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**Improving regional passenger
rail services**

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Improving regional passenger rail services

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Bureau of Infrastructure, Transport and Regional Economics (BITRE)
Department of Infrastructure and Regional Development
GPO Box 501, Canberra ACT 2601, Australia

Telephone: (international) +61 2 6274 7210
Fax: (international) +61 2 6274 6855
Email: bitre@infrastructure.gov.au
Website: www.bitre.gov.au

Foreword

Travel between regions and cities forges ahead, fuelled by growth in population, leisure time and disposable income, and by the rising interdependence of centres of commerce. This is a world-wide phenomenon.

This report illustrates the opportunities, challenges and impediments to applying service upgrades to improve rail service patronage based around existing infrastructure. Upgrade experiences are exposed through the presentation of a diverse range of case studies of local and overseas service upgrades. Physical circumstances, modal competition, demographics and market-mix interplay to negate or encourage upgrading strategies. Either way, upgrades are not necessarily a long-term panacea.

The research was undertaken by Peter Kain, with assistance from Jeremy Dornan.

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Gary Dolman
Head of Bureau
Bureau of Infrastructure, Transport and Regional Economics
May 2014

At a glance

This report reviews the options available for upgrading existing passenger train services, drawing from local and international case studies to inform the conclusions. These case studies illustrate both the range of upgrades available and their effectiveness in increasing rail patronage and mode share.

Context

Upgrades can serve as both substitutes for and complements to high-speed railways. As substitutes to high-speed rail, they involve smaller drain on government budgets, can be introduced sooner, have a lower environmental impact and provide useful commercial proving-ground for subsequent improvements, including high-speed railways, which can reduce investment risks.

As complements to high-speed rail, it is common practice across the world for sections of high-speed tracks to connect to upgraded railways.

Upgrade options

Travellers seek a comfortable, accessible and dependable service with low transit and waiting times which means, for the train provider, delivering reliable, frequent and fast services. These features lie at the heart of upgrades.

There is no rule-of-thumb “best” upgrade option: the effectiveness, scope and cost of improvements of each of the service attributes varies between projects, locations and also the travel markets and competing mode attributes. For instance, while there may be a presumption that “speed” is all-important, the Victorian *Regional Fast Rail* and the Chicago – St Louis case studies illustrate that service frequency enhancement can have a pronounced effect on patronage.

Infrastructure upgrades challenges

Fundamental to delivering good service quality is the requirement for a reasonable standard of infrastructure. The primary *infrastructure* challenges in service enhancements can be summarised as the four “C”s: capacity of infrastructure, crossings with road, and the condition and curvature of tracks.

Improving train speeds and service frequency normally requires enhancement of track capacity. As well as physical expansion of trackage, capacity can be raised by upgrading signalling and by raising speeds for other train types. Additional capacity can also be secured by diverting,

re-scheduling or re-prioritising other train operators, but the costs to those users must not be ignored. This works both ways: in the London *Gatwick Express* case study, the *Express* service quality was downgraded in order to secure additional track capacity to meet growing commuter traffic.

The interface between trains and road vehicles are a major impediment to higher train speeds. If speeds are to be raised, such crossing upgrades/removal may be a major cost component, as illustrated by the Chicago – St Louis corridor.

High-performance services also require a high condition of track maintenance, with associated higher operating costs. Failure to sustain maintenance and renewal works results in service *downgrading*, as experienced on USA's Northeast Corridor.

Other forms of service upgrading

Apart from track re-alignment, a range of track-geometry adjustments can be implemented to lift train-speed constraints on curved tracks. High-performance rolling stock with tilt and flexible-steering bogies can also raise train speeds through curves; this equipment has been applied in a number of countries, including Great Britain, Sweden, Finland, Russia and Canada. However, the tilt technology is largely ineffective where track geometry is poor or curves are extreme.

Aside from applying new technology, time competitiveness may be enhanced through procedural changes, for example, with customs and immigration checks for the Russo–Finnish *Allegro* passengers enroute rather than adding transit time with station-stop checks.

Travel market responses

Upgrading is not necessarily a panacea for severe train service competitiveness. Upgraded services may be less-attractive substitutes for high-speed services if a given market (long-distances, demography, quality of competing modes, poor city-centre accessibility) has attributes that remain highly uncompetitive following the enhancements. In any case, competing modes may enhance their own services or revise their fares.

The upgrades (complemented by fare reductions) in Victoria's *Regional Fast Rail* project tapped into travel markets that were responsive to key rolling stock, reliability and service frequency improvements, resulting in a very strong ridership response. The project illustrates the local application of upgrading principles, while recognising that upgrade opportunities are very market-specific.

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CHAPTER I

Introduction

In recent years there have been many proposals for new high-speed passenger railways across the world. Many of these proposals do not progress. Often, the plans are unrealistic, or premature, due mainly to the combination of high construction and operating costs set against limited economic resources and limited travel markets. Faced with such situations, many authorities look to upgrading existing services to encourage patronage. More generally, though, service upgrades are stepping stones to high-speed services.

