Internal brief

A profile of high-speed railways

Executive Summary

- High-speed trains include those operating on ‘conventional’ track (at speeds of up to 225 km/h) and those operating on ‘dedicated high-speed’ track (at speeds of 250–350 km/h).
- While Japan, Italy and France have led on high-speed train technology, China now has the largest and most rapidly growing dedicated high-speed railway network.
- Dedicated high-speed rail has high up-front costs, with railways costing between A$16m and A$110m a kilometre and trains costing A$30m–A$40m.
- Construction costs can be especially high in urban areas, where housing has to be acquired and work undertaken to reduce the physical intrusion of the line and trains. These costs are much lower when land corridors have previously been safeguarded.
- Given the high construction and operating costs, high-speed services rely on attracting high patronage and revenue. As a rule they require at least 6–12 million passengers a year and so normally connect cities of well over 1 million population that are separated by travel times of less than 3 hours.
- High-speed trains, where successful, take passengers away from air, car and coach modes. This mode shift depends on competitive fares, reasonable transit times, high reliability and services that suit traveller needs. If fares are sufficiently low, high-speed rail can also generate new travel demand.
- A well patronised high-speed rail service has lower ongoing energy and greenhouse emissions than aircraft and similar emissions to car travel.
- The high upfront cost of dedicated high-speed rail means it characteristically requires government support for construction and, in all but the most favourable circumstances, ongoing government financial support.
- Australian experience with high-speed rail suggests:
    - conventional track services have been uncompetitive as they failed to realise maximum speeds due to poor track quality and sharing capacity with slower trains.
    - current demand between potential city pairs is well below the minimum needed to provide a viable dedicated high-speed rail service.

This paper discusses high-speed train services. The paper sets out what is meant by 'high-speed', explains the objective of introducing services and sets out where they have been introduced. The paper also considers funding experiences and Australian high-speed train proposals.

What are high-speed trains?

There is no single definition of high-speed trains. Definitions include trains running

- at speeds of up to 225 km/h on 'conventional' track.
- at 250 km/h or more on 'dedicated high-speed' track.
- on unconventional track — such as the Maglev [magnetic levitation] on concrete guideways.

Most of the services and track are primarily or exclusively for passenger trains.

High-speed train developments

The history of high-speed train operation follows two primary paths: getting higher speeds on existing track, and getting higher speeds on dedicated new, high-specification track.

The essential ingredient in achieving those higher speeds has been the emergence of major manufacturers and engineering groups with the expertise to progress and implement high-speed train principles. Table 1 provides a listing of the principal train and track suppliers.

Table 1 High-speed train manufacturers

Train/brand	Manufacturer (country)	Train type	Some countries of operation
Train à Grande Vitesse (TGV)	Alstom (France)	High-speed	France, Belgium, The Netherlands, Germany, Switzerland, Spain, South Korea, Italy
InterCity-Express (ICE); Velaro	Siemens (Germany) and others	High-speed	Germany, Austria, Switzerland, Denmark; the Velaro in Spain, China and Russia
Pendolino	Fiat (Italy)—now owned by Bombardier (Germany)	Tilt	Italy, Great Britain, Spain, China, Russia, Portugal, Slovenia, Romania, the Ukraine, Finland, the Czech Republic, Switzerland
X2000	ADtranz	Tilt	Sweden
Talgo 350	Talgo (Spain)	High-speed	Spain
Shinkansen (aka 'Bullet Train')	Kawasaki, Hitachi, Nippon Sharyo (Japan)	High-speed	Japan, Taiwan, China

The approaches for implementing high-speed operation are now outlined.

1. Higher speeds on existing trains and track

Since the construction of the first railways, train speeds have increased gradually with increasing train power and track standards. Thus, by the 1970s trains could run at speeds of up to 225 km/h on tracks built in the nineteenth century. An example is Britain's 'InterCity 125 HST' diesel trains (125 mph High-speed Trains), which were introduced from the mid-1970s; a variant developed by British Rail and the State Rail Authority of NSW was introduced in Australia in 1982, running as the 'XPT train'.

British Rail's InterCity 125 HST achieves higher operating speeds through faster-acceleration and lighter carriages. In particular, reducing train weight has enabled these trains to operate at 25 percent higher speeds on Britain's conventional track (up to 200 km/h) than earlier trains. However, the relatively lower standard of Australia's track requires the XPT train to operate at a lower maximum speed.

Where track alignment is relatively straight and line capacity has not been reached, upgrades of existing track can deliver higher speeds and service frequencies without extensive new line construction. For instance, the Hanover–Berlin high-speed line is a combination of new dedicated track and upgrade of existing track where there are straight alignments.

Having tightly curved track on existing railways slows down trains; conventional existing track often has curvatures that prevent sustained high-speeds. Passengers can feel considerable discomfort while the train itself can derail if it tries to go too fast around a tight corner.

'Tilt' trains have been built for the purpose of achieving higher speeds on conventional tracks. Trains such as Italy's Pendolino (in use in a number of European countries and used on Virgin Train's London—Glasgow services) and Sweden's X2000 are relatively light trains that have an 'active' tilt mechanism that allows them to tilt into track curves, enabling the trains to go through bends at higher speeds than conventional trains and reducing passenger queasiness. Thus the train can deliver higher speeds without the higher cost of constructing dedicated high-speed lines. In 1995, a tilt train was trialled between Sydney and Canberra but the tilt mechanism could not deliver enhanced speed because of the severity of the track curves.

Two other deficiencies exist with applying high-speed trains to existing track. First, the maximum speed remains well below that of trains on dedicated lines (say, 225 km/h compared with up to 350 km/h on new track). High-speed trains on conventional track can also be constrained by having to mix with slower services on the tracks. That is, the construction of new track delivers additional track capacity and streams of high-speed trains are not impeded by mixing with slower passenger and freight trains.

