches (of workers with jobs, of businesses with customers) that will increase both the quantity and quality of activities and raises productivity.

As noted, capacity was one of the main motivations for the Tokaido Shinkansen, as the existing narrow gauge railway between Tokyo and Osaka was heavily congested. The new standard gauge line would permit larger rolling stock but more crucially would permit the separation of fast and slow trains as service homogeneity is a key factor in determining line capacity (UIC, 2004). Moreover, separation of service types by the provision of dedicated rights of way for fast services can improve service performance in terms of reliability and has been an important motivation in developments in Italy and the UK (particularly for HS1, which replaced high-speed trains initially operating on conventional lines) (Nash, 2013b). In China, it is intended that the capacity freed-up on the classic rail system would be taken up by freight.

There are also non-transport reasons for the development of HSR. Technological development policy may aim to promote the rail supply industry (and the potential for exports). This was a feature of the early developments in Japan and France and led to the emergence of national champions such as Hitachi and Alstom respectively. National prestige is also an important motivation, for example in China where HSR development was an integral part of recent Five Year Plans, whilst political integration/centralisation has arguably been the main motivation for the HSR network in Spain (Albalate and Bel, 2012, Bel, 2012).

Table 1.1. **Objectives of HSR schemes**

	France	Japan	China	Italy	UK	Chinese Taipei	Spain
Speed	✓	✓	✓	✓	✓	✓	✓
Capacity	✓	✓	✓	✓	✓(HS2)	✓	
Reliability				✓	✓(HS1)		
Econ. Development			✓		✓	✓	
Environment					✓(HS2)		
Supply Industry	✓	✓	✓				✓
Prestige	✓		✓	✓			✓
Political Integration			✓				✓

Economic development is also an important objective of HSR. The key intention of HSR in Chinese Taipei was to unlock development lands at the edge of existing urban areas (Chan, 2013). China's investment in HSR can be seen as a form of Keynesian pump priming at a time when growth rates in other sectors of the economy were declining (Wu, 2013a). In the UK, the arguments for HS2 (described as an 'engine for growth') moved away from transport issues towards wider economic benefits, both in terms of connectivity to labour markets (and hence promoting agglomeration economies) and connectivity between businesses and consumers (thus reducing imperfections in competition transport using sectors of the economy, as well as promoting agglomerations through better business linkages). The argument is now shifting back to capacity and the potential to liberate tracks for the expansion of overcrowded commuting services to the country's major cities.

Environmental betterment is also seen as an objective of HSR. For example, in the UK the key objectives of transport policy are currently creating (economic) growth and cutting CO_2 emissions. However, faster rail services necessarily entail greater energy consumption, and where electricity generation is carbon intensive this also means greater carbon emissions than for conventional rail, although this can be offset by increased load factors and improved train design. Moreover, the construction of HSR lines can be carbon intensive. For example, Booz Allen Hamilton (2007) estimated that taking into account construction adds around 35% to the CO_2 emissions that result from operation in a UK context. Kageson (2009) concludes that though investment in high-speed rail is under most circumstances likely to reduce greenhouse gases from traffic compared to a situation when the line was not built, the reduction is small and it may take decades for it to compensate for the emissions caused by construction. Where HSR attracts large volumes of patronage from air and car, then it is feasible that it will lead to net environmental betterment, at least with respect to CO_2 emissions. Where such abstraction is limited, the converse is likely to be true.

The perceived combination of transport and non-transport advantages of HSR may lead to the setting of targets for HSR development. For example, the European Union Transport White Paper of 2011 (European Commission, 2011) set targets of completing the European HSR network by 2050 and tripling the length of the existing high-speed rail network by 2030[4]. In addition, by 2050 the majority of medium-distance passenger transport in Europe should go by rail (where medium distance refers to inter urban trips of less than 1 000 km) according to the Commission. However, the objective basis for these targets is not clear.

4. The costs and benefits of high-speed rail

Table 1.2 outlines a (simplified) schema for the analysis of the costs and benefits of HSR investments. The original HSR schemes in Japan and France were developed under the auspices of vertically integrated and publicly owned national rail operators, but with separate accounts from other Government activities. In this simple schema, we assume a single rail operator and a single Governmental body but recognise that reality will be more complex. Where the rail markets is both vertically and horizontally separated (as in the UK), a more atomistic (and hence complex) schema is required. It is interesting to note that in Japan, vertical separation in the form of the Shinkansen Holding Corporation (SHC) was relatively short lived (1987-91), with the pre-1987 lines re-instated to the rail operators, although new Shinkansen lines that are not expected to show a commercial return have been developed in a vertically separated manner. In Europe, since Directive 91/440, vertical separation (at least in terms of organisation, if not always in terms of ownership) has become the norm. In some jurisdictions, it may be necessary to distinguish between central and local Government. For example, in Japan since 1996 central and local Government must bear the financial burden of the new, non-commercial projects designed to promote regional development by a ratio of 2:1 (Kurosaki, 2013b). As HSR networks expand, it is likely that regional governments will play a greater role in the development of HSR – a phenomenon that is evident in France.

Table 1.2. **The cost and benefits of high-speed rail**

Incidence Group	**Costs**	**Benefits**
Rail Operator	Construction Costs Operating Costs	Increased Operating Revenue Increased Other Revenue (Grants & Subsidies)
HSR Users	Higher (net) fares	Faster services More reliable services More comfortable services (Indirect tax reductions)
Other Transport Users		Congestion relief on competing rail, road and air services.
Other Transport Operators	Reduced Revenue	Reduced Operating Costs Reduced Capital Investments
Government	(Grants & Subsidies) (Indirect tax losses)	
Wider Society	Noise and Vibration Land take Visual intrusion Shadow price of public funds	CO_2 emissions reductions Accident reductions Additional wider economic benefits

Note*:* Fiscal transfers between Government and other groups identified in brackets. Revenue will also have a transfer element and this needs to be taken into account.

For rail operators, the key costs relate to construction and operation. For a horizontally integrated rail operator, operating costs will include adjustments to classic rail services. A rail operator may receive support from Government in terms of capital grants and (less commonly) operating subsidies, although these are pecuniary transfers (and do not, therefore, have a direct effect on GDP, welfare or the results of CBA)[5]. In cases of public ownership, the support may take the form of the write-off of historic debts. This may reflect general support for the rail system and hence attribution to HSR is difficult and depends on accounting conventions.

For rail operators, the key benefit comes in the form of increased revenue from fares but may also come from other sources, in particular commercial developments in and around HSR stations. However, fare revenues need to be treated with caution (Sugden, 1972). Fares are a transfer between rail users and operators, but if we are concerned with the distributional impacts of HSR these transfer should be highlighted. Furthermore, HSR revenue abstracted from other modes is also a transfer and ideally should be highlighted as such, along with the reductions in operating costs and user benefits of these other modes. Typically, rail revenue is expressed as the net increase over the classic rail system, with the operating cost reductions of the classic rail system (and the impact on user benefits) also taken into account. For other modes (air, car, coach) the usual assumption is that these are perfectly competitive markets and that the HSR revenue gains from these modes reflect the reductions in capital and operating costs that take place, with no impact on the benefits to remaining users of the rival modes. A similar assumption applies to generated revenue. An alternative approach is to directly estimate the cost reductions of the other modes or the increase in government support for such modes where they are state controlled (e.g. Alitalia).

HSR users may be expected to pay higher fares than classic rail services, and a substantial proportion may be expected to be abstracted from classic rail. HSR fares may also be expected to be higher than coach fares. HSR fares may be lower than air fares (although this may not be the case where low cost carriers are present) and lower than out-of-pocket motoring costs where tolled motorways are the norm. However, intermodal comparisons may be distorted by indirect taxation. In particular motoring is usually more highly taxed than rail travel, whilst in some countries (including India, where there is a jet kerosene tax) air travel is also more highly taxed.

HSR users benefit from the increased reliability, speed and comfort of services and, despite likely increases in out-of-pocket costs, generalised costs of travel will have reduced, both for abstracted traffic and for generated traffic, with the resultant changes in benefits often estimated by the rule of half[6], although more precise estimation techniques (such as numerical or direct integration) are preferable.

Overall, it may be expected that there are benefits to other users of the transport system, largely due to congestion relief. On classic rail, where there is latent demand, released capacity may permit enhancements to commuter and regional services, increasing frequencies and reducing overcrowding. Some paths may also be released for rail freight services. However, where large amounts of classic rail demand is abstracted by HSR, there will be reductions in the frequency of classic rail services, possibly initiating a spiral of decline. Intermediate stations may particularly suffer reductions in service, as initially occurred in the cases of Arras and Dijon in France. On the road system, there may be reduced congestion due to some modal shift to both HSR and classic rail services. For air services, there will be reductions in directly competing air services, to the disadvantage of remaining air travellers. However where hub airports are congested, reduced short- and medium-haul services will release slots for long-haul flights. Where airport slots are not allocated using market mechanisms, this may even lead to commercial gains. Furthermore, HSR can be a complement to air services, where hub airports are connected to the HSR network as in the case of Amsterdam, Frankfurt and Paris (Charles de Gaulle) and this in turn may reduce land-side congestion at these airports. In certain circumstances, avoided expenditure on air and road systems as a result of HSR investments may be considered a benefit. An issue here is whether the analysis focuses on the rail network or the wider transport system. Although preliminary analysis might focus only on the rail network, it is advisable that more detailed analysis covers the whole transport system.

Governments may be expected to be adversely affected where grants and subsidies are required and where there are reductions in the indirect tax take, as a result of the switch of traffic from heavily taxed road (and in some instances, including India, air) to more lightly taxed rail.

Costs and benefits to wider society may be classified in three categories. Environmental benefits may relate to reductions in emissions of carbon and other air pollutants but there may be issues along HSR routes with respect to noise and vibration, land take (and the impacts on biodiversity and on water courses), severance and visual intrusion. The main social impact is related to the likely reduction in accidents as a result of the transfer of traffic to HSR, which has an excellent safety record. Although some of these benefits accrue to transport users, the majority may be seen as accruing to wider society. Finally, there are economic impacts. A key feature of these is that they should be additional. Changes in patterns of economic activity may be redistributive rather than generative, although this redistribution may have benefits when it leads to more regionally balanced patterns of economic development. Changes in land values may similarly be redistributive rather than generative, with increased values close to HSR lines at the expense of locations further away. Moreover, these changes in values may be simply downstream manifestations of the changes in the generalised cost of travel and hence changes in accessibility, so to include them would be double counting unless HSR has reduced imperfections in land markets. Another economic impact is the shadow price of public funds, which largely arises due to distortion effects on the economy of taxation, particularly on incomes. In the UK, this deadweight loss might be equivalent to 20% of Government support, in France (with a higher tax regime) the figure may be more like 30%.

In developing the cost benefit schema, it is important to recognise transfers, particularly if distributional effects are a concern, and to avoid double counting (see, for example, Mohring, 1993).

Demand levels

A key factor in any cost-benefit analysis will be the level of demand for HSR services. An issue here is the unit that should be used. The most common unit is the number of passengers per annum. However, this does not take into account trip length, in which case passenger kms per annum is a better measure. Kurosaki (op cit.) posits traffic density (passenger kms divided by route kms) as a key measure for particular routes.

Table 1.3 summarises evidence presented at the roundtable on the demand for some 34 HSR services, or groups of services for a variety of dates, with demand growth over time presented for five services, making 39 observations overall. The mean annual demand level for these 39 observations is 29.2 million, but with a standard deviation of 37.1 million, which emphasises the highly variable nature of the demand for HSR systems. The highest level of annual demand is 207 million for the combined Tokaido and Sanyo lines in Japan in 2011, which compares to 128 million recorded in 1984. The lowest level of annual demand is less than 4 million for the Madrid – Seville AVE service (Nash, 2013c).

There is some evidence of strong growth. Three groups of lines in Japan appear to have had strong demand growth between 1984 and 2011 of 94%, representing compound annual growth of 2.5%, In Korea, demand grew by 76% between 2004 and 2011, representing compound annual growth of 8.4%[7]. Data presented by Chan (2013) for the Chinese Taipei HSR indicates a mean annual usage since opening in 2007 of around 37 million, but with current usage levels indicating 45 million trips per annum. An issue here is the extent to which this demand growth would have occurred anyway (e.g. due to general increases in population and income or structural changes in the economy) and the extent to which the growth has been stimulated by HSR (e.g. due to changes in land use and activity patterns). A further issue is when the 'equilibrium' level of demand is achieved. HSR will have a take-off curve like any other new product. Nash (2013c) implies that this ramp-up effect takes around six years. This is substantially longer than the 2.5 years postulated for new inter-urban rail services by Preston and Dargay (2005) and is an area that is worthy of further investigation as more data on HSR services emerges.

Table 1.3. **Evidence on HSR demand**

Source	Line/ City Pair)	Level of Demand (mpa)	Year
Nash, 2013c (Table 3.2)	TGV Sud Est	19.2	1987 *
	TGV Atlantic	29	1995 *
	TGV Nord	20	1994
	TGV Connexion	16.6	2000 *
	TGV Rhone-Alpes	18.5	1995
	TGV Mediterrane	20.4	2001
	Madrid Seville	3.6	1998 *
	Madrid Barcelona	5.4	2009
	Tokyo-Osaka	80	1970 *
	Seoul-Busan	28	2010 *
NAO (2012) (In Nash, 2013c)	HS1 International	9.7	2011
	HS1 Domestic	8.4	2011
Kurosaki, 2013b (Table 2 and inferred from Table 5[8])	Tokaido & Sanyo	128.3 (207.4)	1984 (2011)
	Tohuku	24.1 (76.1)	1984 (2011)
	Joetsu	11.3 (34.8)	1984 (2011)
Wu (2013b)	Hefei-Nanjing	21.3	2012
	Beijing-Tianjin	21.0	2012
	Qingdao-Jinan	28.0	2012
	Shi-Tai	22.6	2012
	Hefei-Wuhan	11.0	2012
	Coastal HSL	15.1	2012
	Wuhan-Guangzhou	19.7	2012
	Zhenghou-Xian	5.8	2012
	Chengdu-Dujiangyan	4.7	2012
	Shanghai-Nanjing	29.2	2012
	Shanghai-Hangzhou	28.3	2012
	Nanchang-Jiujiang	30.2	2012
	Changchun-Jilin	8.4	2012
	Hainan East Circle	6.4	2012
	Beijing-Shanghai	24.8	2012
Croccolo and Violi, 2013b.	Italy HS Network	Over 12.1	2012
Chan, 2013	Chinese Taipei HSR	36.6	Average 2007 – 13
Jun, 2013	G-Line (Gyeongbu)	22.2 (39.1)	2004 (2011)
	H-Line (Honam)	4.2 (7.3)	2004 (2011)

* Equilibrium demand approximately six years from opening.

Wu (2013b) presents patronage data for some 15 HSR lines in China, although it should be noted that these are based on traffic density rather than patronage per se. This will underestimate patronage where there is substantial intermediate traffic. The mean demand for these lines is 18.4 million (some 36% lower than the overall mean for all countries) but the standard deviation is also much lower (at 8.9 million). HSR demand in China has been dampened by fares that are relatively high as a proportion of income (and hence HSR has a relatively low "effective speed") and are relatively high compared to classic rail (often three times higher). It should be noted that some of the Chinese lines in Table 3 are segments of bigger schemes and demand may be expected to be higher when the whole scheme is completed.

The variation in HSR demand can be explained by the standard gravity formulation, which has been used in this context by SDG (2004) and by SNCF (see Crozet, op cit.). It may be expressed as follows:

$$T_{ij} = K\, A_i\, A_j\, R_{ij}^{-\varepsilon}$$

where:

T_{ij} is the number of (HSR) trips between zones i and j;

$A_{i(j)}$ is the attractiveness of zone i (j);

R_{ij} is a measure of repulsion between zones i and j;

ε is the elasticity of demand with respect to the repulsion factor;

and K is a constant.

The gravity model may be either mode specific or refer to all travel, with a mode split model (usually based on a logit curve) then used to determine HSR shares (see also Figure 1). Attraction measures are normally based on population, but ideally these would also take into account income (by using city GDPs, or an equivalent measure). Repulsion measures are usually based on distance or journey time, but ideally should be based on generalised cost that also takes into account out-of-pocket expenses and income levels. The relatively low levels of demand to date for HSR in China may reflect low income and high fares, but may also reflect the fact that services are new and insufficient time has elapsed for services to build-up. Station location, typically out of town in areas earmarked for new development, is also a factor. National and regional borders can have an important effect on supressing demand. This is partially the explanation for demand on the international services using HS1, the Channel Tunnel link in the UK, being 30% below even the most recent forecasts, with border security arrangements preventing some potential services to intermediate stations being offered. The high degree of regional autonomy in Spain may partly explain the relatively modest levels of usage of AVE services, although the urban spatial structure and spatial distribution of population are more likely factors.

Table 1.4 shows a typical logistic curve that may explain the market shares between rail and air in terms of the travel time excess of rail over air – the key threshold journey time difference appears to be two hours (consistent with an absolute rail journey time of around three hours that permits a return journey within the same day). One of the main outliers is for Madrid – Barcelona (2010) which is below the curve after the introduction of HSR. This might suggest that other factors may be important on this route, including competition from air in terms of frequency and price.

Table 1.4. **High speed rail / air market share**
(Crozet, 2013b)

Line	Market share (train/air)	Shortest journey time	Distance in km	Max speed	Average speed	How many return journeys	Average journey time
Stockholm-Gothenburg	60%	02:45	455	200	165	16	03:00
London-Paris	71%	02:20	470	300	201	19	02:25
Paris-Strasbourg	80%	02:17	475	300	208	16	02:20
Paris-Lyon	90%	01:57	409	270	210	24	02:00
Paris-Marseille	50%	03:02	769	300	254	17	03:20
Hamburg-Frankfurt	40%	03:19	517	250	156	17	03:35
Cologne-Frankfurt	95%	01:03	180	300	171	21	01:15
Hannover-Munchen	40%	04:15	625	250	147	17	04:20
Madrid-Seville	81%	02:20	471	300	202	23	02:35
Madrid-Barcelona	50%	02:38	621	300	236	26	03:20
Rome-Milan	58%	02:59	632	300	212	27	03:30
Tokyo-Osaka	80%	02:26	515	270	212	136	03:00
Osaka-Fukuoka	80%	02:35	554	300	214	90	03:00
Tokyo-Sendai	100%	01:42	325	275	191	64	02:00

Source*:* Trafikverket, International external analysis, High speed rail project, September 2010, Sweden, www.trafikverket.se.

Table 1.4 refers to day travel. There may be a threshold for overnight travel of around ten hours. There may be some origin-destination pairs that might fall in this range e.g. New Delhi-Chennai (2 176 kms by the Chennai Rajdhani Express) and Beijing-Hong Kong (2 475 kms), although the huge capital costs of construction could only be justified if there was also significant intermediate day time traffic. This hypothetical market would generate a second peak, off to the right of the graph. For intermediate journey times passengers may prefer overnight services on conventional rail (as appears to be the case in China) as well as air.

It is important to note that market share between rail and air will also be a function of fare levels and, importantly, structure. Where HSR operators practice revenue yield maximisation techniques (e.g. Eurostar, SNCF) then the fill-up approach will boost market share, whilst also maintaining a high average fare through price discrimination, with the possibility of increasing both commercial returns to the operator and benefits to users.

Costs

Nash (2013b) notes the wide range of construction costs of HSR lines (see also Table 1.5), with the lowest costs being achieved in France, Spain and China (although some lines on the eastern seaboard of China have been built on expensive raised viaducts) and the highest costs being recorded in Chinese Taipei and in the UK.

Table 1.5. **Construction costs per route km of new high-speed lines**
(Million Euros, 2005 prices)

Belgium	16.1
France	4.7 – 18.8
Germany	15.0 – 28.8
Italy	25.5
Japan	20.0 – 30.9
Korea	34.2
Spain	7.8 – 20.0
Chinese Taipei	39.5

Source: Campos, de Rus and Barron, 2009 (in Nash, 2013c).

If the data in Table 1.5 are treated as 12 independent observations, this suggests a mean cost of almost EUR 22 million per route km, with a standard deviation of EUR 10 million. Nash notes that the lowest costs are achieved for passenger only HSR lines, as in France and Spain, with gradients up to 3.5% permitted. By contrast, gradients on mixed traffic lines are not normally more than 1.5%.

Evidence from elsewhere is similarly mixed. NAO (2012) reports that, in the UK, the out-turn construction costs of HS1 (excluding station fit-outs and a new depot) were GBP 25.9 (EUR 31) million for Phase 1, rising to GBP 96.9 (EUR 117) million for Phase 2 (that included 21.5 km of tunnel out of 39 route km). The construction costs for HS1 in its entirety (including stations and depot) was GBP 54.5 (EUR 66) million per route km.

At the other extreme to the UK, Wu (2013b, Appendix 2) reports on the construction costs of HSR lines in China. For the 12 schemes with design speeds of 250 kph, a mean construction cost of EUR 8.8 million per km is found (2010 prices).[9] For the 10 schemes with design speeds of 350 kph, an average construction cost of EUR 16.5 million is reported, almost 90% higher.[10] Wu notes that the split between infrastructure, superstructure and land/other costs are typically 60:20:20, with station costs adding an additional 10% to 30%.

Aside from design operating speeds and gradients (which are inter-related), another key cost driver is population density. This will impact on land costs but will also increase requirements in terms of bridges, viaducts and tunnelling. Topography is also important with costs higher in mountainous terrain (as in Chinese Taipei, where over 76% of the route is elevated and 14% is in tunnel). Nash (op cit.) notes that central area access is a key issue. Where this is provided by existing rail rights of way, as in France, HSR costs may be relatively low. Placing classic rail operations underground as for the RER in Paris, Crossrail in London or the S-bahn systems in Germany, may be one way of releasing rights of way for HSR. Where new rights of way need to be established, as for HS1 in the UK, HSR costs will be correspondingly higher.

In terms of operating costs, HSR has higher energy and maintenance costs than classic rail, but the high speeds lead to high utilisation of rolling stock and accompanying staff, thus offsetting these costs. There may be some trade-offs between construction and operating costs. Compared to conventional ballasted track, concrete slab track may be expected to have higher construction costs but lower maintenance costs, but also greater carbon intensity (Lee et al., 2008).

An important issue is the extent to which HSR construction costs are increasing over time. On the one hand, economies of experience and technological advances might lead to expectations of declining costs over time. On the other hand, higher regulatory standards concerning safety and the environment might be expected to drive costs up. Furthermore, it might be that the lowest cost routes, exploiting existing rights of way and terminal capacity, are developed first and later lines are more expensive.

Benefits

Appraisals in the UK have provided indications of the relative size of HSR benefits. The initial appraisal of HS1 (NAO, 2001) suggested 53% of benefits were to users of international services, 29% were to users of domestic services, 15% were regeneration benefits, 3% environmental benefits and 1% were road congestion benefits. More recently, the appraisal of the full HS2 network (DfT, 2013), indicates that, ignoring tax adjustments and revenue, 61% of benefits will be due to time savings, 10% will be due to benefits from reduced crowding, 7% will be due to reliability benefits, 2% will be accrued by road users and 18% are associated with wider economic benefits. Other impacts (including on the environment) constitute 1% of total benefits.

A fairly consistent picture emerges from HS1 and HS2 with around 80% of benefits (excluding revenue and indirect tax adjustments) accruing to rail users. To the extent that rail users have higher than average incomes, and those with the highest incomes will have the highest values of travel time savings this may be seen to be regressive in terms of income distribution. These distributional effects may be ameliorated in the presence of price discrimination, which will involve higher fares to price inelastic markets (usually higher income groups) and lower fares to price elastic markets (usually lower income groups).

The results that Nash (2013a) presents for Madrid to Barcelona give a slightly different picture with 39% of benefits in terms of time savings to existing users, 15% to generated travellers and 6% due to environmental effects, but with 40% related to costs saved on other modes (although these may reflect the impact of revenue changes). It should be noted that for HS2, revenue is estimated to be worth GBP 31.1 (EUR 38) billion, compared to welfare benefits of around GBP 73.9 (EUR 90) billion i.e. revenue is around 30% of the combined total of revenue and benefits, excluding tax adjustments. The differences between the HSR assessments in Britain (based on market prices) and Spain (based on resource costs) thus reflect a different way of presenting the outcomes, rather than necessarily a real difference. In Britain cost savings on other modes are not directly estimated, just revenue and net user benefits.

Business travellers, despite only being a minority of rail users (typically around 30% of forecast demand) account for over 50% of gross benefits on HS2. This is due to the high value of time ascribed to business travellers, typically the wage rate plus around 25% for employer's costs, whilst the value of time for non-work travel is typically between 25% and 40% of the wage rate. As rail business travellers are in high income occupations, this equates to a value of time of around GBP 32 (EUR 39) per hour (at 2010 incomes and prices), compared to GBP 6 per hour for leisure travellers and GBP 7 per hour for commuters. Recently there have been arguments put forward that given business travellers can work productively on trains, a lower value of time should be used as the assumption of zero productivity whilst on the move is not valid (Lyons et al., 2007).

These arguments are not new, and can be traced back to Hensher (1977). Castles and Parish (2011) have argued that the value of business travel time savings should be based solely on the loss of utility to the traveller, as represented by the value of commuter time (almost 80% less than the value of business time). This assumes that all time savings will be at the expense of work done whilst travelling, that working on the move is as productive as working in an office and that there are no benefits from being able to schedule multiple meetings, avoid overnight stays and arrive at meetings more alert. Where business travellers are able to work more productively on HSR services than alternative modes (which is a realistic proposition), it is possible that adjustments for this effect would in fact increase the value of the benefits of travelling by HSR, although this would reflect the value of travelling in different conditions rather than travel time savings per se.[11] Furthermore, there is a good deal of (but by no means unanimous) empirical support for values of business travel time in excess of the wage rate (see, for example, Wardman, 2013). This evidence also suggests that the value of time will grow over time, broadly in line with income.

A contrasting view is that developments in information technology and communications will continue to reduce the disutility of travel and hence reduce the value of travel time over time. This could be an important issue as current appraisals assume strong growth in the value of travel time savings. In a study of HSR between Edinburgh and Glasgow, Preston et al. (2009) found that in year 1 increases in user benefits were 57% greater than increases in revenue. By year 60, as a result of increasing values of time, increases in user benefits were over nine times greater than the increased revenue (assuming that fares were fixed in real terms). Given the countervailing uncertainties, the conservative response is to moderate business travel time values somewhat. Indeed, the UK government recently reduced the value applied in assessment of HS2 from GBP 45 (EUR 55) per hour (in 2010 prices) to GBP 32 (EUR 39) per hour, primarily as a result of revised estimates of the incomes of rail business travellers (HS2, 2013).

There have been a number of different approaches to estimating the impact of the wider economic benefits of HSR in the UK (Nash, 2013c). For HS1, regeneration benefits (particularly around Stratford) were calculated by estimating the number of new jobs created and this was multiplied by the amount the Government was willing to pay to create jobs in priority areas for regeneration. For HS2, in the most recent assessment, wider economic impacts were calculated by estimating the impact on agglomeration, reductions in imperfect competition (as a result of benefits to business users) and increased labour force participation (and the resultant increases in income tax) arising from reduced commuting costs. The agglomeration benefits were estimated in terms of the reductions in the costs of travel between areas and places of employment as a result of HS2 and associated released capacity on the conventional rail network (HS2, 2013). This assessment approach has been developed using frameworks originating with Venables (2007) and Graham (2007) and outlined in detail in the Department for Transport’s guidance for assessment set out on its WebTAG[12] internet pages. Rosewell and Venables (2013) argue that the WebTAG approach focuses on the benefits of expanding places rather that connecting places. Even this relatively narrow definition permits wider economic benefits to constitute 18% of gross benefits (or an up-lift on conventional benefits of 22%). Some 65% of these wider economic impacts are related to agglomeration, over 30% to increased competition and less than 5% to increased labour force participation. This assumes that land-use is fixed and does not take into account the potential for gains from trade and regional specialisation resulting from HSR promoting business-to-business and business-to-customer connectivity and permitting re-location of activities.

Work by Graham and Melo (2010) shows that although economic theory does not preclude the existence of wider economic benefits across inter-regional distances, the empirical evidence suggests that these may be very small, at least in relative terms. For example, a transport investment that directly affects 25% of long distance rail trips by increasing speeds by 25% might increase output by only 0.0006%. This is because of the small proportion of long distance rail trips in the total travel market. However, it might be argued that there are certain key business markets, focused on major city centres, where rail has a much larger market share. Work undertaken by KPMG (2013) attempted to examine labour and business connectivity by assessing the relationships between labour productivity, rail connectivity and road connectivity, using a framework that permits land-use to change over time. However, these connectivity indicators are correlated with each other (and other indicators such as the quality of labour and land). Furthermore, bi-directional causality needs to be addressed. It is plausible that high productivity areas attract transport investments as well as are generated by such investments. A causal relationship between productivity and rail connectivity was inferred (without a theoretical justification) and there was an estimate that this could lead to benefits of GBP 15 billion (EUR 18 billion) per annum by the year 2037 (at 2013 prices), although this would include conventional benefits. This would represent an increase in GDP of 0.8% in 2037 – a figure that is an order of magnitude different from the theoretical estimations of Graham and Melo. The GBP 15 billion per annum compares to the gross benefits (excluding indirect tax adjustment) of around GBP 74 billion (EUR 90 billion) (2011 prices) for the whole HS2 network over a 60 year project life and with an interest rate of 3.5% for the first 30 years and 3% for the next 30 (from Nash, 2013c, Table 2.14). The KPMG methodology thus seems to give much higher estimates of benefits,[13] that many may consider implausible.

Thus a relatively narrow definition of wider economic benefits based on improvements to the classic rail network in the case of HS2 uplifts gross benefits by over 20%. A more generous definition, including the inter-regional business and labour connectivity effects of HS2 might lead to higher estimates but these have not yet been accurately estimated. Other wider economic benefits of HSR might relate to one-off events such as the World Expo in Seville in 1992 and the London Olympics in 2012, although these can be overstated. For example, the World Expo in Seville attracted around 42 million visitors over a six months period, whilst the first year usage of the Madrid-Seville AVE was only 2.5 million. In the United States, a key area of debate is the extent to which HSR could avoid (or indeed reverse) urban sprawl though, as HSR only affects short distance commuting by releasing capacity where there is already a well-developed conventional rail passenger network, this is unlikely, except to the extent that HSR can reinforce the role of those central cities that have significant rail commuting.

Another line of argument is that the above discussion downplays the diseconomies of agglomeration, not least in the non-traded sectors of the economy, leading to higher costs in, for example, education, health-care and public administration. This could be an important factor in the mega-cities of developing countries, not to mention environmental and congestion diseconomies. Furthermore, much of this economic development may be abstractive (relocated activity) rather than generative (new activity). Studies in France (Bazin et al., 2006, Mannone, 1995, Mannone and Teleme, 1997) and in Spain (Hernandez, 2011) have shown how areas around HSR stations abstract activity from more peripheral areas of the City and/or Region.

Pricing and competition

Economic theory teaches that pricing and investment should be joint decisions (see, for example, Glaister, 1976), but HSR is one of many areas where the practice diverges from the theory. Pricing for railways often has at least two components. The first is the price that the infrastructure authority charges the HSR operator. The second is the price the HSR operator charges the end user. With respect to track access charges, it has been demonstrated that the level of usage will be determined by whether the charges are based on short run marginal costs or long run average costs (Preston, 2009a). Where full cost recovery is required, this may be based on a uniform rate or on Ramsey-Boiteaux discrimination. Crozet (op cit.) demonstrates that such discriminatory mark-ups are essentially a function of the opportunity cost of public funds (set at 0.3 in France) and the elasticity of demand with respect to price. He indicates that for Paris – Lyon the mark up over marginal costs is around six (suggesting a low elasticity in absolute terms or that the mark up is set inefficiently). For other routes it is between 1.5 and 2, suggesting higher price elasticities. UIC (2008) finds that track access charges account for between 25% and 45% of the revenue of high-speed operators. This in turn affects the profitability of HSR services and the ability to compete with other modes (Adler et al., 2007).

For passenger fares, the key distinction is between proponents of revenue yield (such as SNCF, NTV and Eurostar) and those that base HSR fares on the standard fare (itself related to distance) plus express and seasonal premia (essentially the approach adopted by the JRs)[14]. Both approaches may have group travel, advance purchase and loyalty discounts, but revenue yield maximisation is based on a book-ahead system whilst more uniform pricing can have an element of turn-up and go. This may in turn explain variations in load factors, with TGVs achieving around 70% but ICEs more like 50% (though this is also due to stopping patterns). Wu (Appendix 5.A4) estimates that the mean tariff in 2010 for the Tokaido Shinkansen equates to EUR 0.195 per passenger km and for Paris–Lyon TGV it is EUR 0.121, whilst the mean for China HSR (with operating speeds of 350 kph) is only EUR 0.056. Different charging regimes will have important implications on the cost-benefit analysis results in terms of overall demand levels and the extent to which user benefits are captured through the fare box. It should be noted that in the assessment of HS2, even without premium pricing, revenue is equivalent to around 30% of total benefits. The fares that HSR can charge will be determined in part by the pricing regime for the classic rail network – and the extent to which pricing off excess rail demand is being practiced. Different charging regimes will also have equity implications. A revenue yield maximising, book-ahead system that offers cheap advance tickets will be perceived as more equitable than a fixed premium fare, turn-up and go system.

Pricing is closely linked to competition. In Italy, the head-on competition between Trenitalia and NTV HSR operations has reduced average prices by 30%[15], although some of this is believed to reflect increased productivity (Croccolo and Violi, 2013). The head-on competition appears to have increased service levels by around 45% and demand by 40% (first half 2013 compared to first half 2012). Rail's market share on the key Rome to Milan route increased from around 30% to over 65%, mainly at the expense of air. The new entrant is providing 26% of HSR train kms and carrying 36% of traffic in terms of passengers. The key unknown is the extent to which this competition can be sustained. The operations are not believed to be currently profitable and continuation will depend on the depth of the pockets of the shareholders. Competition between classic rail and HSR could also be intense, particularly in the price dimension, but there has been no evidence of such competition to date. Indeed, in France, Italy and Spain, parallel conventional services have often been withdrawn, thus improving the commercial prospects of HSR. Inter-modal competition has been a feature of HSR services with low cost air carriers and ferry operators, providing strong direct competition on some routes, whilst flag air carriers have experimented with shuttle services.

Low cost carriers also provide indirect competition through offering a wide range of non-HSR served destinations. This is believed to have constrained the growth of the leisure market on routes between London, Brussels and Paris, with cheap flights to locations further afield reducing the overall growth in the market for travel between London, Paris and Brussels. There is clear evidence that inter-modal competition places limits on HSR demand levels and fares (Campos and Gagnepain, 2009).

Initial estimates for HS2 indicated that for Phase 1 some 57% of journeys would switch from classic rail, 8% would be from air, 8% from car and 27% would be generated (HS2, 2010, quoted in Preston, 2010). HS2 would thus have a higher level of abstraction from rail and a lower level of abstraction from road and, particularly, air than the five HSR schemes shown in Table 1.6. On average, for these five schemes 32% of demand is abstracted from air, 26% is abstracted from classic rail, 16% is abstracted from road and 26% is induced.

Table 1.6. **Diversion factors resulting from introduction of HSR**

Route	Paris-Lyons[1]	Madrid-Seville[2]	Madrid-Barcelona[3]	Thalys[4]	Eurostar[4]
% HST traffic generated from:	1980 to 1985	1991 to 1996 forecast	'Before HSR' to 'After HSR'	Range not given	Range not given
Induced	29	50	20	11	20
Road	11	6	10	34	19
Conventional rail	40*	20	10	47	12
Air	20	24	60	8	49

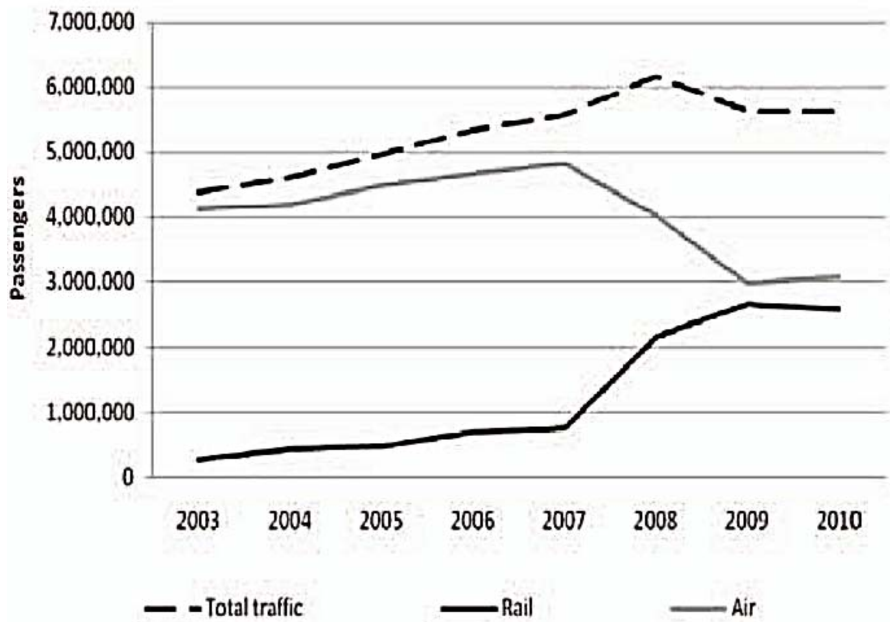
Note: * All Paris-Lyon's 'after' rail travel is presumed to be by HST (i.e. no conventional rail following introduction of HST), since alternative journey time is ~5 hours compared to ~2 hours by HST.

Sources: [1]Bonnafous, 1987. [2]de Rus and Inglada 1997. [3]Coto-Millán et al., 2007. [4]Segal, 2006. Quoted in Preston, 2009b.

The variations shown in Table 1.6 are due to the route-specific nature of the modal split. The level of induced journeys seems to be around 10-30% with the main exception of Madrid-Seville. Givoni (2006) suggests that some of this induced traffic may in fact be due to external growth and this may have been a particular factor on the Madrid-Seville line. Induced traffic may also include re-distributed trips which would have previously gone to a different destination by rail. Differences in definitions may explain the findings of PWC (2010) that induced traffic accounted for around 26% of traffic for Madrid-Seville and 9% for Madrid-Barcelona. According to Coto-Millán et al. (2007), only around 25% of journeys on the Madrid-Seville route were undertaken by air prior to the introduction of HSR compared to 70% of journeys from Madrid to Barcelona. Iberia's high frequency shuttle service (Puente Aereo) helped the latter to make it the busiest air transport route in the EU (4.8 million passenger in 2007), limiting the market share for rail to 13%. The opening of the Madrid-Barcelona HSR in February 2008 led to a decrease in the number of air transport passengers by 0.8 million that year and about 1.0 million the next year, leaving a total of 3.06 million remaining passengers in 2009. Only 160 000 of these were transfer passengers (Pagliara et al, 2012). The financial crisis undoubtedly also affected the number of travellers but despite the crisis, passengers using rail increased by 1 380 000 in the first year and by more than 500 000 in the second year of operation of the new line. This resulted in a modal share of 47% for rail and 53% for air at the end of 2009 (Frontier Economics, 2011).

Figure 1.2 summarises the evolution of market share before and after the introduction of the new line. The total number of passengers traveling by air and train increased constantly to a peak in 2008. The economic crisis saw some passengers move to cheaper and slower transport modes such as coaches as well as an overall reduction in mobility (Pagliara et al, 2012). In September 2008 Renfe decided to increase the daily frequency of trains from 40 to 52 trains, resulting in approximately 5 000 more daily seats. Iberia has reacted by reducing capacity while maintaining frequency with smaller aircraft. Air fares have fallen significantly, although this should partly be attributed to other airlines, mostly low cost airlines (Vueling and Air Europe) entering the market. In addition Iberia has exempted this route from luggage charges, while Air Europe started providing free parking at both airports (Pisonero, 2012). These strategies seem to have produced results as in 2010 a slight increase in modal share for the air mode was registered (rising to 54.4%) with a slight drop to 45.6% for rail (Pagliara et al. 2012).

Figure 1.2. **Evolution of numbers of passengers for rail and air modes**



Source: Pagliara et al, 2012.

Such detailed analyses are generally not available on the Chinese and Indian markets. Wu (op cit.) provides some evidence on traffic sources for China, with the best data being for the Beijing-Tianjin line where in 2011, 48% of traffic was diverted from conventional lines, 9% diverted from road and 44% was generated. It should be noted that in China domestic aviation services are relatively under developed – but might be expected to have grown rapidly in the absence of HSR.

For Mumbai-Ahmedabad, Pal (2013) estimates that current modal shares are 34% by coach, 28% by rail, 28% by car and 10% by air. It is estimated that 15 years after HSR opening (2035), 46% of demand would be by HSR, 24% by car, 16% by bus, 10% by classic rail and 4% by air. Assuming no generation or changes in modal shares due to other factors (such as income growth), a comparison of these modal shares would suggest that 39% of HSR demand would be from classic rail, 39% from bus, 13% from air and only 9% from car.

5. Breakeven conditions

There has been considerable work on ex-post evaluations in France, based on both financial and social criteria, which are compared with the ex-ante appraisals. Some key results are shown in Tables 1.7 and 1.8.

Table 1.7. **Financial internal rates of return for HSR in France**

High-Speed Line	Ex-Ante	Ex-Post
South East	16.5%	15.2%
Atlantic	12.0%	7.0%
North Europe	13.0%	3.0%
Paris Interconnection	10.8%	6.9%
Rhone-Alps	10.4%	6.1%
Mediterranean	8.0%	4.1%

Source*:* Crozet, 2013b.

Interpretation of Table 1.7 depends on assumptions concerning the minimum acceptable rate of return. For purely commercial organisations, 10% is often used, in which case, ex-post, only LGV[16] Sud-Est is financially viable. However, Crozet reports that financial costs were covered because the interest rates applied were lower than those shown in Table 1.7, although it seems that the financial case for LGV Nord is marginal. It is also apparent that the ex-post returns are less that those forecast ex-ante. This is most severe for LGV Nord where outturn traffic was only around 50% of that forecast, reflecting the difficulties in forecasting international traffic. In addition, for some lines, cost overruns of 15% to 25% were found.

Table 1.8. **Socio-economics internal rates of return for HSR in France**

High-Speed Line	Ex-Ante	Ex-Post
South East	28.0%	?
Atlantic	23.6%	12.0%
North Europe	20.3%	5.0%
Paris Interconnection	18.5%	15.0%
Rhone-Alps	15.4%	10.6%
Mediterranean	12.2%	8.1%

Source: Crozet, 2013b.

As might be expected, the socio-economic returns are greater than the financial returns, although again interpretation depends on assumptions concerning the social test discount rate. Detailed figures for TGV Sud-Est are not available but are reported by Crozet to be 'certainly more than 20%' – Conseil

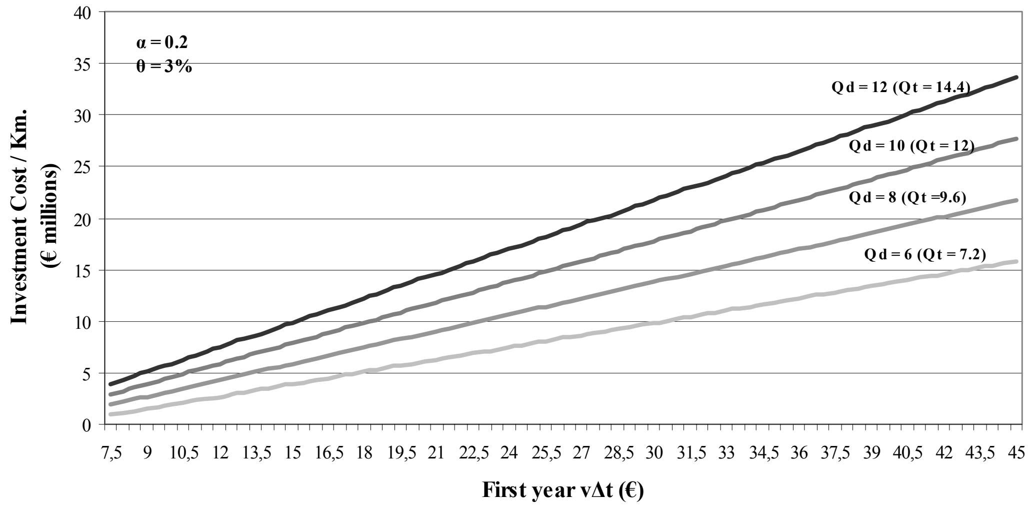
General des Ponts et Chaussees (2006) reports 30%. It seems that most schemes would pass any reasonable assumption concerning test discount rates (set at 8% for most of the period under consideration), with again LGV Nord the possible exception, although here international traffic has picked up following completion of HS1 in the UK and France has moved to a lower test discount rate (4% since 2003).

In Japan, Kurosaki (op cit., Table 4.3) presents results for the financial performance of the first four Shinkansen lines for the period 1982-4. This shows that the Tokaido and Sanyo lines were covering financial costs, but that the Tohuku and Joetsu lines, although covering operating costs, were not covering capital costs. However, it is noted that ridership has increased over time and that the long term debts of the three Honshu JRs, including those related to the Shinkansen, which stood at 12 429 billion yen in 1991, had been reduced to 7 013 billion yen in 2012, a reduction of 44%; although it should be borne in mind that there were substantial debt write offs with the privatisation (or more correctly commercialisation) of JNR in 1987.

For China, Wu (op cit., Tables 5.1 to 5.4) estimates that for the period 2010 to 2012, three lines were making a financial loss (Beijing-Tianjin (data from 2009), Wuhan-Guangzhou and Zhengzhou-Xi'an), although the deficits were tending to reduce over time. Only the Jinan-Qingdao service was estimated as covering financial costs. Annex 5A.3 shows that this service has the highest ridership of the four services considered, at 28 million per annum.