This report considers the range of service upgrades that can be applied, identifies the prime levers of costs and constraints on quality enhancements, and considers the conditions under which the market response would be sufficient to justify the upgrades.

Context

Rail service enhancement seeks to increase patronage; such traffic growth is aimed at achieving a number of goals, including:

- **Mode diversion:** Rail traffic is won from other modes, relieving congestion and capacity problems on those modes;
- **Regional development:** Faster, more accessible and more comfortable services make the origin–destinations more attractive to travel to and from—this can make the location(s) more viable as centres of commerce and leisure; and
- **Aviation capacity strategy:** Making specific locations more accessible can be used for complementary policies, such as encouraging the development of alternative airport locations.

Box I provides examples of situations where line upgrades are aimed at these commerce and activity-diverting goals.

A radical railway solution to achieve these goals is to build a dedicated high-speed railway, noting the perceived inadequacies of existing services. Where it is not feasible to implement such new construction, the key policy question is whether service upgrades can provide a more affordable way that nevertheless can achieve the desired policy objectives. Ultimately, the decision-maker is interested in the effectiveness of service upgrades relative to alternatives—be they high-speed railways or enhancements to other transport modes.

Upgrades have particular appeal since the cost and funding required is usually less, delivery time is shorter, environmental impact is lower and, overall, risk is lower. Where there is a strong

market response to an upgrade, it can underpin the case for subsequent construction of a high-speed railway¹.

A range of upgrading options for existing railways may meet objectives of enhancing the role of passenger railway services, of which the “*fairly fast train*” is foremost. Passengers are drawn to faster trains because travel time is a core attribute when deciding between travel modes². Indeed, the objective in the USA is simply to provide a train service that is sufficiently time-competitive with the other modes.

While recognising the importance of travel time, speed is only one of a number of service attributes that can be improved to attract travellers.

This report does not consider high-speed options; these have been reviewed thoroughly elsewhere³. The focus is on experiences with upgraded existing systems, beginning with an overview of the evolution of conventional and high-speed railways and then a literature review of upgrading principles and the markets to which they might be applied. The range of experiences in Australia and overseas are analysed, along with the market responses. Finally, the report draws conclusions, with particular focus on options for Australian service upgrades.

¹ It is notable that successive upgrades on Britain’s West Coast Main Line (an Anglo-Scottish route) and France’s Paris–Bordeaux railway have provided a foundation to the business cases for the high-speed HS2 (<www.hs2.org.uk/>) and Ligne à Grande Vitesse Sud Europe Atlantique (<www.lgvseuropeatlantique.org>).

² Other important aspects include carriage comfort and safety.

³ See, for example, Department of Infrastructure and Transport, 2013; House of Commons Public Accounts Committee 2013.

Box 1 The wider impacts of railway upgrading

Service upgrading has both transport-related objectives and wider goals.

An example of wider goals is airport capacity distribution. In southern England, there are a number of airports serving London. London Heathrow Airport is airlines' preferred airport. Its role as a major domestic and international hub has led to exhaustion of spare landing-slot/runway capacity. It has good road and public transport links to Central London—far better than links with the other major airports at Gatwick and Stansted. One component for making those airports viable alternatives to Heathrow involves providing excellent rail service links between those alternative airports and the hinterland (regional areas and Central London). The *Gatwick Express* and the *Stansted Express* are key upgraded rail services that form part of the policy counterweights that encourage airlines to transfer their services from London Heathrow to the alternative airports. The *Gatwick Express* upgrade is reviewed below, from page 104. A substantial *Stansted Express* service upgrade is sought, reducing transit time to London from around 47 minutes, to 30 minutes, known as the “Stansted in 30” proposal—see footnote 47.

Upgrades may also be sought in order to encourage regional development. A key driver for the project to upgrade four railway corridors in Victoria (see below, from p. 61) has been to facilitate regional development. The upgrading sought to support the trend of people “lifestyle changing” to regional areas, underpinned by improving the feasibility for long-distance commuting to Melbourne and for accessing city services.

The proposed upgrade of the London–Norwich rail service, known as “Norwich in Ninety” is another example. The objective is to reduce transit time between the centres, from 120 minutes down to 90 minutes. This will “drive growth in the [East Anglia] region”. The region is “establishing itself as a world leader in science, technology and manufacturing... [and] to support this growth we need to have modern, efficient rail services and improved connections”⁴(Osborne 2013).

⁴ A US study has argued that higher hotel and convention rates in city centres arise where the facilities are located near railway stations with airport train services. See American Public Transportation Association, US Travel Association 2013.

CHAPTER 2

The role of conventional railways

This chapter considers the evolution of railways and their changing role in the transport market. Internationally, rail services have lost ground to other modes of transport as those other modes evolved with new technology, as disposable income rose (with travellers preferring private transport over public transport) and settlement patterns evolved.