2. Higher speeds on new track

To increase threshold train speeds above 225 km/h involves building tracks and trains to a very high standard and using electricity drawn from overhead wires. The following is a chronology of this strategy, reported by key countries. Some dtails of dedicated high speed rail networks by country are provided in Table 2.

Japan

Japan was the first country to introduce the high standard of tracks (with low curvature and high track standards) and trains (with light weight) needed to allow high-performance trains to run safely at speeds above 225 km/h. The 'Bullet Train' railway between Tokyo and Osaka opened for the Tokyo Olympics in 1964. The trains (now called Shinkansen) then regularly ran at speeds of 210 km/h, now 300 km/h. The consequence was that the journey time between the cities was reduced from the previous fastest time of 6 hours 40 minutes, to 3 hours 10 minutes. The popularity of the Bullet Train led to Japan's Parliament passing a National Shinkansen Rail Construction Law in 1970, leading to construction of a network of high-speed lines.

Japan now has almost 2500 route-km of Shinkansen. The Japanese traffic far exceeds those of the high-profile high-speed services in France, with the most heavily trafficked line between Tokyo and Osaka recording over 150 million trips per annum.

Italy and France

From the early 1960s there were similar plans for dedicated high-speed lines and high-speed train research in European countries. The Japanese experiences demonstrated the commercial practicalities of purpose-built high-speed trains on dedicated, high-specification track. In 1966, Italy commenced construction of the Rome–Florence 'Direttissima' railway for high-speed operations, albeit that did not initially introduce a bespoke high-speed train.

In 1981, France opened its Paris–Lyon LGV (Ligne à Grande Vitesse) dedicated high-speed railway, on which it introduced its Train à Grande Vitesse (TGV) high-speed train with speeds up to 270 km/h. France now has over 1800 route-km of high-speed railway and the TGVs operate on those tracks, on high-speed tracks in neighbouring countries, and also onto conventional tracks. Patronage has consequently increased greatly, with TGV patronage rising from 6 million in 1982 to 128 million in 2008.

The operating speeds of these trains have also risen, with TGVs now operating at speeds of 300–320 km/h and with the new generation TGV (the AGV, Automotrice à Grande Vitesse) making its debut in Italy in 2011 with a top speed of 350 km/h.

China

China already has trains operating at 350 km/h, between Beijing and Tianjin. China's current railway construction—with over 6700 km of track being built in 2010—overshadows the earlier Japanese and French developments, and complements 3400 km of high-speed lines opened there from 2003, and also 345 km in Taiwan.

The rapid opening and expansion of high-speed railways in China eclipses developments in other countries. China now has the world's largest high-speed railway network and current construction will almost triple the size of the network by 2012. Table sets out the major high-speed plans in China and elsewhere in the world, with developments ranging from single city-pair plans in some countries to significant networks in other countries.

USA

As indicated in Table 2, USA's ambitions are relatively modest compared with China. Only California has advanced plans for the construction of a dedicated high-speed line linking San Francisco, Sacramento and Los Angeles. While the US President has announced a programme to develop 10 designated high-speed railway corridors (Figure 4), it is important to note that these investments are essentially upgrades of existing railways. Following on from the discussion in the previous section, the challenge for the US plan will be to develop high-speed passenger train operation on corridors where capacity is already heavily used by freight trains or local commuter services.

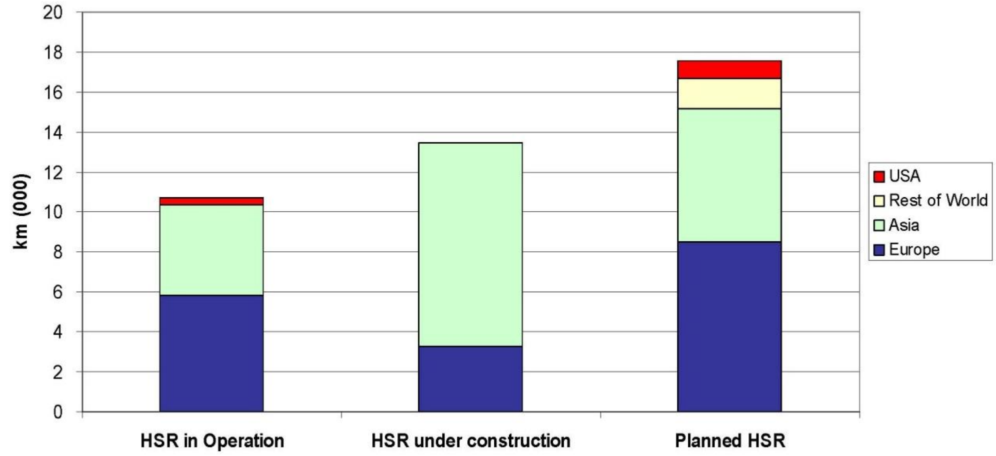
3. Other technologies/unconventional track

There are practical limits on speeds of trains on metal rails. However, scientists have developed alternative technologies to try to achieve higher speeds, notably the 'Maglev' train, which is propelled by magnetic levitation on a uniquely-designed concrete track. That track is incompatible with conventional steel rails on sleepers. The first significant application of Maglev technology is a 30 km service between Shanghai city and its airport. The line has been operating since 2006 and trains travel at up to 250 km/h. The incompatibility of the track with existing railways and high construction costs are obstacles to widespread take up of the technology.

State-of-play

From very modest developments 30 years ago, the pace of expansion of high-speed railways in recent years has been very rapid. While construction of lines continues in Japan, France, Germany, Italy and Spain, the major construction is occurring in China. As Figure 1 illustrates, the amount of dedicated high-speed railway under construction is greater than the total length of lines currently being operated.

Figure 1 Dedicated high-speed lines, by region



Source: UIC

Table lists the length of dedicated high-speed trackage by country. It is evident that the adoption of dedicated high-speed railways remains largely concentrated in the countries that have long-embraced the technology. China is the significant exception to that trend.