There has been surprisingly little ex-post socio-economic evaluation of HSR schemes. Outside of France, the best known example is the work of de Rus and Inglada (1997) on the AVE services between Madrid and Seville, opened in 1992. This scheme had capital costs of some 238 billion pesetas (1987 prices), but a simple financial analysis suggested a loss of 314 billion pesetas (1987 prices, 30 year project life, 6% discount rate, 2.5% GDP growth), indicating that the scheme does not even cover its operating costs. A social cost benefit analysis indicates a negative net present value (NPV) of 258 billion pesetas, suggesting a benefit cost ratio (BCR) of only 0.18. With regards to benefits, some 44% were estimated as accruing to generated travellers, with 23% accruing to abstracted travellers in terms of time savings, 28% accruing to other transport operators in terms of reduced operating costs and some 5% related to congestion and accidents. The figures quoted in Nash (2013a) for the Madrid – Seville route, based on de Rus (2012), are expressed in billions of Euros and 2010 prices. These indicate a present value of costs of EUR 6.8 billion, a present value of benefits of EUR 4.5 billion and hence a Net Present Value of minus EUR 2.3 billion and a BCR of 0.66. This suggests there has been some improvement in the performance of the service over time but not to the extent that it has become socially worthwhile. De Rus (op cit.) also finds that the Madrid–Barcelona route fails to achieve social break-even.

Figure 1.3. **First year demand required for socio-economic break-even**



Notes: α =uplift for generated traffic (Qt = Qd (1+α)) and θ = annual growth rate of net benefits. (From Nash, 2013a).

In a number of papers, theoretical models have been developed to examine social break-even traffic levels for HSR investments (de Rus and Nash, 2006, de Rus and Nombelo, 2007, de Rus and Nash, 2009). As shown in Figure 1.3, this work determines the combinations of investment costs per kilometre (given by the y-axis), demand levels (both abstracted from other modes (Qd) and including generated traffic (Qt)) and the mean value of travel time savings (given by the x-axis and denoted v Δt, where v = value of time and Δt= travel time savings) at which HSR schemes just break even in social terms. These break-even lines are referred to as isoquants. As with all economic models, the results depend on the input assumptions. Assumptions include the interest rate (say 5%), the project life (say 30 years), the proportion of traffic that is generated (say a 30% uplift, implying that around 23% of demand is generated), the annual growth of net benefits (e.g. 3%), the construction costs per km (say EUR 20 million) and the mean value of travel time savings (say EUR 45), based on an average time saving of 50 minutes (from SDG, 2004). Under these assumptions, for a 500 km route, it can be estimated from Table 1.8 that the break-even first year demand is around 9 million passenger per annum – a relatively high figure, especially given all passengers are assumed to travel the full length of the route. De Rus (2012) reports that only around one half of the users of the Madrid – Seville services travel the whole length.

Table 1.8. **Break-even demand volumes in the first year**

Construction cost (£k per km)	Rate of interest (%)	Value of time saved (euros)	% generated traffic (%)	Rate of benefit growth (%)	Break-even Volume (m pass)
12	3	45	50	4	3
12	3	30	50	4	4.5
30	3	45	50	4	7.1
12	3	45	30	3	4.3
12	5	45	50	4	4.4
30	5	30	30	3	19.2
20	5	45	30	3	8.8

Source: Nash, 2013c.

It is important to note that these calculations do not include environmental effects (which we have seen are negligible) nor network effects on competing air, road and conventional rail services (which are more substantial but still relatively modest). It is interesting to note that there are seven city pairs listed in Table 1.3 with demand volumes below 9 million passengers per annum. There may be several with demand levels below 4.5 billion passenger kms, as these indicative calculations assume that all passengers travel the length of the HSR route, which is unlikely to occur in practice. For example, Chan (op cit.) reports that the Chinese Taipei HSR has a route length of 345 km but a mean trip length of 200 km. Similarly, Kurosaki (op cit.) reports mean trip lengths in 1984 of 329 km for the Tokaido and Sanyo lines (route lengths 553 and 644 kms respectively), 254 kms for the Tohuku line (route length 505 km) and 220 km for the Joetsu line (route length 304 km).

Wu uses the framework developed by de Rus et al. to determine break-even values for HSR in China. It is found that traffic density of between 40 and 50 million passengers per annum is required to achieve commercial break-even for HSR lines with 350 kph operating speeds, falling to between 25 and 30 million for lines capable of 250 kph operating speeds. It should be noted that Wu bases these calculations on average demand over the whole life of the project (with demand assumed to grow at 5.4% per annum over the next 50 years), whereas the figures quoted above are based on first year demand. Wu also estimates that the break-even socio-economic level of traffic density is between 90 to 100 million passengers per annum, but this assumes a time saving per passenger valued at most at EUR 4, less than a tenth of the value assumed by Nash. Wu notes that if rail travellers have twice the average income, and hence twice the average value of time, (which is not infeasible for the wealthiest parts of China in which much of the HSR investments are concentrated) then the break-even figure comes down to 50 million. Furthermore, the additional demand required to justify HSR compared to an upgrade of classic rail is estimated at 28 million per year. When these numbers are converted into first year demand, they may be broadly consistent with the calculations of Nash, given the rapid growth rates expected in China

6. Funding

Funding was described at the roundtable meeting as ‘the main hurdle’. Public capital is generally cheaper than private capital but its supply is limited. There may be scope for channelling ‘the irrational exuberance of the private sector’ into legacy infrastructure such as HSR. Private risk capital might be accessed through concessions and Public Private Partnerships (PPPs). Crozet (2013b) reports that the extension of the TGV to Bordeaux is financed by a 50-year concession. The concessionaire will provide EUR 8 billion of finance, albeit much of this is underwritten by the French State and the European Investment Bank, whilst the infrastructure authority (RFF) will contribute EUR 1 billion and central and local government will share a EUR 3 billion contribution. By contrast, the extension to Brittany and the Nimes–Montpellier by-pass will be developed as 30 year PPPs, with rents paid by central and local government and in the Brittany case by RFF. A feature of the current expansion of the TGV network is the increased role of local government funding.

In Japan, new Shinkansen lines (built since 1987) are constructed and owned by the Japan Railway Construction, Transport and Technology Agency, although they are operated and maintained by the JRs. The JRs are charged a usage fee calculated to ensure that they are neither better nor worse off as result of the new Shinkansen (i.e. it is based on the difference between the operating profit with and without the Shinkansen, assuming a 30 year project life). Since 1996, the construction costs net of these usage fees are subsidized by state and local governments by a ratio of 2:1. This regime does not appear to incentivise JRs to cooperate in the development of new lines (with the anomalous exceptions of mini-Shinkansens) and it is perhaps not surprising to note that although 2 032 km of Shinkansen were constructed before 1987, only 588 km have been developed since, although a further major expansion (of 779 km) is currently under way.

An issue that may emerge in certain countries, particularly those that have gone for a 'big bang' expansion of the HSR network through debt financing, is the crowding-out of investments in other economic sectors, through a shortage of capital and high interest rates. Wu and Rong (2013) highlight this issue with respect to China. The Ministry of Railways (MoR) debt has increased from 470 billion RMB[17] in 2005 to 2.4 trillion RMB in 2011, and could reach more than 4 trillion RMB in 2015. MoR interest payments have increased from 39 billion RMB in 2005 to 275 billion in 2011, accounting for 55% of revenue in 2011. The MoR debt:asset ratio increased from 37.53% in 2005 to 60% in 2011. Wu and Rong draw a parallel with Japan where they claim JNR debts were equivalent to 10% of GDP by 1987, although this was largely due to high labour costs and over-manning on the rail system as a whole rather than the Shinkansen investments.

7. Indian context

Indian Railways is one of the major carriers of passenger traffic in the world, with the golden quadrilateral (Delhi – Kolkata – Chennai – Mumbai) linking the four main cities in India. However, the distances involved between the cities in this core market (between 1 400 and 2 200 kms) are too great for HSR to permit day return trips. Instead, there have been preliminary studies of seven shorter corridors on the quadrilateral or with spurs off it. Of these, Mumbai-Ahmedabad and Chennai-Bangalore-Coimbatore have emerged as favourites. Pre-feasibility work on Mumbai-Ahmedabad indicates that rail currently only has a 28% modal share (the same as for car), with bus having a 34% share (and with luxury bus having higher fares than rail) and air a 10% share (but growing very quickly). However, HSR could reduce journey times from 6 hours 45 minutes to 1 hour 52 minutes. Initial demand estimates are for 12 million passengers per annum and a financial internal rate of return of 12.8%, despite relatively low fares, although this could be affected by appraisal optimism. Construction costs are estimated at EUR 15 million per km. Particular issues for India include the need for a segregated right of way, so to prevent incursion from road traffic, pedestrians and animals, which may be difficult to achieve at grade, hence a likely need for elevated structures. There is also the issue of choice of gauge as broad gauge is the norm. This might suggest the need for a largely freestanding standard gauge system or alternatively development of broad gauge high-speed trains just for the Indian market. The other issue is the number of competing demands for rail investment. The conventional network currently has top speeds of around 130 kph, so a move to a semi-HSR of 160-200 kph has some appeal. Dedicated freight corridors are being developed (including the western corridor between Delhi, Ahmedabad and Mumbai), whilst passenger network expansions are also being considered.

At least four delivery options might be considered for HSR in India: conventional public procurement; a Design Build Finance Operate Transfer (DBFOT) PPP (either bundled or unbundled);

public procurement involving Government-to-Government cooperation and funding assistance from multilateral/bilateral agencies; and public procurement with Government-to-Government cooperation but also a 15-20 year concession for operation and maintenance.

For India, the demand side was not seen as a problem at the roundtable, with substantial traffic generation possible and Say’s law applying – if you create the supply the demand will come, although there will be constraints on the level of fares charged. HSR investment was seen as more of a political problem – and a national HSR policy is therefore needed and possibly one that takes HSR away from the Government which will be reluctant to fund what might be perceived to be an elitist project and even if it did it would require public ownership and control which could lead to fares being kept too uniformly low. HSR investment in India may also be dependent on reforms in financial markets to permit the development of tradable bonds.

8. Conclusions

Overall HSR is seen as more than a hardware investment challenge – the development of accompanying ‘soft’ measures will be crucial. The key objectives for HSR remain speed and large scale capacity increases, both for conventional rail and other competing transport systems. Wider economic benefits, in terms of the strengthening of central cities and via redevelopment, are also important. Increases in productivity through agglomeration effects can be significant where capacity is released on conventional lines with crowded commuter services. HSR may be a component of proactive urban planning to structure development of new centres of economic activity around HSR stations in rapidly growing metropolitan areas. However, it is likely that most of this economic development will be abstractive rather than generative.

There are a number of subtly different HSR schemes around the world and the spatial and temporal transferability of indicators of the performance of these schemes requires further study. However, it seems likely that optimal HSR schemes are context specific, driven principally by a combination of economics, politics and geography. The ideal geography for HSR has often posited to be major city pairs around 500 km apart (as with Paris-Lyon) but HSR can serve both longer distance and short distance markets and it may be that a more ideal configuration is where there is a string of large cities along a route (as in Japan).

Alternatives to HSR should be considered, in particular the upgrade of classic rail, alternative technologies such as the Maglev system being proposed by JR Central for Tokyo-Nagoya and competing investments in upgrading the aviation and road sectors. These do-something else options need to be given detailed consideration in assessments of net present value and cost effectiveness of public spending. Where such alternatives have been considered (e.g. classic rail upgrades in the UK) they tend to be smaller investments and have higher benefit cost ratios but incremental analysis (that looks at the differences in costs and benefits between HSR and classic rail investment) still indicates that the larger HSR investments are worth taking forward (Nash, 2013c) and this may be in a situation where the disruption costs of classic rail improvements are difficult to estimate.

A four stage test may be considered for HSR investments. First, does the HSR make a commercial return? If so, arguments concerning HSR being an elitist investment are redundant. Returns can be reinvested in other social projects or the project can be financed and operated by the private sector. However, there seem to be very few HSR schemes that have made a financial return, with the Tokaido Shinkansen and the TGV Sud-Est being notable exceptions, with Gourvish (2010) reporting that in the case of the latter, the capital investment was fully amortised after 12 years. Secondly, does the HSR investment make a social return, based on rail transport benefits only? This is the basis of the social break-even approach discussed above which postulates 9 million passengers in the first year of operation as a key break-even threshold. It appears that many, but by no means all, current HSR schemes may achieve this pass-mark. However, this approach is based on an assumption of a pass-mark BCR of 1. With constrained budgets, opportunity costs might mean that a BCR higher than 1 is required, with the UK focussing on 2 as a key threshold until recently, whilst Germany uses 3. This is a tougher test and as a result will require either higher demand levels or compensating non-rail transport benefits. This leads to a third test, does the HSR make a social return including quantified impacts on other transport systems (air and road) and wider economic benefits? These benefits have been important in establishing the case for HS2 in the UK. Lastly, does HSR have social returns when qualitative wider benefits are taken into account? This may include the role of HSR in nation building (although in the case of Spain, Bel (2012) argues this has an unsustainable economic cost) or as a spur to the development of indigenous technology and modernisation of the economy (China and, possibly, India). In all of these tests, a key metric is the level of passenger demand, with gravity model formulations providing a useful basis for high level strategic forecasts in advance of subsequent detailed modelling estimations.

An important issue is the spatial level and intensity at which such a set of HSR investment tests are undertaken. The SNCF economist, Michel Walrave, has been attributed by Crozet with commenting that stopping the last HSR line to be built is even more difficult than getting the first HSR line built. This suggests that HSR investments should be considered at a network level. The best lines should be identified and then the network evolution planned. It seems likely that line extensions can exhibit economies of scale, e.g. the extension of the TGV south of Lyon or of HS2 north of Birmingham. However, the development of brand new lines may rapidly exhibit diseconomies of scope. This in turn suggests a step-by-step approach to HSR investment may be more appropriate than a big bang.

Notes

1. Source: http://www.uic.org/IMG/pdf/20131101_high_speed_lines_in_the_world.pdf

2. Dunmore and Smith (in Asian Institute of Transport and Development, 2007) note that the average stopping distance on HSR systems is between 100 and 30 km.

3. Suppose the speed (s) of Concorde is 2 000 kph. Suppose the fare is EUR 12 000 for 12 000 km, so that the fare per km (f) is EUR 1 but the average wage rate (w) is EUR 6 per hour. Effective speed is given by $[s^{1} + (f/w)]^{-1}$. In this (extreme) case this is equivalent to around 6 kph, only a little greater than walking speed.

4. As of November 2013, UIC report 2 565 km of HSR line under construction in Europe, with 8 321 km planned. If delivered this would achieve a network of 18 264 km – an increase of 148%.

5. But grants and subsidies do have an indirect effect in term of collection/administration costs, opportunity costs and distortion costs (particularly related to income tax), leading to an expectation that the shadow price of public funds is greater than one. For example, a shadow price of 1.2 suggests the deadweight loss of GBP 1 of subsidy is 20 pence.

6. Let the generalised cost of travel before HSR be GC_1 and the generalised cost of travel after HSR be GC_2. In the case of a transport improvement we would expect $GC_1 > GC_2$. Also let the volume of travel before HSR be Q_1 and the volume of travel after HSR be Q_2, where for a transport improvement $Q_2 > Q_1$. Assuming a linear demand curve, the benefit to users is $Q_1 (GC_1 - GC_2) + ½(Q_2 - Q_1) (GC_1 - GC_2)$. This can be rearranged as $½ (GC_1 - GC_2) (Q_1 + Q_2)$ (see Jones, 1977).

7. The Korean data was presented in terms of trips per day and has been multiplied by 365 to get an annual total

8. Information provided by Fumio Kurosaki, 25 February 2013.

9. If the 12 schemes are treated as independent observations the mean costs are EUR 9.4 million per km, with a standard deviation of EUR 3.6 million.

10. If the 10 schemes are treated as independent observations the mean costs are EUR 17.9 million per km, with a standard deviation of EUR 4.4 million.

11. Suppose in the before situation a mode is being used that does not permit work on the move, this mode take three hours and the value of travel time is estimated at GBP 96 (3 times GBP 32). HSR reduces the journey to two hours, but this time can be used productively. The value of travel time is GBP 14 (2 times GBP 7). The value of travel time savings is GBP 82 – substantially in excess of GBP 32.

12. WebTAG is the UK Department for Transport's online Transport Analysis Guidance – see: https://www.gov.uk/government/publications/webtag-tag-unit-a2-1-wider-impacts.

13. If GBP 15 billion per annum is discounted over 60 years in a similar manner then a present value of benefits of around GBP 398 billion (EUR 486 billion), some 5.4 times the original estimate, is obtained.

14. There can also be hybrid systems – the revenue yield system for Trenitalia is based on adjustments to the historic distance based fare.

15. Minimum prices have had greater reductions. For example, the minimum fare for Rome – Milan declined from EUR 75 to EUR 29 (and even down to EUR 9 for a period, which triggered a predatory pricing competition case).

16. LGV = Ligne de Grande Vitesse, high speed line.

17. As of January 2014, the market exchange rate was one RMB (Renminbi or Yuan) equals 0.12 Euros.

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Chapter 2

When to invest in high-speed rail

Christopher Nash[1]

This paper will start by a general review of the costs and benefits of high-speed rail, of how they are measured in cost-benefit analysis and of the circumstances in which benefits may be expected to exceed costs. It is concluded that the three main factors determining economic success are construction costs, value of time saving per passenger and traffic volume. At typical construction costs and values of time savings something like 9 million passengers per annum are needed to justify a line in cost-benefit analysis terms, and very many more before it becomes financially profitable. We then turn to the British experience of the appraisal of high-speed rail, both for HS1 – the high-speed line already open between London and the Channel Tunnel, and for HS2 – the proposed line linking London to Birmingham, Manchester and Leeds. Controversies over a number of issues, including the value of business travel time savings and wider economic benefits, are discussed. It is concluded that favourable circumstances for High-Speed Rail are typically the result of a combination of low construction costs (often brought about by avoiding the need for tunnelling), high values of time savings per passenger (a wealthy country with a lot of existing travel by rail) and high population (either very large cities or cities located in a corridor which may be served by a single line).

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1. Introduction

High-speed rail (HSR) is usually regarded as services operating at 250 kmph or more, and these invariably require construction of new purpose-built lines. According to the International Union of Railways (UIC), by 2013, a total of 21 472 km of such lines had been built worldwide, of which a third in Europe and the rest in Asia. China had the largest network at 9 867 km, whilst Japan, France and Spain all had over 2 000 km. There are plans for a further major expansion, with the European Commission calling for a trebling of the kilometrage in Europe by 2030.Yet high-speed rail is an enormous investment, with a typical 500 km line costing 6–12 billion euros in 2004 prices (Euros 12-24 billion per km) (de Rus and Nash, 2009). It is necessary to consider very carefully in what circumstances such an outlay is justified.

The first such line, the new Tokaido line in Japan, was clearly built with the twin aims of giving large time savings (and thus competing effectively with air transport) and relieving capacity constraints on the existing railway line. These were also clearly the motives behind the construction of the first TGV line from Paris to Lyons in France. But since then, wider motives have appeared, including reducing carbon emissions by diverting traffic from air and road, and promoting economic regeneration and growth. The first part of this paper will consider at a general level the costs and benefits of high-speed rail, and evidence to date on what determines their magnitude.

We will then consider specifically evidence from the current debate in Britain. The first High-Speed Rail line to be built in Britain, from London to the Channel Tunnel, opened in 2004-7. Possible benefits of regeneration in East London played a significant role in the choice of route and in the appraisal of this line (later dubbed HS1). It was not until 2001 that the Strategic Rail Authority commissioned a study of the case for high-speed rail linking London with cities to the North. This formed the basis of the current proposals for a line from London to Birmingham, branching near Birmingham to form lines going on to Manchester and Leeds (HS2). The government is committed to going ahead with this line, and is just starting parliamentary processes to obtain the powers to build it. However, the project is very controversial, and consequently an enormous effort has been put into studying its effects by both proponents and opponents. The evidence from these studies will be reviewed, before we draw our conclusions.

2. Costs and benefits of high-speed rail

Introduction

The principal costs and benefit of HSR are listed in Table 2.1.

Table 2.1. **HSR costs and benefits**

Costs
Capital costs
Operating costs
External costs (environment, safety)
Loss of tax revenue (from traffic diverted from road to rail)
Benefits
Revenue
Time savings (beyond those recovered in higher prices)
Diversion from other routes and modes – reduced congestion, accidents and environmental costs
Generated traffic
Wider economic benefits

Source: C. Nash.

Costs

We have already noted the high capital costs of high-speed rail. In terms of operating cost, whilst energy consumption and maintenance costs may be higher than for conventional trains, high-speed means staff and rolling stock can achieve much higher utilisation rates per passenger km than conventional rail, offsetting the increased costs. Typical costs for building and operating a high-speed line are shown in Table 2.2.

Of the external costs of high-speed rail projects, noise, global warming and loss of amenity through land take and visual intrusion are the major issues. Noise costs and loss of amenity can be minimised at the expense of additional capital cost, ultimately by tunnelling.

Of these costs greenhouse gases has proved particularly contentious. Firstly, there is obviously carbon used in construction of the line, although in Europe, to the extent that this will mainly be undertaken by industries which are part of the European emissions trading scheme, it may be argued that the cost of offsetting any increase in carbon from this source will already be included in the capital costs of the project. The same argument may be applied to electricity for traction (and jet fuel when the ETS is fully implemented for aviation). Ignoring this argument, the greenhouse gas emissions for HSR depend very much on the source of primary energy used to generate the electricity, and as electricity generation is decarbonised this will go down. It is the source of the marginal electricity generated as a result of the increased demand for electricity generated by HSR that is of interest and this may not be the same as the average source at that point in time.

Table 2.2. **Typical costs of a 500 km high-speed line**
(million euros, 2004 prices)

Capital costs	
Infrastructure construction	6 000-12 000
Rolling stock (40 units)	600
Total	**6 600-12 600**
Operating costs p.a.	
Infrastructure maintenance	32.5
Rolling stock maintenance	36.0
Energy	35.7
Labour	19.8
Total	**124**

Source: de Rus and Nash (2009).

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Safety is not a big issue for HSR. New high-speed lines are invariably built with cab signalling and completely segregated from road and pedestrian traffic (i.e. without level crossings), and there has never been a fatal accident on a purpose built dedicated high-speed line. There have been several serious accidents involving high-speed rolling stock running on conventional lines, however (in Germany, China and most recently Spain).

The cost of reduced tax to the government has also been a contentious issue in the UK. The logic is that if the benefits of reduced congestion and pollution from road traffic are included as a benefit in the appraisal in full, then the loss of revenue that road transport would have paid in the form of fuel and other taxes must be seen as a cost.

Benefits

Turning to benefits, the overwhelmingly important benefit in most transport appraisals is time savings. However, it is not always appreciated than many aspects of comfort and convenience are included in the value of (generalised) time used in economic appraisal. The raw values used in current British appraisals are shown in Table 2.3. For leisure and commuting journeys, these values are based on extensive revealed and stated preference evidence on what people are willing to pay to save time.

However higher values are used for waiting time, for time standing in a crowded train, for time spent walking to access trains and for late arrivals (the evidence is that people are willing to pay something like twice as much to save time walking and waiting and three times as much to avoid being an hour late as they are to save an hour in scheduled journey time). (Wardman, 2004)

Table 2.3. **Values of time used in British rail appraisals**
(GBP per hour, 2010 prices and values)

Business	31.96
Commuting	6.81
Leisure	6.04

Source*:* DfT (2013).

Where passengers are travelling on business, it is assumed that the benefit of faster journeys goes to the employer, not the employee. The approach taken to this in Britain, as in the appraisal systems of most countries, is to assume that this is to be valued at the wage rate of the staff concerned, plus an allowance for the overhead cost of employing labour. In a competitive market, this will equal the value of the marginal product of labour, and thus represents the value of the additional output produced when labour is released from its current occupation. It also represents the cost saving to the existing employer, and thus is a key input into models to estimate land-use transport interactions or wider economic effects of transport investments.

Valuing rail business travel time savings in this way has been widely questioned in recent years. Firstly, it has been noted that business travellers can and do work on trains, and that improved information technology has made this easier and more productive. According to a recent survey a third of rail business passengers in Britain state that this is how they spend much of their travel time (Lyons et al, 2007). However, Batley, Mackie and Wardman (2013) point out that it is not how people spend their time on average that matters, but how this would be affected by a marginal change in travel time, and whether the time is used as productively as time spent in the office. Secondly, business journeys often start and finish in unsocial hours and it is not clear that all time saved on such journeys will be used productively. Hensher (1977) developed a method for adjusting business values of time to allow for these factors, but one which is very demanding in terms of the information needed to apply it. The Hensher approach would generally reduce the value of business travel time compared to basing it on the wage rate plus overheads.

On the other hand, empirical investigations using evidence from both revealed and stated preference studies tends to suggest a value at least as high as currently assumed, with values of time being much higher for first class travel than economy (Wardman, 2004). Possible reasons for this are that employers perceive benefits from staff not being obliged to work such long days and thus being less tired, from not having to compensate staff for unsocial hours as part of their remuneration package and from being able to fit more meetings into a day, thus saving further travel or the cost of overnight stays (Marks, Fowkes and Nash, 1986).

The benefits of diversion from other routes or modes take the form of reductions in congestion and pollution. What is needed then is firstly an estimate of how many high-speed rail travellers have diverted from each mode (including existing rail services; where there are capacity constraints this may lead to additional benefits by freeing up capacity for expansion of other services, including freight).

Once the mode from which passengers have switched is known, information is then required on the marginal social cost of the modes in question. The evidence is that, for the aviation, noise and pollution costs are not fully internalised in prices (Tables 2.4a and 2.4b), the resulting externality might provide a benefit from switching to HSR of the order of 7.5million euros at year 2000 prices for 1million passengers diverted from air. Thus it would only be if there was a very large diversion from air, probably on a route where air had previously totally dominated the market, that this would make a significant contribution to the benefits of HSR.

Table 2.4a. **Air transport externalities**
(Euro cents 2 000 per passenger km)

	Air Pollution	**Climate Change**	
Flight Distance (km)	Direct Emissions	Direct Emissions	Indirect Emissions
<500 km	0.21	0.62	0.71
500 – 1 000	0.12	0.46	0.53
1 000 – 1 500	0.08	0.35	0.40
1 500 – 2 000	0.06	0.33	0.38
>2 000	0.03	0.35	0.40

Note: Indirect emissions are the climate change and air pollution cost of the production and transport of fuel for air transport. Obviously there may be offsetting costs for rail which need to be included in the cost of the high-speed rail project.

Table 2.4b. **Noise costs per landing or take off**
(Schiphol)

	40 seater	**100 seater**	**200 seater**	**400 seater**
Fleet average	180	300	600	1200
State of Art	90	150	300	600

Source*:* Infras et al (2008).

For car, the evidence of GRACE (2005) is that it is only when there is substantial congestion that marginal social cost exceeds charges (Table 2.5) for using cars in European conditions. Whilst we might now believe in a rather higher cost for global warming than applied in 2005, this would not change the conclusion. But that raises the issue that if sufficient traffic is diverted to significantly reduce road congestion, new demand will be generated to occupy some of the space. Thus accurate results can only be achieved by use of a full multi modal model. The additional road traffic would then be the benefit rather than reductions in congestion.

Benefits should also include the net benefits of diverting traffic into the capacity released on existing rail lines. This may be more substantial and include the impact of diverting freight from road (Greengauge, 2012).

Table 2.5. **Long distance car trip externalities and charges**
(Euro cents per passenger km)

	Wear	Congestion	Environment	Accidents	Total Cost	Charges
Route 1						
Peak	0.016	0.147	0.013	0.015	0.191	0.132
Off-peak	0.016	0.002	0.017	0.015	0.050	0.132
Route 2						
Peak	0.032	0.194	0.010	0.008	0.244	0.156
Off-peak	0.032	0.003	0.014	0.008	0.056	0.156
Route 3						
Peak	0.019	0.123	0.011	0.008	0.161	0.114
Off-peak	0.010	0.002	0.015	0.008	0.044	0.114
Route 4						
Peak	0.020	0.122	0.015	0.006	0.163	0.078
Off-peak	0.025	0.002	0.020	0.006	0.048	0.078

Note: Route 1 is Milan-Chiasso, route 2 Chiasso-Basel, route 3 is Basel-Duisburg and route 4 is Duisburg-Rotterdam.
Source*:* Grace (2005).

For generated traffic, the standard argument is that, since the person was unwilling to travel at the previous generalised cost and is willing at the new, the benefit must lie somewhere between that derived by an existing passenger and zero; assuming a linear demand curve the benefit will be half that accruing to an existing passenger. However, if new trips are generated for leisure, commuting or business, they may imply a shifting of economic activity. Whether they also may imply increased economic activity is the source of much debate. The long-held position amongst most cost-benefit analysts has been that, following Mohring and Williamson (1969), in a perfectly competitive economy, there will be no benefits of transport investment over and above the direct user benefits that are measured in a standard appraisal. Whilst a transport investment may change relative prices and lead to expansion and contraction of other industries according to the degree to which transport is an input to them, as long as price equals marginal cost in those sectors, there will be no net benefits of these changes, whilst in the absence of involuntary unemployment, there will be no net benefits of job creation or removal. Transport investments may change property prices, but this will simply be a capitalisation of the benefits received by the users; it will transfer benefits from users to property owners but have no impact on the overall net benefit of the scheme. Recent arguments in Britain that there are in fact such wider economic benefits will be examined in section 4.

3. In what circumstances will benefits exceed costs?

Introduction

Empirical studies (de Rus and Nash, 2009) suggest that three elements of the appraisal of high-speed rail dominate the results: construction cost, (generalised) time saving per passenger and demand. Thus the answer to this question lies in the determinants of these three factors.

Construction costs

Construction cost varies greatly from line to line (Table 2.6)

Table 2.6. **Construction cost per route km of new high-speed lines**
(Million euros, 2005 prices)

Belgium	16.1
France	4.7 – 18.8
Germany	15.0 – 28.8
Italy	25.5
Japan	20.0-30.9
Korea	34.2
Spain	7.8 – 20.0
Taiwan	39.5

Source*:* Campos, J, G de Rus and I. Barron (2009).

It is heavily influenced by the nature of the terrain, the length of earthworks, viaducts and bridges and – overwhelmingly – the amount of tunnelling (SDG, 2004). A contributory factor to the low costs in France and Spain relative to Germany and Italy is said to be that these countries design their high-speed lines for passenger trains only, with gradients of up to 3.5%, whereas more than 1.5% is not usually permitted on mixed traffic lines. Other things being equal, construction in flatter country will obviously be cheaper than in mountainous regions or with a lot of water crossings. But population density is also critical. Where population density is high, more bridges, viaducts and tunnels will be needed. A crucial issue is the approach to city centres. In terms of maximising patronage and time savings, access to a city centre station is critically important. If it may be made on the surface on existing right of way, as is predominantly the case in France then costs will be very much lower than if extensive tunnelling is involved (as in the case of HS1 and HS2 in Britain). One factor which may make this possible is the diversion of local services underground into a cross city tunnel as a way of improving access to city centres (as in the Paris RER network, Crossrail and Thameslink in London and many German S-Bahn schemes).

Value of time saved per passenger

The second major element is the value of the time saving per passenger. The amount of the time saving is determined by the change in the door to door journey time (i.e. amount of in vehicle time, access and egress time) compared with the previous mode. Where the previous mode was rail, this may be substantial (an hour or more for a 500 km line), and it may be even greater for road, particularly where roads are congested. However, for air, the time saved may be more limited. For air journeys over the sort of distances where high-speed rail makes rail competitive, a typical door to door time may be of the order of four hours. For a 500 km journey by rail, it will be similar. Of course, rail will be favoured the shorter the length of the trip (as the higher speed of aircraft becomes less significant) and the more accessible the railway station is relative to the airport. So rail will be favoured in dense cities with good access (probably by public transport) to the central city. Air will do better in low density areas with good access (probably by car) to the airport.

Traffic volume

The construction costs of high-speed rail are largely fixed regardless of traffic. High-speed rail invariably requires a double track main line with cab signalling, and this already has a capacity of 14-18 trains per hour in each direction. Only the costs of rolling stock, stations and depots vary significantly with traffic volumes. Thus high-speed rail systems are traffic hungry.

Volumes of the necessary size may be obtained by linking individual very large cities (e.g. Paris and London) or by linking a chain of large cities so that flows between different cities are aggregated together and trains remain busy throughout the route (the so called 'string of pearls'). Japan is clearly a case of the latter, with 127 million people living at very high population densities mainly in large cities along the coastal strip. France also was able to benefit from this sort of geography to a degree, but by using the ability of TGVs to run at reduced speed on conventional lines to serve additional cities. For instance, trains on the original French TGV line from Paris to Lyons, went on to serve cities such as Avignon, Marseilles and Nice (since then the high-speed line has been extended to serve these places directly). By contrast, Spanish cities are smaller, and arranged around Madrid in a 'hub and spoke' pattern, requiring a different line to link each city to Madrid (Table 2.7).

Obviously the difference in volumes is partly simply a question of population served. For instance, the population of Paris in 2000 was 9.7 million and Lyon 1.4 million, whilst the TGV Sudest line went on to serve many other destinations, including Marseille (1.4 million) and Nice (0.9 million). By contrast, population directly served by Madrid-Seville was around half that of Paris-Lyon; Madrid-Barcelona is more comparable, but there are no further cities currently served beyond Barcelona. Beijing-Nanjing-Shanghai has a population twice that of TGV Sudest in the main three cities alone (although of course per capita inter-city travel in China is way below European levels), whilst Tokyo and Osaka between them have twice as much again.

Table 2.7. **Patronage (m) of HSR**

Line	Traffic 1st Full Year	1 year on	5 years on
TGV Sud Est	15	17	19.2
TGV Atlantic	21.5	22	29
TGV Nord*	19	20	-
TGV Connexion	9	10	16.6
TGV Rhone-Alps	18.5	-	-
TGV Mediteranne	20.4	-	-
Madrid – Seville	2.5	2.8	3.6
Madrid – Barcelona	5. 0	5.4	-
Tokyo – Osaka	35	48	80
Korean HSR	24	27	28

* Including international trains to London and Brussels as well as French domestic services.
Note: Some numbers have had to be estimated from graphs.
Source: Paix (2010), Sanchez-Borras (2010), Hyunkyu (2010), Toshiji (2007) and RFF (2007).

As well as city size, mode share is obviously important. Table 2.8 examines the relationship between share of the rail/air market and rail station to station journey time. It is often argued that in European and Asian conditions a maximum three hour station to station journey time is required for rail to compete with air. The reasoning is that rail fares are normally competitive with air, that for most passengers getting to a city centre rail station is faster than getting to an airport and passengers spend longer at the airport going through security etc., than passengers do at the rail station. With flight times themselves not varying much from around an hour, as most time on short flights is taken up with take-off and landing, a penalty for air approaching two hours in terms of getting to and waiting at the airport and some other advantages of rail in terms of comfort and reliability, a three hour rail station to station journey time is competitive. Thus it is generally considered that high-speed rail is most appropriate for journeys of 400-800 km. Below that range, even a good quality conventional service is competitive with air, whereas above 800 km even high-speed rail finds it difficult to compete (SDG, 2004). (However, high-speed rail may still be worthwhile at shorter distances than this in terms of competing with road traffic, although for journeys below around 150 km, frequency and accessibility in terms of convenience of stops become more important than speed in terms of the comparison with road journey times.)

It can be seen from Table 2.8 that there is some justification for the belief that in European and Asian conditions a 3-hour rail journey time will enable rail to compete with air, in that in every case where a three hour rail journey time is achieved rail has more than half the rail–air market, except marginally Madrid-Barcelona. Whilst 3 hours does indeed seem to be the sort of rail journey time at which rail typically gains more than half the market, it is not however a clear threshold effect. Rail gains market share rapidly as journey times come down towards 2 hours, whilst in some cases it retains nearly half the market with a journey time of around 4 hours. This diversity is to be expected; quite apart from differences in tastes amongst passengers, some passengers will have origins or destinations for which air is more convenient relative to rail, and the importance placed on reliability and comfort will vary.

Table 2.8. **Rail share of rail / air market and rail station to station journey times**

Corridor	Year	Travel Time	Rail Share %
Paris-Brussels	2006	1hr 25min	100
Paris-Lyons	1985	2hrs 15min	91
Madrid-Seville	2003	2hrs 20min	83
Brussels-London	2005	2hrs 20min	60
Tokyo-Osaka	2005	2hrs 30min	81
Madrid-Barcelona	2009	2hrs 38min	47
Paris-London	2005	2hrs 40min	66
Tokyo-Okayama	2005	3hrs 16min	57
Paris-Geneva	2003	3hrs 30min	35
Tokyo-Hiroshima	2005	3hrs 51min	47
Paris-Amsterdam	2004	4hrs 10min	45
Paris-Marseilles	2000	4hrs 20min	45
London-Edinburgh	1999	4hrs 25min	29
London-Edinburgh	2004	4hrs 30min	18
Tokyo-Fukuoka	2005	4hrs 59min	9

Source*:* Campos, J, de Rus G and Barron, I (2009), Sanchez-Borras (2010) SDG (2006).

But there is considerable variability in the rail market share for the same station to station journey time, and there is good reason for this as well. For instance, the advent of low cost airlines means that it can no longer be assumed that rail fares will be competitive, particularly where the journey is composed of legs on different operators, and the through fare is simply the sum of their individual fares. It is understood that fierce fares competition from air in one of their biggest European markets has been the reason for the comparatively low rail penetration of the Madrid-Barcelona rail-air market so far. There is a further warning in the sharp drop in the rail share of the London-Edinburgh market between the two dates recorded; this was a period of rapid growth of low cost airlines. On the other hand, high market shares have been achieved despite low cost airline competition by Eurostar and the French TGV, both of which make use of the same sort of yield management systems as the low cost airlines themselves.

Obviously, it is to be expected that where fewer passengers have city centre origins or destinations, and where more passengers use car as a feeder mode, as is likely to be the case in countries such as the US, rail will need shorter journey times than three hours to achieve high rail-air market penetration. Thus at best, the hypothesis that a three hour rail station to station journey time is sufficient and necessary for rail to complete with air, is a rough rule of thumb, needing verification by modelling competitiveness for any particular application.

Break-even volumes

De Rus and Nombela (2007) and de Rus and Nash (2009) have explored the key parameters determining the social viability of high-speed rail, and in particular the breakeven volume of traffic under alternative scenarios. They built a simple model to compute capital costs, operating costs and value of time savings for a new self-contained 500 km line at different traffic volumes. Typical costs were estimated using the database compiled by UIC (Table 2.2). A range of time savings from half an hour to one and a half hours was taken, and a range of average values of time from 15 to 30 euros per hour. Other key assumptions are the proportion of traffic that is generated, and the rate of traffic growth.

Table 2.9 shows the breakeven volume in terms of millions of passengers per annum in the first year, assuming all travel the full length of the line, under a variety of assumptions about the other factors. If on average passengers travel half the length of the line, then of course the required number is doubled. Note that benefit growth may occur because of rising real values of time as incomes rise, as well as traffic growth. With exceptionally cheap construction, a low discount rate of 3 %, very valuable time savings and high values both for the proportion of generated traffic and for benefit growth, it is possible to find a breakeven volume as low as 3 million trips per annum, but it is doubtful whether such a favourable combination of circumstances has ever existed. Construction costs of 30m euros per km will carry this up to 7 m, and a reduction of the value of time savings to a more typical level to 4.5 million; lower benefit growth and levels of generated traffic will take the result to 4.3 million. An increase in the rate of discount to 5% would take the value to 4.4 million. In other words, it appears to be the construction cost that is the key determinant of the breakeven volume of traffic; all the other adjustments considered have a similar smaller impact. All of these adjustments together would raise the breakeven volume to 19.2 million trips per annum, and even worse scenarios can of course be identified. On the other hand a more modest increase of capital costs to 20 million euros, with a high value of time savings but a discount rate of 5%, 30% generated traffic and a 3% annual growth in benefits leads to a breakeven volume of 9 million. This represents a realistic breakeven volume for a completely new self-contained high-speed line in favourable circumstances. All the breakeven volumes given assume end-to-end journeys; if some journeys only use part of the route, breakeven volumes would be proportionately higher.

Table 2.9. **Break-even demand volumes in the first year**
(million passengers) under varying assumptions

Construction cost (GBP k per km)	Rate of interest (%)	Value of time saved (euros)	Generated traffic (%)	Rate of benefit growth (%)	Breakeven Volume (m pass)
12	3	45	50	4	3
12	3	30	50	4	4.5
30	3	45	50	4	7.1
12	3	45	30	3	4.3
12	5	45	50	4	4.4
30	5	30	30	3	19.2
20	5	45	30	3	8.8

Source: Based on De Rus and Nash (2009).

These representative breakeven volumes ignore any net environmental benefits, but we have given reasons above to expect these to be small. What they also ignore is any network benefits in terms of reduced congestion on road and air, and also within the rail sector, and wider economic benefits. If these effects are significant then HSR may be justified at lower volumes.

The economic success of HSR in France, where the early lines all opened with more than 15 million passengers per year and have been found by ex-post appraisal to be economically worthwhile, compared with Spain where the traffic was 5 million or less and ex-post appraisal suggests that they were poor investments, tends to support the idea that there is a breakeven level of around 9 million passengers per annum in cost benefit terms (de Rus and Nash, 2009). The breakeven threshold for success in purely financial terms (i.e. completely remunerating the capital cost without assistance from the government) must be very much higher. It is understood that the only two high-speed lines to date to have achieved such success are the Tokaido line in Japan and the TGV Sudest in France. The Tokaido line opened with 35 million passengers per annum, and within 5 years was carrying 80 million. Within France, ex-post appraisals suggest that only the Sudest line achieved a financial rate of return in excess of 10% (with the Atlantique line achieving 7%) (RFF, 2006). TGV Sudest opened with only 15 million passengers per annum (and Atlantique with 22 million) but both have seen very substantial growth since, partly due to further extensions to the system, which have not themselves been financially profitable. It is therefore unclear to the current author to what extent the first two French lines can be said to be fully commercially viable at much lower volumes than those in Japan.

4. The high-speed rail debate in Britain

High-Speed 1

Background

The Channel Tunnel Act of 1987 provided for the construction of a rail tunnel under the Channel Tunnel between Britain and France. This was to be privately funded with no government subsidy either to the tunnel or to services using it. These would comprise regular shuttle services between terminals at either end of the tunnel for cars and road goods vehicles, conventional freight trains between terminals across Britain and the continent and high-speed passenger trains between London and Paris and Brussels. Whilst France and Belgium both planned new high-speed lines between their capitals and the Channel Tunnel, the initial intention was that in Britain the services would use existing heavily used surface lines to a new terminal at Waterloo (Butcher, 2010). The trains were to be operated by a consortium of British, French and Belgian Railways and services started with the opening of the Channel Tunnel in 1994.

In the meantime, in July 1988, British Rail published a report suggesting that in the long term extra capacity would be required to cope with international services. Their initial choice was a route approaching London from the South. However, in 1991, the then Secretary of State for Transport, Malcolm Rifkind, announced that the government had decided on a route entering London from the East, via Stratford, with the intention of promoting regeneration of this depressed part of East London. A station called Stratford International was to be built, and indeed was and still has that name, although the operator of international services, Eurostar, has never chosen to call there. It is served by domestic high-speed trains under a separate franchise agreement. Subsequent environmental pressure led to the conclusion that a long stretch of the line of some 19 km at the London end should be in tunnel. The line was to be built by a private consortium, with a government contribution in respect of use of the line by domestic services. After a competition to select a private promoter, a consortium called London and Continental were chosen. As part of the agreement they received, free of debt, the British Rail share of the passenger operator (Eurostar UK) and extensive lands at Stratford and Kings Cross / St Pancras on which to develop the necessary terminals, but also capable of commercial development to help finance the line.

Very early in its existence London and Continental concluded, because patronage of Eurostar was running below forecast, it could not raise the capital to finance the line without further assistance, and in 1998, the government agreed to underwrite its debt. The line opened in two stages in 2004 and 2007, with the long tunnel into central London being part of the second stage. In 2009, domestic high-speed services between stations in Kent and London were added as part of the franchise agreement with the operator in that area, South East Trains.

In 2009, the government bought out London and Continental Railways, with the aim of restructuring it and selling it without further government guarantees. In 2010, it was bought by a consortium of Borealis Infrastructure and Ontario Teachers' Pension Plan. They contract out maintenance and operations to the main British rail infrastructure company, Network Rail, and are subject to regulation by the British Office of Rail Regulation. There is now open access for any passenger or freight operator to use the line upon payment of the appropriate access charges; DB Schenker is running a small number of freight trains over it (one attraction is that it can take standard continental wagons which do not fit the loading gauge on other British tracks) and DB is intending to introduce a passenger service between Frankfurt and London using the line in due course.

The original appraisal

Because the 1998 arrangement exposed the government to some financial risk, a full appraisal of the scheme was undertaken to determine whether or not it was socially worthwhile. The results of this appraisal are shown in Table 2.10.

The transfer of Eurostar services from Waterloo to St. Pancras and the introduction of domestic high-speed rail services to St. Pancras will have made for more convenient access for passengers from North of London than Waterloo and other domestic terminals South of Central London. However, for much of England south of London it is less convenient.

Eurostar's international services have compulsory seat reservation, so crowding takes the form of passengers being unable to get a seat at the time they want. This might have become a problem on the old route at peak times when track capacity was scarce. Transfer of the services to a dedicated high-speed line segregated from slower services is understood to have brought about a major improvement in reliability. At the same time, removing these trains and some domestic traffic (by means of the domestic high-speed train services) from existing lines has reduced congestion, crowding and unreliability there and enabled the system to cope with continued rapid growth of domestic traffic (80% on the system as a whole in the last 15 years).

At the time of the appraisal, standard methods for appraising reduced overcrowding and unreliability did not exist. Methods do now exist which use a higher value of time for travel in crowded conditions and for time lost in delays as opposed to schedule journey time.

It will be seen that benefits to users form the majority of benefits. Benefits from reduced road congestion and reduced environmental externalities are estimated from the forecast reduction in road traffic and standard values for different types of road by time of day. The value of regeneration in the Stratford area was estimated by estimating the number of new jobs that would be created in the area, and multiplying this by the amount the government was willing to pay under other schemes to create jobs in priority areas for regeneration. This was not at the time a standard part of the appraisal process.