In some countries, rail has also adopted new technology—particularly by developing an important travel market niche using high-speed corridors—but this has incurred very high capital costs. Upgrading existing railways at relatively low capital costs may still enable railways to become more competitive. Indeed, contrary to common perceptions, the conventional railway is both substitute and complementary (integral) to high-speed railways; it is anything but “outdated”⁵.

This chapter considers the quest for higher train speeds, the roles of conventional and high-speed operations, as well as the value of other upgraded service attributes.

Evolution of upgrading through railway speeds

Railways have been on a process of technical evolution concomitant with their widespread construction in the nineteenth century. This evolution has resulted in increasing track and train capacities and train speeds. Advances in locomotive traction power (horse, steam, diesel and electric) have complemented rising track standards and systems. By way of illustration, Britain's pioneer Stockton & Darlington Railway commenced passenger operations in 1825, operating with average line speeds that were barely above 9 kilometres per hour⁶. By contrast, in the 21st century, modern built-for-speed railway systems accommodate trains averaging over 300 km/h⁷. See, also, UIC 2012 pp. 56–61, for an overview of train speed milestones.

Over the same period, rising standards of other modes, and an environment of increasing disposable income, more diverse settlement patterns and a constantly-improving road network, have made it more attractive to undertake both frequent and longer-distance travel using private motor vehicles rather than trains. The revolution in aviation technology and that mode's operating costs have provided potential for airline services to be a mass travel service provider for distances above 250 kilometres.

⁵ Sperry and Morgan 2011, p. 1.

⁶ Railway alignments were built to ease gradients (with locomotives having relatively little power to haul trains) and the cost-effective way of doing this was to have curved track. Modern, powerful, locomotives and relatively light passenger trains are suitable for higher — and, thus, straighter — railway alignments.

⁷ For a period after its opening in 2009, the non-stop trains on China Railways' Wuhan–Guangzhou High-Speed Railway averaged 313 km/h between the terminals.

Until the second half of the 20th century, the technical evolution of the passenger railway was essentially one of “gradualism”, with incremental technical improvements but with rail services continuing to lose ground (except, often, for commuter rail services). The fall in traffic levels undermined train economies of density, forcing operators to either withdraw services to save costs or to pursue new technology with the hope of reducing costs and/or enhancing services⁸.

More radically, the construction of new corridors of high-speed track in some countries has led to patronage growth and enhanced market share⁹. These high-speed railways are developed as *complements* to the existing railways (in terms of both speed and capacity) as well as *substitutes*; this aspect is considered in the next section.

High-speed and conventional railways

High-speed railway systems are considered “radical” because they require a new track corridor, bypassing the existing track alignments. At the heart of such systems is the complementary building of bespoke high-performance trains with new direct horizontal route alignments. Examples of this include built-for-purpose Japanese Shinkansen and French Ligne à Grande Vitesse (LGV) high-speed railways.¹⁰

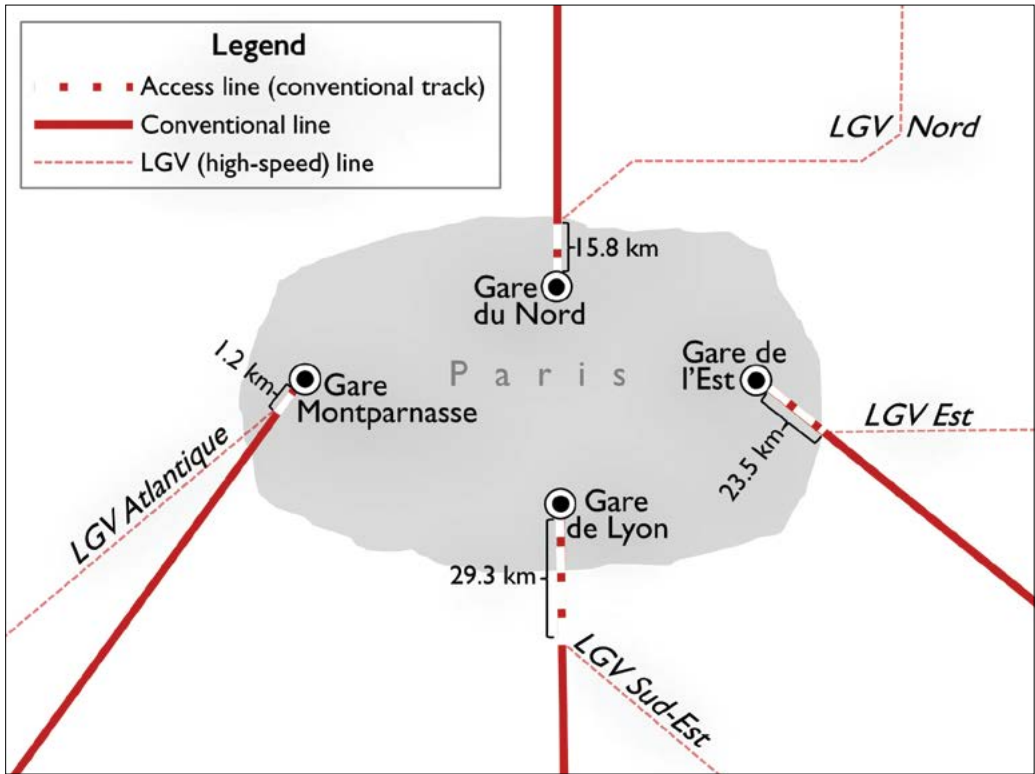
In many situations the radical system complements, rather than substitutes for, the existing railway network. In particular, existing railways are typically used to provide direct access for high-speed trains into city centres (rather than build high-cost new high-speed lines through those areas). By way of illustration, Figure 1 shows that the upgraded conventional urban railways lie at the heart of TGV services accessing central Paris terminals; high-speed (“LGV”) lines commence some distance from the central Paris terminals.