Table 2 Length of dedicated high-speed railways, by country

	Open	Under construction	Planned/proposed
Europe			
Belgium	209	0	0
France	1 872 (network)	299	2 616
Germany	1 285 (network)	378	670
Italy	876 (network)		395
The Netherlands	120		
Poland			712
Portugal			1 006
Russia			650
Spain	1 599 (network)	2 219	1 702
Sweden			750
Switzerland	35	72	
United Kingdom	113		
Asia/Middle East			
China	3 457 (network)	6768 (1407 km opening in 2010; 2259 km in 2011 and 3102 km in 2012)	2 901
Taiwan	345	-	-
India			495
Iran			475
Japan	2 452 (network)	590	583
Saudi Arabia[1]		444	
South Korea	330	82	
Turkey	235	510	1 679
Africa			
Morocco			680
The Americas			
Argentina			315
Brazil			500
USA	362 (Upgrade of existing track, NY–Washington)		900 (San Francisco–Los Angeles)

Source: Union of International Railways, sourced at <http://www.uic.org/spip.php?article573>

Notes: 1. The Saudi 'Haramain High-speed Rail' project links Mecca, Jeddah and Medina and is projected to carry 3 million passengers per annum.

The market and role for high-speed trains

The most important rationale for introducing high-speed trains is to produce a service that is attractive relative to other modes—in particular, to be competitive with airlines. The most important rationales for building dedicated high-speed railways are to produce an attractive train service *and* to provide additional track capacity to improve services on the route. The core considerations in assessing the market for high-speed trains are the construction and operating costs of supplying the service and the demand and revenue from those services.

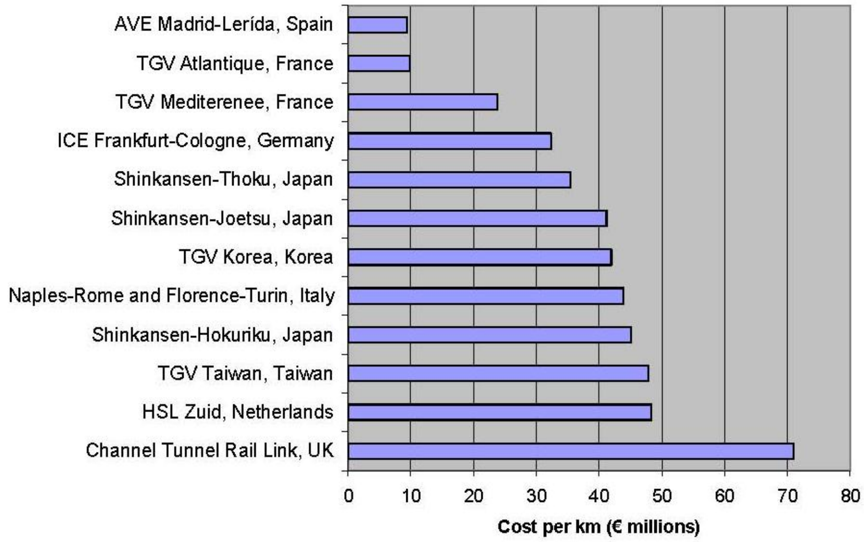
The supply costs of high-speed trains and railways

A crucial decision in high-speed services is whether to build a dedicated new high-speed line rather than upgrade the existing railway. As Figure 2 indicates, the construction costs of new lines can be very substantial. High-speed railway construction costs for a number of new lines ranges from around €10 million/kilometre to €70 million/kilometre (A$16 million to A$110 million).

Key factors that drive up construction costs are terrain and the availability of land, especially when there is high population density in city centres to which a high-speed line needs to access. Figure 2 illustrates the varying costs of line construction; the high cost of the British line was driven by environmental amelioration work and the tunnelling costs to central London. This highlights the importance of land corridors in determining high-speed line viability.

Ongoing costs of maintenance and service provision are also substantial. Exacting standards are required for line maintenance and the high-speed trains themselves are relatively costly—a 9-carriage TGV train would cost in the order of A$30 million–A$40 million. High-speed services are inherently costly.

Figure 2 High-speed railway construction costs per kilometre (€ million)



Source: Commission for Integrated Transport 2004, High-speed Rail: international comparisons, London.

The demand, revenue and non-financial benefits from high-speed services

Given the high construction and operating costs of high-speed services, financial success depends upon attracting sufficient patronage and revenue. The trains should link cities of sufficient size as to provide a strong pool of travellers. Table illustrates the population levels of cities on selected high-speed lines. However, even when 'large' populations are served, it is unclear that any high-speed railways (whether they be new, faster trains on existing track or fast trains on dedicated track) have ever made a commercial rate of return on investment irrespective of the populations served on a given route. For this reason, the realisation of non-financial (economic) benefits—notably, diversion of traffic to other modes—are important parameters in assessing the investment.

Table 3 Populations of cities on selected dedicated high-speed railways, million

Country	City (population)	Intermediate city (population)	City (population)
France	Paris (11.8)	-	Lyon (4.4)
China (Taiwan)	Taipei (10.0)	-	Kaohsiung (3.0)
Italy	Rome (2.7)	Florence (1.5)	Milan (4.3)
France/Belgium/Netherlands	Paris (11.8)	Brussels (1.8)	Amsterdam (2.2)
Germany	Hanover (1.1)		Berlin (5.0)
France/Britain	Paris (11.8)	Lille (1.1)	London (8.3)
Spain	Madrid (7.1)		Seville (1.5)
Spain	Madrid (7.1)		Barcelona (1.7)
France	Paris (11.8)		Strasbourg (0.6)
Germany	Cologne (1.0)		Frankfurt-on-Main (2.3)

The services are generally intended for a mix of medium-distance and long-distance journeys, although they can also be attractive for long-distance commuting and day-leisure trips. With the traditional high-speed railway countries, such as France, Germany, Italy and Japan, the individual city-pair links now form part of wider networks, with intermediate cities and farther-distant cities served. For example, the French LGV-Nord railway (Paris–Brussels) has an intermediate stop at Lille, which is a small city with less than one hour's journey to either Paris or Brussels; this has proven to be popular for commuting. LGV-Nord also attract Rotterdam and Amsterdam traffic, with trains operating beyond Brussels. In Japan, the extremely high traffic levels on Shinkansen services justify constructing lines aimed at commuting traffic as well as serving long distance markets. Elsewhere, fast commuter trains (such as London–Southampton) are accommodated on upgraded existing trackage.