The costs shown in the appraisal are costs to government, including grants and interest payments. The standard benefit-cost ratio on which decisions are taken in Britain is the ratio of net benefits to others per pound of government spending.

Table 2.10. **1998 Appraisal of HS1**
(GBP million 1997 NPVs)

User benefits -International Services	1 800
User benefits - Domestic Services	1 000
Road Congestion	30
Environmental benefits	90
Regeneration	500
Total Benefit	3 420
Costs to government	1 990
NPV	1 430
BCR (all benefits)	1.72
BCR (excluding regeneration benefits)	1.5

Source*:* National Audit Office (2001).

Subsequent appraisals

By the time the National Audit Office examined the project most recently (National Audit Office, 2012) its estimate of the value of time savings had increased to GBP 7 billion present value terms at current prices. The reason for this increase is largely a change in government appraisal methods, including a lower discount rate (3.5%) and a longer (60-year) assumed life, as well as rising values of time over time. However, the cost to the government had increased to GBP 10.2 billion in present value terms. It made no attempt to quantify the other benefits of the line, but noted that these would have to total GBP 8.3 billion for the line to have a benefit-cost ratio of 1.5, the level required for a project to be seen as offering medium value for money in the UK. The main problem was a 30% shortfall on patronage of international services compared with the estimate made at the time of the 1998 appraisal (Booz and Co, 2012). It appears that the main reason for this is not a failure of rail to take the predicted market share, but that whereas the forecast assumed continuing rapid overall market growth, in practice the market ceased to grow. The way in which the project was financed, with a lack of equity capital and the government underwriting the bonds, left the government to pick up the cost of this shortfall (ITF, 2013). The out turn construction costs were as in Table 2.11 and were within the financial provisions made at the time of the approval of the project in 1998:

Table 2.11. **Out turn capital costs of HS1**
(GBP M)

Section 1 construction costs	1 919
Section 2 construction costs	3 778
Station fit-out	109
New depot	357
Total	6 163

Source: NAO (2012).

It should be noted that section 1 comprises 74 km, whereas section 2 is only 39 km; however, section 2 includes a 19 km tunnel into Central London as well as a 2.5 km tunnel under the River Thames. Infrastructure UK (2010) compares the cost per km of building HS1 with five comparable projects elsewhere in Europe using purchasing power parity exchange rates. The mean construction cost of the other five was GBP 19 million per km, for HS1 stage 1 it was GBP 24 million and for stage 2 GBP 94 million. This gives some indication of the very high cost of section 2, which included the tunnels noted above as well as the refitting and extension of St. Pancras station in London and new stations at Stratford and Ebbsfleet.

Regeneration impacts

The opening of the tunnel into central London and the St. Pancras terminal has occurred simultaneously with one of the largest inner-city regeneration projects in Europe. Over a 67 acre site (27.1 hectares) some 8 million square feet (750 000 m^2) of mixed use development including businesses, 1 800 homes, cultural facilities (cafes, bars, restaurants, etc.) and community (health, education, etc.) facilities is under on-going development[1]. The development will end decades of blight and low quality land use in the area with all the attendant social problems.

Hedonic pricing studies have already identified uplift in property values in the vicinity of the rail terminals since the opening of the high-speed tunnel link indicating positive economic impacts. Cascetta *et al.* (2010) for example estimate house prices in the Borough of Camden increased by 13% as a result of the opening of tunnel link and St Pancras station. How much of the increase in property prices is due to the high-speed rail tunnel and train station development and how much is due to the Kings Cross Central regeneration project is of course debatable. Some regeneration may have occurred anyway with just a re-modelling of Kings Cross station and St. Pancras. However, the implicit linking by the government of the high-speed rail tunnel alignment to the area would suggest that the improved transport accessibility and image of the high-speed rail link were major contributing factors.

The regeneration effects of the tunnel and link are not just confined to London. The increased rail capacity permits fast (domestic) trains to run to Central London from Ashford in Kent. Here it is planned that 13 000 new houses and 10 300 new jobs will be created by 2016, increasing to 31 000 homes and 28 000 new jobs by 2031 (Cascetta *et al.,* 2010).

Such re-generation impacts do not enter the cost benefit analysis process, as the overarching guidance of cost benefit analysis in the UK (HM Treasury's Green Book) does not permit the shadow pricing of labour. That is, it is assumed that the economy is in full employment so any jobs generated will be offset by reductions in employment elsewhere. Moreover increases in property values are regarded as capitalisation of other benefits, such as time savings, and are also not allowed as additional benefits. Guidance to decision makers in the UK includes analysis of non-monetised impacts alongside cost benefit assessment. Regeneration impacts are included in the non-monetised part of the appraisal when they are potentially significant and can therefore affect the decision to build new infrastructure even though they are not part of the cost-benefit analysis.

Conclusions on HS1

The HS1 project was very expensive because of the need for a large amount of tunnelling to reach Central London in an environmentally acceptable way, particularly over the route chosen politically on grounds of regenerating a depressed area of inner London. It is not thought that this original decision was based on any detailed appraisal of the options, but an appraisal was undertaken when the government had to step in to underwrite the project's debt in order to enable it to continue. At the time it appeared that the project could be justified given the forecast growth in international rail passenger traffic, but in practice the forecast growth did not materialise, leaving a rather more marginal case. NAO (2012) concludes that, despite carrying 18.1 million passengers per annum (9.7 m international and 8.4 m domestic), the time savings to users were inadequate to justify the capital cost. Its value therefore depends on regeneration and wider economic benefits. In the original appraisal, quantification of the regeneration benefits of locating a high-speed rail station in Stratford was based on inadequate methods; subsequent work has suggested a much greater impact (Colin Buchanan and Partners/Volterra, 2009), although its magnitude and whether it really represents a net addition to economic activity remain controversial. In addition substantial wider economic benefits were estimated. As we shall see in the following section on HS2, quantification of wider economic impacts has remained an important and controversial issue.

High-Speed 2

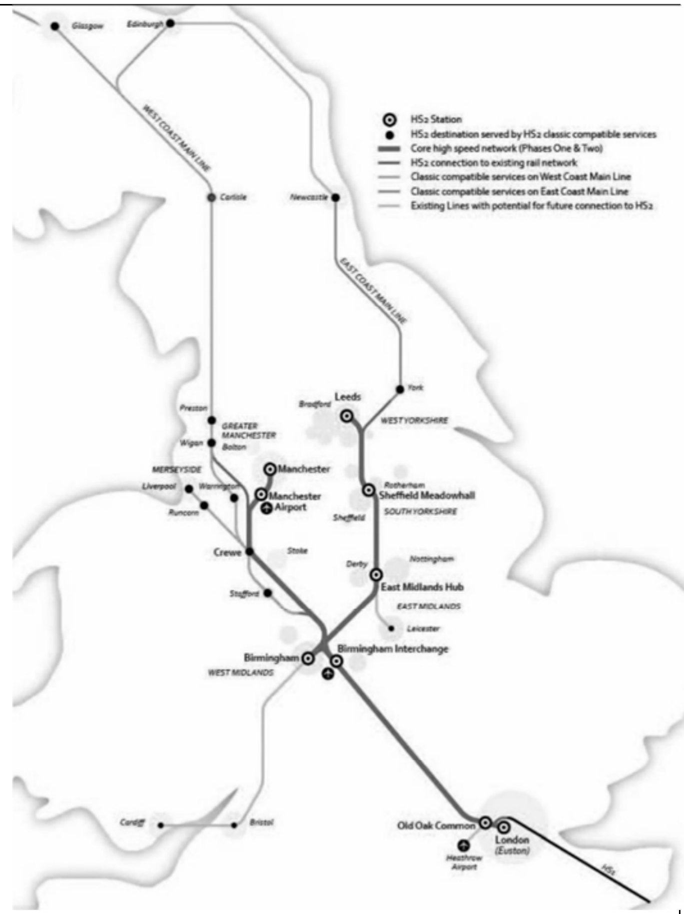
Introduction

In 2001, the Strategic Rail Authority, the government body then responsible for rail planning, commissioned the first study of high-speed rail between London and the North (Atkins, 2002). The background was steady growth in rail demand over the preceding few years which, if it continued, would eventually impose capacity constraints, plus the possibility of substantial savings in travel time. The remit thus required the consultants to examine the case for high-speed rail and the route it might take, bearing in mind the contribution it would make to easing capacity constraints and the amount of travel time saved. The latter objective required concentration on medium distance routes between large centres of population where existing and potential rail demand were high, whilst the former objective concerned routes that would relieve the West and East Coast main lines (the principle constraints on growth) of significant amounts of traffic. Altogether 16 high-speed rail options were examined comprising different combinations of the sections of track shown in Map 2.1. Option 1 was a minimal line from London to Birmingham; option 8 a fairly complete network with a West Coast line from London to Birmingham and Manchester, and a branch to Leeds and on to Scotland. Also considered were building a conventional line, upgrading existing lines, road widening and airport expansion (although airport expansion was not modelled in the study. Extensive sensitivity testing was also undertaken, including examining the impact of four different long run economic scenarios, examining rail pricing policy and sensitivity to costs of other modes of transport.

Map 2.1. **Options considered by the Atkins study for HSR**

Source: Based on Atkins (2002).

Map 2.2. **Route chosen for HS2**



Source: Based on DfT (2013).

Table 2.12**. Appraisal of options 1 and 8 in the Atkins study**

	Option 1	Option 8
Net revenue	4.9	20.6
Non-financial benefits	22.7	64.4
Released capacity	2.0	4.8
Total benefits	29.6	89.8
Capital costs	8.6	27.7
Net operating costs	5.7	16.3
Total costs	14.4	44.0
NPV	15.3	45.7
B/C	2.07	2.04

Source*:* derived from Atkins (2003) Addendum. Table 2.1 with transcription errors corrected.

All but one of the HSR schemes gave good benefit cost ratios, with highest NPV coming from the most complete option, option 8 (Table 2.12). With a BCR close to the smallest option and above 2, this looks like the best option if it can be afforded.

A conventional line could be built for 20% less than HSR, but would lose GBP 5 billion of benefits for a cost saving of less than GBP 2 billion, whilst upgrading of existing lines appeared even less favourable. The road widening option appeared worthwhile but of less value than HSR. Also tested was the issue of timing; it appeared best to build the full HSR network as soon as possible (by 2016) rather than deferring it to 2021 or 2026. Charging premium fares reduced the benefits, although it was noted that the demand model did not permit testing of more differentiated pricing to target less elastic market segments (it is a common problem of rail appraisals that yield management systems are inadequately modelled, leading to an understatement of revenue or demand or both.).

Ultimately the value of a study is only as good as its forecasts, and the fact that this study foresaw the West Coast Main Line running out of capacity by 2016 suggests its forecasts were not accurate (to be fair, few foresaw the financial crisis of 2008 and subsequent recession). But in terms of what it considered, the Atkins study seems to have been a model of its kind, considering a wide range of options, including a road alternative, alternative economic scenarios and examining both fares policy and timing, which are often neglected in appraisals. Extensive sensitivity testing was undertaken.

There was no immediate follow up to this study, but in the light of continued growth in traffic, Network Rail (the infrastructure manager) undertook its own 'New Lines' study in 2009 (Network Rail, 2009). Whilst there was no necessary presumption that new lines would be high-speed rail, as in the Atkins study, the study showed that in general if new lines were built for long distance rail, the extra benefits of high-speed would be worth the extra costs. This study again found a good case for HSR but this time favoured the West Coast Route to Scotland, serving Birmingham, Manchester and Liverpool but not Leeds. (The option of a line diverging to Leeds and the North East was not considered; it was argued that a separate new HSL might in due course be justified for this route.) It found direct connections to Heathrow and to the high-speed line to the Channel Tunnel to be uneconomic given forecast volumes of traffic.

The response of the government however, was to set up a new company, HS2 Ltd, to look at the case for a high-speed line from London to Birmingham as a first stage of a wider network. After reviewing the options, HS2 concluded in favour of a Y-shaped network along the lines of Atkins option 8 (the extensions to Manchester and Leeds forming phase 2). Trains would continue on conventional lines to a range of cities including York, Newcastle, Liverpool, Glasgow and Edinburgh. Euston was chosen as the London terminus for the new line, but it would also call at Old Oak Common, where a high quality interchange would be provided with the new Crossrail line. This would provide an attractive way of reaching all the terminals at Heathrow (a Heathrow terminus would only provide direct access to one terminal with a bus or train ride needed for the others) with Central London, Docklands and East London. It was important because, were all passengers to arrive at Euston, the station and its underground rail connections would be swamped. Subsequently, political decisions were taken to provide direct links to one Heathrow terminal (consideration of this is now postponed pending a review of airports policy) and by a single track link to a heavily used existing line for connection to the high-speed line to the Channel Tunnel.

Appraisal of HS2

Essentially, the British approach to appraisal consists of quantifying as many of the costs and benefits as possible in money terms; other factors are presented as quantitative or qualitative evidence to be taken into account subjectively. The aim of the appraisal is to estimate the net benefits of the project to all sectors other than the government per pound of government spending. Given current constraints on government spending, it is common in Britain to consider that only projects giving at least GBP 2 of benefit per pound of government spending offer good value for money unless there are substantial net unquantified benefits.

Regarding wider economic benefits, for many years the British government followed the conventional wisdom that there would be no economic benefits other than the time and cost savings already included in a standard transport appraisal. The first major questioning of this position in Britain came about in the course of the appraisal of the Crossrail project, a major project to link suburban rail lines East and West of London by a major new tunnel across London, greatly increasing capacity and leading to faster journeys for many commuters (Worsley 2012). Surely, it was argued, this would both raise the productivity of existing Central London employment and permit more jobs to locate in this area of high productivity. A very influential paper was that of Venables (2007) who used the concept of agglomeration economies to show that this argument might well be correct. Firms in highly accessible locations in city centres do indeed tend to have higher productivity (they must to justify the higher costs of such a location). Investments which increase accessibility will both provide an external agglomeration benefit to firms already located there and enable jobs to relocate there from lower productivity locations (to the extent that it had previously been possible to locate there, it may be argued that if additional trips and the consumer surplus associated with them were correctly forecast then this benefit to the relocating firms will already have been taken into account in the appraisal, although there will still be agglomeration externalities accruing to other firms in both the original and the new locations). However, the increased tax revenue implied by relocation to a higher wage and productivity location would not be valued as part of the consumer surplus as it is not received by the consumer but rather by the government.

Subsequent work, particularly that of Graham (2007), enabled these impacts to be quantified and introduced into the appraisal. A further argument has also been allowed for, in that if a degree of monopoly power is the norm, and prices are generally above marginal costs, then anything that reduces the costs of employers and thus increases their output will tend to have an additional benefit of the difference between price and marginal cost of the increased output. This provides a further argument for a multiplier to be applied to the value of business travel time savings in the appraisal. Whilst in principle these effects would apply to all modes of transport, to the extent that rail dominates commuting and business travel in large cities (in Britain, particularly London), they might particularly favour rail investment in those locations. Elsewhere, car travel dominates and the arguments might favour investment in roads.

Graham and Melo (2010) argue that investment in long distance rail cannot have a significant wider economic impact because of the small overall rail market share of journeys in the course of work and the fact that most such journeys are relatively short distance. This is essentially the position of DfT. The appraisal of HS2 therefore allows for the presence of wider economic benefits from improved commuter services using the capacity released by HS2, but not for any wider economic benefits of improved inter-city connectivity.

Table 2.13 shows the results of the 2013 update of the economic case for the line. The principal benefits would again be benefits to transport users. Wider economic benefits were forecast to exist entirely because of agglomeration benefits from the release of capacity on existing lines to improve commuter services into the main cities (in particular London) rather than because of improved inter-city connectivity. Whilst even the first phase of the line from London to Birmingham would benefit a large network of origins and destinations, since it would carry trains to major centres of population such as Manchester and Glasgow which would complete their journeys on the conventional network, the full Y-shaped network actually shows a higher BCR than the first phase alone. The reason is that extending the line to Manchester and in particular connecting it to Leeds and the North East permits better use of the first phase of the network, giving a better overall result.

Table 2.14 shows the breakdown of transport benefits. It will be seen that over half of the benefits are time savings, with business travel time savings being around 40% of the total. But improved reliability and reduced crowding are also estimated to be substantial sources of benefits. Tables 2.13 and 2.14 are based on the simple assumption of pricing parity between high-speed trains and conventional trains.

Table 2.13. **Standard appraisal – discounted costs and benefits (over 60 years)**
(GBP billion 2011 prices)

	Phase One *Oct 2013*	**Full Network** *Oct 2013*
Transport benefits (Business)	16 921	40 529
Transport benefits (Other)	7 673	19 323
Other quantifiable benefits	407	788
Indirect taxes (loss to Government)	-1 208	-2 912
Net transport benefits	23 793	57 727
Wider economic impacts	4 341	13 293
Total costs	29 919	62 606
Revenues	13 243	31 111
Net cost to Government	16 676	31 495
Benefit cost ratio (incl. WEIs)	1.7	2.3

Source: DfT (2013).

Table 2.14. **Breakdown of benefits from the proposed HS2 scheme**

(GBP billion 2011 prices)	**Phase One**	**Full Network**
Time savings	17 334	45 679
Crowding benefits	4 068	7 514
Improved reliability	2 624	5 496
Car user benefits	568	1 162
Total transport user benefits	24 594	59 852
Wider economic impacts	4 341	13 293
Other impacts	407	788
Loss to Government of indirect tax	-1 208	-2 912
Total	28 134	71 020

Source*:* DfT (2013).

The project has been strongly criticised by opponents to the scheme, ranging from some who think the money would be better spent on roads to others who object to its environmental impacts or want the money spent on local public transport. For a systematic presentation of the arguments see Castles and Parish (2011). The most significant criticisms were of:

– *The robustness of the demand forecasts*

The latest version of the business case assumes growth in demand of 2.2% p.a. until 2036, and constant demand thereafter. This is considerably slower demand growth than achieved by long distance train operators in the last 20 years, despite the effects of recession. HS2 Ltd has conducted a risk analysis, which shows a very low probability of the benefit-cost ratio falling below 1.5; if demand growth were to continue beyond 2036 then the benefit-cost ratio could rise considerably higher than the standard case estimate of 2.3. Yet it must be accepted that demand growth is uncertain. It is possible that past relationships with GDP might break down and growth stop before 2036. It is argued that, for instance, developments in information technology might lead to its substitution for much travel, although at present it seems that it is encouraging travel by rail for business and for leisure amongst younger males (Le Vine and Jones, 2012).

– *The valuation of time savings*

It has already been noted that the standard approach to valuation of business travel time, based on the wage rate, is argued to be inappropriate for inter-city rail travel since business travellers work on the train. Castles and Parish argue that the value of business travel time savings should be based solely on the loss of utility to the traveller as represented by the value of commuting time. However, this assumes that all time savings will be at the expense of work done on the train, that work on the train is as productive a work in the office and that there are no other benefits in terms of scheduling more meetings in a day, avoiding overnight stays and arriving at meetings more alert. We have noted above that most evidence suggests that businesses are prepared to pay at least the wage rate for time savings for business travellers.

– *The degree of attention paid to alternatives*

It is argued that too little attention has been paid to optimising a set of alternative proposals to upgrade existing lines, and that a package of alternative measures (including some degree of demand management by price) exists which would meet demand at much less cost. The so-called 51 Million package was put forward by a group of opposing local authorities as such an alternative (Castles and Parrish, 2011).

Atkins was commissioned to appraise this package (Table 2.15). It found that the package would cost only GBP 1.2 billion, and would yield a benefit-cost ratio of no less than 6. However it would not provide sufficient capacity to provide for peak demand. Given its BCR, many people argue that it is clearly a better investment than HS2. However, ranking projects on the basis of BCRs is not an appropriate way to take decisions. What matters is whether the additional cost of a more expensive alternative is justified by the extra benefits. If we look at the incremental costs and benefits of HS2, it shows an incremental benefit-cost ratio of around 2.[2] Thus the additional cost of HS2 is justified by additional benefits, according to the appraisal. But there remains concern that, at a time of constrained government spending, such a large investment will squeeze out many smaller investments that might collectively have provided better value for money.

Table 2.15. **Incremental benefits and costs over 51 M package**
(GBP billion 2011 PV)

	51M	Y-shaped increment
Benefits	7.108	46-52
Costs to government	1.173	25-23
BCR	6.06	1.6-2.3

Source*:* derived from Atkins (2012).

The latest strategic case published by DfT includes a much more thorough examination of alternative rail schemes (diversion of traffic to road or air is dismissed as incompatible with government policy). Several different packages of schemes, including duplicating sections of main line and improving junctions and existing stations were put together. Table 2.16 shows the appraisal of the packages of schemes most comparable to HS2. Neither package provides nearly as much capacity as HS2. Both provide higher BCRs than HS2, but the incremental BCR from the much greater investment in HS2 remains above 2.

Table 2.16. **Capital costs and benefits of alternatives**

	HS2 Phase One	Phase One Alternative	HS2 Both Phases	Phase One and Two Alternative
Capital costs (£bn)	19.4	2.5	38.4	19.2
Benefit-cost ratio	1.7	2.0	2.3	3.1
Benefits £bn	28.1	8.5	71.0	30 .7

Source*:* DfT (2013).

Wider economic benefit

It was noted above that the DfT appraisal contains no wider economic benefits from improved inter-city connectivity, although this – and the idea that HS2 will help reduce the North-South divide in terms of British prosperity – have been influential arguments politically. The DfT position has been challenged in work recently undertaken by KPMG (2013) for HS2. The first step of their methodology is to calculate the impact of HS2 on labour and business connectivity by location. They do this by looking at journey times weighted by the distribution of existing journey lengths for the purpose in question (the so-called distance decay function). As seen in Table 2.17, most areas gain, even when not directly served by HS2 (long distance journeys may still use HS2 for part of their route, whilst other places gain from improved services using the capacity released on the existing network), although it is the Midlands and South Yorkshire that enjoy the greatest gains (they gain for journeys to London but also to other cities in the Midlands and North).

They then regress labour productivity on rail connectivity and similar measures of connectivity by road. The difficulty faced is that these indicators of connectivity are all highly correlated (and may be correlated with other benefits of a city centre location). The result is that only one measure of connectivity can be included in a single regression. They therefore run separate regressions of labour productivity on rail connectivity and on road connectivity. They scale down the parameter value on rail connectivity by assuming that rail connectivity is responsible for a proportion of the benefits equal to the ratio of the parameter values on rail connectivity and road connectivity in the separate regressions. This leads to an estimate that HS2 could add GBP 15 billion per annum to GDP. Whilst this is not entirely additional to the current appraisal benefits, it must represent a substantial uplift. However, there is no theoretical justification for the assumption by which the rail share of the effect is estimated, and a sensitivity test using mode share data to perform this allocation gives a much lower value. Moreover, it has been argued that inadequate attention has been paid to the issue of labour quality. Thus the wider productivity impact of HS2 remains very uncertain.

Table 2.17. **Average change in connectivity by region in 2037 after investment in HS2**

City regions	Change in labour connectivity by rail	Change in business connectivity by rail
Derby-Nottingham	14.7%	23.2%
Greater Manchester	1.4%	18.8%
Greater London	6.9%	8.8%
South Yorkshire	31.8%	22.5%
West Midlands	15.7%	21.1%
West Yorkshire	9.1%	19.7%
Rest of Great Britain	5.3%	11.3%

Source*:* KPMG (2013).

Conclusions on HS2

HS2 represents something of an extreme in terms of HSR. Its costs are exceptionally high (although they contain a large contingency in view of past experience with projects overrunning on cost). But its traffic forecasts (more than 40 million trips per annum at opening of phase 2) are also very high. The high level of traffic is the result of British geography, which if not quite the Japanese string of pearls, enables many of the main cities of Britain (London, Birmingham, Manchester, Leeds) to be served by a single line splitting into two in the Midlands. Moreover, trains can then continue on conventional lines to serve a large number of other cities including Liverpool, Newcastle, Glasgow and Edinburgh. The result is a high estimated benefit cost ratio.

Of the uncertainties surrounding this ratio, the greatest concerns growth in demand. If growth in demand slowed or ceased, it would have a substantial effect on the BCR, although the BCR would be very unlikely to fall below 1. If demand continued to grow long term (in the current forecast growth in demand is capped at its 2036 value) the BCR would be still higher.

The question of whether the improvements in inter-city connectivity would bring greater economic benefits than are included in the official CBA remains uncertain and controversial.

5. Overall conclusions

From the number of studies undertaken and the experience of high-speed lines around the world, it is possible to reach some general conclusions on the circumstances in which high-speed rail will be worthwhile. Of course, the decision is a trade-off between costs and benefits; factors which make for higher costs may be outweighed by other factors making for higher benefits. The dominant factors are construction costs, value of time savings per passenger and the volume of passengers.

Firstly, high-speed line construction costs vary greatly, but a major factor is the amount of tunnelling. If routes can be found which allow access to city centre stations without tunnelling the savings will be large. This might be achieved by placing suburban services underground; this may be a lower cost solution and have other benefits if it enables suburban services to penetrate and cross the city centre.

Secondly, the value of time savings per passenger will vary with the quality of the alternative and the incomes (and therefore value of time) of passengers. HSR will bring greater time savings per passenger where it is substituting for conventional rail or car than where it depends for most of its traffic on a marginal time saving compared with air. Of course other benefits – environmental and reduced congestion at airports – may be greater where it is predominantly diverting from air, but it is unlikely that these will compensate for the smaller time savings in the appraisal.

Thirdly, serving a large population is crucial. High-speed rail requires either to link very large cities, or to serve a string of large cities, possibly by running on conventional lines past the end of the high-speed line. High density cities with strong public transport networks will favour HSR over car and air. HSR journey times of around 3 hours are required to compete effectively with air, however, so HSR will be most effective for routes of up to 800 km. For shorter journeys, HSR may be worthwhile in terms of time savings to existing rail users and diversion from car, but below around 150km, the high-speed of HSR will be irrelevant because of the shortness of the journey.

Fourthly, congestion on existing rail, road and air systems will favour HSR by providing a case for more capacity. However, there are always numerous ways of providing more capacity; a policy which favours rail over road and air on environmental grounds will obviously favour the case for HSR.

Notes

1. Kings Cross Central website: http://www.kingscrosscentral.com/
2. Until recently, 2 was the threshold for the British government to consider a project to give high value for money.

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Chapter 3.

Performance in France: From appraisal methodologies to ex-post evaluation

Yves Crozet[1]

In 1975, France was the first European country to embark on the high-speed rail (HSR) odyssey. Regarded as something of a niche activity initially, high-speed rail has become a national priority. The lines currently under construction will bring the HSR network to 2 600 km by 2017. The French "model" gives us a basic lesson: geography (size of the cities and distance between them) is the crucial factor of success and determines the economic profitability. Due to the lack of new profitable lines, France is now facing some limits to HSR network extensions. It is not surprising; therefore, that in 2013 the French Government declared a slowdown if not a halt to all new HSR works. After 2017, only the Bordeaux-Toulouse line might see the light of day: the other lines for which local politicians lobbied so forcibly pose formidable financing problems.

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1. Introduction

France embarked on high-speed rail travel almost 40 years ago.[1] Today it carries more passengers by far on its high-speed trains than any other European country. Regarded as something of a niche activity initially, high-speed rail has become a national priority in France as evidenced by its 2 033 km network of high-speed lines (LGV). The lines currently under construction will bring this total to 2 700 by 2017.

The purpose of this paper is to set out the reasons for this success and, in particular, the propitious environment in which it was achieved: an environment which certainly does not prevail today. Having had the political courage to launch the first high-speed line in Europe, France will no doubt soon have to summon the courage to say that its LGV network is almost complete. However, this will be a difficult decision to take because France nurtures a kind of "TGV mania" whereby all the regions and most of the large conurbations feel that they must have a high-speed train (TGV) service. The development of high-speed rail in France is a practical experience which has many lessons to offer in terms of the relevance of high-speed rail travel.

- In the first part of the paper, we will present the main phases and the principal performance characteristics of the high-speed rail system in France. We will also explain the need to distinguish between high-speed train (TGV) and high-speed line (LGV).

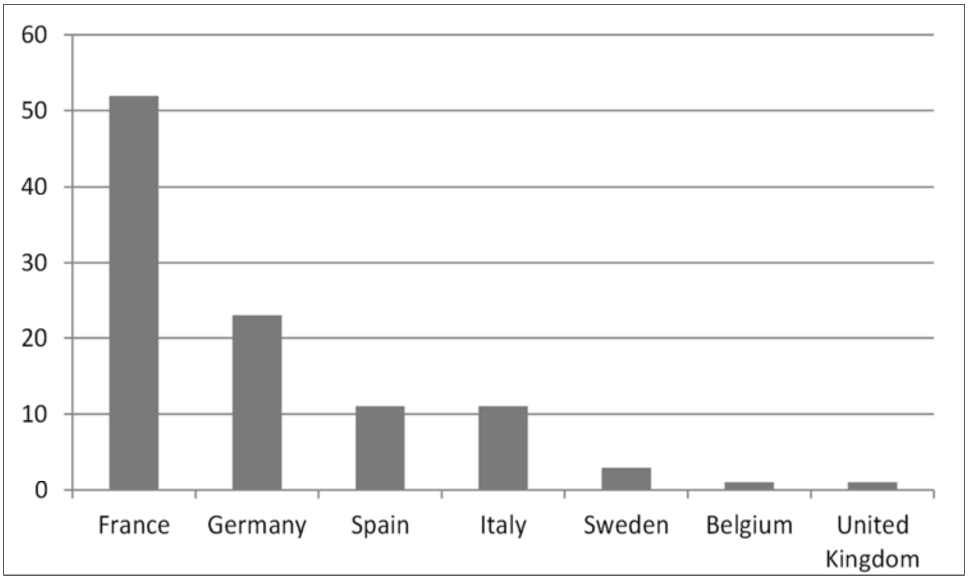
- In the second part of the paper, we shall see that it is more accurate to talk about high-speed rail systems in the plural because there are other "models" in Europe which differ from the one developed by France. High-speed rail is not just a matter of technology; it also depends on the geography of the country, on the country's institutions and on its ability to master the art of project assessments.

- The assessment question is becoming increasingly important in France as the network develops for the simple reason that the more the LGV network expands, the more the profitability of new sections becomes questionable. This is the issue being shown up by the statutory *ex post* assessments now taking place in France. They will help us to answer a delicate question in the third part of this paper: In terms of LGVs, how far is not too far? Which brings us back to the question of what should be done with the traditional rail network.

Main phases and principal performance characteristics of the high-speed rail system in France

In order to understand the success of the high-speed rail system in France, we need to start by comparing "high-speed" traffic in France and in other European countries. In 2010, high-speed rail traffic amounted to 52 billion passenger-kilometres in France as against 23 billion in Germany, 11 billion in Italy and Spain, 3 billion in Sweden and 1 billion in Belgium and Great Britain. This relative domination by France can be explained by its long-held preference for high-speed: a field in which France has played the leading role in Europe on the basis of what we might call the "Paris-Lyon model".

Figure 3.1. **High-speed rail traffic in Europe, 2012**
(billion passenger-km)



Source*:* Eurostat.

From LGV network to TGV services

France was the first European country to embark on the high-speed rail odyssey. Approved in 1975, the first high-speed line, between Paris and Lyon (450 km), was opened to traffic in September 1981and extended in 1983 (427 km). It now carries more than 150 trains a day at a cruising speed of 320 km/h. The success of that line provided the basis for extending the network. As Box 3.1 and Map 3.1 show, the LGV network developed in star fashion,[2] radiating out from Paris. It aims to link the capital to the main cities in order to enable TGV users to travel out and return within the day as allowed by the Paris-Lyon model. This idea of a "Paris-Lyon model" helps us to understand the choices that were made to extend the network. Whether we are talking about the local French network or its connections with neighbouring countries (Belgium, the United Kingdom, Germany, Luxembourg or the Netherlands), the TGV does not aim to reduce journey times for short- and middle-distance travellers; rather, it aims to attract long-distance interurban mobility, in other words business and leisure travellers.

High-speed rail is not part of the universal rail system which is regarded in France as the public system. The TGV is a commercial service aimed at users who can afford to pay. Only about 10%-15% of the French population use the TGV on a regular basis. That often-overlooked statistic explains why a TGV service cannot run profitably to all destinations. SNCF (French National Railways Company), the state-owned company which operates the TGV in France, often points out that, from its own point of view, it is only the routes serving Paris that are financially viable. There is little potential traffic between second-rank cities such as Lille and Lyon or Lyon and Nantes. There are direct TGV services between those cities, but SNCF finances them through cross-subsidies from profitable routes, those which serve Paris.

Box 3.1. **The main dates of LGV network extensions in France**

1981: opening of the Paris-Lyon line (serving the south-east).

1989-1990: opening of the Paris-Tours line (serving the south-west and Brittany).

1993: opening of the Paris-Lille line (serving northern France, Brussels and London).

2001: opening of the Lyon-Marseille line (serving the Mediterranean).

2007: opening of the first section of Paris-Est line (serving Lorraine, Alsace, Luxembourg and Germany). The second section will be opened in 2016.

2011: opening of the first section of the Rhin-Rhône line (first section not linked directly to Paris).

2011-2012: Launch of works on four new lines: Tours-Bordeaux (south-west), Bretagne-Pays de Loire (west), extension of the TGV Est line as far as Strasbourg, Nîmes-Montpellier bypass. These four lines will open in **2017**.

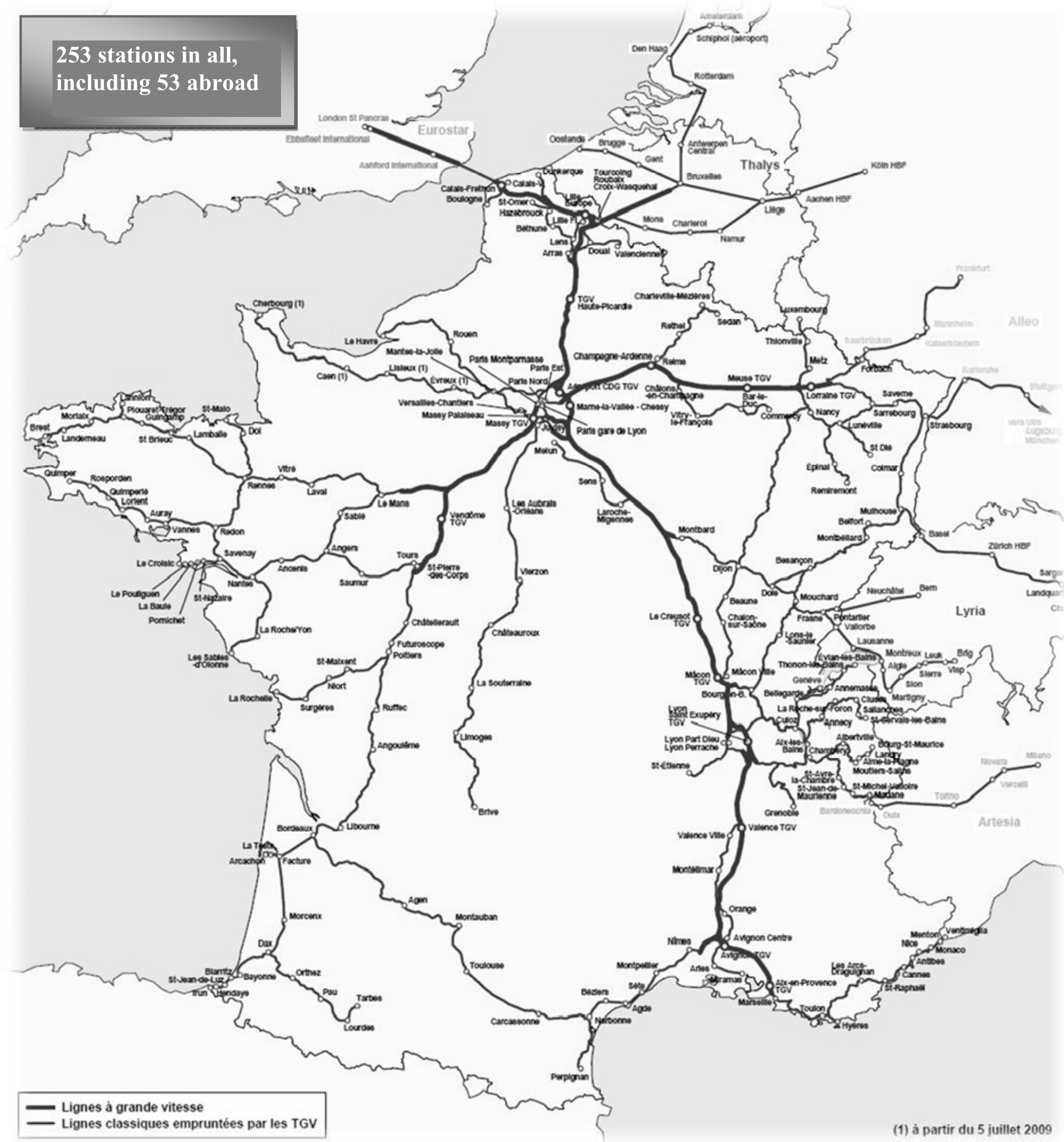
2013: A ten-member ministerial commission comprising members of parliament and experts[3] recommends delaying or abandoning several LGV projects. Only the Bordeaux-Toulouse line may open before 2030.

Cross-subsidies between lines go a long way towards explaining the development of the high-speed rail system in France. Thanks to those subsidies, it has been possible to develop a TGV service even in towns that are located far from LGV lines. Because TGVs can run on conventional lines (provided the lines are electrified), over 200 stations in France are now served by TGVs. This can be seen from Map 3.1. TGVs run on an LGV for part of their journey and on conventional line for the remaining, often long, section. Thus, it is possible to travel from Marseille to Rennes, or from Marseille to Strasbourg, and even to Frankfurt in Germany, without changing TGV. Traffic is only moderate on these links compared to the Paris-Lyon route, but this helps to expand the TGV offer and make it more accessible for customers.

The interoperability of TGVs, in other words the fact that they are able to run on the new LGVs and also on conventional network lines is a crucial factor. Due to this characteristic, the technical progress offered by the TGV is entirely compatible with the former rail infrastructure. Thus, investment in an LGV does not diminish the existing railway heritage. Rather, it gives it a second lease of life, as demonstrated by the renovation of stations and their pivotal role in cities such as Lyon, Lille, Strasbourg, Rennes, Nantes, etc.

There are therefore political reasons for the success of the TGV in France. For local politicians, the arrival of the TGV has often been the springboard for launching extensive city centre regeneration. There has often been extensive regional political lobbying for a TGV service and the construction of new LGV lines meeting the Paris-Lyon standard, in other words lines capable of carrying trains travelling at 320 km/h, or today even up to 350 km/h. In many peripheral French regions, politicians from different towns and with differing political allegiances have come together to lobby for LGVs. This has led government to subsidise the construction of commercially unprofitable lines.

Map 3.1. **High-speed lines and stations served by the TGV in France**



High-speed lines
Conventional lines used by TGVs
From 5 July 2009

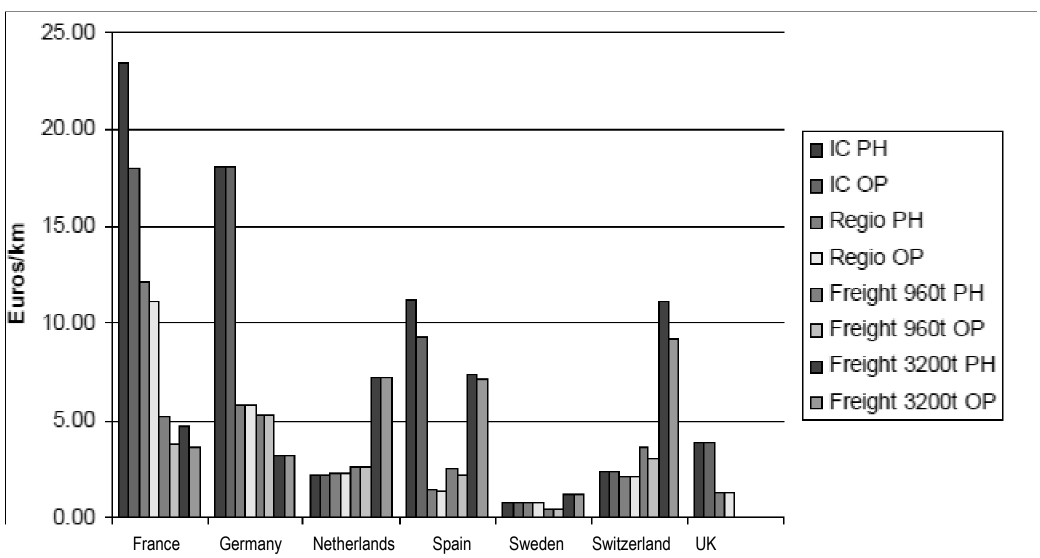
Source*:* SNCF.

The commercial bases for success

In terms of viability, it is essential to distinguish between railway infrastructure and the operation of trains.

- In terms of infrastructure, there is virtually no viable line, with the possible exception of the Paris-Lyon link. It is not possible to obtain precise information on this point because the early years of LGV development marked a time when SNCF was an integrated rail operator (that is, it managed the infrastructure and operated the trains). During that period, the financing of new LGV lines was achieved by increasing the debt of SNCF. That debt amounted to 180 billion francs in 1997 (around EUR 27 billion), at the time when RFF (the infrastructure manager, GI) was separated from SNCF (the rail operator). Two-thirds of that debt was transferred to RFF. This corresponded to debt accumulating from infrastructure investment, maintenance and renewal, including for high-speed lines.
- Following the creation of RFF (Réseau Ferré de France), it is now possible to pinpoint public infrastructure subsidies because they appear in the LGV financing system. Thus, for the LGV Est line, which opened in 2007, the rail tolls levied by RFF cover less than 40% of the full cost of the infrastructure (including financial costs). The LGV has therefore been financed to the tune of 60% by subsidies from central government, territorial authorities and, to a much lesser extent, Luxembourg and the European Union. All the high-speed lines currently under construction or planned are in the same situation. They require a 50%-90% injection of public funding in order to compensate for the fact that it is impossible to finance these lines solely from rail tolls. Even though the tolls are regarded as high in France (see Figure 3.2), they nonetheless represent a degree of undercharging which enables the operator to offer tickets which are somewhat cheaper, for the same service, than in other European countries because French load factors are higher.

Figure 3.2. **Rail infrastructure use charges in Europe**



Note: For each country, the two columns to the left indicate high-speed train charges (IC PH and IC OP).
Source: Vidaud M. & G.de Tilière, 2010.

- Although the LGVs themselves are not economically viable, the same cannot be said of the TGVs which are viable for SNCF. As mentioned above, not all sections are economically viable. More specifically, on the majority of sections, viability is low or negative during off-peak hours. However, that is offset by often high viability at peak times when trains are more frequent. This contrast between off-peak and peak periods has been tackled globally by SNCF in order to turn the constraint into a source of dynamism.

- From the outset, SNCF has applied an effective and constantly updated yield management principle. Ticket prices are geared not just to second- or first-class travel and the distance travelled. They also vary depending on the destination and the day and time of travel. By establishing a mandatory reservation system for all TGV services, SNCF has gained a very accurate, real-time insight into the demand for each destination and each train. The development of Internet booking has reinforced this information. Today, when ticket sales start, three months before a train is due to depart, the price may be relatively low (EUR 25 for a second-class ticket between Paris and Lyon). The nearer the departure date becomes, the more the price goes up (to as much as EUR 80 on peak days).

As a result, average train occupancy rates for TGVs are relatively high (nearly 70%), and the capacity of TGV coach sets has gradually been increased from 350 to 400 and then to 400 seats in eight coaches. This has been made possible by the development of double-deck coaches. By eliminating the buffet car and by installing second-class seats only, it is actually possible to have 600 seats per coach set. Since trains can have two sets, it is not uncommon, at peak times, to see 1 000 people getting off a single train. Then it is the stations which are at saturation point and in need of enlargement works.

The TGV has thus become a core element of the French passenger mobility scene. In 2012, the TGV network carried 54 billion passenger-kilometres, more than four times the number recorded for domestic air transport. Over the past 10 years, TGV traffic has grown by 3.2% per year, whereas the figure for all passenger traffic has risen by only 0.5% per year. This success can be explained, first, by speed gains. In terms of its modal share of long-distance mobility, the TGV has earned a place in the sun, between vehicle and air transport, because of its special characteristics. The average door-to-door rail speed is hugely faster than road and often equal to or faster than air. (P. Tzieropoulos 2010).