⁸ In their 1959 seminal review of the decline of passenger train services, *Trains* magazine focused on development of a low-cost train to “save” the passenger train. (See *Trains* 1959, pp. 36–39). This contrasts with subsequent developments based on both low-cost operations and service upgrading.

⁹ See Whitelegg, et al, p. 28, for further discussion.

¹⁰ It is also pertinent to note that a further radical evolution of the guided vehicle is the abandonment of steel wheel on steel rail, such as with the German Maglev (magnetic levitation) technology and the French Aérotrain (based on hovercraft air-levitation principles).

Figure 1 Use of conventional track in TGV service access to Paris terminals (schematic map; not to scale)



High-speed lines are also built to serve the conventional network, expanding the catchment areas for rail travel. Again, train services on conventional tracks are often upgraded to enhance the complementarity. As Potter notes:

What is often misunderstood is that the new lines in these countries [France, Italy and Germany] have been built to upgrade a much larger network of existing lines. For example, the new high speed 412 kms Paris–Lyon Ligne à Grande Vitesse (LGV Line) permitted a major upgrading of services on more than 1,600 kms linked into it. Although the 270 kph top speed of TGV can only be achieved on the purpose-built LGV line, this fast core trunk route has transformed rail travel over the whole of southern France (Potter 1993, p. 147).

Conventional tracks are used to access local locations, linked to high-speed railways that enable passengers to travel long distances in a short time. The high-speed section is a gateway to a range of destinations on existing track. Within limits, the longer the distance between the major population centre and the provincial cities, the more important it is to have high-speed operation¹¹. That said, the longer the distance, the higher the construction cost of building a new railway and the greater the competition from airline services.

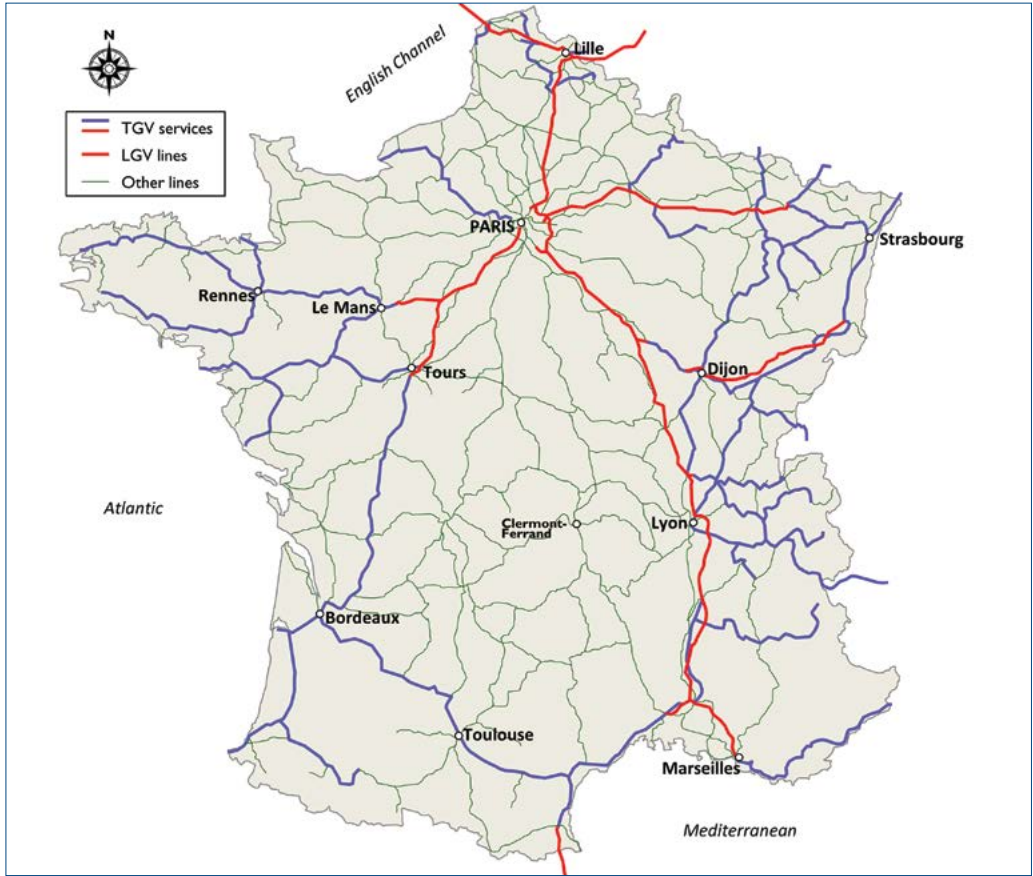
¹¹ As noted by Nash (2003, p. 22), the Californian high-speed train project is based on combining long sections of dedicated new high-speed tracks with use of existing tracks. Nash notes that the inclusion of dedicated new high-speed track arises from the fact that the major market (San Francisco – Los Angeles) is too long to be served simply by upgraded existing track/trains.