There is a mix of financial and non-financial gains from high-speed services:

- existing passengers save time;
- new passengers are diverted from other modes;
- new rail trips are generated;
- because additional track capacity is available for these high-speed services, track capacity on the existing tracks can be released for freight or additional local passenger services;
- additional train capacity can reduce overcrowding;
- more track capacity and reducing the conflict between slow and fast train paths can improve train reliability;
- traffic diverted from air routes can reduce airport congestion and release airport capacity for other, longer routes;
- traffic diverted from cars can reduce road congestion and accidents;
- to the extent rail can offer journeys at lower energy and emissions, there can be environmental benefits; and
- faster links between cities on the route can strengthen bonds between those localities, revitalise local/regional economies and broaden the catchment area for jobs.

As is evident from the foregoing, some of the benefits accrue as financial benefits to the high-speed train/track provider. Other benefits—the so-called 'wider economic benefits'—are not captured by the railways; such non-financial benefits are often put forward as justification for public funding.

One apparent non-financial benefit of high-speed rail is that they are environmentally friendly relative to other modes. Such credentials are primarily a function of the energy consumed in moving the train (and other modes) but also depend on the train load factor (how full the train is) and the source of energy. No matter how little energy a train consumes relative to aircraft, if the train is always empty then the aeroplane will consume less energy per passenger than the train.

Nash reports the results of a study that compares high-speed train energy consumption with other modes. Table 4 shows that high-speed rail has a substantial energy advantage over air transport, is similar to car but worse than conventional rail. Given that high-speed services often use yield management systems to increase load factors (and revenue), Nash argues that a 70 percent load factor can be justified, which reinforces rail's energy consumption advantage over aircraft.

Table 4 Energy consumption by mode, 2010

	Intercity train	High-speed train	Aircraft	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 at 70% load factor)	2.57	0.94

Source: Nash, C 2009, 'When to invest in high-speed rail links and networks?', paper presented to 18th International Transport Research Symposium, OECD/International Transport Forum, Madrid, November.

A related issue is high-speed rail's relative levels of greenhouse gas emissions. Calculation of European high-speed rail services has found that they emit far fewer greenhouse emissions per passenger kilometre than comparable air travel. However, part of the relatively low emissions is that zero-emissions nuclear power is often used in European electricity mix—the relative advantage of high-speed rail is reduced if coal, oil and gas are used to power the generators.

Assessing the impact of high-speed services

The impact of investments must be undertaken on a case-by-case basis. In the examples cited in Table the train has taken considerable market share from air and also reduced road share. Figure 3 illustrates the impact of the new Paris–Lyon service on road and air traffic in succeeding years. After an initial collapse, road traffic subsequently reverted to its longer-term growth; aviation traffic also collapsed and (as has occurred on other high-speed routes) has not recovered.

Table 5 Before and after high-speed market shares

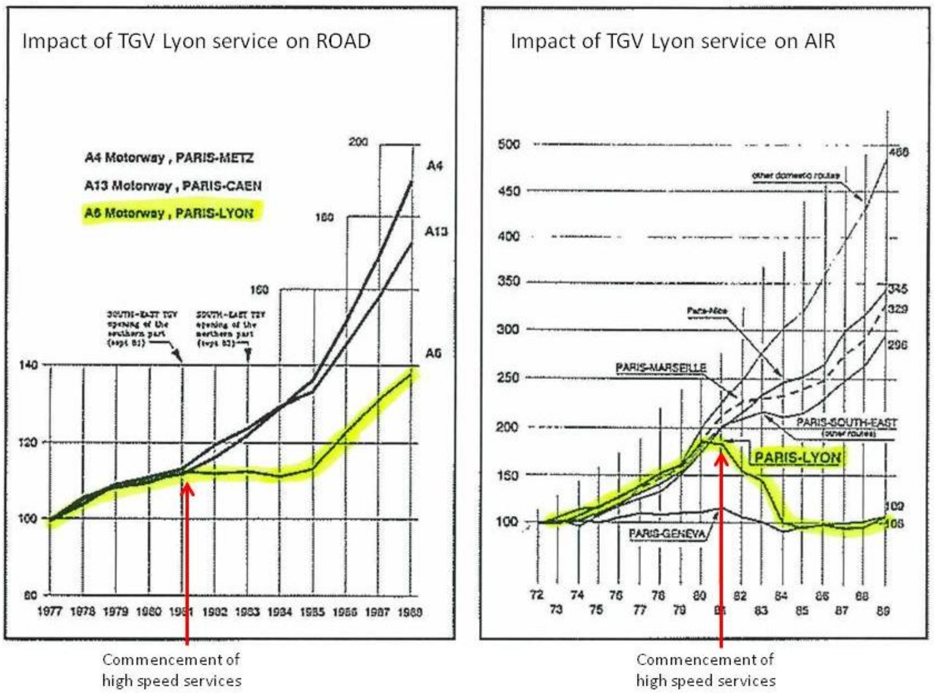
	Paris–Lyon		Madrid–Seville	
Mode	**Before**	**After**	**Before**	**After**
Aeroplane	31%	7%	40%	13%
Train	40%	72%	16%	51%
Car and bus	29%	21%	44%	36%

Source: Cited in Nash, C 2009, 'When to invest in high-speed rail links and networks?', Paper presented to 18th International Transport Research Symposium, OECD/International Transport Forum, Madrid, November.