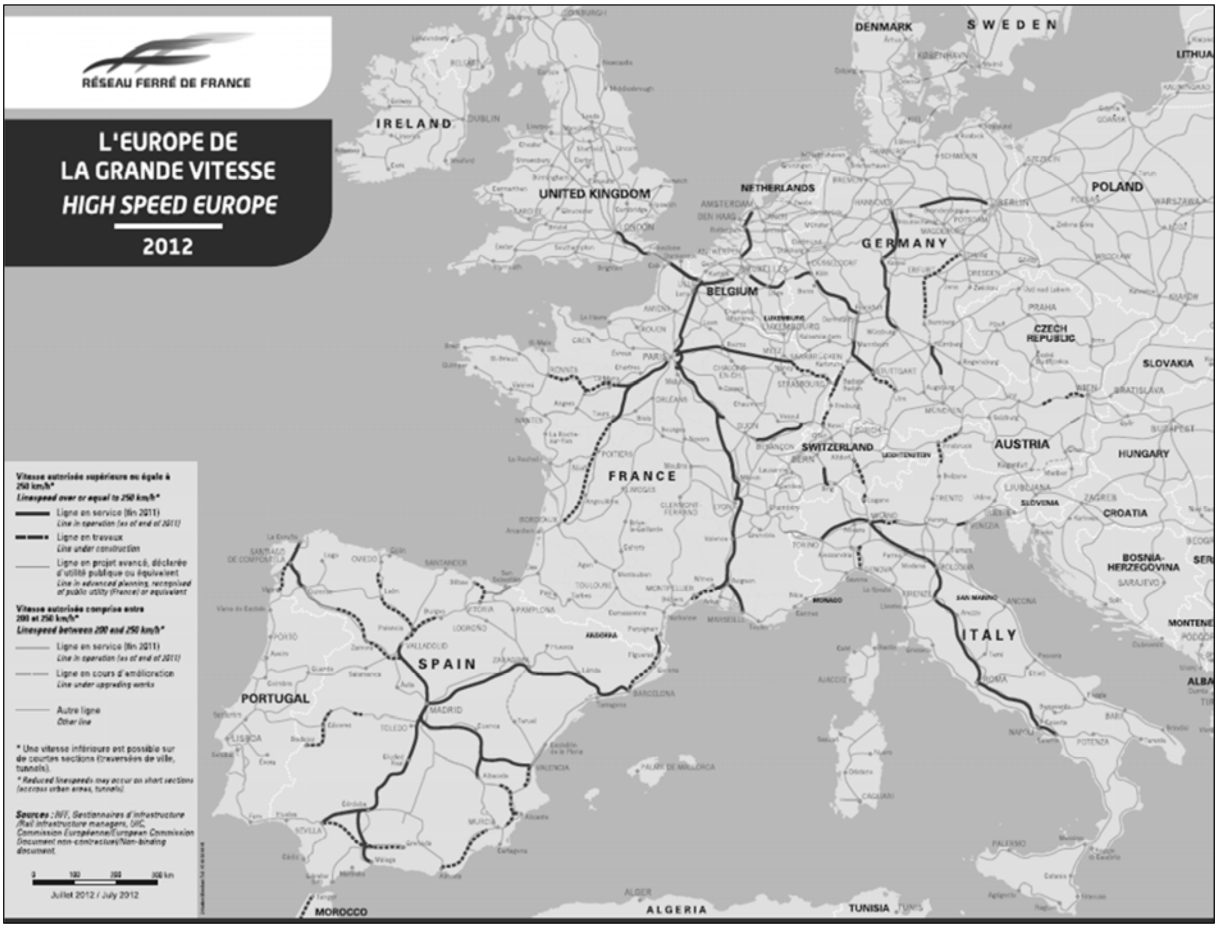
- Many TGVs terminate in old stations, at the heart of metropolitan areas where employment and population is often densest. This is one of the reasons that led businessmen to back the TGV.
- In addition, the TGV offers passengers a much higher degree of comfort and enables them to make much better use of their time than the two competing modes of transport, especially since security checks have increased the time and annoyance involved in boarding aircraft.
- Frequency is often a decisive factor in favour of TGV travel. Between Paris and Lyon, but also between Paris and Nantes, Rennes, Marseille, Lille and Strasbourg, there are often more than 20 return journeys per day. This means one train per hour during off-peak periods and one every half hour at peak times. As it is easy to change a reservation, even on the platform, users have greater flexibility in terms of managing their use of time. New information and communication technologies and the computerisation of travel documents (e-tickets) are improving still further the flexibility of timetable alteration management.

High-speed rail in Europe

The initial success of the TGV in France led other countries to extend their LGV network and TGV offer. There are two different underlying logics behind this development.

- The first, which can be seen on Map 3.2, consists of applying the "Paris-Lyon model" to destinations outside French territory. This was the logic underlying the construction of the Paris-Brussels and Paris-London links (the opening of the Channel Tunnel dates from 1993, as does the Paris-Lille line). Following Brussels, there are now extensions as far as Amsterdam (the new HSL Zuid line) in the Netherlands and Cologne in Germany. Since 2007 and the opening of the LGV Est line, it has also become possible to reach German cities such as Karlsruhe, Stuttgart and Munich by direct TGV. It is worth noting that these lines have not been developed as part of a competitive structure but in co-operation between the national rail operators of France, Belgium, the United Kingdom, Germany and the Netherlands. Thus the company Thalys, which serves Paris, Brussels, Amsterdam and Cologne, is a subsidiary of various historic operators (SNCF, SNCB, NS, etc.). The same applies to Eurostar, the company that serves London, Brussels and Paris via the Channel Tunnel.
- There is another form of high-speed rail development which can be seen in Germany in particular, but also in the United Kingdom. This is shown by the yellow lines on Map 3.2. These are, for the most part, old tracks which have been upgraded to allow speeds of between 200 and 250 km/h. This is why it is necessary to talk about high-speed rail systems in the plural. If one focuses too closely on what has happened in France, there is a tendency to forget that LGV does not necessarily mean a new line capable of carrying very high-speed trains (320 or 350 km/h). The German scenario is interesting in that the TGV offer is not linked directly to the existence of an LGV which is capable of carrying very high-speed trains. This type of LGV does exist in Germany (red lines on the map) but it is only part of the TGV offer (known as ICE in Germany). A large proportion of the 23 billion passenger-kilometres registered for the German TGV system relates to upgraded conventional lines. Unlike France, where investment in LGVs has, for some time, gone hand in hand with delays in upgrading the classic network, Germany has developed a more balanced and integrated approach to the modernisation of its network.

Map 3.2. **The high-speed rail system in Europe**



Source: RFF.

When we come to examine southern Europe, we find that there is an extensive LGV network in Italy and Spain which, to a certain extent, mirrors the "Paris-Lyon model".

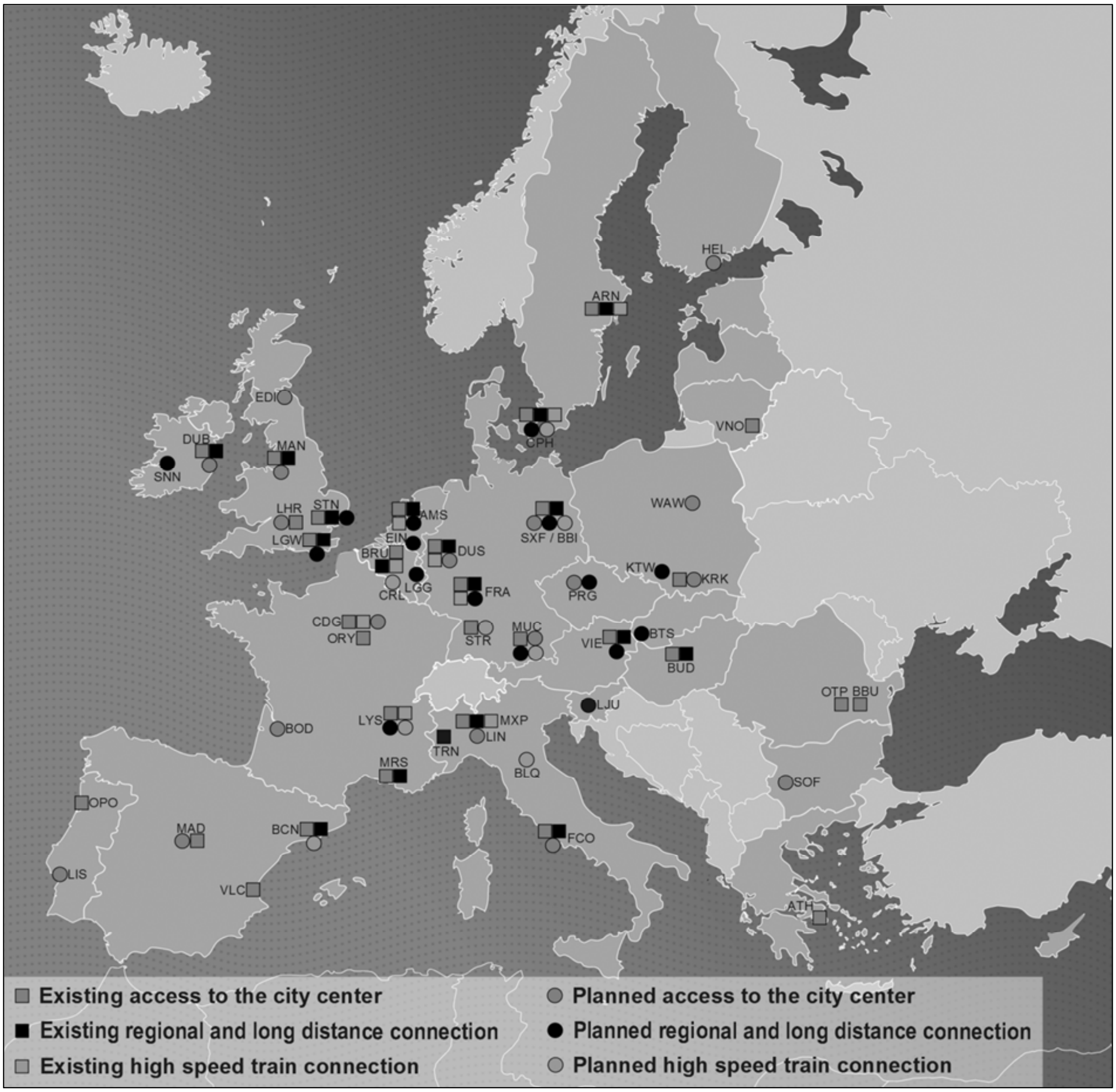
- In Spain, the introduction of LGVs can be explained by the fact that the classic Spanish network was not built to UIC gauge. Connecting the Spanish network to the European network entailed adjusting to the UIC standard, and so Spain opted, with the help of the European Union, to embark on the construction of an entirely new LGV network. Like France, Spain first built lines between the capital (Madrid) and the main conurbations such as Seville and Barcelona. However, Spanish ambition does not stop there. Spain aims to create a whole new rail network covering the entire territory, including links between medium-sized towns. The Spanish LGV network is therefore the most extensive in Europe. It already possesses 2 300 km of lines, and new LGVs are still under construction. The flip side of this ambition is the high cost for users (tickets are relatively expensive) and, in particular, for the regional authorities which have to subsidise the infrastructure heavily. It is worth noting that a network which is 20% more extensive than the French network carries only 20% of the TGV traffic that France carries.
- In Italy, the LGV network has also expanded rapidly in recent years. Today, it links the main cities in the Italian peninsula, namely, from south to north, Naples, Rome, Florence, Bologna and Milan. What distinguishes the Italian system is that it opted throughout for competition

between several rail operators over the same section. This is a relatively rare case (Crozet, Nash & Preston2012) of on-track competition because competition in the rail sector is usually off-track.[4] On the dorsal line running along the spine of Italy, traffic has increased rapidly because TGVs offer a genuine alternative to air travel.

Relationships between the TGV and air transport are not governed by competition alone. There is a strong complementarity between the high-speed rail system and the operation of the major air hubs. One of the objectives of the White Paper on the Future of Transport, published by the European Union in 2011, is to triple the length of the existing European high-speed rail network by 2030. This ambition is linked to another objective, that of reducing aviation greenhouse gas emissions. In this context, TGV traffic is regarded as replacing air traffic for at least a proportion of intra-European journeys (Adler N., Pels E. & Nash C., 2010). This reasoning is based on the fact that when certain LGVs opened, competing flights were considerably reduced, or even axed. Thus, there are no longer any flights between Brussels and Paris (LGV Est) or between Strasbourg and Paris (TGV Nord). Between London and Paris, Eurostar has maintained a higher market share than air travel, and likewise between Paris and Marseille. Between Paris and Lyon, rail traffic is ten times greater than air traffic.

The latter statistic is very revealing as regards the complementarity between high-speed rail and air transport. There are direct trains linking Lyon (but also Lille and Strasbourg, among others) to Charles de Gaulle Airport at Roissy, Paris. Travellers from these cities are increasingly fed into the Air France hub by TGV. This is not an isolated case. As Map 3.3 shows, several European airports have a high-speed rail terminal which provides good intermodality between air and rail. This has even become a strategy of the major air hubs such as Frankfurt (Germany) and Schiphol (Netherlands). Other airports intend to develop such facilities, not just to link the airport to the city centre but with a view to middle- and long-distance TGV links, as shown below. To a certain extent, therefore, high-speed trains increase the attractiveness of air transport. Whereas there is substitutability between high-speed rail and air traffic at domestic level, there is complementarity in regard to international and, in particular, intercontinental flights.

Map 3.3. **Existing or planned air-rail links at European airports**



Source*:* ACI Europe.

2. The TGV in France: The product of an environment and ex-ante assessments

It is no accident that France was the first European country to develop the high-speed train. In the early 1970s, there was a conducive institutional but also historical and geographical environment. Against that background, *ex ante* socio-economic assessments played a key role.

Institutional and socio-technical background

Rail transport played a leading role in France, as in other European countries, at the beginning of the 20th century. However, increased carriage of goods and passengers by road later caused a secular drop in the market share of rail transport. To the extent that, by the 1950s, rail seemed to be an out-dated mode of transport. The French rail network gradually shrank from 40 000 km in 1 900 to 30 000 km (its current size) in just a few decades. In the 1960s, the mass transport mode of the future appeared to be the aeroplane, but there was also a new technology being developed to the south of Paris by an engineer by the name of Bertin: the aerotrain. This vehicle, which rested on an air cushion, was propeller-driven. It ran on a concrete track and was capable of speeds approaching 200 km/h. It was regarded by its promoters as the future, replacing the fastest lines.

In the face of this innovation and with the backing of the public authorities, rail engineers developed a competing product. Taking their inspiration from the progress achieved in Japan with the Shinkansen, they embarked, both within SNCF and in undertakings such as Alstom, on research aimed at outdoing the very high-speeds so far achieved. These engineers had to improve the power of electric traction units, aerodynamics and train stability, the quality of rails, wheels and bogeys, braking techniques, the ability of the pantographs to receive high-speed energy and the resistance of the catenaries to high speeds, etc. That research gave rise to new technologies and new patents which gave the French industry a significant technological edge. High-speed rail does not fall out of the sky; it results from a close connection between the railway industry, transport research and entrepreneurial flair. In the majority of countries that have developed high-speed rail systems (Spain, Italy, Korea, Germany, etc.), there has been that close link between industry, research and rail operators.

In France, SNCF has obviously played a pivotal role, and its engineers were at the heart of the collective learning process which led to the emergence of high-speed rail. The latter came about in a context of integrated and monopolistic rail entrepreneurship. Many people in France are still very much wedded to that view. Any country today wanting to embark on a high-speed rail system should therefore ponder the socio-technological context in which that decision is going to operate. Will technology be mostly imported? Will implementation take place in a competitive environment or be based on competition between operators? Will there be vertical integration or de-integration?

Another important element of this context is the political and institutional dimension. In 1975, France enjoyed stable political power and a central government with wide-ranging powers compared to the territorial authorities, which were largely dependent on decisions taken in Paris. Moreover, French law was not subject to “common law”, which ascribes considerable powers to judges and courts, but was governed by a Napoleonic tradition inherited from Roman law whereby power lies with the legislative and executive authorities. In terms of LGVs, as well as motorways and airports, that means that there is a "declaration of public utility" procedure under which it is perfectly legal to expropriate from owners the land needed for the LGV. If we add a French tradition of generosity in terms of building transport infrastructure, it is not hard to understand why it was easier in France than in other European countries to construct over 2 500 km of new railway lines in about 40 years.

High-speed rail and geography: a matter of urbanisation

Another factor which facilitated the construction of new lines was the low density of population in France. With a population of a little over 63 million in an area of 550 000 km^2, France has only 114 inhabitants per km^2. This means that, outside the major conurbations, there are vast tracts given over to agriculture and forests. Other than at its extremities, the Paris-Lyon LGV does not cross any urban areas. This factor reduced construction costs, as did the fact that there are no tunnels and few bridges on that line. However, the principal geographical factor affecting the development of the TGV in France is urbanisation.

The vast majority of French provincial conurbations are some distance from Paris but no further than 800 km. That is the ideal distance for a TGV, in other words for customers who wish to make the return journey on the same day. The 3-hour travel time threshold is often presented as being the limit beyond which the relevance of high-speed rail travel diminishes rapidly in comparison with air travel. The explanation is simple. With a travel time of 2 or 3 hours, it is possible to make the return journey the same day and still do a meaningful day's work at the other end. It means leaving home early and returning late, but as long as it doesn't happen every day and the journey is comfortable, it is acceptable. Beyond the 3-hour threshold, the aeroplane regains its relevance in relation to the TGV (see Figure 3.3).

Box 3.2. **Speed and time-saving**

As shown in the works of Schafer (2009), economic growth goes hand in hand throughout the world with increased mobility. There is kind of "iron law" of coupling (or positive elasticity) between increased distance travelled and higher GDP (Crozet, 2009). However, since this increased mobility occurs without a significant increase in travel time budgets, this means that the distance/GDP elasticity is based on a speed/GDP elasticity. That can be explained by the fact that greater speed provides access to new activities, which reflects the preference for variety. It is not surprising, therefore, that mobility increases more or less in line with income because that mobility is the enabling condition for the "economics of variety" (Gronau & Hamermesh 2001).

Increased mobility is therefore a logical by-product of higher income. The demand for speed reflects increasingly varied and intensive consumption. However, intensification in turn places specific constraints on planned activities which are linked to the trend increase in the value of time. When income increases more rapidly than the amount of time available, the scarcity of time also increases which means that the time budget that we are prepared to devote to each activity is potentially reduced. The key problem for individuals in the modern world is therefore the problem of time management.

In a work which appeared in 1973, at the time when Club of Rome issues were being aired, Ivan Illich developed the idea that there was an inverse relationship between energy consumption and equity: as the demand for speed, and hence energy consumption, increased for the privileged minority, so inequalities grew. His reasoning led him to the following conclusion: "It is time to recognise that, in the field of transport, there are speed thresholds which must not be exceeded. If they are, not only will the physical environment continue to be ruined but the social fabric will continue to be threatened by the proliferation of social divisions created in it and reinforced every day as a result of the use of time by individuals."

Illich pinpointed a genuine problem but was making a similar error to those who, at the same time, thought that we were under threat of poverty. As Illich said, there is a scarcity of time, but it is not linked to the fact that it is necessary to work more in order to travel (see Annex 2 on the general concept of speed) but, on the contrary, to the fact that, by working as much or less, one can travel more. Thus it is the potential abundance of places, and hence of accessible goods and services, that leads to a scarcity of time. A scarcity which is not absolute but related to our income.

How then should we allocate this rare resource – time – to the various activities? As Linder (1970) predicted, we have reduced our average sleeping time and also the time spent on household upkeep and on maintaining our possessions. We have so many possessions that we are unable to devote much time to any of them.

Can we apply this reasoning to travel time? Because time is a scarce resource, couldn't we reduce our mobility in order to gain time and increase the usefulness of our activities? This is the advice given by all those who "sing the praise of slowness": give time, give each activity the time to develop and stop flitting between multiple successive activities. Even though this sounds like good sense, we have to understand that activity is undermining the central thesis of the economy of decreasing marginal utility. Which is no small matter, because the inverse reasoning would be tantamount to taking the view that marginal utility increases or, at any rate, does not diminish as the duration of an activity increases. Is that realistic when the standard of living is increasing? What we are seeing today is not a reduction in travel times but a reduction in the average duration of each of our activities accentuated by the increased speed of passage (whether physical or virtual) from one activity to another. We do more things, and spend less time on each of them. However, the time spent travelling does not decrease because maintaining it is the very pre-condition for intensifying our programme of activities.

As shown in Table 3.1 below, the modal split between high-speed rail and air between two cities depends not only on the difference in shortest journey time. It is also necessary to take into account the number of daily return journeys and the average journey time. When the journey time is less than 2 hours, the train captures almost the entire market. Once the journey time by rail exceeds 3 hours the rail market share decreases rapidly thereafter. Some other factors play an important role like the location of stations and airports, or their links with urban transport.

Table 3.1. **Difference between TGV and air journey time and relationship with market share**

Line	*Market share (train/air)*	*Shortest journey time*	*Distance in km*	*Max speed*	*Average speed*	*How many return journeys*	*Average journey time*
Stockholm-Gothenburg	60%	02:45	455	200	165	16	03:00
London-Paris	71%	02:20	470	300	201	19	02:25
Paris-Strasbourg	80%	02:17	475	300	208	16	02:20
Paris-Lyon	90%	01:57	409	270	210	24	02:00
Paris-Marseille	50%	03:02	769	300	254	17	03:20
Hamburg-Frankfurt	40%	03:19	517	250	156	17	03:35
Cologne-Frankfurt	95%	01:03	180	300	171	21	01:15
Hannover-Munchen	40%	04:15	625	250	147	17	04:20
Madrid-Seville	81%	02:20	471	300	202	23	02:35
Madrid-Barcelona	50%	02:38	621	300	236	26	03:20
Rome-Milan	58%	02:59	632	300	212	27	03:30
Tokyo-Osaka	80%	02:26	515	270	212	136	03:00
Osaka-Fukuoka	80%	02:35	554	300	214	90	03:00
Tokyo-Sendai	100%	01:42	325	275	191	64	02:00

Source: Trafikverket, International external analysis, High speed rail project, September 2010, Sweden, www.trafikverket.se.

Table 3.1 also tells us that Germany is a special case. Population density is higher in Germany than in France or Spain and cities are often medium-sized and not far distant from one another. That has led to a high-speed rail model which is noticeably different from the "Paris-Lyon" model.

- France opted to build new lines, completely separate from the conventional network, over long distances. This is a door-to-door logic between major centres of population. When the TGV passes close to a medium-sized city, it avoids it. Where necessary, a special station is built outside the town to provide access to the high-speed system. There are many of these purpose-built out-of-town stations in France (Le Creusot and Macon-Loché on the Paris-Lyon line; Valence, Avignon and Aix on the Méditerranée line, Besançon, Belfort-Montbéliard on the Rhin-Rhône line, etc.). To bring the LGV into the traditional station in a medium-sized city would have increased the journey time between Paris and the conurbation served, and the number of potential passengers in a medium-sized city would be modest. The daily frequency of TGVs is closely linked to the size of the conurbation. If there are fewer than 100 000 inhabitants, there are no more than three trains a day in each direction. That can rise to five where there are 200 000 inhabitants. Only in excess of that number will there be ten or more trains per day in each direction.
- Germany, which has a totally different urban geography, made a different choice. High-speed trains always run from traditional stations in the heart of cities. Since those cities are not very far from one another, a maximum speed of 200 to 250 km/h is sufficient. Even though Germany has built a few long LGV sections, the latter are more integrated into the conventional rail system because the high-speed train makes frequent incursions into it in order to reach stations, following a logic that might be described as "cabotage". High-speed rail is therefore used mostly for regional journeys of short and medium distance. Reservations are not necessary. High-speed rail is more integrated into the overall rail offer. In Germany, high-speed rail accounts for only one-third of all rail traffic (in passenger-kilometres) as against 60% in France.

Ex ante assessments, the key role of economic calculations

The development of high-speed rail in France also owes much to economic calculations (de Rus, G. and C. Nash, 2007 & 2009). Whilst French engineers have been able to respond to the challenges of high speed, French economists[5] have managed to apply to the TGV the work done by their predecessors on consumer surplus and its contribution to the general interest. Consumer surplus is a key variable which is not taken on board by national accounts. The normal indicators such as added value or gross domestic product fail to take account of the utility that a customer derives from a given good or service. Economic calculation seeks to remedy this shortcoming. It does so by applying a rationale which takes account of the fact that the cost of transport is made up of two key variables, the monetary cost and the journey time cost, which are a function of the journey time and the value of time.

Because high-speed rail can reduce journey time, it may, if ticket prices do not rise excessively, lead to a lower generalised transport cost. This represents an increased surplus for users who used another mode of transport before the high-speed rail service was introduced as well as an increased surplus for new users.

To illustrate this key role played by speed gains, here is the rationale that has allowed France to make high-speed rail projects an economically credible proposition. It is a question of calculating the traffic on the new line based on the modal split between rail and air. This model combines a gravity model with a price-time model.

- The gravity model states that the volume of traffic between two zones i and j depends on the population in each of those zones, weighted by the generalised cost of travel between i and j.

$$T_{ij} = K \frac{P_i P_j}{C_{g_{ij}}^{\gamma}}$$

Thus the volume of traffic can be expressed as follows:

where:

P_i and P_j : respective population of the two geographical zones i and j

Cg_{ij}: generalised cost of the transport in question between zones i and j

γ : elasticity of traffic to the generalised cost

K : adjustment parameter

The numerator contains the factors of attraction and the denominator the factors of repulsion or resistance. High elasticity in this instance means high sensitivity to a rise (or fall) in generalised cost and, in particular, the reduction in travel time afforded by higher speeds. It is therefore necessary to take into account the speeds of the various competing modes of transport, which is what the price-time model does.

- The price-time model, for given elasticities for each mode, shows how a change in relative speeds entails a change in market shares. This model is based on the theory that a traveller's choice between two modes is made by reference to the value that he places on his time and the transport cost and time characteristics of each of those modes. Thus, user k chooses the mode whose generalised cost, taking into account the value of his time h_k, is lowest. For a modal split between rail and air, the respective prices of rail and air are P_F and P_A; T_F and T_A are the journey times (including final legs), and the generalised costs for user k are expressed as follows:

$Cg^k_A = P_A + h_k T_A$

$Cg^k_F = P_F + h_k T_F$

On a given route i, there is a time value h^i_0 such that:

$Cg_A = Cg_F$

which is known as the time indifference value on route i.

If h_k is less than h^i_0, user k will choose rail, or failing that air travel. It is assumed that the passenger population on a given route is characterised by a passenger time value f(h) whose function is:

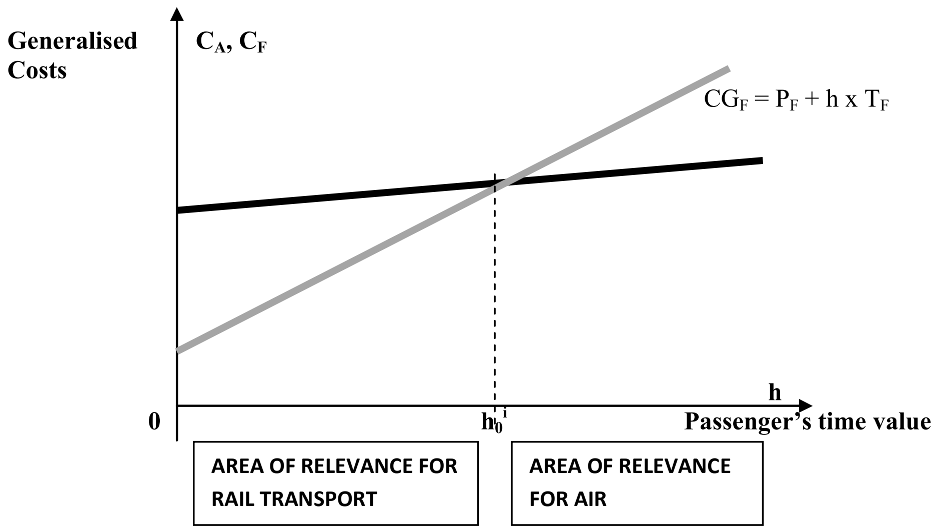
$F(h) = \int_0 f(x)\, dx$

which gives the proportion of trips whose time value is less than h. Accordingly, the proportion Y_i of air users in total traffic will be given by:

$Y_i = \int_0^{+\infty} f(x)\, dx = 1\text{-}F(h_i)$

This is illustrated in the two figures below:

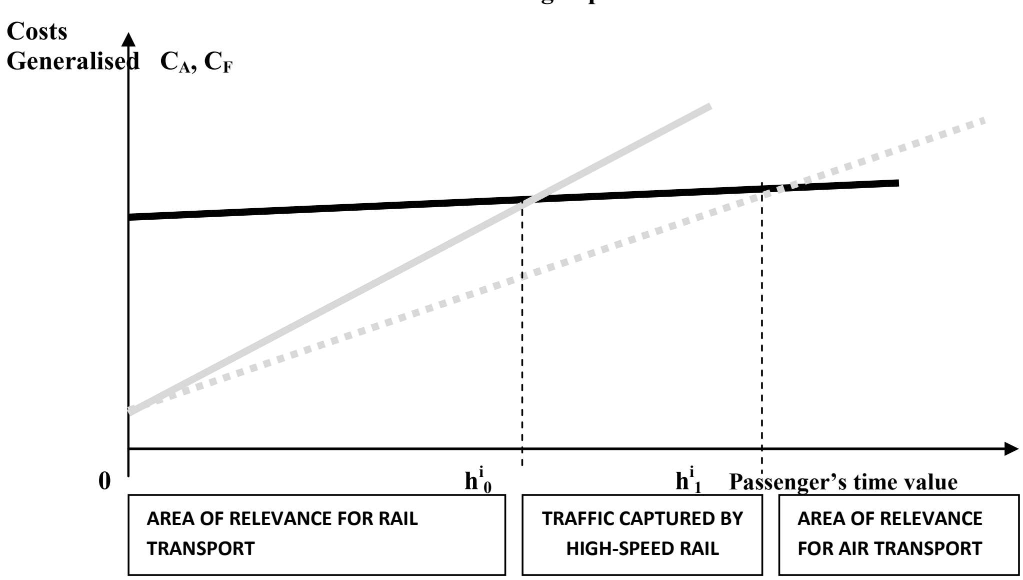
Figure 3.3. **Comparative generalised costs of rail and air**



Source: Crozet.

If we now put in place a high-speed train allowing substantial time savings, this will modify the generalised cost of rail travel, all things being equal. The gradient line Cg_F will now shift.

Figure 3.4. **Improvement of the market share of rail as a result of the introduction of high-speed services**



Source: Crozet.

In this example, the high-speed train captures the major share of the traffic because there are few passengers with a very high time value. This is exactly what was observed with the Paris-Lyon line. *Ex post* assessments have shown that the traffic studies were not far wrong. They anticipated the success of the high-speed train.

3. Ex-post assessments and extension of the LGV network: How far is not too far?

Since 1982, France has had a legal instrument which requires the administration, for all major infrastructure projects, to carry out an *ex post* assessment in order to compare traffic and socio-economic viability with forecasts. This enables us to state that the development of the TGV has provided a collective surplus. On that basis, it is not unreasonable to ask users, who benefit from real time savings, to contribute to the cost of developing the network. This requires the levying of relatively high infrastructure charges, aimed at reducing state subsidies to RFF, the infrastructure manager. *Ex post* assessments also show that the economic viability of TGV lines decreases in line with the expansion of the network, a sign that the latter has probably now reached its optimal size.

What ex post assessments can teach us

Ex-post assessments of new transport infrastructure projects have been mandatory in France since 1982 and the "LOTI Law" (guidelines for internal transport). These assessments are made by Ministry of Transport staff and are available on the Internet (in French *http://www.rff.fr/fr/mediatheque/textes-de-reference-francais-45/loti/*). The two tables below set out the principal results of those assessments for two key parameters: the TRI (internal rate of return) in economic terms and the TRI in socio-economic terms (see Box 3 for definitions).

Box 3.3. **From net present value (VAN) to internal rate of return (TRI)**

The net present value (VAN) of a project compares the investment made by an operator (Ij) and the financial costs (F_j) to income (Rj) from which operating costs (Cj) are deducted. These predictive values for each year of the life of a project are discounted values for the reference year, obtained by applying discounting rate a. At the end of the period, the residual present value of the infrastructure is added. The VAN can therefore be expressed as follows:

$$VAN = \sum_{j=t_p-t_r}^{j=t_n-t_r} \frac{-\Delta I_j + \Delta R_j - \Delta C_j - \Delta F_j}{(1+a)^j} + \frac{K_{t_n}}{(1+a)^{t_n-t_r}}$$

When calculating the VAN, amounts are in current coin. The VAN is a financial indicator which can be used to compare different projects. The higher the VAN, the higher the sums generated by the investment. From the financial VAN, we have to deduct the financial TRI (internal rate of return). This is determined by the value of a (discounting rate) which cancels out the VAN. It is also possible to calculate an economic TRI by not taking financial costs into account.

On this basis, it is also possible to calculate a socio-economic VAN, also known as discounted cash flow (BNA) for which the formula is the following:

$$BNA = \sum_{j=t_p-t_r}^{j=t_n-t_r} \frac{-\Delta I_j + \Delta R_j - \Delta C_j + \Delta A_j}{(1+a)^j} + \frac{K_{t_n}}{(1+a)^{t_n-t_r}}$$

The BNA is the other facet of the VAN, but takes into account the interest for the community. Its calculation is subject to the proviso that it is possible to estimate in monetary terms the various external costs and benefits (A) of a public investment. Of the monetised benefits, time savings are particularly important. It is worth noting that financial costs which represent a transfer between members of the community are not taken into account. The calculation is made in constant money of the discounting reference year. As with the financial VAN, the calculation of the socio-economic VAN is accompanied by that of a socio-economic TRI, which is the value of the discounting coefficient which cancels out the discounted cash flow.

Table 3.2 provides a comparison, for the various LGVs, ordered by date of construction, between the predictive economic TRI and the *ex post* result. It appears that *ex post* economic viability is lower than predicted. However, with the exception of TGV Nord, the differences are not great, and the economic viability achieved made it possible to cover financial costs because the interest rates applied were lower than the economic TRI. It will be noted that the return diminishes for the Rhône-Alpes and Méditerranée high-speed lines to the point where it only just covers financial costs.

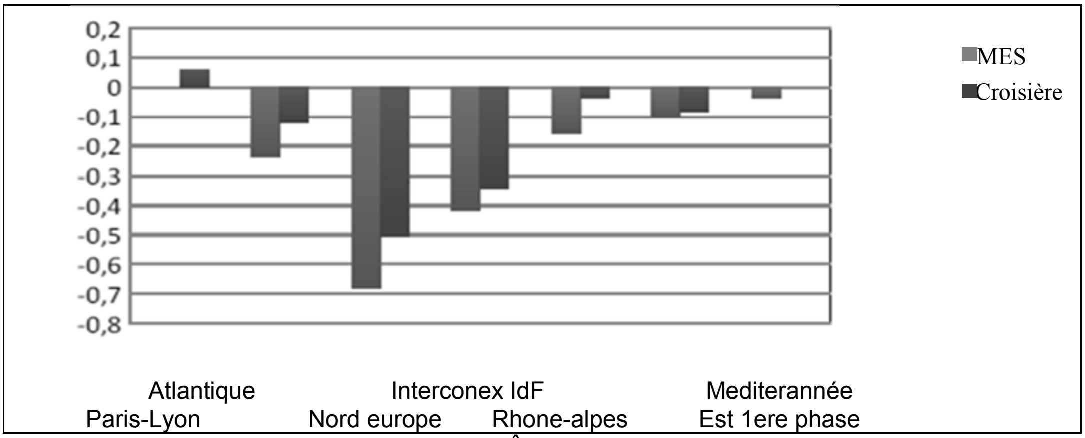
Table 3.2. **"Economic" TRI**
ex ante and *ex post* values

	Ex ante	Ex post
LN 1 (Sud Est)	**16.5%**	**15.2%**
LN2 (Atlantique	**12.0%**	**8.5%**
LN3 (Nord Europe)	**13.0%**	**3.0%**
Interconnexion	**10.8%**	**6.9%**
LN4 (Rhone-Alpes)	**10.4%**	**6.1%**
LN5 (Med)	**8.0%**	**4.1%**

Source*:* J. P. Taroux (op. cit.).

The discrepancies between *ex ante* and *ex post* rates of return are often linked to a lower-than-predicted level of traffic, as shown in Figure 2.6. Certain lines have experienced significantly lower-than-predicted traffic, both on entry into service (MES) and in full operational mode (croisière), as much as -50% in full operational mode for the TGV Nord and -35% for the Sud-Est/Nord link situated to the east of Paris.

Figure 3.5. **Variations between predicted and observed traffic**

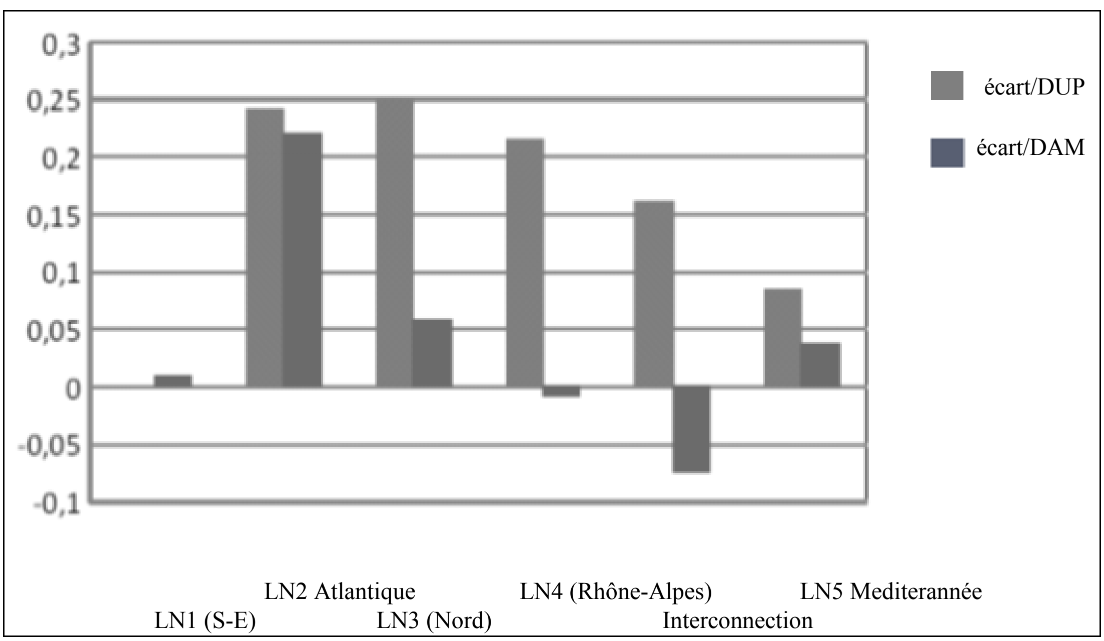


Note : Interconex IdF = Île de France inter-connection

Source*:* J. P. Taroux (op. cit.)

It is also necessary to take into account the fact that the cost of works has sometimes slipped as shown in Figure 3.7. Several lines have exceeded forecasts by 15% to 25%, and this has affected the rate of return.

Figure 3.6. **Observed variations in the cost of works**



Compared to cost estimate for Declaration of public utility (DUP)
Compared to cost estimate at time of Ministerial approval (DAM)
Source: J. P. Taroux (op. cit.).

Thus, the results of the *ex-ante* economic calculation should not be taken at face value. Sensitivity tests should be carried out on these results because it is not unknown for project promoters to inflate projected traffic figures and to play down construction costs (Flyjvberg and Rothengatter).

Although this type of manipulation has happened in France, it has not led, over the 25 years since the introduction of the TGV, to any poor quality investments. This fact is apparent from Table 3.2, which relates to viability for the community, and hence to the socio-economic TRI.

Table 3.3. **Socio-economic TRI**
(ex ante and ex post values)

	Ex ante	Ex post
LN 1 (Sud Est)	**28.0%**	**?**
LN2 (Atlantique	**23.6%**	**14.0%**
LN3 (Nord Europe)	**20.3%**	**5.0%**
Interconnexion	**18.5%**	**15.0%**
LN4 (Rhone-Alpes)	**15.4%**	**10.6%**
LN5 (Med)	**12.2%**	**8.1%**

Source: J. P. Taroux (op. cit.).

French LGVs have provided the community, as a result of time savings and lower levels of pollutants, with good socio-economic TRIs, especially when they are compared with the discounting rate in force in France during that period, namely 8%. The figure for the first LGV is not known, but it is certainly more than 20%. The low economic and socio-economic TRI for the TGV Nord arises from the fact that traffic, towards London in particular, has taken a very long time to pick up. Today, 20 years after the opening of the Channel Tunnel, returns are achieving levels which are finally enabling Eurostar to become a profit-making company. However, the journey has been a long one, and it has been necessary to wait for the new line to be opened on the British side and also for access to St Pancras Station. *Ex post* assessments after the first 25 years of TGV operation in France have shown that the net increase in the collective surplus was EUR 45.9 billion for line 1 (south-east), EUR 23.8 billion for the Atlantic line (south-west) and EUR 4.9 billion for the northern line. In other words, a total of EUR 74.6 billion in terms of constant 2005 money, earned to a very large extent as a result of time savings for passengers.

The key question of rail tolls

The extension of the LGV network in France made relatively little call on central funding up until 2009. The extension was made possible through an ambitious policy of rail tolls when SNCF separated from RFF. Just as SNCF has practised yield management at peak times, so RFF has gradually raised the level of infrastructure charges, which operate a space-time modulation taking into account the ability of the various TGVs to pay.

As Sanchez-Boras *et al.* pointed out (2010), there are several ways of determining the level of rail tolls. As against the traditional method of marginal cost (CM), there is the full cost method. The latter has been the aim of RFF in France between 1997 and 2013. For LGVs, the infrastructure operator has to set tolls at a level which enables it to cover the full cost of the line, less any public subsidies. In order to do so, RFF has applied a mark-up method. Thus, RFF identifies a marginal cost to which it applies, by way of a binomial tariff, a supplement which depends on the elasticity of demand on the one hand (Oum & Tretheway 1988, Nilsson 1992), and on the opportunity cost of public funds on the other. (See Annex 1 for a detailed presentation of “Ramsey-Boiteux” pricing).

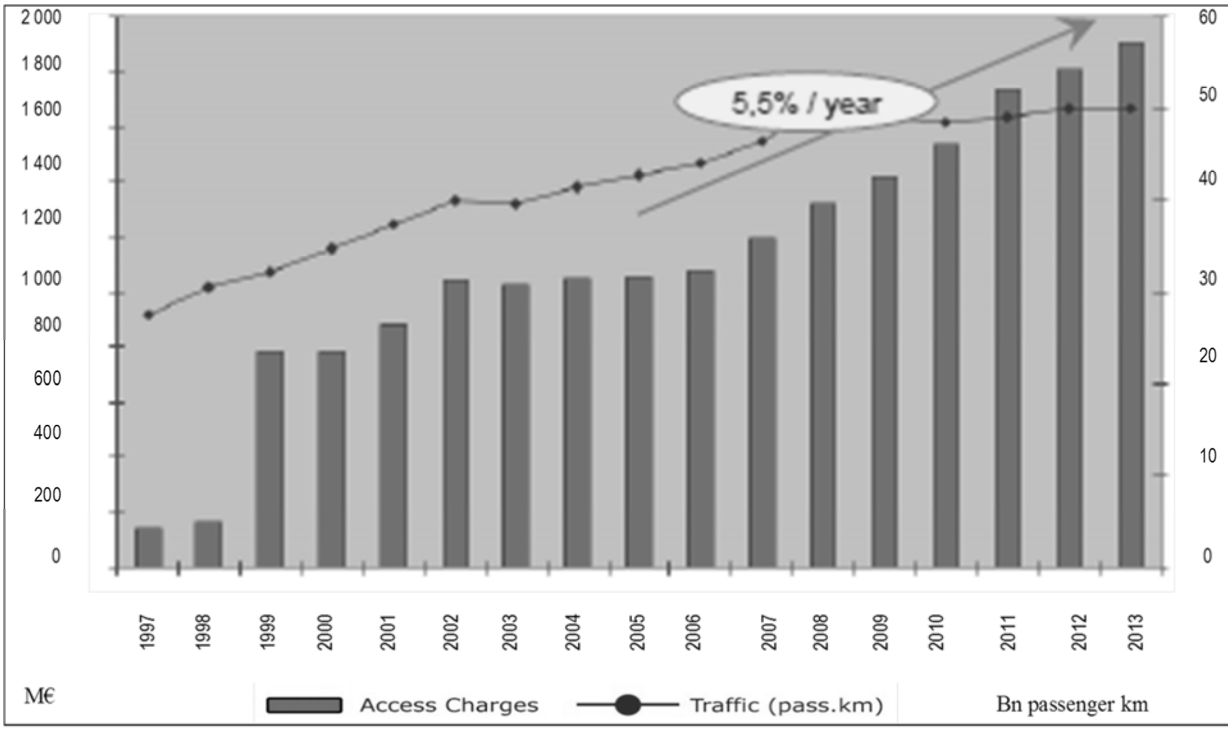
In the first place, RFF calculates, for a given rail line, the total revenue needed to cover its investments. On that basis, it then calculates the tariff modulations which can be applied by varying the tolls in time. Between peak and off-peak periods, elasticity of demand is not uniform and it is possible to charge widely varying tolls. Logically, a study of this policy throws up situations where demand is sufficiently sustained, and inelastic, to allow the tolls charged to bring in more revenue than was originally aimed for. In that case, a general equalisation is applied between the LGVs, and to a certain extent over the rest of the network. An alternative choice could have been made. Profitable lines could provide dividends for the owner of SNCF, the State (SNCF pays taxes on profits), leaving the state to subsidise unprofitable lines. But the authorities preferred internal balancing of accounts (péréquation).

It would appear that the principal objective of the State, which controls RFF, is to limit public subsidies. This constraint is especially strong in that, despite a deep public finance crisis, one which is common to most of Europe, there is a strong political will to develop the network of high-speed lines (LGV). As a result, on the Paris-Lyon line, the busiest section, tolls represent up to six times the marginal cost. Paradoxically, that is also the most profitable line of SNCF, despite the high tolls (Crozet & Chassagne 2013). On the other hand, on less busy lines, the toll may be only equal to or double the marginal cost. We see here another function of tolls, which is to send out a signal to users. Rail companies need to take into account the fact that, in the busiest areas, rail corridors are a rare resource which needs to be put to the best possible use. Tolls therefore act as a productivity incentive. Where the pressure of demand is greatest, it is sensible for tolls to rise because it is a way of regulating demand and adjusting the offer. Thus in 2008, before the economic crisis, TGV occupancy rates were 77.5% in second class and 67.7% in first class

Increasing capacity and regulating its use will become increasingly important with the announcement that TGV lines are being opened up to competition. For the moment, this is affecting only international journeys. However, it is no secret that the long-term trend is to open up all traffic to competition. Is this going to alter the deal for TGVs significantly? This is by no means certain if we are to believe recent papers by J. Preston (2009) and C. Nash (2009) who point out that, the higher the tolls, the less likely it is that there will be competitors on an LGV line. To a certain extent, high tolls would protect SNCF. If an undertaking has to pay tolls which represent between 30% and 40% of its turnover, potential competitors know that this reduces the probability of their obtaining a profit margin.