It should also be noted, however, that where non-urban distances are short, the high-speed trunk has less advantage over a conventional line because it saves *relatively* little time.¹²

Existing railways strongly complement dedicated high-speed lines and are substitutes for new high-speed lines.

Thus, blending the conventional network with high-speed spines means that conventional lines are upgraded to complement the development of high-speed services. In fact, two-thirds of the TGV train-kilometres is undertaken over conventional (or “classic”) lines (House of Commons 2011, p. Ev 245). As illustrated in Figure 2, the TGV high-speed trains operate along trunk routes using conventional track (the blue lines in the map) as well as the dedicated LGV (high-speed) tracks (coloured in red). Even on the network where the TGV services do not operate (the fine green lines), the conventional train services feed and are fed by the high-speed services, improving patrons’ overall door-to-door transit time.

Figure 2 French high-speed lines (LGV) and high-speed services (TGV)



¹² The relative strengths of high-speed and conventional tracks can be illustrated. A 60 km route served by a train averaging 60 km/h will take 1 hour to traverse the distance while a train averaging 240 km/h will take 15 minutes. With the same average speeds, a 120 km route would be traversed in 120 minutes, and 30 minutes, respectively. The high-speed operation in the longer corridor generates a relatively bigger impact (90 minutes, than 45 minutes). This time differential can be particularly important on corridors where there is the potential for commuting or other day-return trips.

Thus, high-speed operations are inter-spliced with conventional railway networks. Further, even high-speed railway corridors can include using “upgraded conventional” track as well as the new high-speed track. Indeed, high-speed routes often combine elements of conventional tracks, such as extensive use of existing railway rights-of-way by LGV routes on the approaches to Paris termini. This mixed-system of high-speed and conventional track is the rule, not the exception, in the case of the German InterCity Express (ICE) train service network: a network of existing railway corridors with key sections of new tracks¹³. Similarly, the proposed Californian high-speed railway system (San Francisco – Sacramento – Los Angeles) will use (at least initially) a “blended” railway. This network is to be anchored on a core of high-speed track inter-spliced with large lengths of conventional track; the latter will apply especially around urban and city-centre line sections. While the blending will add time (and reduce available capacity) on 186 km (one-quarter of the corridor’s route-km), it is estimated to reduce construction costs by around US\$30 billion (just under one-third of the original costs) (Johnston 2014a, p. 50).

In brief, then, upgrading existing railways can serve to complement high-speed railways as well as being a strategy in itself, as a lower-cost substitute for high-speed railways.

Thinking beyond train speed

When thinking of ways to make railway services more competitive, emphasis is often placed on the train’s speed, even though it is just one of a range of service quality attributes that attracts patrons. The overall attractiveness of the passenger service involves much more than the headline maximum train speed.

In the *first* instance, the concept of the train’s headline speed needs to be abandoned. As noted by Nash (2003, p. 37):

The name ‘high-speed rail’ may mislead people into thinking that high maximum speed is the objective, but customers care about total travel time, not maximum speed.

while it has been noted that

A high top speed is very expensive and doesn’t necessarily mean much. Total trip time and schedule reliability are more important. Crawling through yards and urban areas wastes tons of trip time, but can usually be fixed for far less money than the cost of high speed upgrades (Lind 2002, p. 60).

More generally, however, what matters is train service quality, *relative to other modes*, of which relative travel time is one component. The USA’s Federal Railroad Administration says a high-speed rail system is “intercity passenger ground transportation... that is time-competitive with air and/or auto for travel markets in the approximate range of 100 to 500 miles” [160 to 800 kilometres] (Federal Railroad Administration 1997, p. 2-1).

¹³ Proposals for a high-speed railway network in eastern Canada envisage a core high-speed railway linking Montréal, Ottawa, Kingston and Toronto, and with upgraded existing tracks beyond, to other cities. See <[www.hsl-canada.net/en/canada.php#The Corridor](http://www.hsl-canada.net/en/canada.php#The%20Corridor)>.

There are a number of key factors that impact on the attractiveness (or otherwise) of train travel:

- the time-competitiveness is for the **door-to-door journey time**, rather than simply the main mode distance;
- **cost** of travel (such as fares and fuel costs of the different mode options);
- **comfort** of the different modes;
- **reliability**; and
- **convenience** of the mode, measured mainly by the ability to travel at desired time (meaning, in public transport terms, high **service frequency**).