Mode shift alone cannot be used as the sole criteria for determining the success of the investment. For example, the strong modal shift reported for the Madrid–Seville high-speed railway (Table 5) might suggest that that investment was a success. This is not the case, when success is judged on financial or economic grounds. After the high-speed line opened in 1992, the high-speed trains carried less than 3 million passengers and even now the patronage is only 5 million. The estimated economic benefits of the Madrid–Seville line (which are related to overall patronage) were initially lower than the train operating costs. This implies that even if the line had been constructed, it would have been better to have left the line unused. The line is characterised by low patronage and (typically) high operating costs. High-speed railway costs are inevitably very substantial, but even with relatively modest construction costs[1], the Madrid–Seville railway was of arguable benefit.

[1] Campos, J and Barron, I 2007, 'A review of HSR experiences around the world', MPRA Paper No. 12397, Munich, <http://mpra.ub.uni-muenchen.de/12397/1/MPRA_paper_12397.pdf>

Figure 3 Impact of a new high-speed train service on competing modes



Source: Whitelegg, Hultén, S and Flink, T 1993, *High-speed trains. Fast tracks to the future*, Leading Edge Press, Hawes, North Yorkshire.

Thus, an important parameter when considering building a high-speed railway is the underlying demand on the route, of which city size is just one contributing factor. The market for travel has to be substantial and sustained over time. For instance, some high-speed routes have the benefit of a continual 'churning' of (different) international travellers moving through the turnstiles. The Paris/Brussels–London TGV service—called 'Eurostar'—has the benefit of repeated infusions of new non-Western European travellers: at least one-quarter of the travellers on the route are tourists from North America, Japan, the sub-continent and Australasia. Thus, while local travellers might have 'done' their Eurostar trip, new international travellers continually replace the international travellers of earlier years: the pool of demand on that route is potentially every visitor to Europe. The route also benefits from a high proportion of users travelling beyond the three linked cities, so the services feed and draw from a high density of travellers to/from surrounding cities.

The Paris/Brussels–London route currently attracts around 9 million passengers per annum. However this is well below the pre-opening forecast of 25 million per annum for 2010. This lower-than-forecast patronage means that the very modest financial return of 4 percent on the British section of the new high-speed route is not being achieved. The forecast total (financial plus economic) return for the British line was estimated to be 11 percent so the actual result is considerably less. The 11 percent estimate, made in 1993, also does not reflect the actual (higher) costs of the railway that were incurred which, as illustrated in Figure 2, were considerably higher than other new high-speed railways.

As with the Madrid–Seville railway, Eurostar now dominates the rail+air market, with almost 85 percent of the share of the London and Paris/Brussels/Lille market. The prospects for the intercapital service seemed good, with the Paris–London air service being the busiest international route in the world. Thus, even having captured most of the air traffic, the Eurostar traffic is well below forecasts. Put another way, even though Eurostar is attractive enough to capture most of the core-route aviation traffic, the British high-speed line that was built for it earns very low rates of return and still attracts well below the traffic levels that had provided the basis for its construction. The fact is that the business case relied upon passengers who would be diverted from other modes and also newly-generated traffic.

Thus, the Eurostar experience provides important considerations in high-speed train economics. Travellers' switch from air is important, but also important is the switch from other modes and the generation of new trips as a result of the high-speed service.

Switching travellers from air

Service quality—transit time, transit contiguity and reliability—and (to a lesser extent) fares are the most important parameters determining why airline travellers switch to high-speed trains.

1. **Transit time**

   Transit time is origin-to-destination time, not airport-to-airport or station-to-station time. This works in rail's favour when travellers are moving from one city centre to the other: the railway station is typically in the city centre. By contrast, an air traveller undertaking the same city-centre movement uses a fast flight but incurs slow overground movement between the airport and the city centre. This is a particular attraction for tourists, who often want to stay in city centres. If business travellers are going from the office in one city centre to the office in another city centre, the train also has an advantage. From other origin–destination pairs, however, the time advantage of the high-speed train declines. For instance, if travellers live near the airport, they are unlikely to travel past the airport to get to the city centre to take the train. In a related situation, if the cost of the surface transport (such as a taxi) to the city centre is significant relative to driving to the airport, the traveller will be inclined to fly.

   Three hours is the rule-of-thumb length of train journey time that is often cited as the turning point for high-speed competitiveness. That is, as train journey time between two cities falls below 3 hours, rail mode share rapidly increases. Conversely, as train journey time exceeds 3 hours, the rail competitiveness quickly declines.

2. **Transit time contiguousness**

   Transit time contiguousness is an important attribute of high-speed trains relative to air. For city-centre-to-city-centre journeys in particular, air services are fragmented into parcels of time. For business travellers, for instance, the trip may involve a journey from the office to the airport, checking in luggage, waiting in the club lounge, queuing for the aircraft, takeoff and in-flight time and then the reverse activities at the destination end. Travelling by high-speed train can involve less trip fragmentation, with the traveller able to enjoy a journey (or work) from origin to destination with minor interchanges.

3. **Reliability**

   Service reliability is an important factor in choosing between air and rail. The Eurostar service, in particular, suffered from poor reliability due to the initial use of existing conventional track in Britain, where high-speed trains were often delayed by slow commuter trains. The switch of the service to a dedicated high-speed line has significantly improved reliability, increasing traffic—especially—high-fare-paying business traffic.

An additional factor that determines the likelihood of switching from air to rail is whether the destination airport is the final airport or whether it is used for interlining to subsequent air services. For instance, historically, around one-third of the London–Paris air traffic was interlining traffic to further-European or non-European destinations. In such circumstances, travellers are more inclined to stay with air as the destination airport effects easy transfer to onwards flights.