SNCF also points out that tolls have now reached a level which threatens the long-term profitability of the TGV, especially since traffic, on a constant network, is increasing very little. This is the logical outcome of the coupling between mobility and GDP. At the end of 2013, France's GDP has just regained its 2008 level.

Figure 3.7. **Comparison of LGV tolls and TGV traffic**



Source*:* SNCF.

Figure 3.7 shows a steep increase in tolls, over the period 2000-2013. In the same time traffic is levelling out. This scissor effect is indicative of a dual phenomenon.

- The increase in tolls is indicative of the State's intention to reduce subsidies to SNCF and hence to require the TGV to act as a sort of cash cow for the rail system. Annex 3.A1 shows that this is not possible because the level of tolls cannot rise above a certain threshold (Crozet 2010).
- The stabilisation of traffic reminds us that the LGV network is reaching its optimal size in France, especially since four lines are still under construction.

How far is not too far when extending the network?

Between now and 2017, the French LGV network is due to be extended considerably. At the beginning of this decade, under pressure from local authorities and with the aim of supporting the economic activity of French undertakings (construction and civil engineering, rail construction, SNCF, etc.), the Government instructed RFF to launch new LGV lines or new LGV sections. Table 3.4 summarises the principal characteristics of these projects.

Table 3.4. **Principal characteristics of the four lines under construction**

	EAST	BPL	CNM	SEA	Total
Total cost (million euros)	2 000	3 300	1 800	7 800	14 900
Length (km)	106	182	80	303	671
Cost/km (million euros)	18.9	18.1	22.5	25.7	22.2
Paid by RFF (million euros)	520	1 400	0	1 000	2 920
Paid by central government (million)	680	950	1 200	1 500	4 330
Paid by local government (million)	640	950	600	1 500	3 690
Paid by EU + Luxembourg	160	0	0	0	160

Source*:* RFF.

The aim of the projects is to extend the network in order to reduce journey time to Strasbourg (LGV Est), Bordeaux (Sud Europe Atlantique, SEA) and Brittany (Bretagne Pays de Loire, BPL). The Nîmes-Montpellier bypass (CNM) does not save time in its current configuration. It aims to resolve a capacity problem so that it will be possible, at a later date, to connect with the Spanish network because the new tunnel between France and Spain is already operational and there is an existing LGV line from the border to Barcelona and beyond.

On reading the table, the extent of the financial constraints becomes apparent. The additional 671 km of LGV cost nearly EUR 15 billion (EUR 22 million per km). This is a sum that cannot be covered by rail tolls alone because increased traffic levels will not be very significant. It was therefore necessary to provide an injection of public funds. However, because central government could not, by itself, cover total subsidies of a little over EUR 7 billion, the regional authorities were asked to come up with nearly half that amount. The private sector was also involved:

- Either in the form of a concession for the SEA. The company LISEA (a subsidiary of Vinci) is to construct and operate LGV SEA for 50 years and to fund this by means of tolls. However, even in the best-case scenario, these will cover less than half the total cost, hence the need for public financing.
- Or in the form of public-private partnership (PPP) contracts. In the case of the Brittany-Loire Valley (BPL) line, it is the company Eiffage which is to construct and maintain the line for 30 years in exchange for rent paid partly by the State and partly by RFF. The same logic was applied to the CNM where the line is being constructed and maintained by the Bouygues consortium.

The outcome of this rapid expansion of the size of the LGV network is that the financial viability of the whole project is becoming increasingly fragile. The State and the regional authorities have committed themselves for several years to expenditure which will inevitably limit their future financing abilities. RFF has incurred a debt of EUR 3 billion in order to contribute towards works which may well not bring in enough money in future tolls to cover the debt. Finally, the private sector has taken a big risk, particularly in relation to the SEA line, because with the current sluggish economic growth it is not at all clear that traffic forecasts will materialise once the line opens.

It is not surprising, therefore, that in 2013 the French Government declared a slowdown if not a halt to all new LGV works. After 2017, only the Bordeaux-Toulouse line might see the light of day. The other lines for which local politicians lobbied so forcibly pose formidable financing problems.

- Construction costs are the first problem. Each of the projects, such as Lyon-Turin, Marseille-Nice or Paris-Lyon via Clermont-Ferrand, incurs costs in excess of EUR 15 billion if not EUR 20 billion for traffic which will not attain, sometimes by a very large margin, the traffic on lines already open. Even taking into account the time savings for users, the collective gain may, for the community, become a loss.
- On the environmental front, we should not forget the pollution caused by the construction of LGVs (Nilsson J.E. & Pydokke R., 2009). A Bilan Carbone® (carbon assessment) carried out by RFF on the eastern section of the Rhine-Rhône high-speed line (opened to traffic at the end of 2011) showed that it would take 12 years of traffic to offset, through the lower CO_2 emissions associated with the TGV, the emissions caused by the construction works. As an indication, 100 m^3 of earth have to be moved for each metre of new line. To that, we have to add emissions caused by the production and transport of concrete, steel, etc. Furthermore, TGV unit emissions have been revised upwards, in particular to take account of the fuel mix which supplies them with electricity.

Another difficulty arises with projected lines serving heavily urbanised areas. For LGV projects from Paris towards Orleans or Rouen and for the Marseille-Nice project, there is a great temptation to opt for a regional TGV, somewhat closer to the German model. This would come at the risk of increasing the number of stations and hence journey time even though the distances are not great. In addition to the cost of the infrastructure, there are questions regarding optimal level of services and potential demand. In order to attract passengers, will it be necessary to subsidise operation as well as infrastructure, as in the case of regional trains? The risk here would be to provide everyday high-speed hyper-mobility at an exorbitant financial cost (see Annex 2 on effective speed for social purposes).

There are question marks surrounding the relevance of LGVs that aim to substitute rail traffic for air traffic. Taking the development of the European high-speed network alone as a basis (see Map 3 2), it will be possible in a few years' time to travel by TGV from London to Madrid, from Brussels to Barcelona or from Amsterdam to Geneva, etc. However, such journeys fall outside the TGV zone of relevance because, even at high speed, they exceed the 5 or 6 hours parameter, in some cases by a considerable margin. In such cases, air travel remains entirely relevant, especially with the emergence of low cost airlines which are now offering prices for those destinations that rail cannot match. The origin-destination pairings for which the TGV is a genuine substitute for air travel have been amply covered already in France, if we take into account operational LGVs and those projects that are now at an advanced stage. Increasing constraints on air transport might affect the rail-air split slightly. However, this effect will be limited, especially since the boarding of TGVs may well become subject to security checks.

It is therefore perfectly legitimate to raise questions about the optimal size of the high-speed network, both in France and in other European countries. This does not mean that we have to bring everything to a halt and give up in despair, but rather than we should entertain some doubts. How far is not too far? That is a question which applies to the extension of the LGV network but also to other variables such as the level of tolls and the type and extent of competition.

4. Conclusion

In the European rail landscape, France enjoys a privileged position. It made the choice to build a vast LGV network. That choice resulted in greatly increased traffic, and the lines under construction are pursuing the same objective. However, that does not prevent us questioning the content of those choices for the coming decades. It is necessary to take stock so that developers can gear their projects to local needs and financial constraints. The French dream must not turn into a nightmare through the proliferation of structurally loss-making lines, following the Spanish "model".

The French "model", like the German "model", teaches us a basic lesson: it is geography not economics that is the crucial factor. The key element for a high-speed line is optimal distance (between 400 and 1 000 km), sufficiently large centres of population to justify 15 to 20 return journeys per day and a customer base with the means to pay. The success of the TGV in France is largely dependent on the fact that our geography makes links such as Paris-Lyon, Paris-Nantes or Rennes, Paris-Marseille, etc. viable, even at the cost of public funding for the construction stage.

We should not base this model on services which relate to everyday mobility. The TGV is not there for the purpose of proliferating dormitory towns 100 or 150 km from Paris, Lyon, Marseille or Bordeaux. Demand linked to everyday mobility must be satisfied by everyday trains whose main feature is frequency. Rather than pursuing an obsession with speed (see Annex 2), choices should be guided by considerations as to the type of service that users require. Where two cities are 100 or 150 km apart, the appropriate reaction is not to announce that high-speed rail will enable the journey to be completed in 30 or 40 minutes. What matters is the number of users and the frequency of trains that will allow the journey to be made in just over an hour. Basically, this can be done by improving the existing network (renovation, signalling, command-and-control measures) sometimes by replacing materials and not really by investing in rail hubs, stations and other saturated zones. High speed has its place, but it should not be the default option. There are a number of other ways of improving the rail offer. Before deciding which option is best, we should take the time to study each situation on its own merits.

Annex 3.A1. Ramsey-Boiteux pricing: opportunity cost of public funds and price elasticity (Crozet 2010)

Formally, in a situation of natural monopoly producing n final products in quantities $q_1,\dots,q_n$ (or a product on n parts of the market), Ramsey-Boiteux prices are solving the following :

$$\max_{\{q_1,\dots,q_n\}} \{S(q_1,\dots,q_n) - CS(q_1,\dots,q_n)\}$$

$$subjectto \quad \sum_k p_k * q_k - C(q_1,\dots,q_n) \geq X \quad (\lambda)$$

with:

S, CS and C : functions of respectively consumer surplus, social cost and private cost

q: quantities and p: prices

X amount of desired profit or authorised deficit

λ Lagrange multiplier of the budgetary constraint: it indicates by how much the social profit would increase if X were decreased by a unit.

Assuming that cross-elasticities are null between different products (independent demands) and with no externality (social cost = private cost), we obtain the well-known rule of the mark-up proportional to the inverse of the price elasticity of the demand, that is:

$\frac{p_k - Cm_k}{p_k} = \frac{\lambda}{1+\lambda} * \frac{1}{\eta_k(p_k)}$ where $\eta_k(p_k)$ is price elasticity of demand for demand of good k.

Let us call $\alpha = \lambda/(1+\lambda)$, a parameter reflecting the cost opportunity of public funds λ

And if we call ε the price elasticity of traffic : $\eta_k(p_k)$

We find that α/ε is the key ratio to determine the mark-up value. More precisely, if α is a constant, the relative price increase above marginal cost is all the higher as demand is not sensitive to prices.

So, Ramsey pricing provides a useful theoretical guideline. However, it requires a great deal of information. Both marginal cost and elasticity of demand must be quantified with a certain degree of accuracy. And we also must take into account the opportunity cost of public funds, according to the fact that RFF is subsidised by government. If we try to apply such reasoning, we obtain the following formula:

$(P - C)/ P = (a - Ci)/ P$ (1)

and

$(a - Ci)/ P = \alpha /\varepsilon$ (2)

with

P: Price of the final service, paid by train user, because we take into account the elasticity of final user.

a: Level of infrastructure charge

ε: Traffic price elasticity (absolute value)

$\alpha = \lambda/(1+\lambda)$, λ = opportunity cost of public funds

C: Marginal cost with two components:

Ci = infrastructure cost

Cs = Train service cost

If we combine C = Ci + CS with the equation (1), we obtain P = a + Cs and equation (2) becomes

$(a – Ci)/ (a + Cs) = \alpha /\varepsilon$ (3)

so

$a = (Ci + \alpha /\varepsilon *Cs) / (1 - \alpha /\varepsilon)$ (4)

Therefore, it is interesting to observe the variations of the mark-up "a" in relation with the various values of α, ε, Ci and CS. Table 3A below summarises the result by taking into account the official value of opportunity cost of public funds in France (λ = 0,3) which leads to α = 0.23. Columns of Table 3 combine various level of elasticity ε with this fixed value of α. The lines show different combinations of Ci and Cs. We give the value of 100 to Ci, and then we suppose that Ci can be higher, equal or lower than Cs. The impacts are very clear: the higher the elasticity and Ci/Cs ratio, the lower the value of "a". On the contrary, when elasticity and ratio Ci/Cs decline, "a" increases. The mark-up is even equal to ten times Ci, but only if elasticity is very weak (0.3).

Table 3.A1.1. **Value of the mark-up "a" for Ci = 100**

	$\alpha = 0.23$	$\alpha = 0.23$	$\alpha = 0.23$	$\alpha = 0.23$	$\alpha = 0.23$
	$\varepsilon = 0.3$	$\varepsilon = 0.5$	$\varepsilon = 0.8$	$\varepsilon = 1.3$	$\varepsilon = 2$
	$\alpha/\varepsilon = 0.76$	$\alpha/\varepsilon = 0.46$	$\alpha/\varepsilon = 0.28$	$\alpha/\varepsilon = 0.176$	$\alpha/\varepsilon = 0.115$
Ci/Cs = 1.5	a = 625	a = 241	a = 164	a = 135	a = 121
Ci/Cs= 1	a = 733	a = 270	a = 177	a = 142	a = 126
Ci/Cs = 0.5	a = 1 050	a = 355	a = 216	a = 164	a = 138

Source: Crozet.

The actual pricing scheme of RFF is already close to the optimal situation. For Paris-Lyon, the mark-up is close to 6, but for the other parts of the network, with a lower level of traffic, and probably a higher elasticity, the implicit mark-up is close to 2 or 1.5. Finally the total revenue of infrastructure charges for HST is not far from an optimal situation. HSTs are not a "cash cow". The present infrastructure charges are close to the optimal pricing scheme. It would be efficient neither to reduce them nor to increase them sharply.

Annex 3.A2. Effective speed and effective speed for society, another indicator for determining the critical zone for a TGV

The concept of effective speed (I. Illich, J. P. Dupuy) demands that, in order to know the actual speed of a journey, it is necessary to take into account not only the journey time but also the time spent working in order to obtain the money to fund the financial cost of the journey. It is necessary to distinguish between three related concepts:

- **Generalised cost**, a concept developed in the 1960s by economists. Generalised cost expresses in monetary terms the total cost of a journey (monetary cost plus cost of time).

- **Generalised time**, indicates in hours or minutes the total time needed for the journey, in other words the journey time itself plus the working time required in order to obtain the necessary money.

- **Effective speed** (Tranter 2004), a concept which relates the distance of a journey to the total time taken to make the journey and to obtain the necessary money.

Let us focus on effective speed (Vg – vitesse généralisée) which can be defined as follows:

$Vg = 1/[(1/V) + (k/w)]$

We find, first, that because we are dealing with speed we have a harmonic mean involving both the physical journey speed (V) and the purchasing power of the hourly wage (w) in terms of kilometres (k = cost per kilometre). On that basis, it will be realised that effective speed cannot increase indefinitely). As V approaches infinity, effective speed evolves in the k/w ratio. In order to increase effective speed, it is therefore necessary either to reduce k or to increase w. Symmetrically, even with a very high V value, effective speed can decrease if the cost per kilometre increases faster than the hourly wage.

As I. Illich (1973) pointed out, it is true that, in some cases and for certain journeys, effective speed decreases for the majority. This is what brought to a probably final close the era of supersonic commercial aviation. In 2000, a Paris-New York return on Concorde (average speed 2 000 km/h) cost around EUR 12 000 for 12 000 kilometres, in other words EUR 1 per kilometre, which is expensive but not exorbitant. However, in terms of effective speed, for a worker earning around EUR 6 net per hour, that calculation gives a speed of about 6 km/h, not much faster than walking speed.

By contrast, at the same time for the same worker, the effective speed of a subsonic flight to New York (average speed 800 km/h) which cost EUR 600 return (EUR 0.05 per kilometre) was just over 100 km/h – a much faster speed than walking or cycling. This situation is not the one that Illich sought to demonstrate, but it is one that explains the success of air transport and its popularisation, even in this time of crisis.

Thus, by applying a strict definition of effective speed, we find that the concept has evaded the aims of its creators. There are situations where even a person earning the minimum wage can significantly increase the effective speed of some of his journeys. Contrary to Illich's hypothesis, the evolution of the automobile, and also that of the TGV and aeroplane, have allowed as many people as possible significantly to increase the effective speed of their journeys.

Viewed from this angle, it is not surprising that demand from the community is strong, yesterday for motorways, today for TGVs. The problem is that this demand entails increasing costs for the community. Let us return to a quotation from I. Illich, "*Beyond a critical (speed) threshold, the output of the industrial complex established to move people costs a society more time than it saves*." The concept of effective speed for society enables us to take into account that collective dimension rather than just the individual dimension of the cost of what he describes as the industrial complex. In order to do this, we simply need to replace the value k in the definition of effective speed by a value Ks which no longer represents the cost per kilometre for an individual but the cost per kilometre for society. In this way, we get an indicator of "effective speed for society" (Vgs) which can be expressed as follows:

$$Vgs = 1/[(1/V) + (Ks/w)]$$

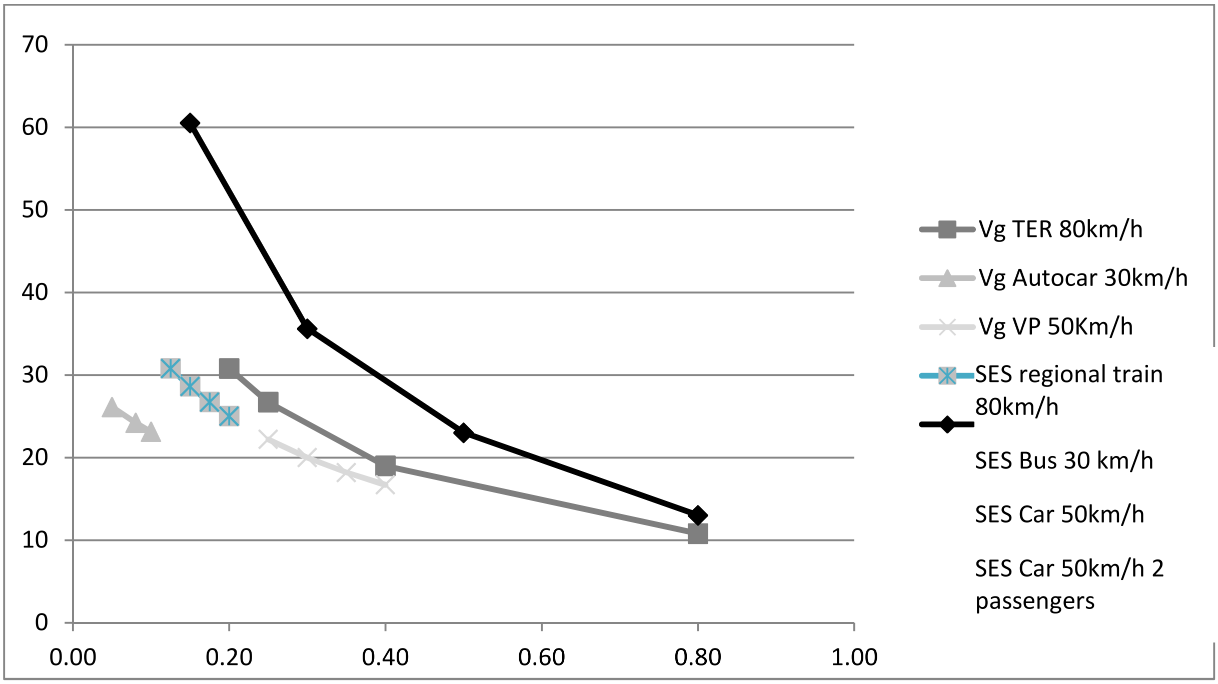
By applying this formula to certain French TGV projects, we find that infrastructure costs translate into a low effective social speed for the TGV. The value k of the cost per kilometre of the TGV (EUR 0.15 per kilometre) is the cost borne by users. However, if it is necessary to pay EUR 0.35 per passenger-kilometre in subsidies for infrastructure and potential operation, the social cost per kilometre becomes EUR 0.50 per kilometre and slightly more if we include external costs (noise, polluting emissions, etc.). In this case, the effective speed for an individual earning an hourly wage of EUR 10 remains 50 km/h, but the effective speed for society is only 23 km/h assuming an average hourly wage for society as EUR 13 per hour. This value of 23 km/h should be compared with the potential cost of a regional train or coach with the same destination.

Figure 3.A2.1 shows the variation in the effective speed for society (SES, vertical axis) as a function of the social cost per Km. We can see that for the same social cost per Km, the high speed train is "faster" than all the other modes because of its physical speed. However, once the social cost of high-speed rail reaches 50 or 80 Euros cents a Km, other modes including conventional rail, buses and even cars carrying only 2 people become worth considering.

- A classic train carrying 50 passengers gives a social cost per passenger-kilometre of EUR 0.40[6]. If its physical speed is 80 km/h, the effective speed for society, assuming an hourly wage of EUR 13, is 23 km/h, as it would be for some high-speed rail projects that need large subsidies. The TER (regional express transport), whilst subsidised, is therefore more economic for an identical yield, despite a low occupancy rate.
- For a coach travelling at an average speed of 30 km/h, the social cost is around EUR 0.10 (the direct cost for users being about EUR 0.07). Assuming an average hourly wage of EUR 13 per hour, the effective social speed would be 24 km/h, but 36 km/h if it travels at 50 km/h. It is easy to understand why the motorway coach offer developed, in France and also in Germany.

It is no accident that coach transport has been fully liberalised in Great Britain. Even though it receives no subsidies, despite the external costs of road transport, the effective social speed of coach travel is much faster than that of trains. It is on these bases, therefore, that we should challenge the priorities of mobility policies by making a comparison of effective social speeds.

Figure 3.A2.1. **Social effective speed (SES) and social cost/km**



Source: Crozet.

Notes

1. The decision to build a high-speed line between Paris and Lyons was taken in September 1975.
2. The same logic was applied in the 19th century at the beginning of the railway age. In France, people speak of the "Legrand star" after the name of the engineer who devised the layout of the first French rail network.
3. The author of this paper was one of the four experts.
4. There will be more "on-track" competition in 2014 in the Channel Tunnel. The German company Deutsche Bahn is due to introduce links with Brussels to compete with Eurostar.
5. Michel Walrave, SNCF economist who led the socio-economic studies on the Paris-Lyon line, and who, in the 1950s, attended the economics symposium led by Maurice Allais (Nobel Prize for Economics, 1988). Other students included Claude Abraham, Marcel Boiteux and Gérard Debreu (Nobel Prize for Economics, 1983).
6. Only EUR 0.20 if there are 100 passengers and EUR 0.80 if there are only 25. For the TGV, we have assumed a high rate of occupancy (85%), in the absence of which the effective social speed is even lower and might fall to only 12 km/h where occupancy is 40%.

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Chapter 4.

Shinkansen investment before and after JNR reform

Fumio Kurosaki [1]

The high-speed railway system, namely Shinkansen, was initially introduced by the Japanese National Railways (JNR) in 1964. As JNR was reformed in 1987, the schemes for construction and operation of Shinkansen were also modified accordingly. This paper primarily discussed Shinkansen's effects on the operating companies and tried to evaluate the financial effects of Shinkansen operation depending on its traffic density. The study also showed that Shinkansen transport is competitive against other transport modes and is increasing its transport revenue by a much higher rate than conventional lines operated by those railways. Along with the passenger increase in the inter-city services such as the Tokaido and Sanyo Shinkansen Lines, the number of Shinkansen commuters has been also increasing especially around Tokyo metropolitan area. As a result, the share of revenue brought from Shinkansen operation has been increasing in those railway companies in Japan.

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1. Introduction

"Shinkansen" refers to Japan's dedicated high-speed intercity rail system, and it was initially introduced between Tokyo and Shin-Osaka in 1964 prior to other countries. This event accelerated the development of high-speed railways in other countries. In Japan its total length and the number of lines have increased since then contributing to the economic development of the country. As with other conventional railways, Shinkansen was constructed and operated by the Japanese National Railways (JNR).

There is another issue which Japan's railway experienced prior to other countries, namely railway reform which was implemented in April 1987. This separated JNR into six independent passenger railway companies. Since then, the financial resources for Shinkansen construction were modified so as not to worsen the financial situation of the new companies, and public finances have been utilised in order to extend the lines. Even after separation into independent companies, operation of Shinkansen trains, including through-service trains crossing borders between companies, has been smooth. This article outlines how construction and operation of Shinkansen lines has been modified through JNR reform.

As Shinkansen lines have been built in various markets in Japan over a half century, traffic volume varies greatly depending on the line. Based on published data, this paper examines the changes to high-speed rail transport and appraises its outcomes including the financial aspects of the operating companies.

2. Outline of JNR reform

This section outlines the history of JNR and background to JNR reform. In 1949, the government reorganised the railways and established the Japanese National Railways (JNR) as a public enterprise. Due to the lack of other means of transport, the railways dominated post-war passenger and freight markets in Japan. In 1950, Japanese railways had 92 percent of the passenger market (passenger-km) and 52 percent of the freight market (tonne-km), and they continued making profits through the 1950s and early 1960s (Aoki et al., 2000 p.181). However, from the 1960s, motorisation and air transport progressed dramatically in tandem with the high economic growth, and the modal share of railways decreased.

Owing to the competitiveness of other modes of transport, JNR continued to lose its freight businesses along with local passenger transport. In addition, JNR shouldered the burden of construction costs of new railway lines. Thus, JNR ran a deficit in 1964 and the annual deficit continued for many subsequent years. JNR accumulated long-term debt each year, and at the time of JNR reform in 1987 it amounted to 25 trillion yen, which was roughly equivalent to the combined national debts of several developing countries (ibid, p.183).

In addition to financial difficulties, JNR also faced severe criticism of its ineffective management. Thus, JNR reform was finally undertaken in April 1987. Through the reform, JNR was split into six regional passenger companies and a single nation-wide freight company (JR Freight). (Map 4.1).

Map 4.1**. JNR reform in 1987**

Source: MLIT(2013).

3. Shinkansen projects in JNR and its management

Shinkansen Projects before JNR Reform

An original aim of constructing Shinkansen lines in Japan was to accommodate increasingly heavy traffic demand along the trunk lines. Although the gauge of Japanese conventional lines is 1 067 mm, it was decided that Shinkansen lines would be constructed with a standard gauge of 1 435 mm after serious discussions among concerned persons. Along with technology that permitted higher speed, construction of a dedicated track for high-speed passenger trains made it possible to operate a larger number of trains. At present, high-speed trains are operated with a 3-minute train headway during the peak hours in the Tokaido Shinkansen Line, and this kind of concentrated train operation could not have been realised if the track had to be shared with slower conventional and freight trains.

The first Shinkansen project connecting Tokyo and Shin-Osaka started construction work in 1959 and was opened in October 1964. Traffic volume increased steadily, and the number of trains was also increased. Following the first line, the Tokaido Shinkansen Line, JNR constructed the second high-speed line, namely, the Sanyo Shinkansen Line. The section between Shin-Osaka and Okayama opened in 1972, extended to Hakata in 1975.

Although the original aim was to overcome the capacity constraints of the trunk lines, as mentioned above, the success of the Tokaido and Sanyo Shinkansen Lines aroused the local interest to extend Shinkansen lines to other cities, focusing on its high speed rather than transport capacity. As a result, the government promulgated the Nationwide Shinkansen Development Law in 1970, and planned a nationwide Shinkansen network (*ibid.* p.144). This plan proposed to construct a Shinkansen network with a total of more than 68 000 km.

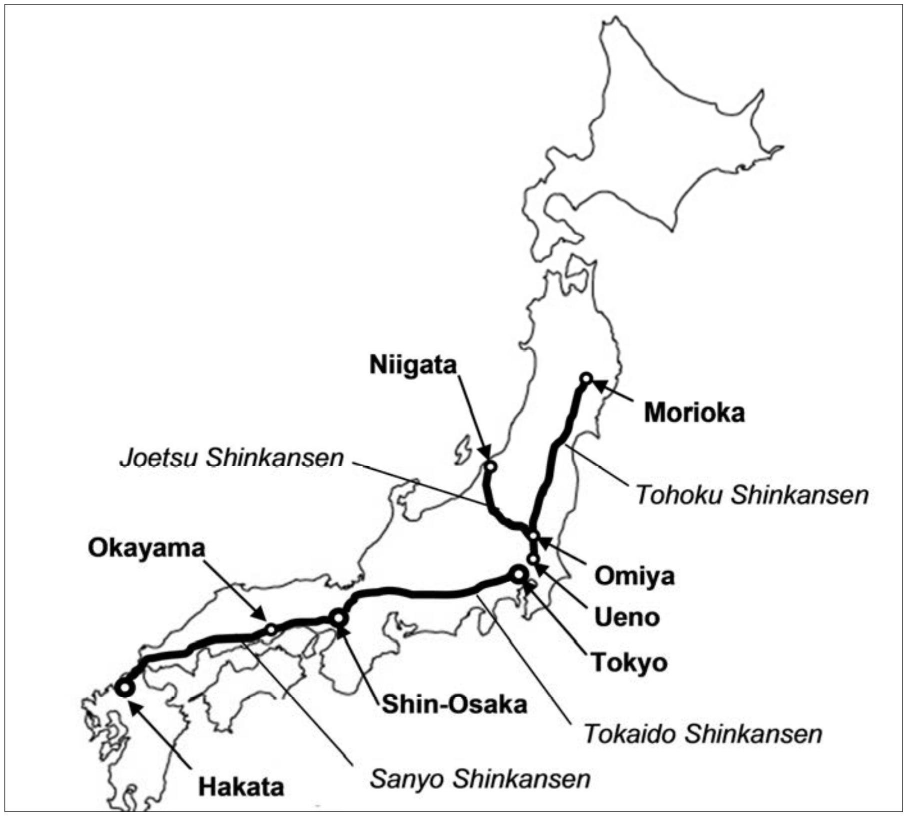
Prior to JNR reform, both conventional and Shinkansen lines had been constructed with interest-bearing loans. This means that it was a precondition that the construction costs be paid back from sales revenue after the opening of operations. Owing to the financial constraints, JNR could not allow a large investment to construct new Shinkansen lines. Nevertheless, construction work steadily continued, and the Tohoku and Joetsu Shinkansen Lines were opened before JNR reform, bringing the network of Shinkansen lines to 2 031.9 km in 1987 (Table 4.1).

Table 4.1. **Shinkansen lines completed before JNR reform**

Shinkansen Line	**Section** (Operating Company after JNR Reform)	**Operating Line Length**	**Date Open**
1) Tokaido Shinkansen	Tokyo – Shin-Osaka (JR Central)	552.6km	1 Oct. 1964
2a) Sanyo Shinkansen	Shin-Osaka – Okayama (JR West)	180.3km	15 Mar. 1972
2b) Sanyo Shinkansen	Okayama – Hakata (JR West)	463.7km	10 Mar. 1975
3a) Tohoku Shinkansen	Omiya – Morioka (JR East)	505.0km	23 Jun. 1982
3b) Tohoku Shinkansen	Ueno – Omiya (JR East)	26.7km	14 Mar. 1985
4) Joetsu Shinkansen	Omiya – Niigata (JR East)	303.6km	15 Nov. 1982
Total Length of Shinkansen Lines in 1987		2 031.9km	

Source: MLIT (2013).

Map 4.2. **Shinkansen network**
(1987)



Source: MLIT (2013).

Shinkansen performance during JNR Era

This section examines the performance of Shinkansen lines opened during the JNR era. Table 4.2 shows the transport performance of Shinkansen Lines from 1982 to 1984.

Table 4.2. **Transport results of Shinkansen lines**
(1982–1984)

Item	Unit	Line name	1982	1983	1984
Number of Passengers	Thousands	Tokaido & Sanyo	124 830	127 613	128 363
		Tohoku	14 000	23 409	24 127
		Joetsu	4 077	10 327	11 300
Transport Volume (passenger km)	Millions	Tokaido & Sanyo	41 489	42 186	42 197
		Tohoku	3 743	5 989	6 142
		Joetsu	873	2 265	2 487
Traffic Density (passengers/day)	Thousands	Tokaido & Sanyo	95.0	96.6	96.6
		Tohoku	26.3	32.5	33.3
		Joetsu	21.0	20.4	22.4

Source: JNR (1985).

It is very difficult to allocate correctly the overhead expenses by line. But, in the latter period of JNR, in order to analyse management of JNR in preparation for reform, an audit report analysed the profitability of the lines.

Based on the report, the transport and financial results of operating Shinkansen lines are shown in Table 4.3.

Table 4.3. **Financial results for Shinkansen lines**
(1982 – 1984)

Unit: billion yen

Name of Lines	Accounts	1982	1983	1984
Tokaido & Sanyo	1. Operating Revenue	816.1	829.9	893.1
	2. Operating Expenses	343.8	342.9	348.2
	3. Operating Profit	472.3	487.0	544.9
Tohoku & Joetsu	1. Operating Revenue	104.5	187.7	206.7
	2. Operating Expenses	43.6 [160.3]	69.1 [283.2]	76.5 [298.8]
	3. Operating Profit	60.9 [-55.8]	118.6 [-95.5]	130.2 [-92.1]

[ ]: Indicates total expenses/profit including depreciation and other capital costs.
Source*:* JNR (1985).

The above table shows that the Tokaido and Sanyo Shinkansen Lines were very profitable, though there is no data which includes expenses of capital costs. JNR (1986) also noted that the Tokaido and Sanyo Shinkansen Lines were the second most profitable lines within JNR network following the Yamanote Line, which operates in the center of the Tokyo metropolitan area.

Regarding the Tohoku and Joetsu Lines, the above table shows that, although they were profitable if capital costs related to infrastructure were not included, the inclusion of those costs resulted in net loss.

JNR Reform and Transfers of Shinkansen Assets

In JNR reform, Shinkansen operation was divided among the three Honshu JR passenger companies: JR East, JR Central, and JR West. Nevertheless, it was assumed that profit adjustment among the three companies would be indispensable. Accordingly, Shinkansen Holding Corporation (SHC) was established, which owned the assets of the Shinkansen infrastructure and also shouldered the same amount of debt as their market-based revaluation. Then, each line was leased for operation to each of the three JR companies, and the above-mentioned profit adjustment was realised through the amount of lease charges paid (Sumita, 2005).

Nevertheless, although the three companies had aimed to become listed companies, this organisational structure faced a disadvantage in that the assets of the companies would be indefinite even if they finished paying the lease fees in the future. In addition, as the JR companies did not retain ownership of their infrastructure assets, it was impossible for them to reserve for depreciation, and even the investment for infrastructure assets had to be treated as an expenditure of a single year rather than depreciated over several years.

In order to resolve these issues, the assets of the Shinkansen infrastructure were sold to the three JR companies in October 1991, and SHC was dissolved. Since then, the three JR companies have retained ownership of Shinkansen infrastructure assets which had been constructed during the JNR era. Thus, unlike new Shinkansen lines which have been constructed/opened since JNR reform, these initial Shinkansen lines constructed before 1987 have been operated by an integrated structure since the sale of the assets in 1991.

4. Shinkansen projects since JNR reform

Finance and management of new Shinkansen lines

Even since JNR reform, construction works have been implemented to extend Shinkansen lines. A construction and operation scheme for these works was modified reflecting the management failures of JNR. Since JNR reform, the new lines and extensions of Shinkansen lines have been constructed and operated based on the new scheme, and Japan Railway Construction, Transport and Technology Agency (JRTT), a wholly government-financed entity, carries out Shinkansen construction works as public projects.

JRTT not only implements construction work but also retains ownership of the infrastructure assets after completion of the projects. It leases the assets to the JR passenger companies, which provide high-speed railway services. Thus, different from the initial Shinkansen lines which had been constructed during the JNR era, the newly constructed sections form a vertically separated structure. The JR companies pay usage fees based on the calculation explained in the following section. Regarding financial resources, except for the usage fees which would be allocated for construction works, the current financial scheme, which was revised in 1996, stipulates that the state and local governments bear the financial burden of the projects by a ratio of 2:1.

Usage fees and maintenance costs

The amount of usage fees paid by an operator of new Shinkansen lines is an essential factor in the relationship between the JR passenger company and the public sector.

Payment of usage fees is regulated by the Japan Railway Construction, Transport and Technology Agency Law. The Law stipulates that JRTT basically calculates the amount based on the benefits received as an operator of the new Shinkansen lines after opening. The above-mentioned benefits are calculated by comparing the following two amounts:

1. The estimated revenues and expenses generated by the new Shinkansen lines and related line segments after opening; with
2. The estimated revenues and expenses that would likely be generated by parallel conventional lines and related line segments if the new Shinkansen lines were not opened.

In brief, the amount equals to the operator's net increase of benefits through the commencement of operation. Then, the above-mentioned amounts are calculated based on expected revenue and expenses over a 30-year period after opening.

As a rule, in commencing the construction works, the local communities are to agree to separate the management of the conventional lines parallel to newly constructed Shinkansen lines from the JR companies. Since these conventional lines are unprofitable, this separation alleviates the financial burden of JR companies, and in general the regional governments are to manage the railways including their finances if they wish to continue the operation.

As for expenses of JR companies, the taxes and maintenance fees are included in the above-mentioned calculations. As such, the scheme is designed so that the operation of newly constructed Shinkansen lines should not worsen the financial situation of the JR passenger companies and the burden of the operator would be kept within the limits of the benefits received as an operator of new lines (JR East, 2004).

Regarding payment of maintenance costs of infrastructure, each JR passenger company pays within its own budget. Although both new Shinkansen lines and European railways form vertically separated structures, the payment of the maintenance costs shows a stark contrast. For railways in Europe, an infrastructure manager pays the maintenance costs, although the amount of usage fees can cover the maintenance costs in some cases. However, in the case of Japan, the infrastructure owner (JRTT) does not pay any cost for operation and maintenance works of the infrastructure, and received usage fees are utilised for a part of construction costs of other projects.

The above-mentioned new scheme for constructing Shinkansen line is accepted by concerned parties, since, in theory, a JR company neither gains nor loses because of the projects promoted as public works.

Sections of new Shinkansen lines

Based on the schemes explained in the above sections, construction work continued even after JNR reform. Table 4.4 shows new segments of Shinkansen lines which have opened since JNR reform.

Table 4.4. **New Shinkansen lines opened since JNR reform**

Shinkansen Line	Section (Operating Company)	Operating Line Length	Date of Opening
1a. Tohoku Shinkansen	Tokyo – Ueno (JR East)	3.6km	20 Jun. 1991
1b. Tohoku Shinkansen	Morioka – Hachinohe (JR East)	96.6km	1 Dec. 2002
1c. Tohoku Shinkansen	Hachinohe – Shin-Aomori (JR East)	81.8km	4 Dec. 2010
2. Hokuriku Shinkansen	Takasaki – Nagano (JR East)	117.4km	1 Oct.1997
3a. Kyushu Shinkansen	Hakata – Shin-Yatsushiro (JR Kyushu)	151.3km	12 Mar. 2011
3b. Kyushu Shinkansen	Shin-Yatsushiro – Kagoshima-Chuo (JR Kyushu)	137.6km	13 Mar. 2004
Total length of Shinkansen lines opened after 1987		588.3km	

Source: MLIT (2013).

In addition, the government has already permitted the promotion of other construction projects, and the following lines are now under construction:

1. Hokkaido Shinkansen: Shin-Aomori – Sapporo (360km)
2. Hokuriku Shinkansen: Nagano – Tsuruga (353km)
3. Kyushu Shinkansen: Takeo-Onsen – Nagasaki (66km)

As for other Shinkansen lines/segments, although the government had planned to construct a nation-wide Shinkansen network as mentioned at the beginning of Section 3, it has not yet permitted promotion of those construction projects.

New sections/ lines financed by JR companies

Besides the above-mentioned scheme, there are other projects which particular JR companies have been promoting. One of these is the Central Shinkansen Line, promoted by JR Central, and another is Mini-Shinkansen Lines promoted by JR East.

Central Shinkansen line

The financial schemes for the Central Shinkansen Line between Tokyo and Osaka are completely different from the above Shinkansen lines, and JR Central made a decision to construct the section between Tokyo and Nagoya utilising its own financial resources. The technology of the Central Shinkansen is different from other Shinkansen lines; it will adopt Maglev technology. JR Central has been preparing for the project since the government's approval of the plan in May 2011 according to the government's new Shinkansen line plan.

Mini-ShinkansenlLines

Mini-Shinkansen lines are not covered by the government's new Shinkansen line plan. And, as the definition of Shinkansen in Japan stipulates that it does not have a level crossing with roads, mini-Shinkansen lines are not categorised as Shinkansen lines.

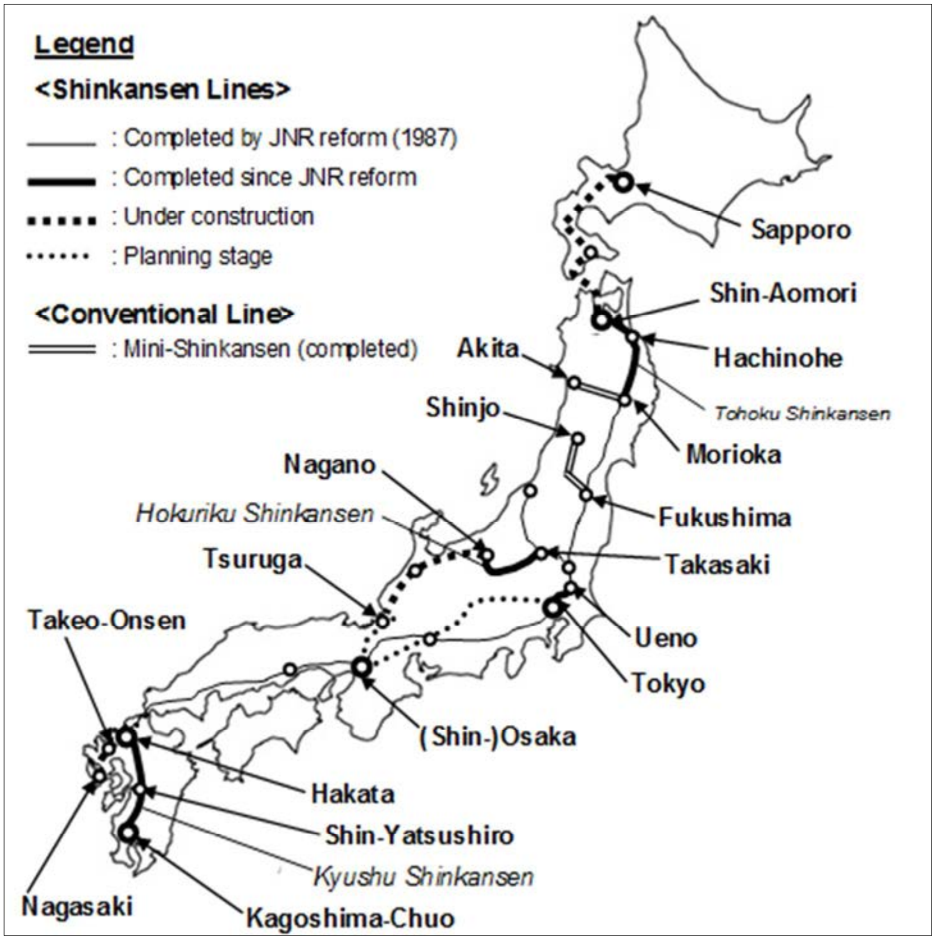
In order to provide faster service to cities not on the Shinkansen, JR East promoted two projects with its own finances:

1. Yamagata Shinkansen (section between Fukushima and Shinjo)
2. Akita Shinkansen (section between Morioka and Akita)

In these sections, the track gauge was changed from conventional-line 1 067 mm gauge to standard gauge, so that trains with standard gauge bogies could run on those lines. JR East then started through-train services between dedicated high-speed lines (which are standard gauge) and these modified sections by utilising rolling stock of the same car-body size as conventional trains.

As mini-Shinkansen lines are categorised as conventional lines, the Shinkansen statistics in this paper do not include their data.

Map 4.3. **Sections extended since JNR reform**

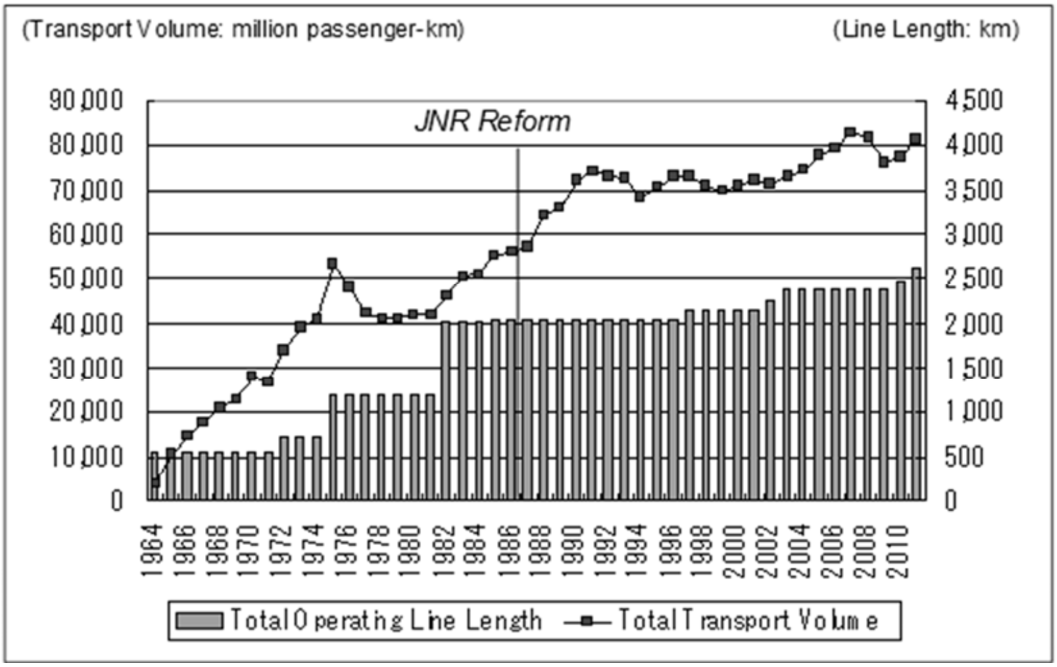


Source: MLIT (2013).

In summary, although construction projects of Shinkansen lines were implemented by JNR utilising interest-bearing loans, railway reform brought about a chance to revise that scheme, which was then modified so that the government would implement the projects and pay the construction costs of the infrastructure. Regarding construction of new Shinkansen lines, the public entity (JRTT) retains the ownership of the infrastructure and forms a vertically separated structure, so that the project does not affect the financial condition of JR companies.