These factors are often “bundled” under the term the *generalised cost of travel*, with the cost being these travel characteristics converted to a monetary term for each transport mode. Apart from motoring costs and public transport fares, the travel time is a key element of the generalised cost of travel; service frequency (essentially waiting time for a preferred departure time) is another important element.

In a sense, then, upgrading services involves more than the high-speed rail (HSR) focus on speed:

“The goals for any major capital investment project are rarely unidimensional. However, in the case of HSR, the goals are not only multidimensional but also sometimes conflicting. While some focus on the need for the highest speeds, others argue that accessibility, frequency, and on-time performance are more important (basically, more efficient and reliable intercity rail). These different goals lead to very different markets, technologies, funding sources, and overall outcomes, with those focusing on speeds proposing new HSR and those focusing on other attributes looking toward incremental HSR” (Cerreño and Mathur 2006, p. 4).

Thus, “train speed”, or its counterpart “transit time”, is just one of the levers to enhance service quality and it is not necessarily the most cost-effective way to make services more appealing. For example, in its examination of upgrading the Quebec–Windsor Corridor, the Canadian Transport Commission concluded that the most cost-effective solution for enhancing public transport in the corridor was to undertake “modest investments in *existing track* in order to permit higher speed operation and more frequent service” (Soberman 1995, p. 97).

Hence, to achieve a reduction in the generalised cost of travel, it may be more cost-effective to increase service frequency than to reduce a train’s transit time through increasing train speed. For example, in the USA, the “*Capitals*” service between Oakland and Sacramento service commenced operation in 1990, with three return trips per day, rising to sixteen return trips in 2011; patronage rose from 864 passengers per day in 1991–92, to 4 640 per day in 2007–08. These gains have been attributed to increased frequency: “Instead of competing based on speed [which is essentially unchanged], the *Capitals* continue to draw riders with frequent, reliable service” (Clement 2011, pp. 101–02).

This example illustrates a major difference between investing in line upgrades and in dedicated new lines. In the case of new lines, the ramp-up in the service is essentially overnight. By

contrast, line upgrades are, by their very nature, incremental, with changes occurring over time as various stages or increments are completed.

Given the foregoing discussion, this review of service upgrading looks beyond train speeds. The first aspect investigates options for upgrading railway services. The second aspect looks at the travel markets where such upgrades could be directed. The third aspect is to look at local and overseas corridors where upgrades have been undertaken; this includes a review of the government policies that have facilitated such upgrades.

CHAPTER 3

Upgrading options

Railway service upgrading is undertaken in a range of areas and in systematic (programmed) project packages, as well as in piecemeal processes that are undertaken as infrastructure or equipment is renewed. As noted in Chapter 1, this report considers those systematic packages, which are undertaken to pursue given policy goals.

Just as the dedicated new high-speed railways attract monikers such as “High Speed Rail” and “Bullet Train”, so too are names assigned to upgraded railway projects; these include:

- High(er) performance rail;
- Accelerated rail;
- Accelerail;
- “Fairly Fast Train”;
- “Regional Fast Train”;
- Regional High Speed Rail;
- “Emerging High Speed Rail”;
- Shared-use high speed rail systems; and
- Higher Speed Rail (often denoted as “HrSR”).

These concepts are largely, but not exclusively, focused on providing passenger train services on essentially existing railways where the infrastructure has been upgraded to enable higher track speeds.

“Speed” is emphasised in these projects even though, as noted earlier, a broad range of service upgrade options can enhance conventional railway operations. In any case, track upgrades enhance passenger services but *other* upgrades can also increase average or top train speeds. These include raising track capacity, boosting train performance specifications, modernising signalling systems and communications standards and supplementing train services.

When determining which upgrades are most suitable, there are two fundamental parameters that determine the outcome:

- **Time-saving benefits from higher speeds are greater on longer distances than very short distances.** The length of the corridor needs to be sufficiently long such that the time savings are sufficient to attract travellers from other modes—savings on a short journey will be small and the consequently small time savings are unlikely to lure travellers to the rail service.

- **Travel time savings decline with higher base (pre-upgrade) speeds.** Accelerating average train speeds from a low base reduces total travel time by relatively more than a speed increase of a train that is already travelling fast. For example, for a 50 kilometre journey, a train averaging 50 km/h will take 60 minutes, but will save 10 minutes if its speed is increased by 10 km/h. However, a train averaging 150 km/h will save just 1 ¼ minutes on a 50 kilometre journey when average speed is raised by 10 km/h. Thus, the speed increase from 50, to 60, km/h is more effective in decreasing travel time than an increase from 150, to 160, km/h.

Another important element (considered further in the case studies) is that costs (construction and operating) of achieving higher speeds rises more than proportionately with increasing speeds¹⁴. Accordingly, it is not surprising that upgrades that increase the *top* speed are not necessarily the most cost-effective option:

...raising top speeds in a corridor may provide only one of many ways to reduce trip times but may not be the most cost-effective way. (Federal Railroad Administration 1997, p. 2-1).