Switching travellers from other modes

Relative journey time is one important factor that would-be travellers consider when choosing modes. For business travel (where journey time can be at the expense of productive work time), travel time can be of relatively higher importance than fares. For leisure travellers, time is generally of less importance than fares.

When the alternative mode is the car, the upfront costs may be less than for the train. If more than one traveller is in the car, the costs per person are reduced significantly relative to the train. To appeal to such travellers, high-speed train operators sometimes provide significantly discounted fares for group travel during off-peak periods and weekends.

As with air travel, the journey origin and ultimate destination are important factors influencing mode choice because they can strongly influence overall journey time. That is, the journey time that matters is the overall journey time and not just the travel time spent on the main (rail, road, air) mode. Thus, for instance, if the journey origin and destination are on city perimeters, it might take more time to travel by public transport to the city centre and then take the train, than by taking a car directly.

Traffic generation

Bringing cities and communities closer together, time-wise, inevitably leads to additional trips. This experience of traffic 'generation' also can arise when introducing high-speed trains. The observation that generation 'can' arise is a qualification based on the attractiveness of the destination city concerned: with due respect, Brussels does not have the attractiveness of Paris as a destination. The extent to which traffic is generated also depends on the fares that are set. For example, if the high-speed train makes day-return leisure trips achievable but the traveller faces a fare comparable with flying by air, then it is unlikely that there would be much 'trip generation'.

Initiating and funding high-speed train services

The experience with the initiation and funding of high-speed train services is that government has often pursued the idea and has typically banked the project. This is not always the case. For instance, in 1956 in the USA, General Motors developed a fast lightweight train that was used by the private Pennsylvania Railroad and, later, Union Pacific Railroad. A decade later, the US Congress passed the High-speed Ground Transportation Act. This Act spurred the development of the Turbotrain and the Metroliner train for use on the Washington-New York-Boston 'Northeast Corridor'.

Experiences elsewhere show that the impetus for high-speed service development normally comes from government, or that government has provided a central facilitating/supporting role from the outset. Where new railway construction is involved, such facilitation/support is essential. However, as noted earlier, newly-built railways (in particular) involve very high upfront costs and the presumption is that high levels of public funding are required for the schemes to proceed.

Attempts have been made to use Public Private Partnerships (PPPs) to finance high-speed railways. However, private financing is not a panacea for chronic low returns that underlie most schemes. Substantial public funding is essential for most lines to proceed. For instance, the construction of Britain's high-speed railway (on which the Eurostar operates) was set up in 1996 as a PPP. The line's construction was intended to be part-financed by cash flow from the Eurostar service operating at lower speeds on existing conventional track. In the event, the Eurostar service was (and remains) deeply unprofitable (with revenue that was around one-half of its operating costs) and in 1998 the government was forced to bail out the private partner.

PPPs have been used elsewhere, such as for constructing the Dutch 'HSL-Zuid' high-speed line between the Belgian border and Amsterdam. It is unclear how this partnership has fared, with construction cost overruns and a 3-year delay to the opening of the line.

Are high-speed lines 'viable'?

High-speed train services using dedicated track involves very substantial upfront construction costs. Just servicing the loans on those investments can absorb much of the cashflow. Professor Nash (Institute for Transport Studies) has noted that, to justify the construction of new lines, at least 6 million passenger trips per annum are needed 'in the most favourable conditions' and more commonly at least 12 million trips will be required. Crucially, he notes that the 'most important variable in determining the breakeven volume is the construction cost, which varies enormously according to circumstances'.

Taiwanese experience illustrates what happens when those 'most favourable conditions' does not apply. Despite attracting more than 30 million patrons and (Taiwanese) T$23 billion in revenue in 2008, the Taiwan high-speed train operator incurred interest charges of T$17 billion. By 2009, the private company had lost over T$67 billion since the commencement of services; the government took majority control of the company in late 2009.

The failure of the Taiwan operation to operate profitably, despite apparently-high patronage, is partly due to the relatively high upfront costs—as Figure 2 illustrates, the Taiwanese scheme was at the high end of the unit construction cost scale, costing almost 5 times the cost-per-kilometre of the LGV-Atlantique railway in France. Topography, population density (land costs) and environmental amelioration are important factors that determine those unit construction costs.

To be more accurate, it should be noted that it is revenue that matters more than traffic volumes. For viability, high patronage needs to convert into high revenue (yields). Thus, if there is deep fare discounting (for instance, to attract new traffic or to divert it from air services), then even higher patronage levels will be required to break even.

The rapid recovery of upfront construction costs is imperative to viability: financing costs are incurred from the outset of planning/construction and provide a significant cashflow challenge. In this context, delays to opening new lines will place a severe strain on finances. As noted earlier, the Dutch HSL-Zuid line opened in 2009, three years late.

Is upgrading existing lines a viable option?

New dedicated high-speed railways generally provide the highest practical train speeds, making reliable train travel attractive relative to other modes—at least when the train journey is less than 3 hours (as a rule of thumb). Thus, if large population centres/demand are in appropriate proximity to each other, they may generate high traffic/revenue volumes. New dedicated lines also provide a big increase in track capacity, enabling frequent services on the new lines and releasing capacity on the existing lines for expanded local passenger services and without impinging on freight operations.

However, the high cost of new dedicated high-speed railways is a major obstacle both to justifying high-speed line construction and funding the construction and subsequent train operation.

Upgrading existing track to higher speeds and standards is therefore an important alternative strategy. This is the core feature of the USA's designated national high-speed railway corridors that was announced in 2009. The corridors are illustrated in Figure 4. Of the corridors, only Californian Bay Area–Los Angeles would involve a dedicated new high-speed railway. The other corridors would be upgrades of existing lines.