Based on the above-mentioned schemes, the total Shinkansen operating line length has reached 2 620 km, and transport volume exceeded 80 billion passenger-km in 2011. (Figure 4.1)

Figure 4.1. **Growth in line length and transport volume of Shinkansen lines**



Source: Institute of Transportation Statistics (1995), MLIT (2013).

5. Characteristics of train operation in Japan

Train operation before JNR reform

During the JNR era, JNR in general owned the infrastructure and operated the trains. Since Shinkansen trains did not run through onto other railways, JNR took all responsibility of railway operation for all Shinkansen lines: Tokaido, Sanyo, Tohoku and Joetsu.

Train operation after JNR reform

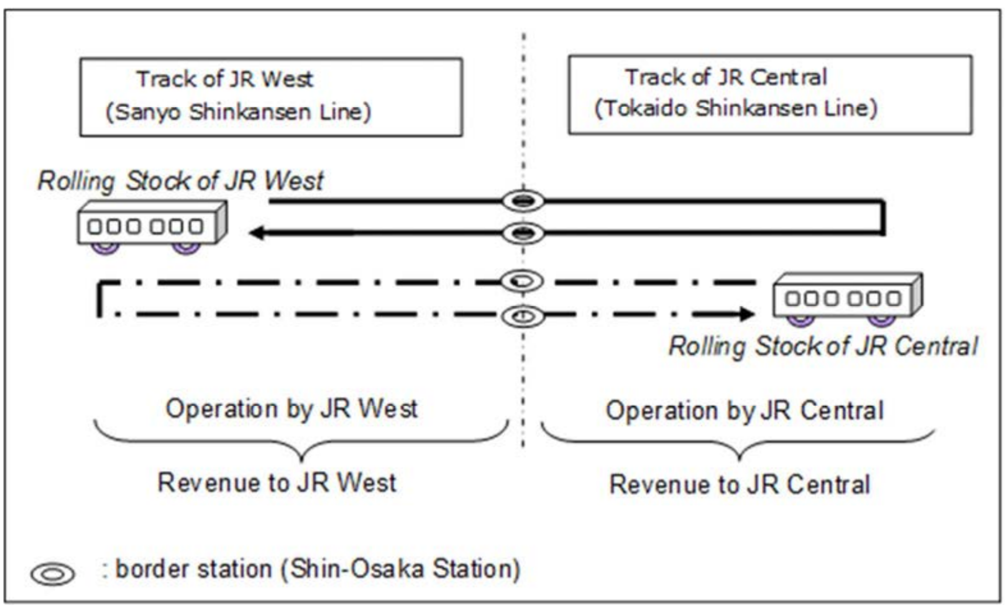
The above-mentioned status changed at the time of JNR reform, and Shinkansen operation has also been taken over by the respective companies: JR East, JR Central and JR West. There has been no through-train service between the Tohoku/Joetsu (JR East) and Tokaido (JR Central) Shinkansen Lines because: 1) many passengers start/terminate their travel at Tokyo Station; and 2) their electric power supply systems are different. On the other hand, many trains run through between the Tokaido (JR Central) and Sanyo (JR West) Shinkansen Lines. Since the open of the Kyushu Shinkansen Line in March 2011, through-trains also operate between the Sanyo (JR West) and Kyushu (JR Kyushu) Shinkansen Lines.

Through-train services yield benefits for passengers, such as the reduction in travel time by omitting the need to change trains, as well as benefits for the railway companies by reducing terminal congestion for both passengers and trains. As the concerned railways can achieve these merits without heavy investment in the infrastructure, through-train services are common in Japan not only on Shinkansen lines but also on conventional lines.

These through-train services are operated in the same way for both Shinkansen trains and conventional trains in Japan, but in a completely different way from the recent European international / intercity trains. Thus, the operation of through-train services reveals one of the most distinct characteristics of train operation in Japan. Accordingly, this section explains how services are provided between two railway companies.

Briefly, through-train services in Japan are provided by two vertically integrated railways as outlined in Figure 4.2. This example shows through-train services between the Tokaido and Sanyo Shinkansen Lines.

Figure 4.2. **Through-train services between two railway companies in Japan**



Source: Revised from Kurosaki (2008).

Since JNR reform, the Tokaido Shinkansen Line has been operated by JR Central, and the Sanyo Shinkansen Line by JR West. Although a number of trains start and terminate at the border station, Shin-Osaka, the two railway companies, JR Central and JR West, operate dozens of through-service Shinkansen trains per day.

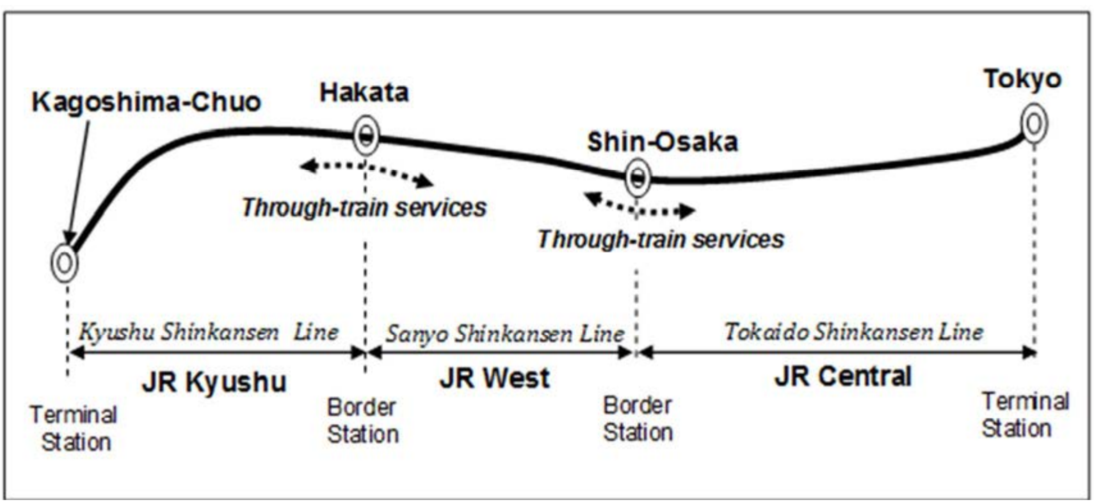
For through-train services between the two railway companies, for example, a train owned by JR West leaves its own line and continues on the tracks of JR Central. The fares paid for travel using JR West's tracks belong to JR West even if JR West uses JR Central's rolling stock. When JR West uses JR Central's rolling stock, JR West pays rent-fees for the rolling stock to JR Central.

This kind of through-train operation is common not only on Shinkansen lines but also on conventional lines. As the railways arrange for access for other railways' rolling stock, before this service begins, the concerned railways negotiate about terms regarding the conditions of access. For example, they have to agree regarding rolling stock design and performance such as type of car body and bogie, electrical systems, signaling apparatus, train-control systems, weight of rolling stock, passenger capacity, brake performance, telecommunication systems, and safety measures. The two railways have to keep in close communication and promote understanding regarding their integrated schedule and rolling stock operation to avoid problems and accidents (Kurosaki, 2008).

For through-train services in Japan, the responsibilities in train operation are clearly separated at the border station, and each railway is fully responsible for train operation on its own tracks. As a rule, the drivers change at the border station and therefore drive trains only on their own network. This helps guarantee operational safety, and this kind of measure has become fundamental policy since a serious train accident occurred on the Shigaraki Highland Railway in 1991. Since this accident, in order to guarantee greater safety, each railway company has taken measures to more clearly distinguish its own operational responsibility from that of other railways. Similar to the Shinkansen trains shown above, most conventional inter-company trains, such as those between two JR passenger companies and those between a JR passenger company and a private railway, are operated in the same way (*ibid.*).

Taking the Shinkansen Lines from Tokyo Station to Kagoshima-Chuo Station for example, a number of trains operate crossing border stations between JR passenger companies. Nevertheless, operational responsibilities are clearly separated at the border stations, and each integrated railway company takes responsibility of train operation within its own network only, as shown in Figure 4.3.

Figure 4.3. **Operational responsibilities of the three Shinkansen lines**



Source: Revised from “Kurosaki and Okuda (2012)”.

As discussed in Section 4, vertical separation has been adopted in the sections which were constructed since JNR reform. Nevertheless, even in these sections, single railway company implements all operation, similar to an integrated railway. This integrated train operation is largely different from the recent case in European railways, where train operation has been separated into train operators and an infrastructure manager.

Both Shinkansen and conventional trains in Japan have gained a high reputation in terms of safety and punctuality even under conditions of very dense traffic. It should be noted that through-train services in Japan have been operated as described above, and there is no case of competition on the same track on any railway network in Japan.

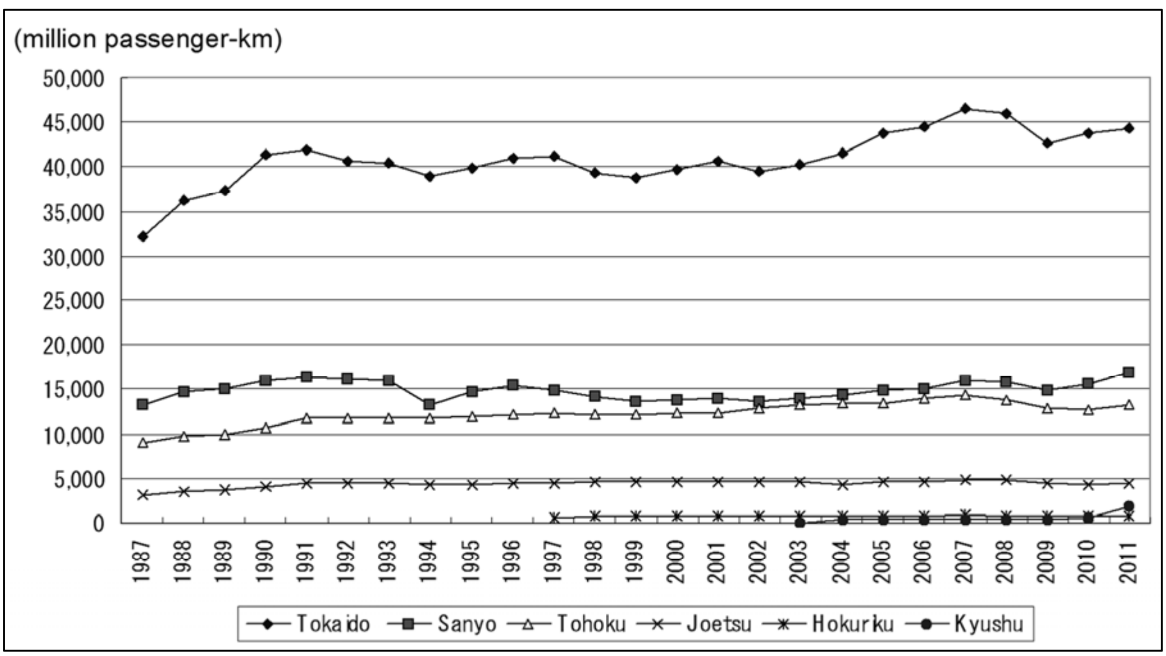
6. Changes in performance and its evaluation

Changes in transport volume

As discussed, construction of Shinkansen lines started from the most important trunk line with heavy congestion and was gradually extended to other outlying cities. Thus, conditions of transport market vary to a large extent, and transport volume of Shinkansen also differs between the initial line, the Tokaido Shinkansen Line, and other lines which were constructed later.

Figure 4.4 shows the changes of transport volume (passenger-km) of each line since JNR reform in 1987.

Figure 4.4. **Changes in transport volume on Shinkansen lines**



Source*:* MLIT (2013), JR West (2013), JR Central (2007; 2013a).

The Tokaido Shinkansen Line, which operates between Tokyo and Shin-Osaka, has the largest transport volume, and it has increased by 38% in the 24 years since JNR reform. Although transport volume of the Hokuriku Shinkansen Line, operating between Takasaki and Nagano, has remained level, all other Shinkansen Lines have increased in traffic volume since JNR reform or the line's opening.

Traffic density and management of the lines

Table 4.5 shows traffic density on each Shinkansen Line in 2011. Traffic density (passengers/day) can be calculated dividing transport volume (passenger-km) by the operating line length (km) and operating days (normally 365 days). As shown, the traffic density also varies among these lines.

Table 4.5. **Traffic density of Shinkansen lines in 2011**
(Unit: thousand passengers/day)

No.	Name of Shinkansen Line	Traffic Density
1	Tokaido	219.6
2	Sanyo	71.8
3	Tohoku	50.8
4	Joetsu	39.6
5	Hokuriku	17.8
6	Kyushu	17.3

Source*:* Calculation based on MLIT (2013), JR West (2013), JR Central (2013a).

It is very difficult to practically allocate the company's expenditure by line. Thus, since JNR reform, no JR company has publicised the revenue and expenditure by line. Thus, officially, the profitability of each line is unclear. But, according to Table 4.5, it is assumed that there are large differences in the profitability of each Shinkansen Line. In the following, the level of profitability is to be estimated based on the financial results of the operating company.

Firstly, it is certain that revenue from the Tokaido Shinkansen Line sufficiently covers operating expenses and depreciation of the assets, as JR Central has been profitable even though the company inherited a part of JNR's debt. As noted in Section 3, JR Central also bought Shinkansen infrastructure assets from SHC, and its long-term debt amounted to 5 456 billion yen in 1991. But, this amount had decreased to 2 615 billion yen by 2012 (JR Central, 2013b). The smoothness of this financial transition supports the above.

Secondly, it is also certain that the Sanyo Shinkansen Line gains profits with its sufficient traffic density. When JR West bought Shinkansen infrastructure assets from SHC in 1991 the long-term debt of JR West amounted to 1 595 billion yen. It has decreased to 973 billion yen by 2012 (JR West, 2013). As a number of local lines in JR West are not profitable, this financial transition shows that the Sanyo Shinkansen Line is profitable including capital costs and cross-subsidise unprofitable local lines.

Thirdly, regarding the Tohoku and Joetsu Shinkansen Lines, during the JNR era, they were profitable in operating cost but were not profitable when capital cost was included (JNR, 1985). As transport volume has increased significantly on some sections since then, it is assumed that the profitability has largely improved as well. In terms of the financial change of JR East, which operates Tohoku and Joetsu Shinkansen, its long-term debt amounted to 5 378 billion yen when the company bought the assets of two Shinkansen Lines in 1991. Then, the debt had decreased annually and amounted to 3 425 billion yen in March 2012. Nevertheless, JR East operates a profitable network of Tokyo metropolitan area, and the operation of these conventional railways also contributes to the profits of the company. Thus, different from JR Central and JR West, above-mentioned financial transition does not necessarily verify that the two Shinkansen lines cover the capital costs. In addition, since the line provides long distance inter-city transport services, covering 714 km in the Tohoku Shinkansen Line and 304 km in the Joetsu Shinkansen Line, the level of traffic density of each section varies to a large extent as the following section shows. Thus, it is possible that the lines still have some unprofitable sections on which are difficult to cover the capital costs.

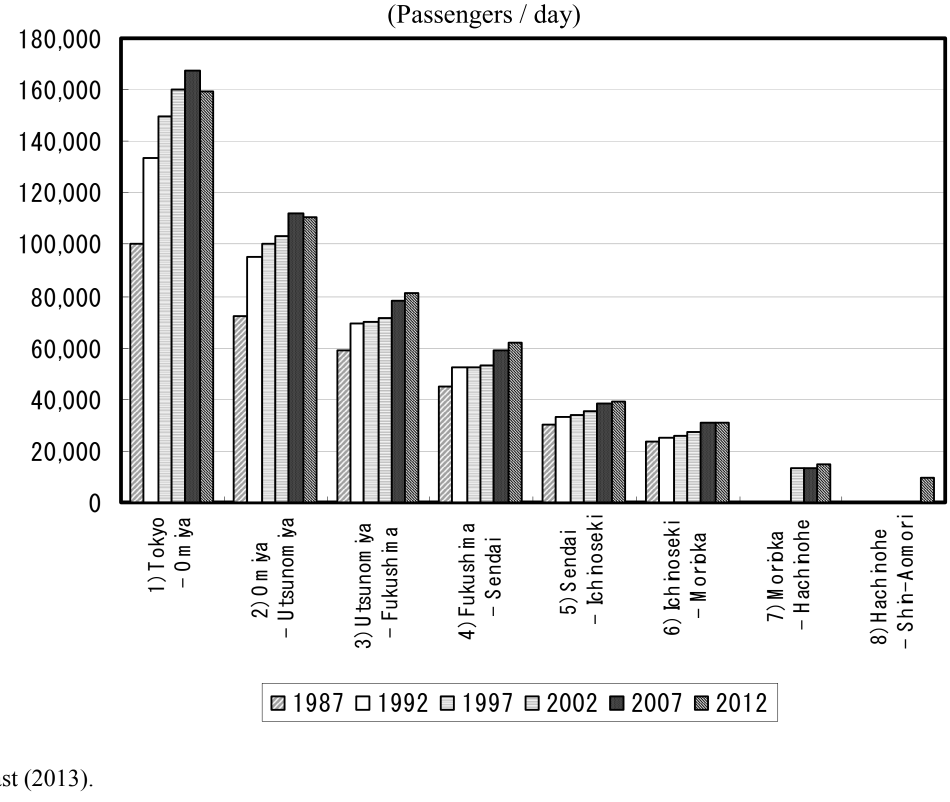
The level of traffic density of the Hokuriku and Kyushu Shinkansen Lines is less than half of that of the Joetsu Shinkansen Line, and it is not quite certain whether the operation of these lines covers the capital costs through the revenue. But, passengers on Shinkansen lines usually transfer to conventional lines, and the increase in ridership contributes to the profit of other lines. In addition, JR companies are active in promoting non-rail businesses such as real estate development around stations, operation of hotels and shopping center in their station buildings, etc. Passenger increase is also beneficial for promoting these non-rail businesses. Thus, it is possible that the operating company can report a profit with these related businesses. It is worth noting that the scheme, which is explained in Section 4, is not designed so that JR companies should cover capital costs in these lines, as JRTT had invested into the infrastructure and retains it.

Changes in traffic density by sections: A case of JR east

JR East operates the Tohoku, Joetsu and Hokuriku Shinkansen Lines, and publicises the level of traffic density of each section. Figure 4.5 shows that they are largely different according to the distance from Tokyo. It is clear that the sections closer to Tokyo have larger traffic.

Figure 4.5. **Traffic density of the Tohoku Shinkansen line**

(Passengers / day)



Source*:* JR East (2013).

Table 4.6 examines how the traffic density of each section has increased from 1987 to 2012. It shows that the sections closest to Tokyo have increased in ridership much more than the other sections further from Tokyo.

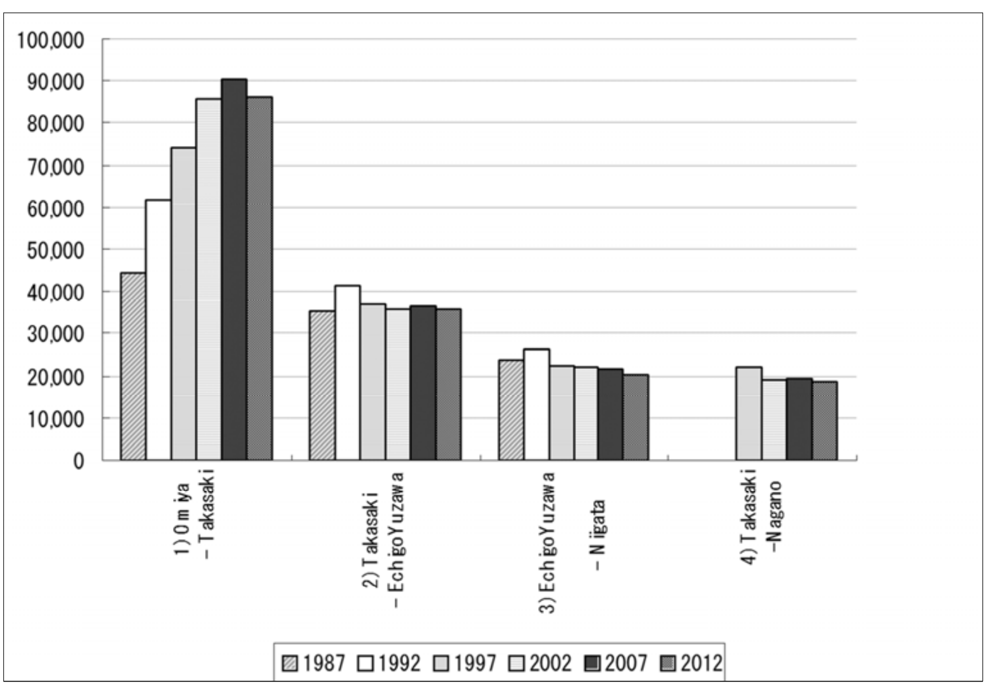
Table 4.6. **Increase of traffic density of the Tohoku Shinkansen line**
(1987 to 2012)

No.	**Section between Station (A) and Station (B)**			**Increase of traffic density from 1987 to 2012**	
	Station (A)	Station (B)	Distance to Station (B) from Tokyo Sta. (approximate time) *1	Increase of Traffic Density (passengers/day)	Increase Rate (%)
1	Tokyo	Omiya	30 km (0.4H)	59 556	59.5
2	Omiya	Utsunomiya	110 km (0.8H)	38 489	53.1
3	Utsunomiya	Fukushima	273 km (1.6H)	22 173	37.7
4	Fukushima	Sendai	352 km (1.7H)	17 174	38.2
5	Sendai	Ichinoseki	445 km (2.3H)	8 495	28.0
6	Ichinoseki	Morioka	535 km (2.5H)	7 995	34.3
7	Morioka	Hachinohe	632 km (3.1H)	14 758	8.9 *2
8	Hachinohe	Shin-Aomori	714 km (3.2H)	9 453	-

*1: Travel time varies depending on the types of trains; *2: This figure is the increase rate since the first days after opening.
Source*:* Calculation based on JR East (2013) and JR Group (2013).

In the same way, Figure 4.6 shows traffic density of the Joetsu Shinkansen Line (by section) and the Hokuriku Shinkansen Line.

Figure 4.6. **Traffic density of the Joetsu and Hokuriku Shinkansen lines**
(Passengers/ day)



Source*:* JR East (2013).

Figure 4.6 shows that the section closer to Tokyo, between Omiya and Takasaki, on the Joetsu Shinkansen Line has more ridership than the other sections further from Tokyo.

Table 4.7, which shows the changes in traffic density of each section, also indicates that the section closer to Tokyo has increased its traffic density largely. As opposed to this, the sections further from Tokyo lessened their traffic density during the years as shown in the segment between Echigo-Yuzawa and Niigata in the Tohoku Shinkansen Line and the segment between Takasaki and Nagano in the Hokuriku Shinkansen Line.

Table 4.7. **Increase of traffic density of the Joetsu and Hokuriku Shinkansen lines**
(1987 to 2012)

No	**Section between Station (A) and Station (B)**			**Increase of traffic density from 1987 to 2012**	
	Station (A)	Station (B)	Distance to Station (B) from Tokyo Sta. (approximate time) *1*	Increase of Traffic Density (passengers/day)	Increase Rate (%)
1	Omiya	Takasaki	105 km (0.8H)	41 826	94.1
2	Takasaki	Echigo-Yuzawa	199 km (1.2H)	208	0.6
3	Echigo-Yuzawa	Niigata	334 km (2.0H)	-3 224	-13.7
4	Takasaki	Nagano	222 km (1.4H)	-3 430	-15.6 *2*

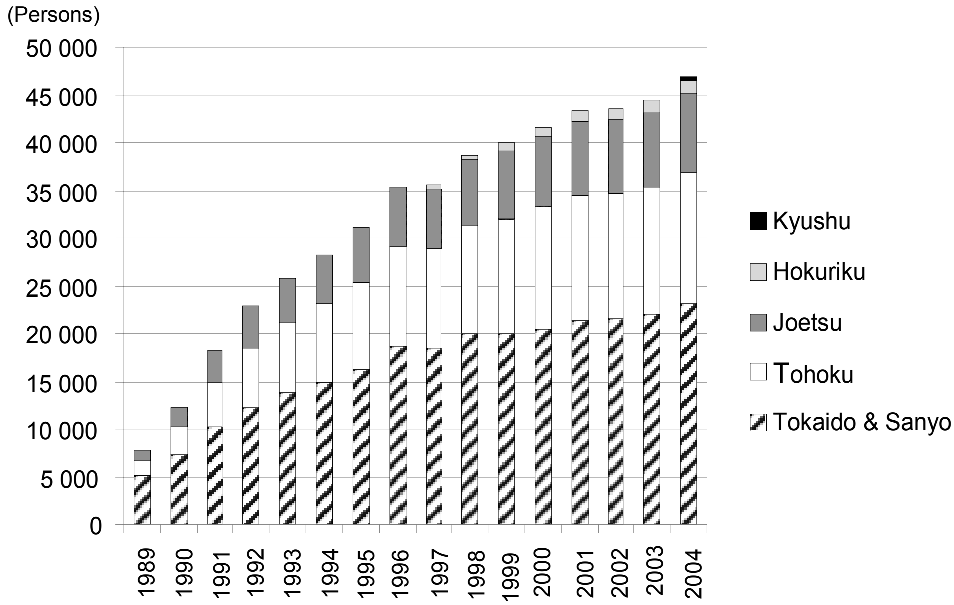
1: Travel time varies depending on the types of trains; *2*: This figure is the increase rate since the first days after opening.
Source: Calculation based on JR East (2013) and JR Group (2013).

The above statistics clearly show that the section closer to Tokyo metropolitan area not only has large transport volume but also has been increasing its ridership further since opening of the lines.

In relation to this change, Figure 4.7 shows the average number of Shinkansen commuting passes sold in a month, and the figure shows that the number has been increasing steadily.

Railways, including high-speed railways, have significant external effects such as increasing the land values along the lines. This means that people prefer to live around stations, and railway lines serve to develop residential/commercial areas around stations. The increase of the Shinkansen commuting passes sold, shown in Figure 4.7, provides evidence that Shinkansen has expanded the commutable area especially around metropolitan areas.

Figure 4.7. **Average sale of Shinkansen commuter passes**
(Per month*)

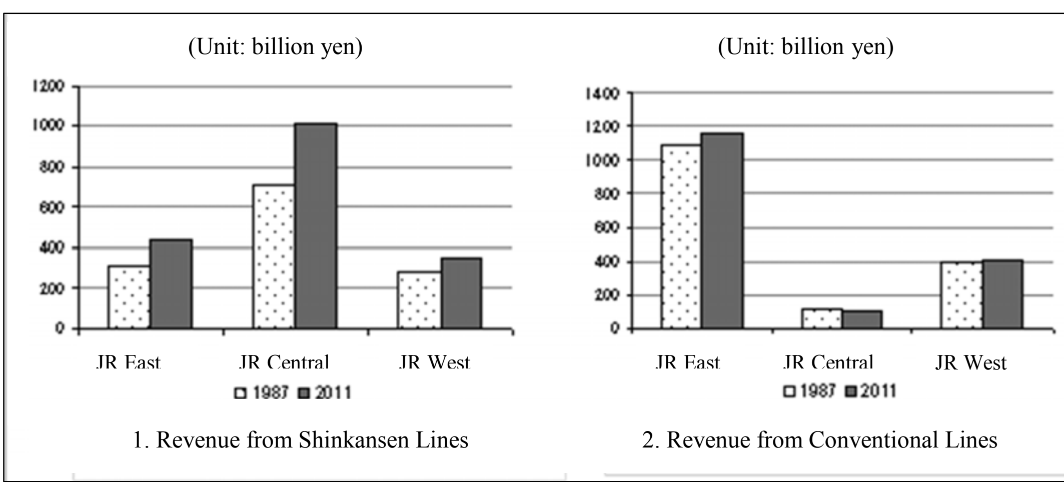


*: The statistic shows the number of commuters. A pass valid for three months is counted here as three one-month passes.
Source*:* MLIT (2013).

Evaluation of the performance with conventional railways

This section compares the performance of Shinkansen Lines with conventional lines in each JR passenger company. Figure 4.8 shows 1987 and 2011 revenues from Shinkansen and conventional lines in the three companies.

Figure 4.8. **Changes in revenue from Shinkansen and conventional lines**



Source*:* JR East (2012), JR Central (2013a), JR West (2013).

Figure 4.8 shows that the revenue from Shinkansen Lines has increased to a large extent in all the three companies since the establishment of the companies in 1987. It is worth noting that JR Central and JR West have attained the increase without extending new segments of Shinkansen lines since 1987.

In addition, the increase in Shinkansen lines is in contrast to the situation on the conventional lines, where revenues have been stable or show a slight decrease.

As a result of these changes, the Shinkansen share of the total revenue has also increased in all the three companies. Table 4.8 shows the change in the share of Shinkansen lines' revenue in total transport revenue in each company.

Table 4.8. **Share of revenue and rolling stock kilometers of Shinkansen operation**

	Shinkansen share of transport revenue *1		**Shinkansen share of rolling stock kilometers** *2
	1987	**2011**	**2011**
JR East	22%	28%	20%
JR Central	87%	91%	81%
JR West	42%	46%	37%

*1: Shinkansen revenue / total transport revenue.
*2: Shinkansen rolling stock kilometers / total rolling stock kilometers.
Source: Calculation based on JR East (2012), JR Central (2013b), JR West (2012; 2013).

To compare the effectiveness of Shinkansen operations, Table 4.8 also listed the share of Shinkansen's rolling stock kilometers compared with total rolling stock kilometers. It shows that the share of revenue is higher than the share of rolling stock kilometers in terms of Shinkansen operation of each company. This means that if rolling stock km is taken as the basic unit, a unit of Shinkansen operation brings in more revenues to the company than a unit of conventional train operation.

The results of this section show that, despite the severe competition from other transport modes, Shinkansen operation retains its competitiveness and has been increasing its transport volume, especially in the segments close to metropolitan areas. In terms of the revenue per rolling stock kilometer, Shinkansen operation is a better revenue earner than conventional train operation.

7. Conclusions

The high speed railway system, initially introduced by JNR in 1964, has been extended and now covers most of Japan. As JNR was reformed in 1987, the schemes for construction and operation were also modified accordingly. At present, the construction of the system is implemented as a public works project, and it is mostly financed by the public sector without adversely affecting the financial situation of each railway company.

Although the operation has been divided into independent companies, many Shinkansen trains are operated smoothly over tracks of two of these companies. Although the new segments constructed since JNR reform have a vertically separated structure, each railway company controls its entire system. This is also the case for the operation of through-train services crossing the borders between companies. This way of train operation is in stark contrast to the recent European railway operation.

It is true that Shinkansen operation has large impacts on the social and economic development. For example, it provides economic benefits such as raising real estate value, easing highway congestion, stimulating job creation, etc. In order to evaluate the effectiveness of the project, it is of course necessary to include these social and economic benefits.

But, to narrow the focus, this paper primarily discussed Shinkansen's effects on the operating companies. The paper examined the changes in transport on each Shinkansen line opened so far, and found that the traffic density of Shinkansen lines varies to a large extent depending on the lines and segments.

Since it is difficult to allocate the overhead expenses, each JR company does not publicise the profitability of each line. Thus, based on the financial change of the companies, this study tried to evaluate the financial effects of Shinkansen operation depending on its traffic density.

The study also showed that Shinkansen transport is competitive against other transport modes and is increasing its transport revenue by a much higher rate than conventional lines operated by those railways. Along with the increase of the inter-city passengers as shown in the Tokaido and Sanyo Shinkansen Lines, the number of Shinkansen commuters has been also increasing especially around Tokyo metropolitan area. Owing to its competitiveness, the share of revenue brought from Shinkansen operation has been increasing in those railway companies in Japan.

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Chapter 5.

The financial and economic assessment of China's high-speed rail investments: A preliminary analysis

Jianhong Wu [1], [2]

China has suffered railway capacity constraints for more than several decades and the need for a large increase in rail capacity has been viewed as the primary challenge. The former Chinese Ministry of Railways believed that building a national wide high-speed railway (HSR) network was the most efficient solution to China's rail capacity problems. By 2012, 9 000 km of HSR line has been completed which accounted more than half of the total in the World and the other 9 000 km HSR line is either under construction or in the planning stage.

This paper attempts to discuss the initial operational, financial and economic result of such a large scale HSR investment in China where the establishment of an appraisal system for a HSR project is still underway and the public data in need are not available. Based on some trial studies carried out on several HSR projects, however, the paper shows that except for a limited amount of HSR projects in the most developed areas of the country, the initial financial and economic performance of most HSR lines are generally much poorer than expected. The scale of investment seems to be difficult to justify, given that investment in HSR lines is very expensive, especially for those with design speed of 350 km/h, and the high level of debt funding. Moreover the values of time of the ordinary Chinese are still low by European standards.

For a developing country planning HSR projects, one lesson that can be learnt from China is that it would be ideal if a comprehensive appraisal can be taken into account before investing in HSR. Such appraisal includes examination of different options for technical and operational standards, timing of investment, construction scale and pace, train operational scheme and service level, pricing and regional development policy (political consideration). At the very least, a step by step development strategy should be adopted to cope with the huge uncertainties and risks.

1. Beijing Jiatong University.

2. Opinions expressed in this paper are those of the author alone and does not reflect the opinions of the University and other related organisations.

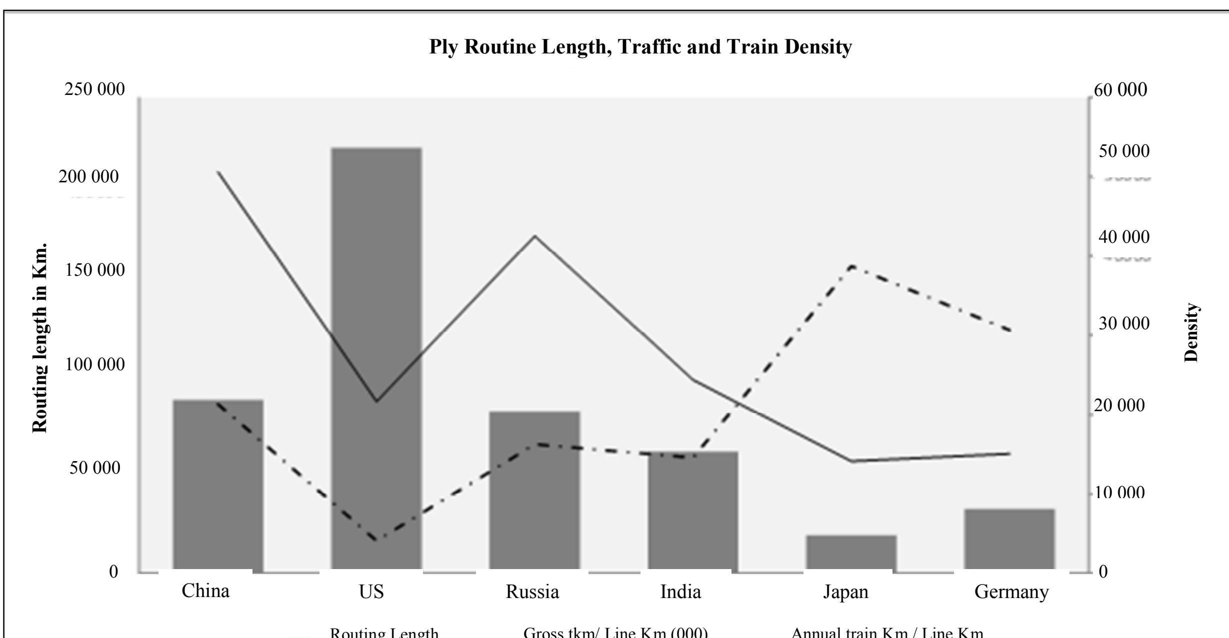
1. Introduction

In the next section we introduce the background information on HSR planning and its radical implementation by 2012 in the Chinese situation. We then consider in turn the construction costs of HSR and its composition in China, the initial operational and financial performance of the selected HSR projects. After this we assess the initial economic results of several HSR projects via their impact on mode split, the competition between HSR and air, time savings, additional capacity, reduced externalities and three actual project benefit analyses on a trial base. Finally the issue of wider economic benefits is discussed before reaching our tentative conclusions.

The background of building HSR in China

For more than 30 years, the extremely rapid growth of the economy in China has generated a continuing demand for basic commodities, while increasing wealth in China, where there is over 1.3 billion population, has also put extreme pressure on passenger demand. As Figure 5.1 shows, the net result of these trends is that Chinese Railways (CR) now has by far the highest traffic density network in terms of Gross Ton-Km per line Km in the World.[1] This capacity stress is aggravated by the fact that the coexistence of relatively fast passenger trains and slow freight trains further strains reliable operations.

Figure 5.1. **Comparison of Traffic Density**



Main source：UIC, 2009 and 2010.

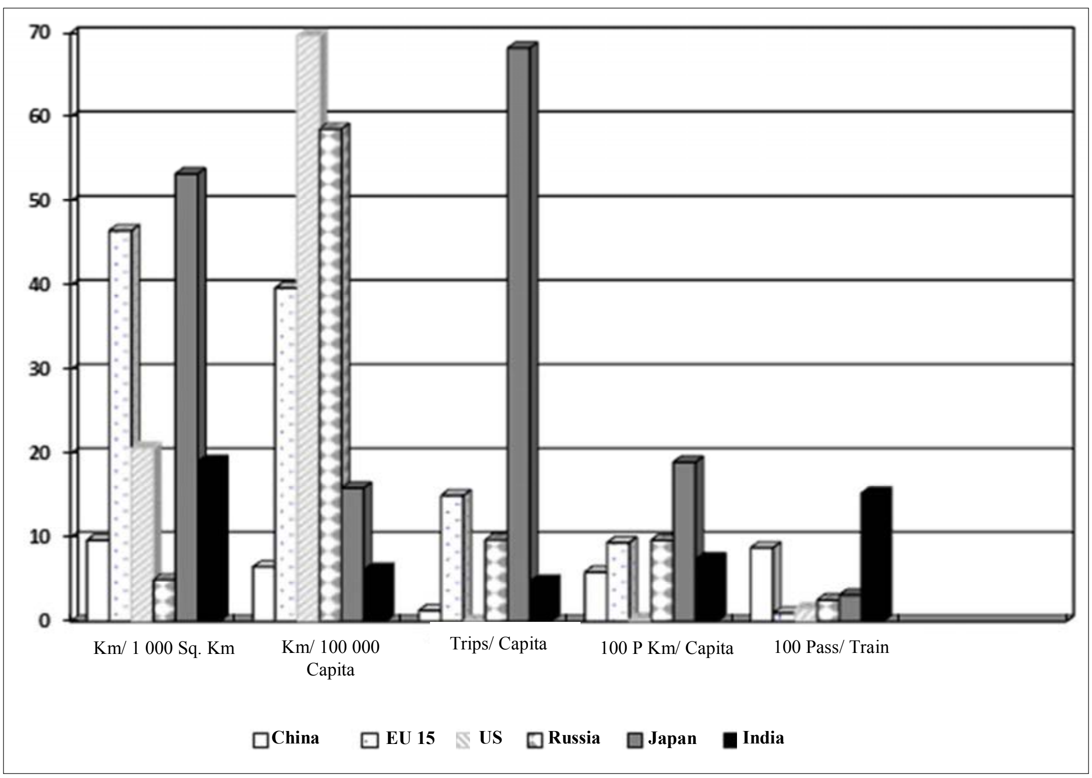
For example, in China there are Six Artery Lines, namely Beijing-Shanghai Line, Beijing-Guangzhou Line, Beijing-Harbin Line, Beijing-Hong Kong Line, Longhai Line and Zhejiang-Jiangxi

Line. For those lines, capacity is almost saturated. Also there are restricted corridors for entrance and exit in some areas. Furthermore, CR has been facing seasonal capacity constraints for many years, especially during Chinese New Year and Summer Holidays.

International comparison shows that in terms of railway network density, trips and pass-km per capita, China is much lower than the major railways in the world, while the average load of conventional passenger train is far higher. Figure 5.2 indicates that:

- China has less than half the ratio of rail line-km/1 000 square km of land area than India has, and is even farther below Japan and the E.U.
- China has less rail line kms per100 000 population than India, only half that of Japan, and well below that of the U.S.
- Chinese people take only one-third the rail trips per capita of India, and one-seventieth that of Japan.

Figure 5.2. **Network density, average annual rail trips and pass-km per capita**



Main source：UIC, 2009 and 2010.

Finally, international experience also shows that railway transport is a powerful tool to support sustainable development. A study (INFRS/IWW 2004) illustrates that in the E.U. the average external cost of the railway is less than a quarter of road for freight and only one third of the passenger car. In China's case, a trial study (C. Nash, J. Shires et al, 2008) has been completed with the help of the World Bank. The preliminary conclusions show the average external cost of railways in China was only 1/25 of that of road for freight and was 1/8 of that of autos for passengers.

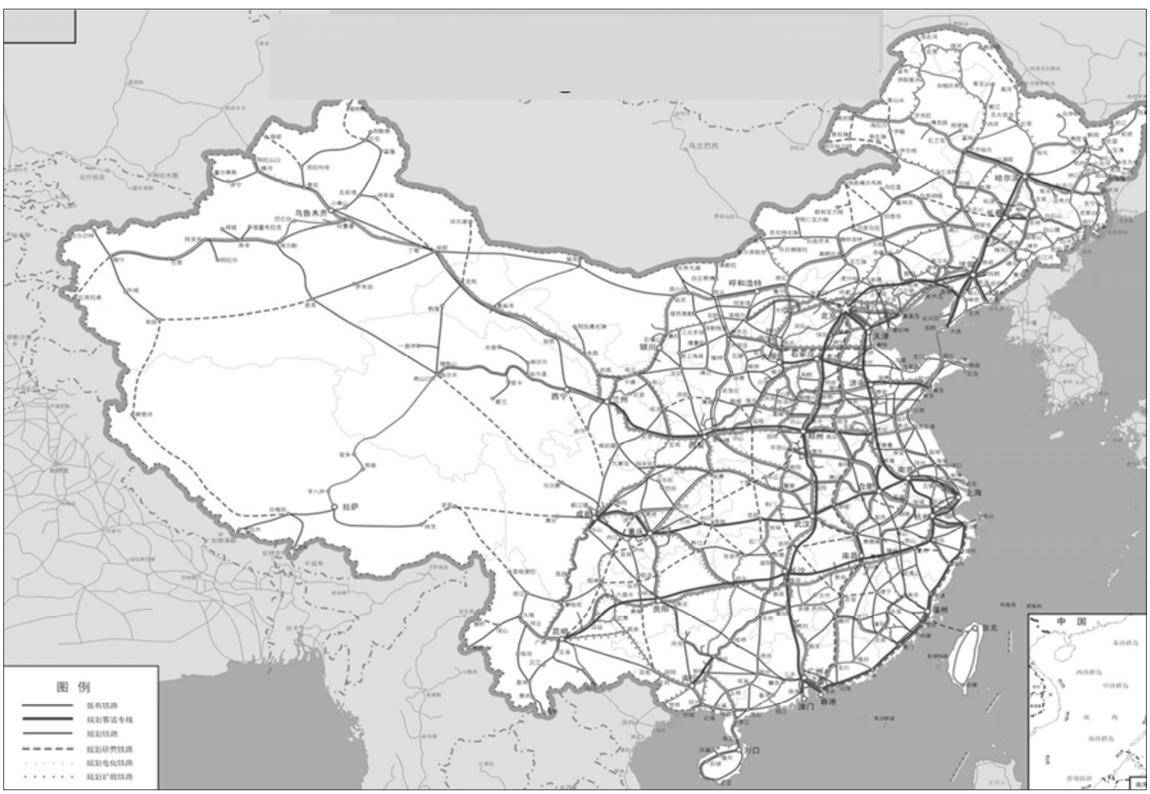
All the reasons mentioned above can conclude that China has the most heavily used rail network in the world and that railway will have to keep a major share of both passenger and freight markets for China's sustainable development. The former Chinese Ministry of Railways (MOR)[2] viewed the primary challenge as simply being a lack of capacity.

The key role of HSR plan in China's rapid railway development plan

Accordingly, a mid-and Long-term Railway Network Program (MLRNP) in China was drafted by former MOR and approved by the State Council in 2004. The MLRNP was further modified in 2008 to accommodate the various kinds of demands from the provincial governments. The major content of the MLRNP can be summarised as follows (see Map 5.1):

1. By 2020, railway operating route will exceed 120 000 km, of which the high-speed railways (HSR) and the intercity high-speed lines will take 1 8000 km, and both the ratio of double-track and electrified line will be increased to 60%.

Map 5.1. **Mid-and long-term railway network development map**



Source: Chinese Ministry of Railways (2008).

2. Through construction of HSRs and upgrading of existing lines, an express passenger transport network with a total length of more than 40 000 km(including 18 000 km of HSRs) will be formed to serve 90% of cities with population over 500 000 (Map 5.2).

Map 5.2. **Map of an express passenger transport network in China**

Source: Chinese Ministry of Railways (2012).

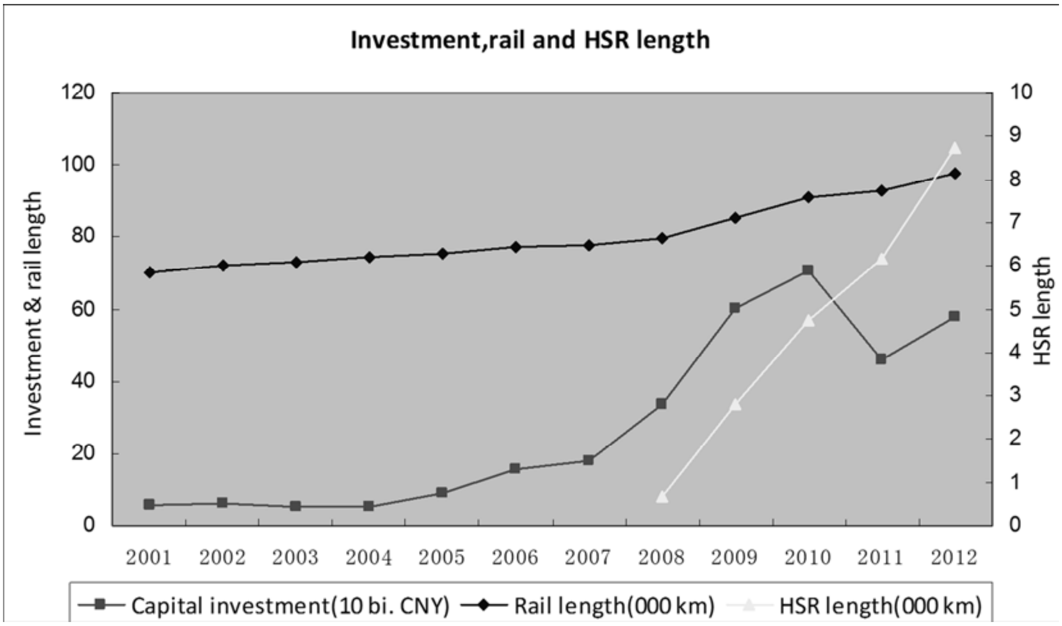
3. Completion of the Backbone of Large-capacity Freight Transport Corridors, namely: Coal transport corridor, South-North corridor, Northeast corridor, Southwest corridor and Northwest corridor.