Safely and comfortably raising average or maximum train speeds can be achieved by upgrading the existing railway infrastructure. There are a number of factors that determine the maximum speed of a train on a given railway. These factors include:

- the nature of the interface between the railway track and road networks;
- speeds dictated by track standards (quality and age of components and the existing track geometry quality).
- whether a train shares the track with a different type of train, notably, where passenger and (slower, longer) freight trains share trackage; and
- the signalling system and train control systems (active or passive).

Maximum permitted speeds are determined on the basis of these factors. In the case of the USA,

Top speeds and speed restrictions for all train operations, passenger and freight, are regulated by the Federal Railroad Administration (FRA), based on a well-established set of civil engineering criteria and a proven, necessarily conservative body of knowledge concerning the physics of railroad vehicle and track dynamics... The FRA classifies track condition and allowable speed over that track by a series of Classes. Each FRA Class carries with it specific standards for roadbed condition, crosstie [sleeper] and rail condition, maintenance and inspection, and alignment and consistency of the track surface. Two top speeds are normally quoted, one for freight train maximum speeds, and a higher one for passenger train maximum speeds. This recognizes the generally higher tolerances of passenger equipment to tipping and rolling stock condition, based on lower centers of gravity, lighter loads, and more frequent inspections. (TEMS, Inc., p. 3-26).

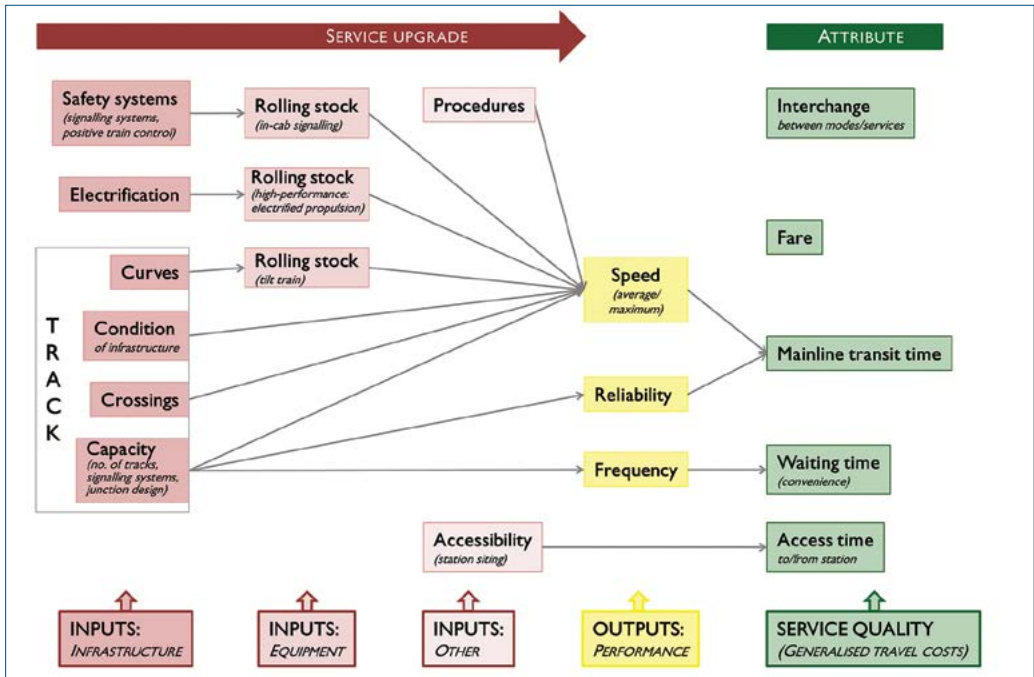
¹⁴ See Vuchic and Casello 2002, for further discussion of these aspects. Working in the opposite direction to these factors is the market-competitiveness of the service: to make the rail service competitive, it may be necessary to spend substantial sums of money in order to reduce transit time and/or enhance other service attributes sufficiently to divert patrons from other services. See page 34 for further discussion.

Upgrades are often complementary investments, which must all be undertaken in concert in order to achieve higher train speeds. For instance, to raise a train's speed may require the railway to be electrified and for level crossings to be removed, but investment in signalling and train control may *also* be required. Thus, the appropriate strategy may involve an evaluation of a set of upgrading options and it is a package of options that needs to be appraised.

In the following sections we consider the three principal forms of upgrade: those to the infrastructure, those to the rolling stock and those to the service. Figure 3 presents a simplified chart that illustrates the relationship between the service provider's inputs and outputs and service quality experienced by the traveller.

These three upgrade forms then impact on the “output”, or service quality/attributes of the service. These attributes are, in particular, those that influence the train speed, those that influence service frequency and those that influence service reliability. These service characteristics define, in particular, travellers' transit time and their waiting time, that is, their generalised travel costs (as discussed earlier, on page 10).