The principal upsides to track upgrading rather than building a dedicated new railway are:

- **lower cost:** considerably lower construction costs and, thus, lower funding/financing issues;
- **less risk:** lower financial risk as improvements can be introduced incrementally to see how patronage responds to individual investments;
- **shorter lead time**: likely that there will be much lower lead time to introduce the improvements.

The principal downsides to upgrading track rather than constructing new track are:

- **services may remain uncompetitive:** that train speeds are lower than on dedicated track and so the '3-hour threshold' journey time may not be achieved and so rail competitiveness may be severely impeded; and
- **constrained capacity:** use of existing track may be severely constrained, with limited additional capacity available to be constructed. This means that high-speed trains have to mix with slower passenger and freight trains, limiting the number of high-speed services that can be operated and probably having much lower service reliability compared with services on dedicated lines.

High-speed train operation in Australia

Australia's low, and dispersed, population makes it relatively unsuitable for the type of high-speed services that have thus far been introduced in other countries. As noted above, high-speed railways are often introduced as head-to-head competitors with airlines albeit that such diverted traffic may

still be a small proportion of the high volumes required to make the service viable. This rail–air competition is achievable when the rail journey time is, at most, 3 hours from city to city.
The viability of high-speed trains in Australia is very low (even compared with the generally low viability of overseas systems) due to the country's very modest population concentrations, absence of 'adjoining' cities, very modest tourist throughput and very limited commuter potential.

As listed in Table , there are several train services in Australia that travel at moderately fast speeds on upgraded existing tracks. Because the track has not been built to a standard and dedicated to high-speed operation and because there is often limited capacity on the track (with high-speed trains sharing capacity with slower trains) it means that the trains themselves are often used at well below their speed potential.

Table 6 Existing 'fast' trains in Australia

	Maximum service speed	Comment
Queensland 'Tilt Train' - Brisbane–Rockhampton (electric) - Brisbane–Cairns (diesel)	160 km/h 160 km/h	Some sections of track permit trains to operate to maximum service speed
NSW's 'XPT'	160 km/h	In recent years, poor track condition has restricted trains to below maximum
Kalgoorlie–Perth 'Prospector'	200 km/h	Currently operate at a maximum speed of 160 km/h
Victorian 'VLocity' Regional Fast Trains (eg Ballarat, Bendigo, Geelong)	160 km/h	Services on some lines operate at maximum service speed

Over the last 30 years, there have been proposals and considerations for the construction of dedicated high-speed railways, despite these adverse financial and economic circumstances. Table 7 presents geographic and demographic data for the principal Australian city pairs that have been considered as contenders for high-speed train services; the populations should be compared with the more substantial numbers presented in Table for countries with high-speed railways. Table sets out a chronology on the major schemes that have been proposed to build high-speed railways in Australia. The two principal schemes advocated were the Very Fast Train (VFT) between Sydney and Melbourne (via Canberra), and the later Speedrail proposal for a high-speed Sydney–Canberra train.

The VFT and the Speedrail schemes faltered as they remained inherently unviable without public funding. The latest Commonwealth report (East Coast Very High-speed Train Scoping Study) from 2002 acknowledged that the substantial cost of any scheme would overwhelm any estimated benefits. In 2008, Infrastructure Australia has shortlisted the concept for further analysis. The Canberra Airport operators have advocated a Sydney–Canberra high-speed service linking their Airport with Kingsford Smith, with a view to making their airport as Sydney's second airport. In January 2010, Rail CRC released an information report that considered the potential for high-speed railways in Australia.

The three key parameters in viable high-speed train services are the prevailing construction costs, demand levels and revenue. Demand is a necessary but not sufficient parameter in determining whether a high-speed service would be viable. The demand for the services will be a function of the size of the cities involved and the economic and social interaction between those cities that encourages travel. While Sydney and Melbourne appear to be of a reasonable size (table 8) their distance apart places them on the cusp of the distance that could be covered in 3 hours by a train travelling at a maximum 350 km/h. Thus, while there is a well-used airline service between the two cities, a high-speed rail service would struggle to offer a competitive time to lure airline travellers. The relatively low population density (table 8) also places travellers' homes further from the city centres (where the high-speed trains would commence and terminate); this also reduces the appeal of the rail services compared with air.

Table 7 Chronology of high-speed railway proposals in Australia

Date	Proposal	Outcome
December 1979	Electrify Sydney–Melbourne line, which would reduce travel time and energy consumption	Senate Standing Committee rejected report
October 1981	Institution of Engineers proposed Bicentennial High-speed Railway Project linking 5 capitals of south-east	
June 1984	Chairman of CSIRO proposed Sydney–Canberra–Melbourne TGV-inspired line for Bicentennial project	Bureau of Transport Economics find scheme to be uneconomic
September 1984	Elders IXL and TNT become involved in CSIRO idea	
September 1986	Establishment of Very Fast Train (VFT) Joint Venture (Elders IXL, TNT and Kumagai Gumi) for Sydney–Canberra–Melbourne line via Gippsland or Albury. Later (1989) Brisbane–Sydney is added.	Pre-feasibility study completed in June 1987. Feasibility study initiated July 1988. Concept report completed December 1988
August 1989	Senate Inquiry initiated into VFT proposal	Interim report tabled May 1990
1989–1990	Opposition organised to VFT proposals, on environmental grounds; Victorian concern at coastal route leading to inquiry into routes	Victorian government released Final Report in June 1991, supporting inland route
August 1991	VFT Joint Venture ends—failure to win tax concessions to make project viable is cited as a reason	
August 1993	Speedrail group proposes Sydney–Canberra line	
December 1996	Prime Minister announces joint Commonwealth–NSW–ACT government venture to investigate Sydney–Canberra options, on basis of no net cost to taxpayer	
July 1997	Short-listing of 6 consortiums to build Sydney–Canberra line	Four consortia (including the original Speedrail) join the final tender process, submitted in March 1998.
August 1998	Speedrail announced as preferred party to build a new line, from 2003	A feasibility study was released in October 1999 but the proposal was abandoned by the government in December 2000
December 2000	After Commonwealth decided not to proceed with Speedrail proposal, it announced an East Coast Very High-speed Train Scoping Study for a Brisbane–Sydney–Canberra–Melbourne high-speed railway	The Final Report of the scoping study was released in March 2002.
December 2008	Infrastructure Australia shortlists concept of Sydney–Canberra–Melbourne high-speed line for further analysis	
February 2009	Canberra Airport proposes high-speed railway between Sydney and Canberra to make its airport a second airport option for Sydney	