Without examining sufficient alternatives to solve the capacity problem[3], the decision makers of former MOR believed that building a national wide HSRs network was the solution to maintain present and future economic development. Further, the decision maker also believed that passenger trains could be transferred from existing lines to the HSRs to realise the separation of passenger trains from freight ones, resulting in a great increase of the freight transport capacity on existing lines. So completing the HSRs network has been a top priority task for former MOR since 2005.

HSR construction and its implementation by 2012

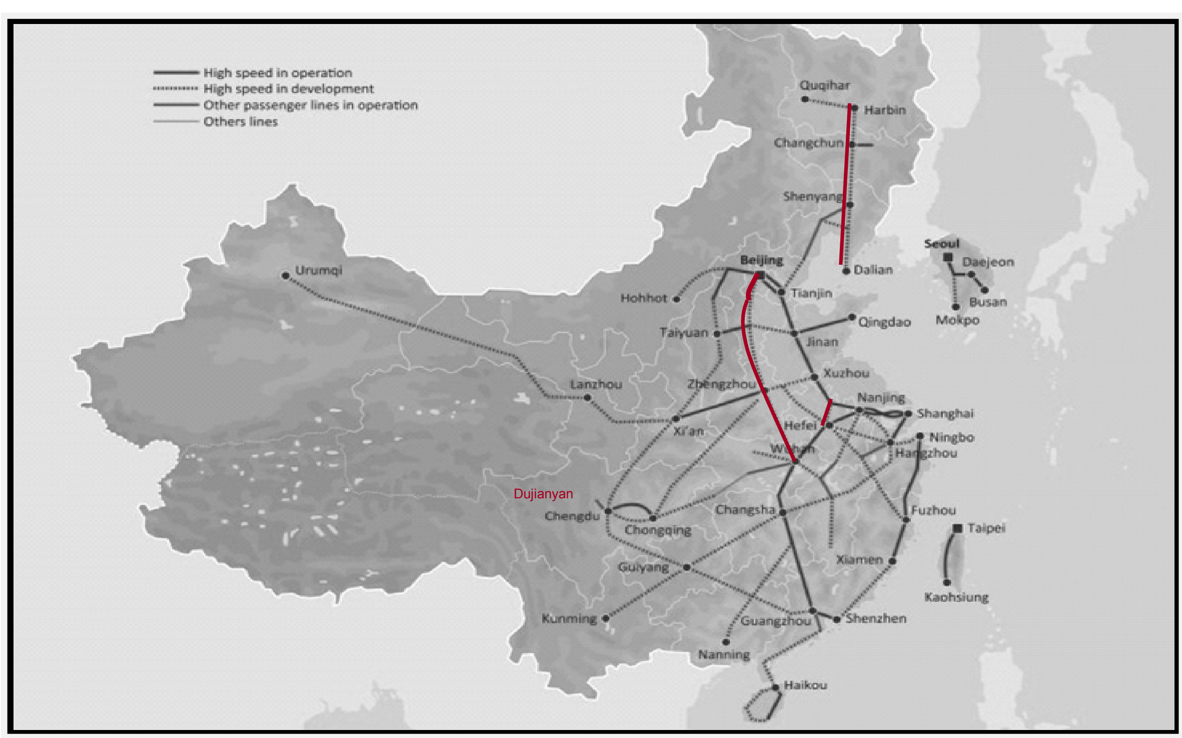
The development of HSR lines is seen as the most significant task in the long-term development plan of former MOR and has been the key part of the 11th FYP (2006-2010) and 12th FYP (2011-2015) of the railway sector. The first round of HSR construction with two kinds of technical standards in terms of design speed, i.e. 250 km/h and 300 km/h or above was initiated in China from 2005 (Annex 5.A1). The construction process and engineering period were radically accelerated to serve as a strong tool to stimulate the Chinese economy and to cope with the global financial crisis (Keynesian policies). Accordingly, a "Great Leap Forward" Railway Expansion was implemented. The total capital investment in the 11th FYP (2006-2010) approached nearly 2 trillion RMB[4] (Figure 5.5), with capital spending reaching an all-time record of 700 billion RMB in 2010, which is 9 times the level of investment in 2005. The investment in HSRs will account for around 70% of the total railway investment between 2006 and 2015, while the length of new HSR line increased from 410 km in 2008 to 5 143 km in 2010, ranking first in the world within only 3 years. By 2012, the routine length of HSR in China reached 9 000 km, which accounted for more than half of total HSR line in the world, including 5 700 km of lines for speeds above 300 km/h (Figure 5.3).

Figure 5.3. **Dramatic increases of rail capital investment and HSR length since 2005**



Source*:* Former MOR’s documents on issuing railway bonds.

Map 5.3. **HSRs network plan and its implementation in China by 2012**



Source: CR & UIC.

2. The cost of building HSR infrastructure and its composition in China

As shown in Annex 5.A1, two kinds of HSR lines, defined as either a rail system having a maximum speed of 250 km/h, or a maximum speed of 350 km/h, have been developed in China since 2005. Annex 5.A22 lists the unit cost of building HSR infrastructure based on public data. The construction cost per km of 12 projects with design speed of 250 km/h ranges from 6.03 to 18.10 million Euros, with an average cost of 8.84 million; while the construction cost per km in 10 projects with design speed of 350 km/h or over varies between 12.07 and 27.57 million Euros, with an average value of 16.50 million.

In most projects with a design speed of 350 km/h, stations in big cities such as those in Beijing, Shanghai, Tianjin, Wuhan, Guangzhou, Jinan, Shenzhen and so on, are independent projects with an architectural design, huge space and associated costs far beyond the minimum needs for train operating purposes. The total infrastructure cost of HSR with design speed of 350 km/h or over could be increased by from 10% to 30% if the construction cost of the big stations is included.

Annex 5.A2 also shows that the average unit construction cost of high-speed rail with design speed of 350 km/h was about 90% higher than that of 250 km/h. The major reason for the incremental cost being so high is because it has to be elevated to accommodate the common use of slab (ballastless) tracks: many parts of China have soft soils, and thus bridges/viaducts are used instead of road bed at ground level (Wu and Rong, 2013). The average ratios of the bridges (including viaducts) and tunnels length to the route length was 74% for the HSR with design speed of 350 km/h (Liu, 2010) and it rose as high as 90% for some specific projects (Wang, 2009). This is much higher than in the EU.

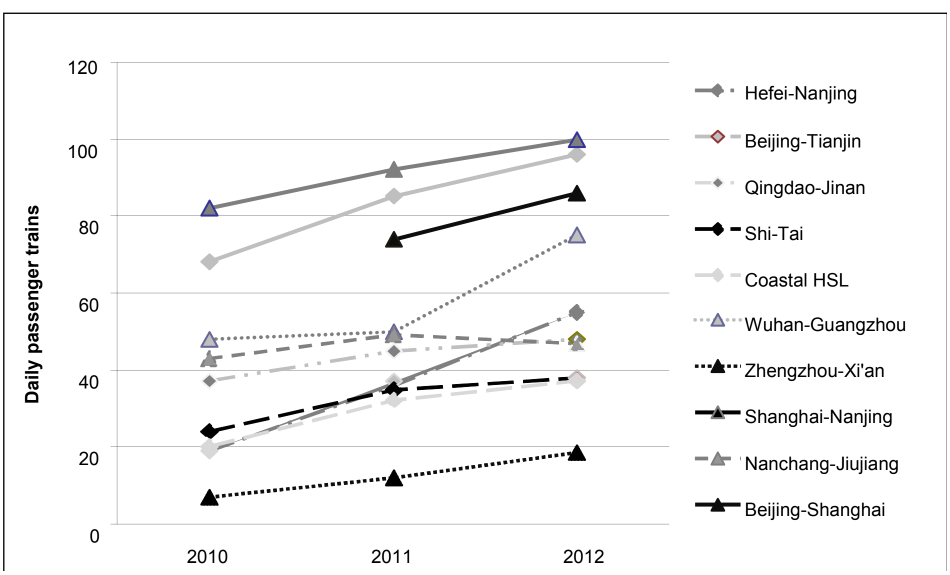
The cost composition of HSR infrastructure includes the infrastructure, superstructure, land and other costs. The average cost ratio of the infrastructure and superstructure are respectively around 60% and 20% (Liu, J., 2010), of which the bridges (including viaducts) and tunnels are over 45% of the total cost. This is well above that in the EU, where it usually represents between 10% and 25% of the total HSR infrastructure cost (Campos, and De Rus, 2009).

In general, the unit construction cost of HSR line in China varies enormously, between 8 and 30 million Euros, and depends mainly on the technical standards adopted and other circumstances. This is not as low as some people supposed when compared with European standards as 12-40 million Euros (Nash, 2009) and adjusted by purchasing power parity (PPP).

3. The initial operational performance of HSR in China

So far, there is little public data on line-by-line operational performance of HSRs in China. However, based on the number of pairs of trains available on an electric train time table named JPSKB, the load factors and the seating capacity of different kinds of trains and the initial operational performance of 15 HSRs can be estimated as shown in Annex 5.A3, and Figures 5.4 and 5.5. The traffic density of the HS lines in 2012 can be classified in 3 groups. The first group is composed of eight HS lines whose traffic densities are more than 20 million passenger trips per annum[5]. Among them, four are lines with design speed of 350 km/h and located in the richest and densest population area in China (such as Beijing-Shanghai HS line and Shanghai-Hangzhou HS line), and four are lines with design speed of 250 km/h, located mainly in the East part of the country or linking its middle part with the East (such as Qingdao-Jinan HS line, Nanchang-Jiujiang HS line and Hefei-Nanjing HS line). The second group is composed of three HS lines, whose traffic density is greater than 10 million passenger trips per annum, but less than 20 million, including Wuhan-Guangzhou HS line and Coastal HSL. The third group is composed of four HS lines with traffic density less than 10 million and mainly located in the less, relatively, developed areas of China, such as Zhengzhou-Xi'an HS line, Chengdu-Dujiangyan HS line and Changchun-Jilin HS line.

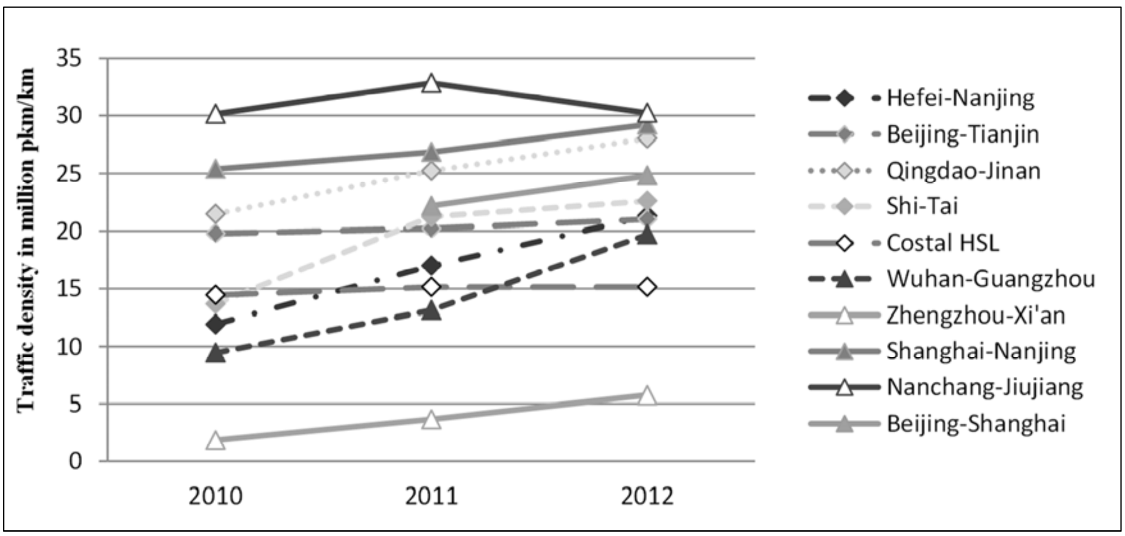
Figure 5.4. **Daily average number of passenger trains on selected HSRs**
(From 2010-2012)



Main source: Author's calculation based on data obtained from JPSKB (http://www.jpskb.com), an electric train time table in China.

Annex 5.A3 also shows that in terms of annual traffic increase rate from 2010 to 2012, the selected 15 HSRs can be also grouped into three categories. Category one is composed of seven HS lines whose average annual traffic increase rate is greater than 20%. Most of them suffered from heavy rail capacity constraints before the opening of HSR, which are the case for the HS lines of Wuhan-Guangzhou, Hefei-Nanjing Shijiazhuang-Taiyuan and Beijing-Shanghai (except for that of Zhengzhou-Xi'an[6]). Category two is composed of three HS lines whose average annual traffic increase rate is greater than 7%, but less than 15%, while category three is composed of five HS lines, whose average annual traffic increase rate is less than 4% or stable, and whose demand for high speed services develops more slowly than expected. The reasons for the lines with the lower traffic increase rate are either due to the parallel line competition (e.g. between Beijing-Shanghai HSL and Beijing-Tianjin HSL, or Shanghai-Nanjing HSL), or to the lower economic growth rate, which is the case for HSLs of Changchun-Jilin and Nanchang-Jiujiang.

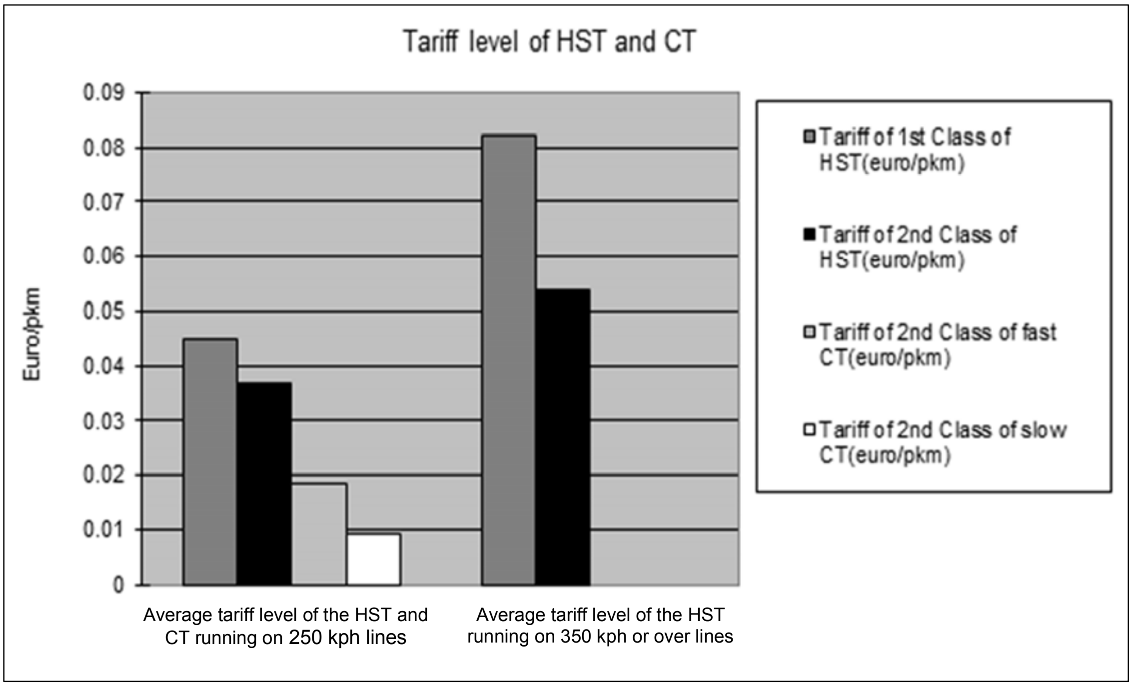
Figure 5.5. **Estimation of traffic density on selected HSRs**
(From 2010-2012)



Main source: Author's calculation based on data obtained from JPSKB, China.

Furthermore, the 250 km/h HS lines with ballasted tracks can accommodate both the HS train (HST) and the conventional train (CT), while the 350 km/h HS lines with slab track and lower axle load limitation (≤17t) prevents the CT, whose axle load is≥21t, to run on it. This important technical characteristic made the 250 km/h HS lines gain higher traffic volume and better train load factor than those of the most 350 km/h HS lines, given that the tariff level for the HST running on 350km/h lines is about 2 to 4 times higher than that of the CT (Figure 5.6 and Annex 5.A6).

Figure 5.6. **Average tariff level of HS train and conventional train in China**



Main source: Author's calculation based on data obtained from JPSKB, China.

4. Financial assessment of China's HSR investment

A preliminary analysis for the initial financial performance of HSRs

It is rather difficult to have a precise financial assessment of China's HSR investment at current stage, not only because most of HSRs have been opened less than 3 years ago, but also because very little information is publicly available on the financial performance of the HSRs. However, a brief analysis or projection can be made based on some empirical data disclosed by media, author's professional knowledge and international experience so far.

From the financial performance point of view, international experience shows that so far only Tokaido-Shinkansen and Paris-Lyon TGV are financially profitable worldwide. In China, due to the limited financial investment from the government, 50%-60% of HSL investment was from market borrowing. Therefore, very large traffic volumes are needed to support the high financial, depreciation, and operating and maintenance costs when a HSL is put into operation. For most of the HSRs listed in Annex 1, the initial financial performance was poor when compared with the ex-ante appraisals. Indeed, the actual construction cost of most lines was about 30-50% higher than expected in the feasibility study stage, while the actual traffic volumes were far lower than the forecast. An estimation of the initial financial performance of four HSR projects has been made and is described in Tables 5.1-5.4.

Table 5.1. **Estimation of the financial performance of Beijing-Tianjin HSL**

Item	2009	2010	2011	2012
Total traffic volume（m. pass-km）	2 244	2 640	2426.4	2 522.4
Interest payment(m. CNY)	600	600	600	600
Depreciation(m. CNY)	613	613	613	613
O & M cost(m. CNY）	600	705.93	648.82	674.49
Total cost (m. CNY）	1 813	1 918.94	1 861.82	1 887.49
Average rate（CNY/Pass-km)	0.49	0.49	0.49	0.49
Total ticket sale (m. CNY）	1 110.41	1 306.36	1 200.66	1 248.18
Financial result (m. CNY)	-702.59	-612.59	-661.16	-639.32
Annual average repay of the principal（m. CNY)	854	854	854	854

Source*:* Author's own computation mainly based on information from WENG Shuping (2010-04-05), "The Financial Result of Leap Forward: The Annual Operation of Beijing-Tianjin HSR Cause a Loss of 700 million CNY", *Economic Observer* Newspaper.

Table 5.1 indicates that the financial loss of Beijing-Tianjin HSL mainly comes from very high capital investment (20.51 m. Euros/km)), high financial costs and lower annual traffic increase rate at 3.05%. This situation is difficult to be changed unless there is a rather high traffic increase in the next few years.

Table 5.2. **Estimation of the financial performance of Wuhan-Guangzhou HSL**

Item	2010	2011	2012
Total traffic volume（m pass-km）	1 0870	16 304	21 087
Interest payment(m. CNY)	2 600	2 600	2 600
Depreciation(m. CNY)	3 000	3 000	3 000
O & M cost except energy (m. CNY）	2 000	3 000	3 880
Energy for Train(m. CNY)	655	946	1 223
Total cost (m. CNY）	8 255	9 545.65	10 703.04
Average rate（CNY/Pass-km)	0.46	0.46	0.46
Total ticket sale (m. CNY）	5 000	7 500	9 700
Financial result (m CNY)	-3 255.00	-2 045.65	-1003.04
Annual average repay of the principal（m. CNY)	5 000	5 000	5 000

Source*:* Author's own computation mainly based on information from SONG Jing, 2010-11-29, "5 Billion CNY: The Knack of Wuhan-Guangzhou HSL for Doing Business", *The Economic Report in 21st Century.*

Table 5.2 shows that the financial loss of Wuhan-Guangzhou HSL mainly comes from high capital investment (15.69 m. Euros/km), high financial costs and a lower traffic density (19.71 m. passenger trips per annum) although it exhibit a very high annual traffic increase rate at 44.34%. It seems that the commercial viability of this kind of project will be achieved if the traffic can keep increasing at 20%.

Table 5.3 shows that the heavy financial loss of the Zhengzhou Xian HSL project mainly comes from a very low traffic density (5.75 million passenger trips per annum), rather than high financial costs, although its capital investment (12.07 m. Euros/km) is relatively low. This kind of project, i.e. a HSR project in the middle and west part of China, is unlikely to break-even financially in the foreseeable future.

Table 5.3. **Estimation on the financial performance of Zhengzhou-Xi'an HSL**

Item	2010	2011	2012
Total traffic volume（m pass-km）	929.00	1 858.00	2 903.12
Interest payment(m. CNY)	1 254.76	1 254.76	1 254.76
Depreciation(m. CNY)	1 140.69	1 140.69	1 140.69
O & M cost except energy (m. CNY）	170.94	341.87	534.17
Energy for Train(m. CNY)	53.88	107.76	168.38
Total cost (m. CNY）	2 620.26	2 845.08	3 098.00
Rate（CNY/Pass-km)	0.46	0.46	0.46
Total ticket sale (m. CNY）	427.34	854.68	1 335.43
Financial result (m CNY)	-2 192.92	-1990.40	-1 762.56
Annual average repay of the principal (m. CNY)	2 100	2 100	2 100

Source*:* Author's own computation, based mainly on information drawn from Tables 5.1 and 5.2.

Table 5.4 **Estimation on the financial performance of Jian-Qingdao HSL**

Item	2010	2011	2012
Traffic volume（m. pass-km）	8 434.57	9 914.92	1 1016.58
Interest payment(m. CNY)	561.76	561.76	561.76
Depreciation(m. CNY)	510.69	510.69	510.69
O & M cost except energy (m. CNY）	489.32	575.20	639.11
Energy for Train(m. CNY)	221.31	260.15	289.05
Total cost (m. CNY）	1 783.07	1 907.79	2 000.60
Average rate（CNY/Pass-km)	0.21	0.21	0.21
Total ticket sale (m. CNY）	1 786.99	2 100.62	2 334.02
Financial result(m CNY)	3.92	192.83	333.42
Annual average repay of the principal（m. CNY)	850	850	850

Source*:* Author's own computation, based mainly on information drawn from Tables 5.1 and 5.2.

Table 5.4 shows that, unlike the previous three 350km/h HSL, the financial result of Jian-Qingdao HSL is positive, which is unique among the operating HSLs. This is simply because of the very low capital investment (6.27 m. Euros/km) from lower technical standard (with 250 km/h), a rather high traffic density (28.03 m. passenger trips per annum) and a middle annual traffic increase rate at 14.29%.

The estimation of commercial break-even traffic density of HSRs in China via international comparison and their initial financial performance

Given the level of unit construction costs, the high level of debt funding structure (up to 60% of the total investment), the current tariff level and the operating and maintenance costs of the of HSRs, the breakeven traffic density in China for the HSRs with 350 km/h is estimated to be about 40-50 million passenger trips per annum, while that for the HSRs with 250 km/h is estimated about 25-30 million passenger trips per annum (Annex 4). For HSRs with traffic density less than 10 million passenger trips per annum, if other trains could not run on them, their operating incomes will have difficulty to cover operating costs and interest repayment. If so, these lines will become long-term loss making assets.

5. Economic assessment of China's HSR investments

In China, the establishment of an economic assessment system for a HSR project is still underway and there is almost no published ex post cost-benefit analyses of specific HSR projects. In this section, we discuss some key issues related to the economic assessment of China's HSR investments and then introduce some trial studies for the appraisal of several HSR projects.

Mode split, generated traffic and the competition between HSR and air

The official data on the HSR impact on mode split is not yet available in China, not only due to the short period of time of HSR operation, but also due to the lack of a sense of importance for those data from the Chinese Railway authority. However, several case studies have been made to estimate the HSR impact on modal split.

As has happened in other countries where HSR services have been introduced, China's HSR investments lead to shorter travel times, somewhat cheaper price and much higher frequency compared to air transport, and improved travelling conditions, which have resulted in different levels of modal shift and generation of new demand on different routes (Givoni, 2006). Most of the demand shifted to the HSR services from other modes is either from aircraft for long distance travel, which was the case on the Wuhan-Guangzhou route and Beijing-Shanghai route (Tables 5.10 and 5.11), or from bus for shorter distance travel, which was the case on the Beijing-Tianjin route (Table 5.7). However, it is also true that at least half of the demand for new HSR services is demand shifted from the conventional railway, leading to reductions in passenger services on the conventional rail network (Vickerman, 1997). For example, on the Jinan-Qingdao HSR, over 90% of the traffic on the new line was diverted from other rail lines (Table 5.7), while the numbers are over 50% for both routes on Wuhan-Guangzhou and Beijing-Tianjin (Tables 5.5 and 5.6).

In some cases, the traffic generation effect of new HSR services is substantial. On the Wuhan-Guangzhou route, total rail traffic within this transport OD pairs increased by 38% one year after the opening of the HSR services, of which a total of 4% is related to the trend of growth and 34% is considered as induced and shifted traffic from other modes. Also on the Beijing-Tianjin route, total rail traffic within this rail transport OD pair increased by 71.52% one year after the opening of the HSR services. A total of 5% is related to the trend of growth and 66% is considered as induced and shifted traffic from road. Some informal investigations show that quite a large part of the new generated traffic for Wuhan-Guangzhou HSR is from tourism, induced by shorter travel time and better quality of service. Further, at the beginning when the Beijing-Tianjin HSR started in service, part of the generated traffic was related to passengers who were just curious about the experience of riding the new HSR train service.

Table 5.5. **Estimate of the composition of Wuhan-Guangzhou HS traffic in 2010**

Diverted from conventional lines	52%
Diverted from aircraft	6%
Generated or shifted from road	42%

Source: (1) Bullock et al (2012). (2) Wu, Cui, et al (2011). (3) The Civil Aviation Publishing House, China (2010-2013), The Annual Statistics of Civil Aviation in China. (4) Statistics Centre of the Chinese Ministry of Railways (2009-2010), Annual Statistics Year Book of Chinese Railways.

The air traffic in the Wuhan and Guangzhou corridor was reduced by about 50%, of which the air traffic between Wuhan and Guangzhou OD was reduced about 40% while that between Changsha and Guangzhou OD was reduced 60% (Wu, Cui, et al., 2011).

Table 5.6. **Composition of Beijing-Tianjin HS traffic**
(From 2009 to 2011)

	2009	**2010**	**2011**
Diverted from conventional lines	55.39%	49.76%	47.73%
Generated or shifted from road	44.61%	50.24%	52.27%
inc. road	11.09%	9.50%	8.68%
inc. generated	33.53%	40.74%	43.59%

Source: (1) Bullock et al (2012). (2) Author's computation based on S. Wen, (2010).

Table 5.7. **Composition of Jinan-Qingdao HS traffic in 2012**

Diverted from conventional lines	93.61%
Generated or shifted from road	6.39%

Source: Statistics Centre of the Chinese Ministry of Railways (2008-2010), Annual Statistics Year Book of Chinese Railways.

The competition between HSR and air

In the EU, one of the two desires for building a new high-speed line is to compete with air in the major railway corridors, which has been proved very successful. Table 5.8 indicates the market shares of plane and train before and after the introduction of high-speed rail. The impact on rail market share is very substantial (Nash, 2009). Moreover, the figures in Table 5.9 demonstrate that when journey times are within 4 hours (or with a distance less than 800 km), HSR tends to have a rail/air market share of at least 60%, and sometimes effectively drives air out of the market when rail journey times are below three hours. This is also the case in Japan.

Table 5.8. **Before and after rail/air market share comparison in France and Spain**

	TGV Sud-Est		AVE Madrid-Seville	
	Before	**After**	**Before**	**After**
Plane	44%	9%	71%	20%
Train	56%	91%	29%	80%

Source: COST318 (1998).

Table 5.9. **Travel time (distance) and rail/air market share in EU and Japan**

OD pair	Travel time on board(h)	Rail/air share %	Distance (km)
Paris-Bruxelles	1.4	95	310
Paris-Lyon	2	90	430
Madrid-Seville	2.25	82	471
Paris-London	2.65	70	494
Stockholm-Goteborg	3	60	455
Tokyo-Osaka	2.5	85	515
Tokyo-Hiroshima	3.85	56	894
Rome-Bologne	2.55	74	358
Paris-Amsterdam	4	45	450
Rome-Milan	4.5	38	560

Main source: 1. De Rus et al (2009); 2. SDG (2006).

In China, the rail share increases very impressively after the introduction of HSR on the main truck lines, such as Wuhan-Guangzhou transport corridor since 2009 and Beijing-Shanghai transport corridor since 2011. As indicated in Table 5.5, the air traffic share in the Wuhan-Guangzhou corridor was reduced from 7.01% to 2.86%, of which the air traffic between Wuhan-Guangzhou OD (1 000km) was reduced by about 40%, while that between Changsha-Guangzhou OD (700km) was reduced by 60% (Wu, Cui, etc., 2011).

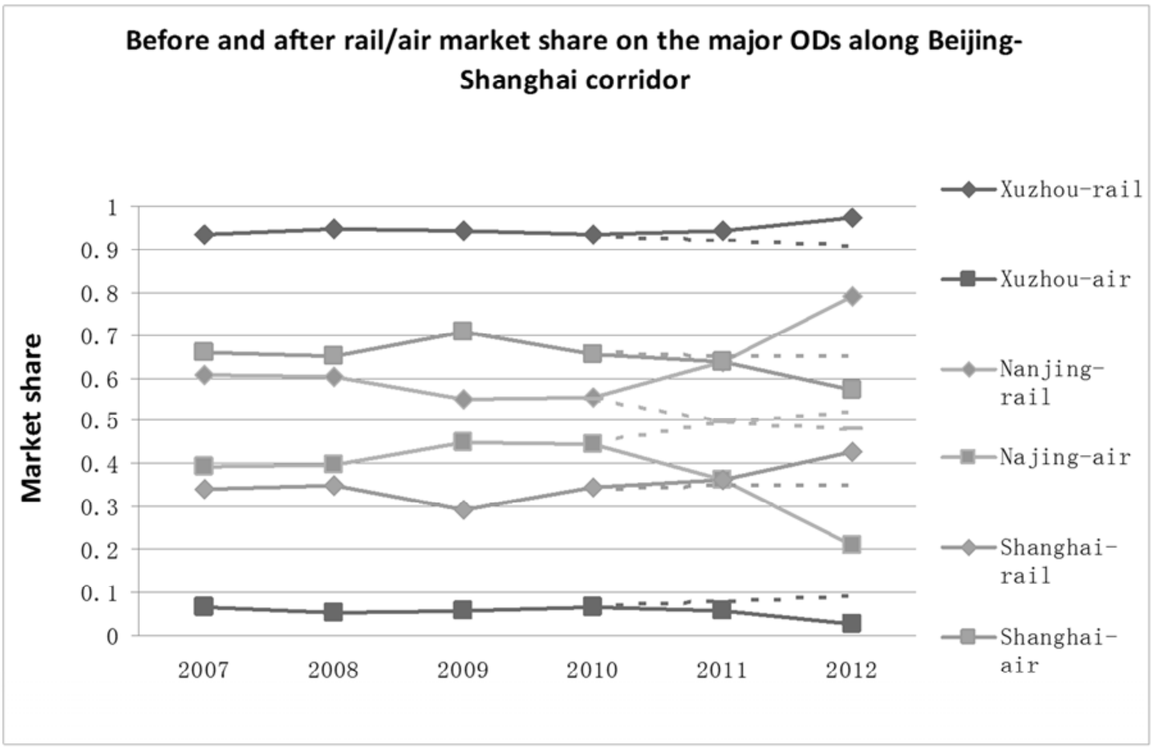
Table 5.10. **Before and after rail/air share in Wuhan-Guangzhou transport OD pairs**

	Before (2009)	After (2010)	Change
Aircraft	7.01%	2.86%	-4.16%
Conventional Train	92.99%	55.92%	-37.06%
HS Train	0.00%	41.22%	41.22%
Total	100.00%	100.00%	

Source: (1.) Bullock et al (2012); (2). Wu, Cui, et al (2011); (3.) The Civil Aviation Publishing House, China (2010-2013), The Annual Statistics of Civil Aviation in China; 4. Statistics Centre of the Chinese Ministry of Railways (2009-2010), Annual Statistics Year Book of Chinese Railways.

For the Beijing-Shanghai transport corridor, Figure 5.7 shows that the rail shares of 3 ODs, namely Beijing-Xuzhou, Beijing-Nanjing and Beijing-Shanghai, were in the trend of declining at different extent until 2011 when the HSRs were put into operation.

Figure 5.7. **Rail/air market share on the major ODs of Beijing-Shanghai corridor**



Main sources: (1) The Civil Aviation Publishing House in China, 2010-2013, The Annual Statistics of Civil Aviation in China. (2) Authors' estimation based on the data collected from various websites, including JPSKB.

Further, the data in Table 5.11 illustrate that the actual impact of HSR to air traffic along the Beijing-Shanghai transport corridor is much stronger than forecasted by some experts (Peng and Hu, 2009; Ding, et al., 2013). It seems clear that in China HSR tends to have a market share of about 80% when rail journey times are within 4 hours or travel distance around 1 000km, which is significantly higher or longer than those of the EU and Japan. This can be explained by the HSR's rather cheaper price[7] and higher frequency when compared with the air (Annex 5) and also the heavy airport delay that happened so frequently in recent years.

Table 5.11. **Change of rail/air market share and airport's impact caused by Beijing-Shanghai HSR**

Airport	Rail distance to Beijing	Rail journey time to Beijing	Expected Impact to air before	Market Share %				Actual impact to air after
				Before (2010)		After (2012)		
				Rail	Air	Rail	Air	
Jinan	406 km	1.63 hrs	-36%	91%	9%	98%	2%	-78%
Xuzhou	692 km	2.85 hrs	-67%	93%	7%	98%	2%	-64%
Nanjing	1 023 km	4.10 hrs	-4%	55%	45%	79%	21%	-53%
Wuxi	1 210 km	4.90 hrs	-2%	57%	43%	70%	30%	-31%
Shanghai	1 318 km	5.53 hrs	-2%	34%	66%	43%	57%	-13%

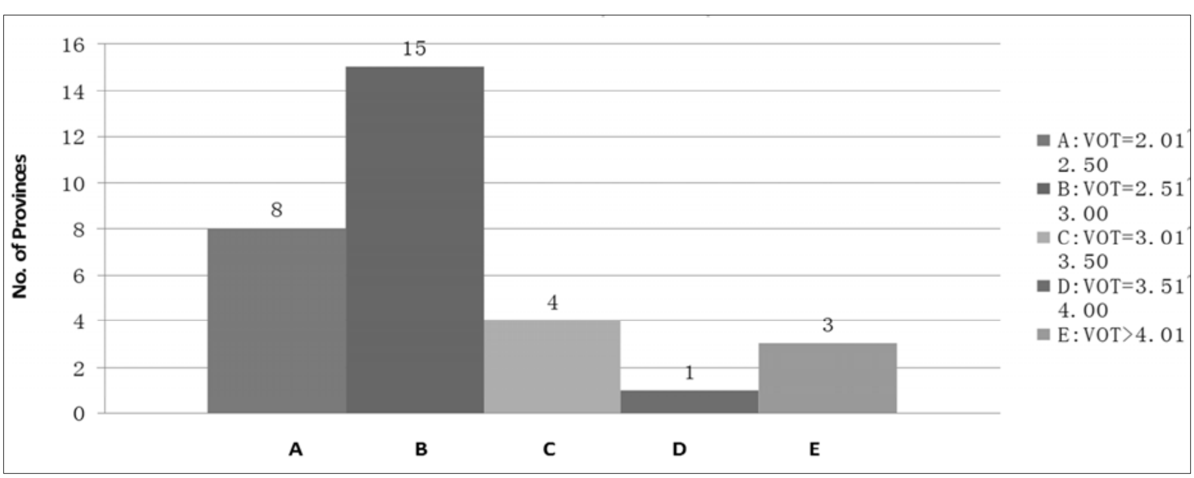
Source: (1) Ding, etc., 2013. (2) The Civil Aviation Publishing House in China, 2010-2013, The Annual Statistics of Civil Aviation in China. (3) Authors' estimation based on the data collected from JPSKB.

Time savings[8]

Estimation of VOT in China

In European countries, numerous studies have been undertaken into the value passengers place on time savings (VOT). For travel in working time, it is usually assumed that the value is what the employer pays for the time in question (i.e. the wage rate plus the overhead cost of employing labour). In China, there is neither an official parameter for VOT nor a reliable specific study in this field. However, the willingness to pay principle for estimating VOT was written in the government document for railway project evaluation (MOHURC, NDRC and MOR, 2012) and the common practice is to use the average hourly wage plus welfare payment of employee in urban units for business travellers and 30%-50% for non-business travellers, as an estimate of VOT. Accordingly, we estimate the average VOT of business traveller in different provinces in Euros/h and divided them into five groups (Figure 5.8).

Figure 5.8. **Estimate average VOT of business traveller in different provinces**

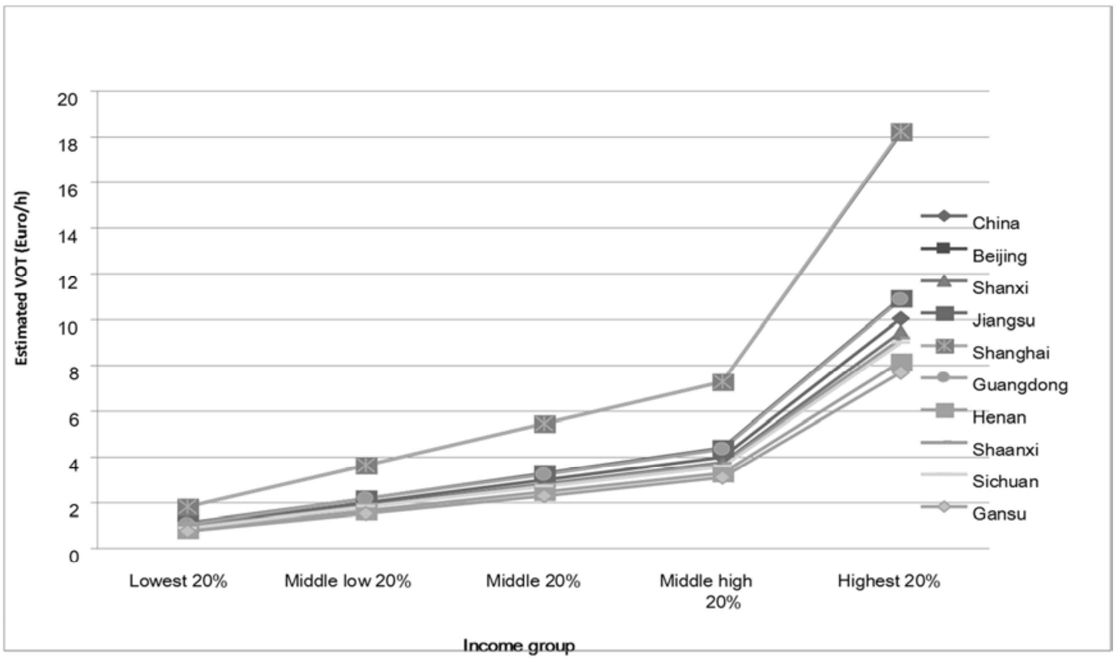


Source: China Statistics Year Book (2011).

Figure 5.8 shows that China, despite its astonishing economic growth in recent decades, remains a relatively poor country and values of time remain low by European standards; moreover they differ enormously between regions. Further, there could be also large income gaps within the same province.

As indicated in Figure 5.9, the VOT of the highest income group in Shanghai could be as high as 18.21 Euros/h, while the VOT of the lowest group could be lower than one Euro/h in provinces like Gansu, Henan and Sichuan, which will be about one twentieth of that in Shanghai.

Figure 5.9. **The unbalanced distribution of estimated VOT within the same province**



Source: (1) Author's estimation based on the data obtained from China Statistics Year Book (2011). (2) Dong (2010).

Estimation of the time savings per passenger

Before the introduction of the HST, the Chinese Ministry of Railways has carried out seven rounds of raising train speed in the existing lines. The maximum technical speed of conventional train (CT) could reached to 200 km/h or even 250 km/h for EMU in some part of the main truck lines, such as Beijing-Shanghai, Beijing-Wuhan. Accordingly, the average operational speed of CT was 120 km/h on the main truck lines, while those of CT on Beijing-Shanghai and Beijing-Guangzhou were 138 km/h, 136 km/h respectively.

Table 5.12 lists the estimate result of average value of time saving per passenger for a 500 km journey in Euro when we compare the HSR train with the fast CT[9].

Table 5.12. **Estimation of average value of time saving per passenger for a 500 km journey**
(Euros)

	Time savings per trip	Average VOT	Value of time saved per trip
The operational speed of HS train with a max design speed of 250km/h at national average level	0.88	2.27	1.99
The operational speed of HS train with a max design speed of 350km/h at national average level	1.79	2.27	4.05
Beijing-Shanghai HS Line	1.58	2.84	4.49
Wuhan-Guangzhou HS Line	1.68	2.09	3.51
Zhengzhou-Xian HS Line	1.69	1.97	3.34

Source*:* (1) He, H., (2007). (2) Authors' study based on the data collected from JPSKB.

Estimation of the break even traffic required to justify the investment of a high-speed line only in terms of time savings (Wu, Nash and Wang. 2013)

Based on the methodology developed by de Rus and Nombela (2007), we built the following formula:

$$B = \sum_{i=1}^{T} \frac{Q_i * \Delta t * VOT_i}{(1+\gamma)^{i-1}} - I_C \qquad (1)$$

B : Total net benefits of a HSR project in its project evaluation period;

T: Project evaluation period, T= 50 year;

Q_i : Demand in i year and $Q_{i+1} = Q_i * (1+\alpha_i)$

α_i : Annual growth rate of traffic; assumption of 5.4% for next 50 years

Δt : Average travel time saving per passenger;

VOT_i : Average value of travel time in year i and $VOT_{i+1} = VOT_i * (1+\theta_i)$;

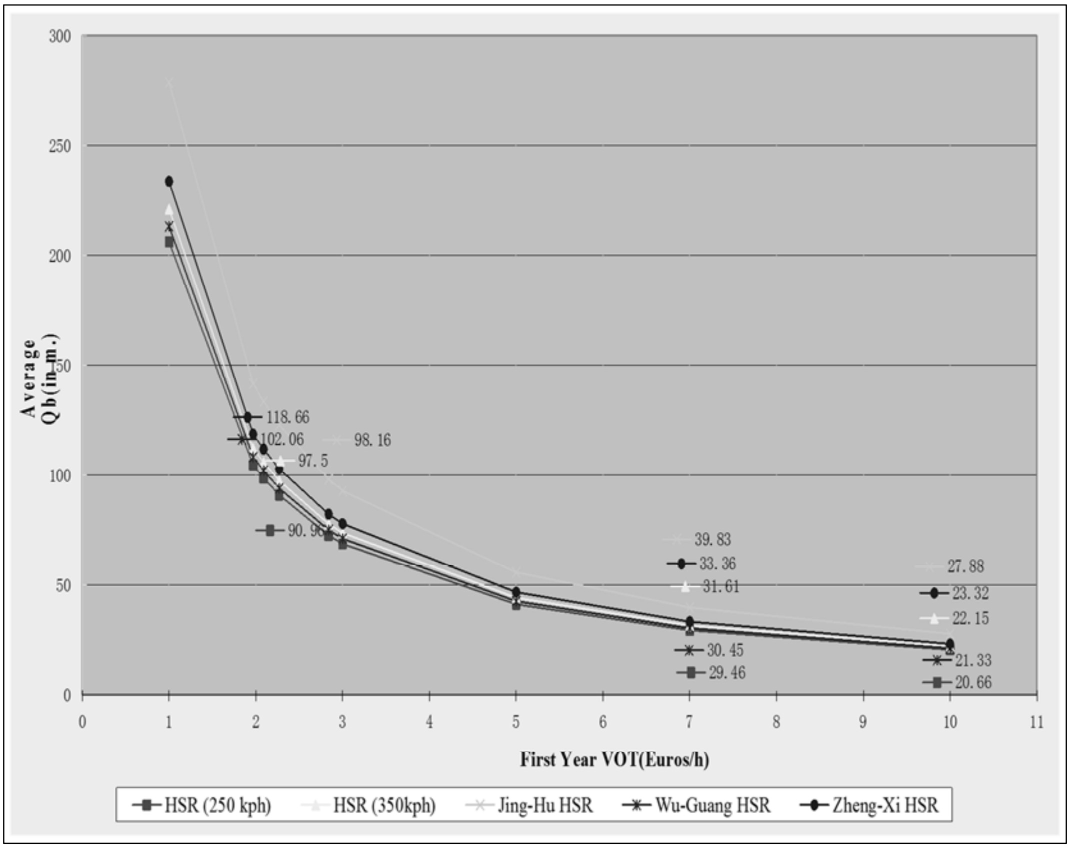
θ_i : Average growth rate of personal income; assumption of 4.45% for next 50 years

I_C : Total investment cost of a HSR line;

γ : Social discount rate, 8% in China

If we assume that an average passenger trip is 500 km, we can compare the infrastructure construction cost with the benefits of time savings. Based on formula (1) and the assumptions we have made above, if B=0, or NPV≥0, then we can draw a set of curves illustrating the relationship between an average demand thresholds (Q_b) and VOT for a positive NPV during the project evaluation period, ignoring any increase in operating costs. (Figure 5.10)

Figure 5.10. **Estimation of breakeven traffic level for different HSR lines in China**



Source: The figure is based on the formula (1) and the assumptions we have made above.

From Figure 5.10, solely in terms of time savings, we can conclude that it would require of the order of 90-100 million passengers per annum to justify HSR even at 250km/h given typical Chinese values of time. Even if we assumed that on average rail passengers had twice the income of the population in general, at least 50m trips per annum would be needed. Only in the richest parts of the country, such as Beijing, Shanghai and Jiangsu province, are values of time high enough that HSR may be justified on the basis of time savings at the traffic densities currently found.

Additional capacity and its benefits

One of the advantages of building HSR is to transfer conventional passenger trains from existing lines to release capacity for freight trains, but in the Chinese case many passengers of conventional trains refused to change to the passengers of the HSR with 350 km/h, mainly due to the high level of tariff (Figure 5.6) and because the lower axle load limitation of HSL with 350 km/h prohibits the conventional passenger trains to run on it. Accordingly, a large number of conventional trains have to be kept running on the existing lines (Table 5.13). So it is difficult to free up substantial capacity for freight trains on most of the existing lines. For the HSRs in operation, the additional revenue cargo volume that can be actually achieved in recent years is quite low, between one third and one tenth of that expected (Wu and Wang, 2010). One of the problems is that high-speed lines have only been built on some sections, and bottlenecks remain elsewhere on the main freight routes. Obviously, when a more complete network is open, and if there were not such a pronounced difference in fares, HSR might provide more relief to existing lines. However, it also means that more investment is needed to complete the rest of the HSR network and that maybe more financial loss has to be expected when the whole HSR network would be put into operation.

Table 5.13. **Before and after CT numbers on the selected existing conventional lines**

Conventional line	Before (No. of CT)	After (no. of CT)	Change
Wuhan-Guangzhou	32	28	-12.5%
Zhengzhou-Xi'an	48	43	-10.4%
Beijing-Shanghai	6	2	-66.6%
Total	**86**	**73**	**-15.1%**

Source: (1) For the number of CPT running on Wuhan-Guangzhou existing line, see JPSKB (http://www.jpskb.com) in 2009 and JPSKB in 2013. (2) For the number of CPT running Zhengzhou-Xi'an line, see JPSKB in 2009 and 2013. (3) For the number of CPT running on Beijing-Shanghai Zhengzhou-Xi'an line, see JPSKB in 2010 and 2013.

Reduced externalities from other modes (Nash, 2009)

In the EU, it is frequently argued that HSR has substantial environmental advantages since it diverts traffic from road and particularly air, where greenhouse gas emissions are much greater, however, a part of the traffic is diverted from conventional rail whose energy consumption could be lower because of lower running. As Table 5.14 indicates, in Germany, HSR accounts for 30%-40% of energy consumption as air transport, and 150%-200% energy consumption as conventional rail. At the same time, these figures are about 11% and 60% respectively in France (SNCF, ADEME, 1997), mainly due to higher loader factor and better infrastructure layout of the TGV system. So, whilst HSR can reduce externalities from other modes, the degree of benefit varies from case to case.

Table 5.14. **Energy consumption by mode 2010**

	Intercity train	HST	Air (500km)	Diesel car on motorway
Seating capacity	434	377	99	5
Load factor	44%	49%	70%	36%
Primary energy (MJ per seat km)	0.22	0.53	1.8	0.34
MJ per passenger km	0.5	1.08 (0.76*)	2.57	0.94

*At 70% load factor.
Source*:* CE Delft (2003).

In China, an unofficial study made in a specific transport corridor shows that the unit energy consumption of a HST, where given rather lower load factor and much higher speeds, is more than 2.4 times higher than that of a conventional intercity train, although it still has substantial environmental advantages when compared to air (Table 5.15).

Given the composition of the HS traffic from mode shifting and generation listed in Tables 5.5, 5.6 and 5.7, the energy savings seem to be very limited. The introduction of HSR cannot lead to a substantial environmental advantage and where there is only limited diversion from air, it will undoubtedly lead to an increase in energy consumption. So the objective to reduce negative externalities will not happen unless HST can raise its load factor substantially and shift huge traffic from the other modes, especially from potential future car traffic, given the fact that about 70%-80% of electricity generation in China still rested on coal in 2011.

Table 5.15. **Energy consumption by train and air on a specific transport corridor**
(2010)

	Intercity train	High-speed train	Air (900km)
Maximum speed	160	350	700
Seating capacity	1200	600	180
Load factor	90%	50%	81%
KWH per gross ton km	0.016	0.043	n.a
KWH per 100 passenger km	1.63	5.59	n.a
MJ per passenger km		0.61	1.28

Source*:* Wu, Cui and etc. (2011).

Wider economic impact

The wider economic impact of HSR in China could be greater than in the EU. This can be partially illustrated by the much higher generated traffic along the more economic advanced HSR corridors, such as Beijing-Tianjin, Wuhan-Guangzhou and Beijing-Shanghai. However, it is still difficult to quantify it at this moment not only due to their short time operation, but also because of the difficulty in separating the agglomeration economies induced by HSR from other reasons, such as the additional large investment to other sectors. Officials from Dezhou city and Xuzhou city claimed that the land price around their stations of Beijing-Shanghai HSR rose more than 20 times after the operation of HSR. Further, as it has happened in the EU, there is also a negative impact of HSR on regional economic development, e.g. a decrease of the total tourism income from Mountain Tai in Taian city was reported because of a dramatically reduction in the number of one night stay tourists as the opening of HSR now makes the one day return trip possible. Most importantly, we doubt whether the wider economic impact, even if it is rather substantial, can compensate the heavy financial and economic loss that the large scale construction of HSRs has brought to China.

Some trial ex-post cost-benefit analysis of HSR projects

Up to now, there are no published ex post analyses on specific HSR projects in China and the establishment of a system for cost benefit analyses of the HSR projects is still underway. However, some trial studies in this field have been carried out on several HSR projects when the first round of HSR projects were put into operation since 2008 (Wu and Wang, 2010).

During the research process, we divided the HSR projects into 3 types (A, B, C) according to their values of FIRR and EIRR. A summary of the appraisal is given in Table 4.16.

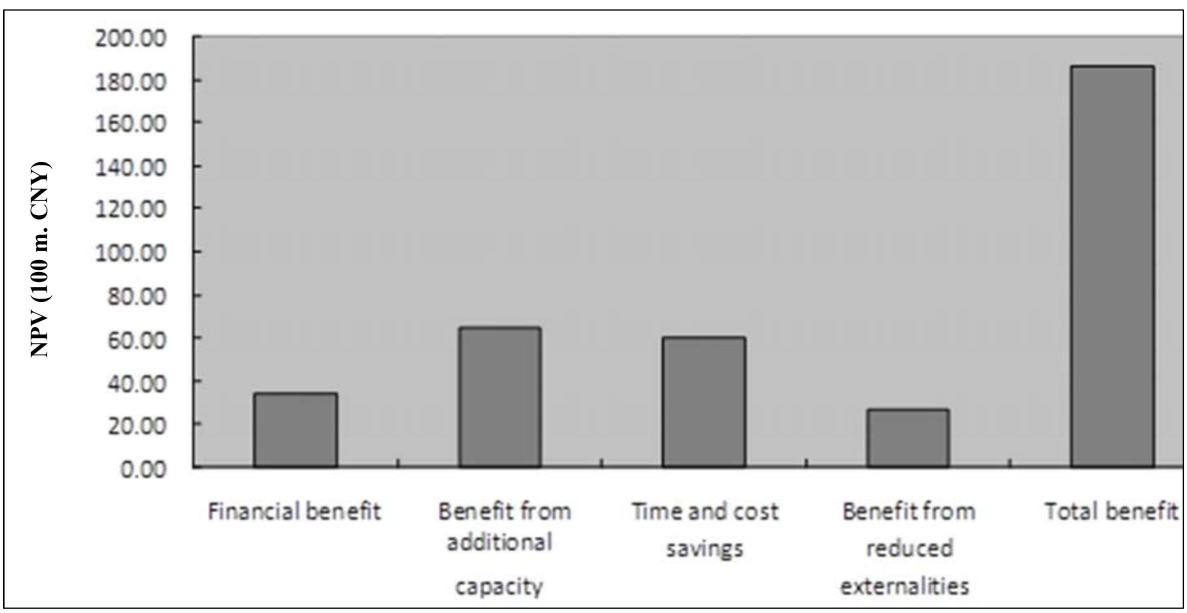
Table 5.16. **Ex post appraisal of HSR project in China**

<table>
<tr><th></th><th></th><th>Project A</th><th>Project B</th><th>Project C</th><th rowspan="5">In China, the official discount rate for financial evaluation is 3% and was 6% before 2006, while that for economic evaluation is 8% and was 12% before 2006. The rail project evaluation period has been 25 years since 2006</th></tr>
<tr><td rowspan="2">FIRR</td><td>Ex ante</td><td>≥6%</td><td>≥6%</td><td>≥6%</td></tr>
<tr><td>Ex post</td><td>6.00%</td><td>positive, but less than 3%</td><td>negative</td></tr>
<tr><td rowspan="2">EIRR</td><td>Ex ante</td><td>≥20%</td><td>≥20%</td><td>≥20%</td></tr>
<tr><td>Ex post</td><td>10.90%</td><td>10.00%</td><td>8.50%</td></tr>
</table>

Source: (1) NDRC and MOHURD (2006). (2) Wu and Wang, 2010.

Table 5.16 shows that all the 3 projects were justified during the feasibility study stage, while our ex post study indicates that only project A can be justified both financially and socially (Figure 5.11).

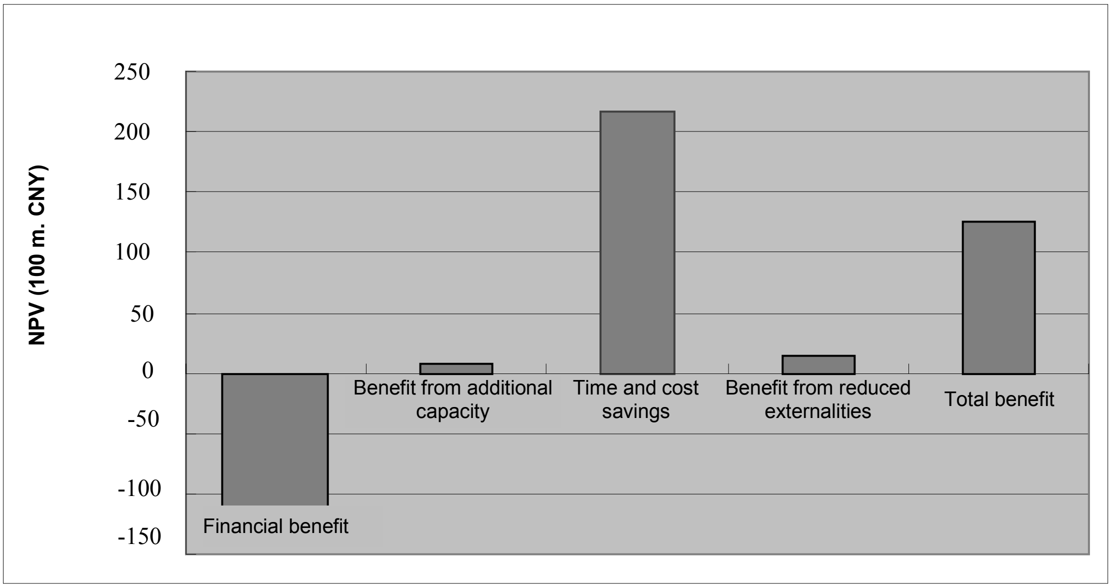
Figure 5.11. **Total CBA for the HSR project A**
(with an ideal scenario)



Source: (1) NDRC and MOHURD (2006). (2) Wu and Wang (2010).

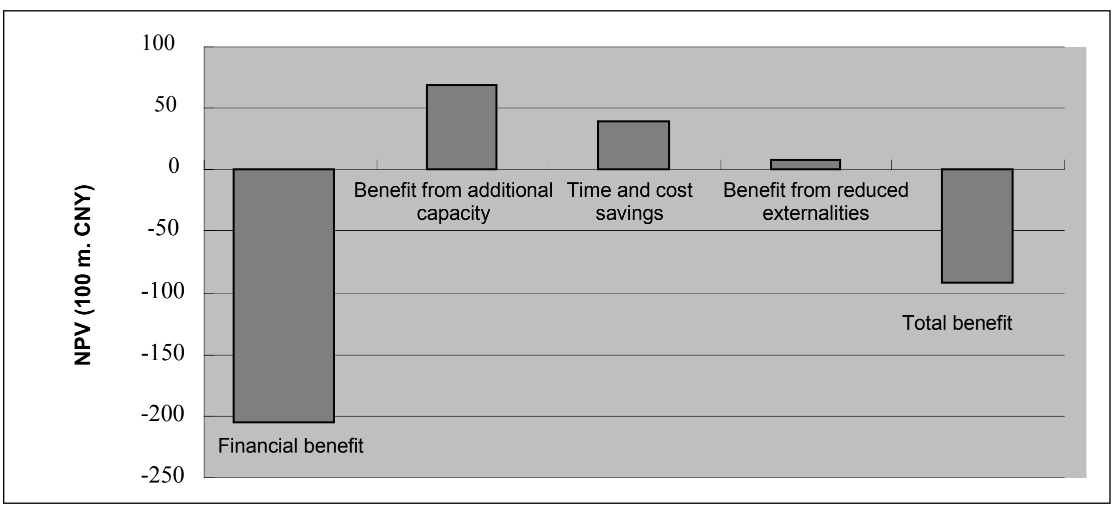
Project B represents the case where both FIRR and EIRR are positive, but FIRR is less than the official rate. As Figure 5.12 shows project B's financial net present value (NPV) is negative, while its economic NPV, mainly composed of time and cost savings, is quite substantial and can cover its financial loss. Therefore, this is a good social project although it implies a financial loss.

Figure 5.12. **Total CBA for the HSR project B**



Source: (1) NDRC and MOHURD (2006). (2) Wu and Wang (2010).

Figure 5.13. **Total CBA for the HSR project C**



Source: (1) NDRC and MOHURD (2006). (2) Wu and Wang (2010).

Project C represents the case where FIRR is negative, while EIRR is marginally larger than the official rate. As Figure 5.13 shows project C's financial NPV is negative, while the economic NPV is positive. Its economic benefits mainly come from additional capacity on conventional rail for freight, while the environmental benefits are very limited. Here again this is a social project, but the economic benefits cannot cover the financial loss.

6. Some tentative conclusions

From the preliminary studies undertaken and the four years of experience of HSR operation in China, it is possible to reach some tentative conclusions that could be useful for a developing country that is planning HSR projects.

Firstly, a comprehensive appraisal should be undertaken before investing in a HSR project. Both demand for a large increase in rail capacity and a commercial need for higher speeds are important for successful investment in HSR (Nash, 2009). These factors are especially important in the case of a developing country.

The initial financial and economic performance of HSR in China indicates that deployment of HSR throughout the country to high technical standards is unlikely to be justified[10]. This allies to most HSR lines built and to be built in the middle and west part of China, where most people are not rich enough to afford HSR tariffs that are much higher than for travel by conventional train.

Secondly, the commercial breakeven traffic density in China for the 350 km/h HSR lines is about 40-50 million passenger trips per annum, while that for 250 km/h HSR lines is about 25-30 million passenger trips per annum. The unit construction cost and the level of debt funding are the most important variables in determining the breakeven volume.

Thirdly, for a positive social cost-benefit ratio in China, solely in terms of time savings, it would require of the order of 100 million passengers per annum to justify HSR. For a new advanced conventional line (electrified double tracks for mixed traffic and a maximum speed of 160 km/h for passenger trains) the figure is 28 million passengers per annum.[11]

Fourthly, HSR in China seems to be more successful at competing with air than in the rest of the world. In China HSR tends to have a market share of about 80% when rail journey times are within 4 hours or travel distance around 1 000 km. This can be explained by the cheaper price and higher frequency of HSR in China when compared with air and also severe delays at airports that are increasingly frequent.

Fifthly, the introduction of HSR in China is unlikely to have significant environmental benefits unless load factors can be raised substantially and large volumes of traffic can be shifted from other modes in the future.

Sixthly, there is an urgent need to design and adopt a package of new HSR policies in China, both for improving the operational, financial and economic efficiencies of the existing HSR lines and for re-evaluating the HSR projects that are under construction or still in the planning stage. For HSR lines in the western part of China additional significant subsidy from central and regional governments will be needed not only for construction of infrastructure but also for high-speed train operations.

Finally, network effects and evaluation of the wider economic benefits of HSR are important issues to be addressed for the future planning of HSR in China.

Annex 5.A1. HSR construction, design speed and HSR scale in China by 2012

	HSR Line	Time for starting construction	Design speed (kmph)	Length (km)	Time for opening into traffic
1	Hefei-Nanjing	2005.07	250	156	2008.04
2	Beijing-Tianjin	2005.07	350	120	2008.08
3	Qingdao-Jinan	2006	250	393	2008.12
4	Shijiazhuang-Taiyuan	2005.06	250	190	2009.04
5	Hefei-Wuhan	2005.10	250	333	2009.04
6	Coastal HSL	2004.12	250	650	2009.09
7	Wuhan-Guangzhou	2005.06	350	980	2009.12
8	Zhengzhou-Xi'an	2005.09	350	456	2010.01
9	Fuzhou-Xiamen	2005.09	250	275	2010.04
10	Chengdu-Dujiangyan	2008.11	250	67	2010.05
11	Shanghai-Nanjing	2008.07	350	300	2010.07
12	Nanchang-Jiujiang	2007.06	250	131	2010.09
13	Shanghai-Hangzhou	2009.02	350	154	2010.10
14	Changchun-Jilin	2007	250	96	2010.11
15	Hainan East Circle	2007.09	250	308	2010.12
16	Beijing-Shanghai	2008.04	≥350	1318	2011.07
17	Guangzhou-Shenzhen	2005.12	350	104	2011.12
18	Wuhan-Yichang	2008.09	250	293	2012.07
19	Hefei-Bengbu	2009.01	250	131	2012.10
20	Zhengzhou-Wuhan	2008.09	350	536	2012.09
21	Harbin-Dalian	2007.08	350	921	2012.12
22	Beijing-Zhengzhou	2008.09	350	684	2012.12

Major sources: (1) MOR's documents on issuing railway bonds. (2) Study data by author.

Annex 5.A2. HSR infrastructure construction costs in China by 2012

	HS Line	Design speed (kmph)	Length (km)	Estimated unit construction cost (m euro /km)*
1	Hefei-Nanjing	250	156	6.03
2	Qingdao-Jinan	250	393	6.27
3	Shijiazhuang-Taiyuan	250	190	14.48
4	Hefei-Wuhan	250	333	7.00
5	Coastal HSL	250	650	7.24
6	Fuzhou-Xiamen	250	275	7.24
7	Chengdu-Dujiangyan	250	67	18.10
8	Nanchang-Jiujiang	250	131	7.24
9	Changchun-Jilin	250	96	10.81
10	Hainan East Circle	250	308	8.69
11	Wuhan-Yichang	250	293	9.78
12	Hefei-Bengbu	250	131	12.53
Average construction cost of the HSL with 250kph				8.84
1	Beijing-Tianjin	350	120	20.51
2	Wuhan-Guangzhou	350	1068	15.69
3	Zhengzhou-Xi'an	350	456	12.07
4	Shanghai-Nanjing	350	300	18.10
5	Shanghai-Hangzhou	350	154	22.93
6	Guangzhou-Shenzhen	350	104	27.57
7	Zhengzhou-Wuhan	350	536	15.66
8	Harbin-Dalian	350	921	13.30
9	Beijing-Zhengzhou	350	684	15.66
10	Beijing-Shanghai	≥350	1318	19.31
Average construction cost of the HSL with 350kph				16.50

*Euro exchange rate to CNY was about 8.28788 on 2010-06-30.
Major sources: 1. MOR's documents on issuing railway bonds; 2. Study data by author.

Annex 5.A3. Estimation of traffic density on selected HS lines from 2010 to 2012

HS lines	Design speed (kmph)	Year 2010: Daily number of trains			Year 2010: Estimated traffic density	Year 2011: Daily number of trains			Year 2011: Estimated traffic density	Year 2012: Daily number of trains			Year 2012: Estimated traffic density	Average annual increase rate
		Total (pairs)	HST*	CT*	m. pass per annum	Total (pairs)	HST	CT	m. pass per annum	Total (pairs)	HST	CT	m. pass per annum	
Hefei-Nanjing	250	19	11	8	11.93	36	26	10	16.99	55	42	13	21.29	33.59%
Beijing-Tianjin	350	68	68	0	19.80	85	85		20.22	96	96		21.02	3.05%
Qingdao-Jinan	250	37	17	20	21.46	45	27	18	25.23	48	30	18	28.03	14.29%
Shi-Tai	250	24	13	11	13.67	35	13	22	21.22	38	14	24	22.60	28.60%
Hefei-Wuhan	250	12	10	2	6.45	26	20	6	9.81	27	18	9	11.04	30.78%
Coastal HSL	250	20	20		14.45	32	32		15.13	37	37		15.13	2.30%
Wuhan-Guangzhou	350	48	48		9.46	50	50		13.14	75	75		19.71	44.34%
Zhengzhou-Xi'an	350	7	7		1.84	12	12		3.68	18.75	18.75		5.75	76.78%
Chengdu-Dujiangyan	250	14	14		3.68	17	17		4.47	18	18		4.73	13.39%
Shanghai-Nanjing	350	82	82		25.40	92	92		26.86	100	100		29.20	7.21%
Shanghai-Hangzhou	350	33	33		12.53	89	89		28.59	88	88		28.27	50.21%
Nanchang-Jiujiang	250	43	0	43	30.13	49	11	38	32.85	47	13	34	30.22	0.15%
Changchun-Jilin	250					31	31		8.15	32	32		8.41	3.23%
Hainan East Circle	250					35	32	3	6.66	28	27	1	6.44	-3.29%
Beijing-Shanghai	≥350					74	74		22.17	86	86		24.81	20.52%

HST* for high-speed train, CT* for conventional Train.
Main source*:* Authors' estimation based on the data collected from various websites, including JPSKB, an electric train time table in China.

Annex 5.A4. Estimation of break-even traffic density of HSR in China via international comparison

	Tokaido-Shinkansen*	**Paris-Lyon TGV***	**Beijing-Shanghai HSL**	**Wuhan-Guangzhou HSL**	**Qingdao-Jinan HSL**	**Beijing-Tianjin HSL**	**Zhengzhou-Xi'an HSL**	**China HSL (with 350 kph) on average**
Tariff (Euro/pkm) in 2010	0.195	0.121	0.051	0.056	0.037	0.058	0.058	0.056
Traffic density (m pass per annum) in 2010	80	20	25	14	25	20	4	
Annual revenues per Km (m Euro/Km)	15.6	2.42	1.275	0.784	0.925	1.16	0.232	
Unit construction cost (m Euros /km)	34.00	15.20	19.31	15.69	6.27	20.51	12.07	15.68
Debt / Asset ratio	55%	n.a	n.a	50%	50%	50%-60%	50%	50%-60%
Input/Output ratio per Km **	0.4589	**0.1592**	0.0660	0.0500	0.1475	0.0566	0.0192	
(Initial) financial performance	Full recovery of investment within 8 years	FIRR=15%	Loss	Loss	Break-even	Loss	Loss	Break-even
Break-even traffic density corresponding to I/O ratio=0.145 (m pkm/km)	25.28	18.22	54.90	40.63	24.57	51.28	30.18	40.60

*: Revaluation value in 2003.

**: Refers to traffic revenue per line km of HS lines /construction cost per line km of HS lines.

Annex 5.A5 The air and HSR comparison between China (Beijing-Shanghai) and Japan (Tokaido and Sanyo Shinkansen)

	O-D Pairs	Rail Distance (km)	Market Share %		Travel time （h）		Daily frequency （pairs）		Tariff （JPY or CNY trip ）	
			Air	HSR	Air	HSR	Air	HSR	Air*	HSR
Tokaido， Sanyo Shinkansen	Tokyo-Nagoya	366	0%	100%			0	120		
	Tokyo-Osaka	553	14%	86%	1	2.5	57	120	18800	13750
	Tokyo-Okayama	733	18%	82%	1.25	3.27	18	61	23800	16360
	Tokyo-Hiroshima	894	44%	56%	1.28	3.85	30	32	26300	18050
	Tokyo-Fukuoka	1 180	88%	12%	1.58	4.97	47	17	31300	21720
Beijing--Shanghai HSR	Beijing-Jinan	406	2.08%	97.92%	1.1	1.63	2	58	317	125**-185***
	Beijing-Xuzhou	692	2.42%	97.58%	1.60	2.85	1	31	615	215-310
	Beijing-Nanjing	1 023	21.13%	78.87%	2	4.1	13	60	676	315-445
	Beijing-Wuxi	1 210	29.61%	70.39%	2.1	4.90	5	21	761	375-515
	Beijing-Shanghai	1 318	57.29%	42.71%	2.17	5.53	48	54	789	410-555

*: The air tariff in China=air distance*0.75CNY/pkm*0.75+fuel surcharge+airport tax.
**: For the fare of HST with max speed of 250 kmph.
***:For the fare of HST with max speed of 350 kmph.

Main source:
1.. WANG Meijia,2009, Taking the Challenge of Rail Speeding, Airbus China.
2. The Civil Aviation Publishing House in China, 2010-2013, *The Annual Statistics of Civil Aviation in China*.
3. Authors' estimation based on the data collected from various websites, including JPSKB.

Annex 5.A6. Tariff level and estimated load factors of selected HSR lines in China in 2012

HS Lines	Design speed (kmph)	Tariff for 1st class in HST* (euro/pkm)	Tariff for 2nd class in HST(euro/pkm)	Tariff for 2nd class in fast CT** (euro/pkm)	Tariff for 2nd class in slow CT (euro/pkm)	Estimated load factor (%)	
						HST	CT
Hefei-Nanjing	250	0.057	0.047		0.010	60	90
Qingdao-Jinan	250	0.044	0.037	0.017		70	100
Shijiazhuang-Taiyuan	250	0.042	0.035	0.020	0.008	60	90
Coastal HSL	250	0.042	0.036			70	
Chengdu-Dujiangyan	250		0.032			60	
Nanchang-Jiujiang	250	0.042	0.035	0.019	0.009	60	90
Changchun-Jilin	250	0.042	0.034	0.018	0.008	60	
Average level of the HST and CT running on 250kph lines		0.045	0.037	0.019	0.009	65	93
Beijing-Tianjin	350	0.066	0.055			50	
Wuhan-Guangzhou	350	0.083	0.052			60	
Zhengzhou-Xi'an	350	0.088	0.055			70	
Shanghai-Nanjing	350	0.088	0.056			50	
Beijing-Shanghai	≥350	0.085	0.051			70	
Average level of the HST running on 350kph or over lines		0.082	0.054			55	

* HST for high-speed train, **CT for conventional train.

Main source: Authors' calculation based on the data collected from JPSKB, an electric train time table in China.

Notes

1. The train density in the truck lines in China is 2-3 times higher than that of the average.

2. Chinese government decided to dismantle the Ministry of Railways into administrative and commercial arms in the annual session of the country's top legislature on March 10, 2013.

3. Unlike the twin desire for building a new high speed line Worldwide (Nash, 2009), the competition from air is not so server in the major railway corridors, e.g. the passenger market share of different modes in Beijing-Shanghai corridor was 78.7% for road, 18.8% for rail and only 2.5% for air in 2009.

4. At January 2011 rates, that was equivalent to USD 316 billion.

5. It is defined as there are 20 million passenger trips running through per km of route line per year.

6. The high annual increase rate of Zhengzhou-Xi'an HSL is mainly due to the network effect which caused by the opening of Zhengzhou-Wuhan and Zhengzhou-Beijing HSL in 2012.

7. Further deregulation both in air tariff and in air market by the introduction of low cost carriers to compete with HSR on the main transport corridors has been proposed by some experts from air industry.

8. Based on (Wu, Nash, and Wang, 2013).

9. We assume that the business/leisure traveller split is 50/50, and value of leisure travel is 50% of business travel shown in Figure 411.

10. "HSR's Great Leap Froward" has led to the former Ministry of Railways, now the Chinese Railways Corporation, becoming very heavily in debt.

11. The unit construction cost of advanced conventional lines is estimated at 5.5 m Euros per route km in China.

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Chapter 6.

New entry in the Italian high-speed rail market

Fabio Croccolo[1]

The purpose of this presentation is to examine a specific rail transport sector, namely high-speed (HS) rail, in Italy. This analysis will cover the main features of the Italian HS system by studying aspects such as: the legislative framework, infrastructure, services, traffic data and market shares, in addition to regulatory matters.

1. Ministry of Infrastructure and Transport, Italy.

1. The Italian high-speed rail market

The European context

In the early 1990s (Directive 91/440/EEC), the European Union launched a thoroughgoing programme to reform the rail sector, a programme which was notable for its socio-economic repercussions and for its economic and environmental sustainability aspects. The end result, which was initially to be reached by harmonising the various national systems and liberalising international transport at European level, was gradually refined until it achieved the declared aim of creating a single European rail space and an integrated, safe and interoperable market.

That target was to be achieved by constructing new lines, particularly high-speed lines, aimed at making rail travel genuinely competitive in relation to road and air transport over distances up to 700 km and beyond.

The HS network (speed ≥ 250 km/h – max. speed today 360 km/h with an operating speed of 300 km/h, in the near future 400 km/h with an operating speed of 350 km/h) is now the pride and joy of the European and Italian rail system.

Italian infrastructure

The Italian high-speed network was planned with a view to linking the most densely populated and highly productive areas of Italy, a country whose geographical configuration is long and narrow. Thus, the initial concept was to develop a Y-shaped system between Rome (with southern extensions towards Naples and Salerno) and Milan and Venice (via Florence and Bologna), capped by an east-west transverse line between Venice and Turin (via Padua, Verona, Brescia and Milan).

The Italian high-speed line currently in operation therefore connects the cities of: **Turin-Milan-Bologna-Florence-Rome-Naples-Salerno**, with additional operational sectors between **Milan and Treviglio** and between **Padua and Mestre** (dark blue line on the map).

Although the **Padua-Bologna** and **Verona-Bologna sections** (both shown in light blue on the map and to the north of Bologna) are not yet HS lines, they have been fully upgraded ready for integration into the high-speed network.

The network described above extends to about 1 000 km and has completed the project which was launched with the opening, in 1977, of the first section of the Rome-Florence Direttissima line.

The following sections of the HS network will shortly be completed:

- About **200 km** between **Treviglio and Padua (via Verona)** (orange line on the map, to the east of Milan).
- **Additional lines** – some new and some already in existence are being gradually upgraded with a view to integration with the rest of the HS/HC (high-capacity) system – along the

transalpine pass routes connecting with the rest of Europe and on the Italian **Mezzogiorno** network, notably between Naples and Bari, Salerno and Reggio Calabria, and in Sicily between Palermo, Catania and Messina, and the Terzo Valico dei Giovi Milan-Genoa route.

The high-speed rail infrastructure is also integrated into the old conventional network in order to maximise potential rail traffic more effectively.

The conventional rail network in Italy consists of around 16 500 km of other lines and hubs, whereas regional interoperable and interconnected infrastructures amount to around 2 000 km.

Technical characteristics of HS lines

High-speed lines are constructed according to the most advanced infrastructural and technological standards in order to provide the best possible services in terms of **safety, speed and interoperability** with the principal existing railway lines and with the European HS network.

Innovative technological equipment of special importance developed by and/or adopted by the Italian HS system include the European Railways Traffic Management System (**ERTMS**), the HS-compatible control-command system (**SCC-AV**), the mobile radiotelephony system **GSM-R** and the **25 kV AC** electric traction supply system.

The principal technical characteristics of the new infrastructure are as follows:

Table 6.1. **Technical characteristics of new infrastructure**

Traffic type	**Mixed (passengers and freight)**
Operating speed/max.	300 km/h/360 km/h
Minimum radius of curvature	5 450 m
Maximum cant	18%
Maximum axle load	25 t
Track bed width	13.6 m
Distance between track centres	4.5-5 m
Natural tunnel section	82 m^2
Supply new lines	25 kV AC 50 Hz
Supply urban sections	3 kV DC

Key features of the HS network

Based on Italian experience, some key factors to consider when planning and constructing a high-speed network are:

Major infrastructure projects, which facilitate the construction of an increasingly high-performance network.

Distances: High-speed rail is competitive up to a distance of 1 000 km, provided that it is not interrupted by too many stops, otherwise optimal distances fall to between 500 and 700 km depending on the forecast operating speed. The latter factor is crucial for a proper cost-benefit analysis, a higher forecast operating speed implies significantly higher deployment costs.

Population: it becomes essential to connect the most populous and important cities in the country in order to justify the investment and achieve satisfactory socio-economic returns.

ERTMS–ETCS: these are the interoperable European standards in terms of rail infrastructure and on-board control-command and signalling (CCS) chosen by the European Union for the European high-speed network: they allow totally safe movement of high-speed trains, eliminating the possibility of disasters associated with human error (as, unfortunately, the recent one in Europe).

Capacity: this is normally measured by the number of trains that can circulate on the reference infrastructure in the chosen unit of time; however, the two main variables which are capable of increasing the value are the technical characteristics of the CCS system used and the type of traffic (specialisation of lines and types of service, especially in urban hubs).

Tolls: are payable on the entire network, but, of course, those on the HS network are higher and in part designed to compensate the infrastructure operator for the lower returns deriving from the reduced toll on the conventional networks. Italian Decree No. 43T/2000 lays down the method of calculation. At any rate, this toll tends to cover only the direct and indirect costs of operating and maintaining the infrastructure.

Railway stations: a fundamental link in the network which makes it possible to increase the efficiency of the high-speed system, improve hub transit and increase the attractiveness and profitability of the rail network by integrating it with local urban public transport networks, the most highly populated areas and the commercial areas of cities.

Trains

The rolling stock currently used on the high-speed lines in Italy is a new, interoperable design (standards are: kV 25 AC and kV 3 CC, ERTMS 2.3.D, minimum 7 coaches, operating speed 350 km/h). In line with this ongoing development of rolling stock, initiated with the Settebello and Pendolino trains and continuing up to the models currently operating (Bombardier ETR "Le Frecce" and Alstom AVS ITALO), we have now arrived at the new ETR 1000 commissioned by Trenitalia SpA, part of the Ferrovie dello Stato Italiane (FSI) group. The ETR 1000 is being built by Ansaldo-Breda and Bombardier in their facilities at Savona, Italy; it is designed to operate at a speed of 350 km/h and is currently in the testing phase.

Trenitalia SpA, part of the Ferrovie dello Stato Italiane group, and the "Frecce" trains

The trains operated by Trenitalia SpA, as part of the Ferrovie dello Stato Italiane group, are currently of three types known as "Freccia", each with a different cruising speed, destination and frequency.

The premium, dedicated high-speed services are operated by trains from the Frecciarossa and Frecciaargento fleet whose frequency and journey times are set out below:

Frecciabianca trains, on the other hand, are used on all other main lines not dedicated to high-speed trains.

The table below sets out the principal productivity indicators for Trenitalia for 2012 and the first half of 2013:

Table 6.2. **Productivity indicators for Trenitalia**

Description	2012 (full year)	2013 (1 January – 30 June)
No. of trains	over 60 000	over 32 000
Train-kms	over 30 000 000	over 16 000 000
Passengers carried	over 10 000 000	over 5 500 000

Source: Trenitalia (2012).

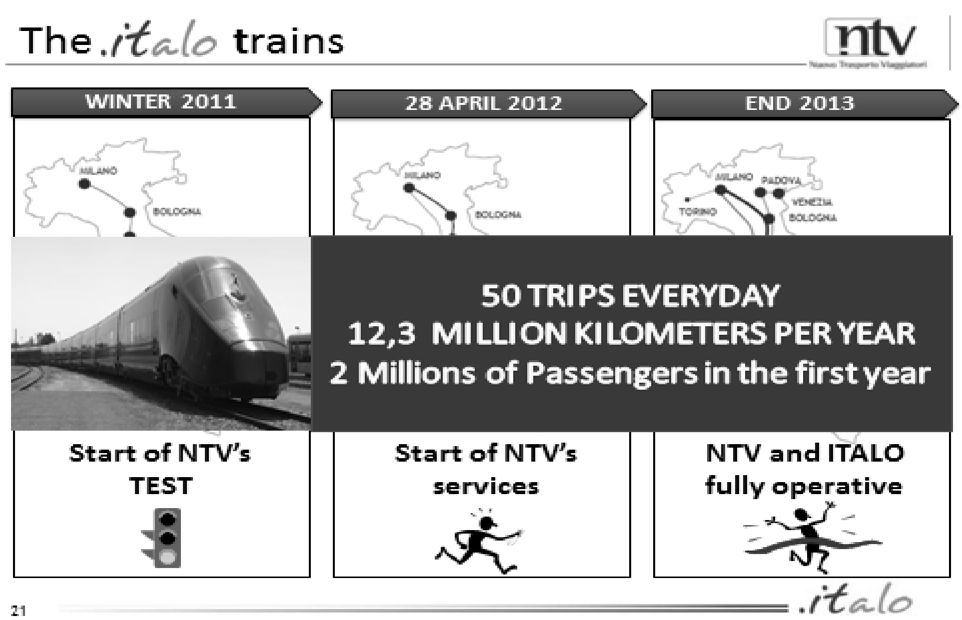
Nuovo Trasporto Viaggiatori (NTV) and the Italo trains

The new high-speed service operated by the company NTV with its ITALO trains came into operation on **28 April 2012** purely on the Naples-Rome-Florence-Bologna-Milan route.

The Italo trains suddenly put their services on the market in competition with the incumbent operator, Trenitalia.

As the fleet came into service, the number of daily journeys increased. NTV was initially predicting that full operational mode would be achieved with the next change of timetable on 15 December 2013.

Figure 6.1. **New high-speed service**

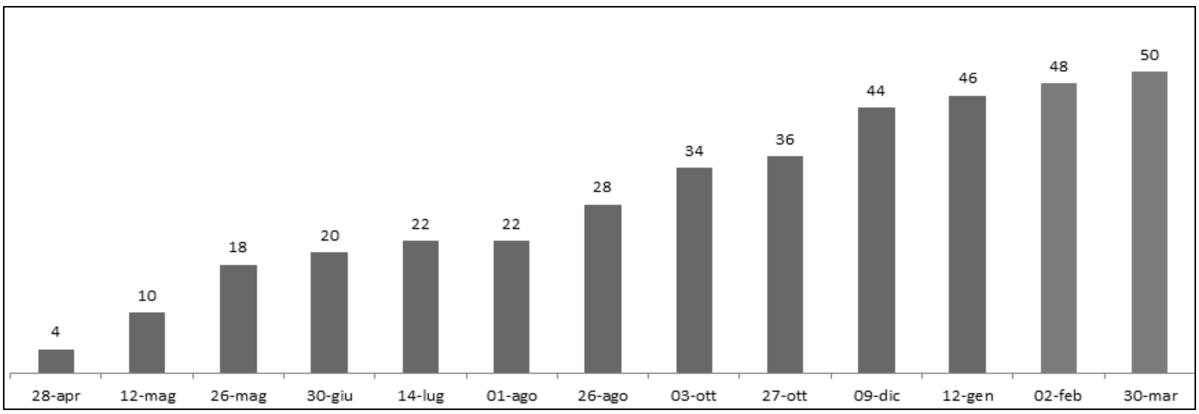


Source: NTV.

However, the market for NTV, and HS rail in general (as stated above), has grown faster than predicted, and it reached 50 journeys per day by 30 March 2013, in other words earlier than scheduled by the company itself.

Since their launch, the Italo services have developed as shown in the following chart in terms of delivery of rolling stock and number of journeys offered in the ramp-up phase:

Figure 6.2. **Train journeys per day**



Key: 28 Apr., 12 May, 26 May, 30 June, 1 Aug., 26 Aug., 3 Oct., 27 Oct., 9 Dec., 12 Jan., 2 Feb., 30 Mar.

Italo trains now link 10 Italian cities and 14 stations (Venice, Bologna, Rome and Milan each have two stations).

Figure 6.3. **Italo train services**

Source: NTV.

The principal productivity indicators for NTV for 2012 and the first half of 2013 are given below:

Table 6.3. **Productivity indicators for NTV**

Description	2012 (28 April to 31 December)	2013 (1 January to 30 June)
No. of trains	6 488	8 682
Train-kms	4 197 661	5 692 764
Passengers carried	2 051 705	3 154 823

Source: NTV.

The high-speed system and the modal split

The numbers given above demonstrate that, despite the unfavourable economic climate and the economic crisis, which have, in general terms, held back transportation, high-speed trains have managed to increase the number of passengers carried.

The new competitor on the market has not had the effect of eroding the number of passengers carried by the incumbent but has generated supplementary traffic, thanks to a general reduction in fares, a better standard of services and an increased offer in terms of frequency and number of stations served.

In other words, rail has shown that it can compete successfully with road and air transport and even with conventional passenger rail services over medium- to long-distance high-traffic routes. It appears that there is also a willingness, especially in the first-class business and leisure sectors, to pay relatively high prices, with a resulting low elasticity of demand in relation to the tariffs needed to cover costs, even though there is a general shrinking of the relationship between first- and economy-class passengers.

In terms of the overall split of transport demand, it is estimated that, between 2009 (the year that the HS network and modern HS services were launched in Italy) and 2012, the modal share of HS rail increased from 39% (transfer of Inter-City and Pendolino customers to the new HS Frecce services then offered by the sole rail operator Trenitalia) to 54%, whereas the road share fell from 28% to 21% and the air share from 26% to 21%.

On the Rome-Milan route in particular, the increase in the modal shift is even more marked, both because the distance between the two major centres is ideal (about 700 km) and because the traffic is predominantly business traffic, where speed, frequency and service quality are key factors of its success. On this route, until 2008 (the year prior to the launch of the HS network and modern HS services in Italy) the modal share of air travel was not only dominant but also greater than the shares of all other forms of transport available to users.

Today, however, the modal share of HS rail has rapidly overturned the figures, despite the fact that the number of travellers between the two Italian cities has increased only slightly.

It is worth noting that the market share of rail transport has increased from 36% in 2008 (without modern HS services) to 65% for the first half of 2013, and this has been accompanied by a sharp fall in the modal share of air transport from 45% to 26%.

This last share, which some commentators believe can go no lower, is however, in our view, likely to fall even further. There are important developments in the pipeline which are capable of tipping the scales even more. For example, there is the forthcoming upgrade of the HS network (which should bring operating speeds over the whole network up to 300 km/h), the completion of the new underground station in Florence (which will cut journey time by about 15 minutes due to removal of the need to reverse) and Trenitalia's new interoperable ETR 1 000.

Investment in high-speed rail is also having knock-on effects for the conventional network, either because it frees up sections which are useful for commuter or goods traffic, or because the greater speed equivalence thereby obtained increases available capacity. However, it is essential also to invest appropriately in urban hubs (a sector in which Italy is a world leader, not least because of the difficulties of crossing historically and culturally important cities).

It is the ability of high-speed trains to connect city centres that is creating new demand and new possibilities for work-related travel, including return journeys, due to reduced time frames and the resultant creation of macro residential areas as a result of increased regional integration (known as long-distance commuting: the HS network and trains in Italy have been dubbed "Italy's metro" because of their success in the first few years of operation), and because of increased tourism as a result of attracting visitors away from other modes of transport.

Rail system regulation

The high-speed rail system, which connects all the largest and most important Italian cities, is based on:

- Interoperability, safety and advanced technology.
- Reduced travel times (high operating speed).
- Passenger service quality in stations and on board.
- Environmentally sustainable development.

Italian experience shows, however, that the best results can be obtained only by liberalising competition on the market. Indeed, competition has brought the following benefits:

- Reduction of minimum prices (-30%).
- Improved offer quality and better returns.
- Diversification of the services offered.
- Increased number of stations served (also in urban areas).
- Increased frequency.
- Enhancement of the image of both competitors.

Unexpectedly – although not entirely – competition has not led to a loss of market share on the part of the incumbent but to a broadening of its passenger base, to the extent that it is genuinely possible to talk about market expansion.

Clearly, that expansion does not appear to have made significant inroads into the returns of the transport companies, resulting from the lowering of basic prices; rather, it has had a meaningful economic impact in terms of increasing the efficiency of both players, who have undertaken to produce more and better with limited resources.

Conversely, there has been a marked improvement in the financial situation of the network operator, given that fees for access to the HS infrastructure will amount to over EUR 300 million in 2013, as well as increased benefits for users.

However, development of this nature requires a regulatory framework which is geared to a liberalised market and an independent and powerful – but more importantly authoritative – regulator which can seamlessly oversee the process of growth and fair competition between the players.

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The Economics of Investment in High-Speed Rail

High-speed trains can compete successfully with road, air and conventional rail services on densely trafficked routes where willingness to pay is sufficient at the relatively elevated fare levels needed to cover costs. High-speed rail investments can also relieve congestion on the conventional rail network, and the capacity for high-speed rail to provide fast city centre to city centre services creates new possibilities for day-return business trips and short-stay leisure trips.

The long cost recovery periods for high-speed lines imply government involvement in the financing of most investments. The high costs mean that governments can be exposed to accumulation of large debts, particularly if demand develops more slowly than expected. Where high-speed rail investments are designed to promote regional integration rather than meet commercial demand, significant subsidy from central and regional governments will be needed for the construction of infrastructure and possibly also for train operations.

This report examines the key factors that drive the costs of high-speed rail investment and reviews the economic benefits delivered by high-speed rail services on the basis of experience in countries that have developed large high-speed rail networks.

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