Table 8 Population and travel statistics for city pairs where high-speed proposals have been mooted

	City pair		
	Sydney–Newcastle	Sydney–Canberra (Speedrail proposal)	Sydney–Melbourne (Very Fast Train proposal)
Populations (million)	3.6 – 0.3	3.6 – 0.3	3.6 – 3.4
Population density (persons/square km)	2036 – 1103	2036 – 1105	2036 – 1566
Area (square km)	1788 – 262	1788 – 291	1788 – 2153
Straight-line distance between cities (km)	117	249	713
Journey-to-work travellers between cities (number)	13 158	2 383	4 402
Annual air passenger movement between cities (number)	41 975	983 675	6 192 225

A scheme has been advocated for Newcastle–Sydney but it is like the Speedrail Sydney–Canberra proposal in that it involves linking a very modestly-sized city with a large city. Estimates of commuting between Newcastle and Sydney in 2006 (table 8) suggest a total commuting market between the cities of between 15 000 and 35 000, well below the 6 million—12 million estimate for the most favourable construction cost circumstances that could deliver a viable operation.

Annex

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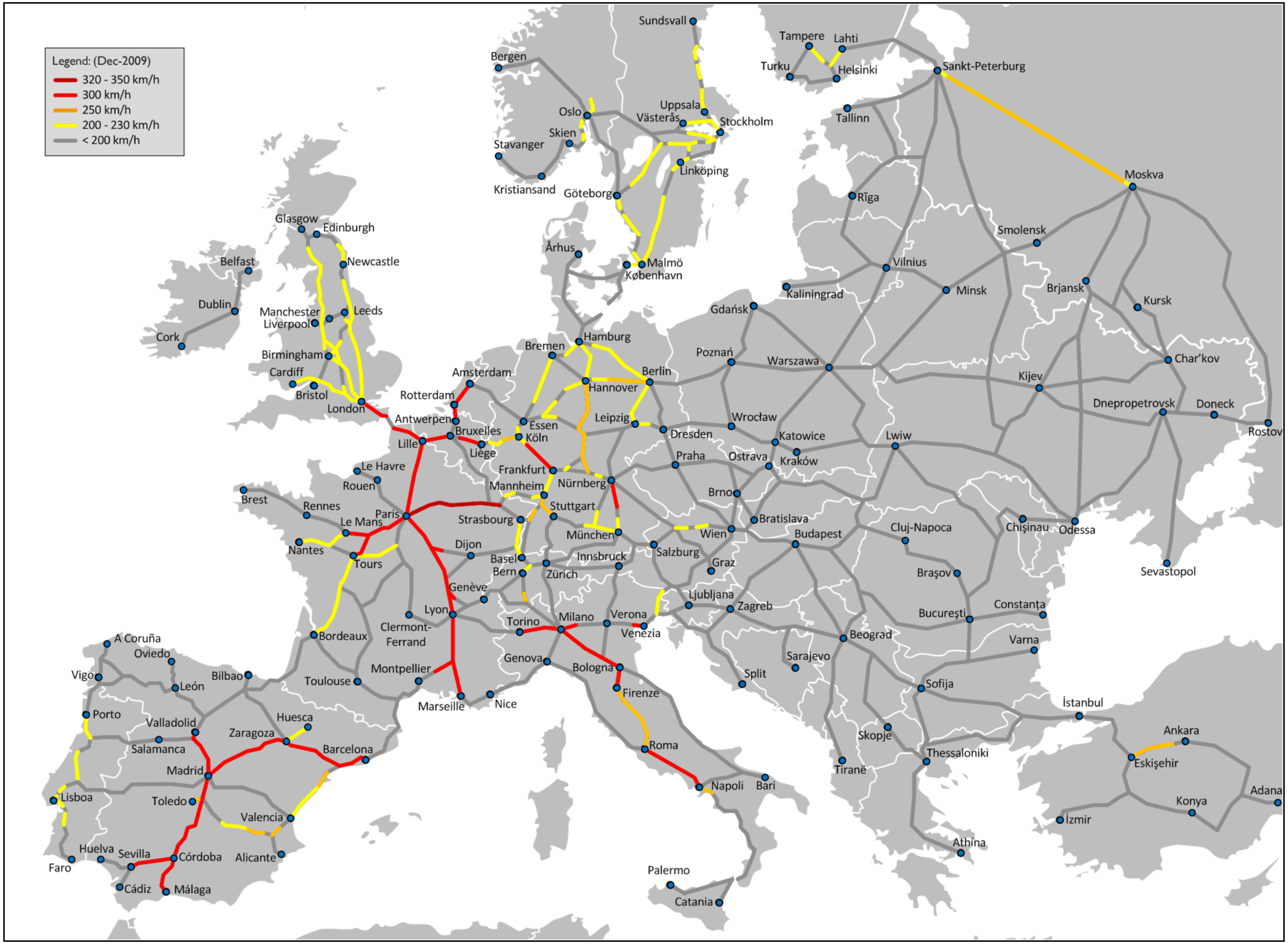
EUROPE: Existing high-speed railways in Europe, December 2009



CHINA: High-speed railways in China: existing, under construction and planned

Figure 4 Designated high-speed railway corridors in USA, from 2009