Figure 3 Simplified chart of service upgrade and market product relationships*



Note: * Some product attributes, such as carriage comfort, are not considered here but may be important factors in travellers' choice of mode.

The range of upgrade options, based around infrastructure, rolling stock and train service attributes, are now considered.

Infrastructure upgrades

Infrastructure can be upgraded using existing railways in three forms: to renew existing tracks, to substantially upgrade existing tracks, or to use the existing railway corridor to insert a new

(parallel) passenger railway—also known as a ‘dual-corridor’ operation. (Welty 1995, p. 10; Judge 2003, p. 35). Irrespective of the form chosen, there are common issues of level crossing standards, track standards, capacity levels and signalling and communications.

Railway–road interface (crossings)

The nature of the interface between railway and road networks is an important parameter that normally caps the train speed irrespective of railway track, signalling and communications standards. In the case of Canada’s Windsor–Quebec railway, Soberman concluded that the level crossing issue was “probably the single most important impediment to increasing speed on existing track” (Soberman, p. 101). The speed cap is in recognition of the heightened physical consequences for train drivers and passengers when road vehicles collide with trains.

The presence of level crossings can be a major impediment to service upgrading.

How the speed cap varies to reflect the risks associated with the interface is well illustrated by the regulations in USA. Irrespective of which class that the FRA assigns to the railway, the *default* maximum train speed is 79 mph (126 km/h) for a level crossing with warning bells. Higher standards of level crossing are required in order for trains to exceed this speed. Active level crossing systems (gates and signals, for instance) are required for speeds over 79 mph and up to a maximum 110 mph (176 km/h)¹⁵. Beyond 110 mph, a maximum speed limit of 125 mph (200 km/h) is permitted if a level crossing is fitted with a barrier device that guarantees against intrusion of vehicles onto the track. Speeds exceeding 125 mph are permitted only where there are no level crossings; the corridor is effectively sealed from external movements. (Nash 2003, p. 58; Johnston 2014a, p. 50) Similarly, in Canada the trains are limited to 144 km/h where trains operate on tracks with level crossings. In Australia, for example, passenger railcar (DMU) trains between Bendigo and Echuca are restricted to a maximum speed of 75 km/h due to the absence of active (light/bell) warning systems. Similar speed caps are applied in other countries.

To increase train speeds above given thresholds requires authorities/infrastructure managers to address the at-grade crossings. This can involve enhancing the type of at-grade crossing, closing the crossing or building grade separation between railway and road.

Depending on the site and their number, the cost of eliminating level crossings can be onerous. Even over extended distances, some railway corridors involve few level crossings; on other corridors the level crossing is a very common feature. For example, there are 324 crossings on the 454 km Chicago – St Louis railway (discussed as a case study, below, from page 134) while before its upgrade there had been 57 crossings on the 286 km Berlin–Hamburg railway (below, page 76), that is, one crossing each 1.4 km versus one crossing each 5 km.

While closing level crossings is a much lower-cost option for the railway than grade-separation, it inevitably leads to higher road-user costs and, consequently, strong opposition. In the case of the upgrading of the Chicago – St Louis railway, the project proponents aspired to close 28 per cent of the 324 level crossings (Travis 2000, p. 14).

¹⁵ Federal Highway Administration 2007, Section 4.

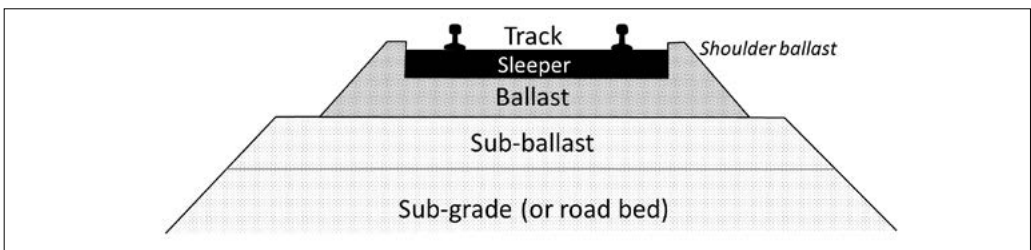
Track and route standards

Train speeds on existing track can be raised by improving track standards and route alignment. These improvements can be achieved in a number of ways, including:

- higher standards of the track sub-grade structure (see Figure 4);
- deeper ballast bed and shoulder ballast;
- stronger sleepers, such as concrete (instead of wood or steel) sleepers¹⁶;
- improved rail fasteners;
- use of heavier, continuously welded rails instead of jointed rails;
- high-speed turnouts (i.e., switches or points); and
- strengthened bridges.

These standards must be accompanied by more thorough and frequent inspections and remedial actions to ensure the resilience of track performance and strength of track geometry alignments.

Figure 4 Key components of railway track structure (not to scale)



Given the service frequency and reliability requirements of passenger services (especially on high-quality infrastructure), it might be expected that less engineering attention would be required. However, while higher standards can reduce the intensity and frequency of maintenance possessions it does require a higher degree of inspections and spot maintenance.

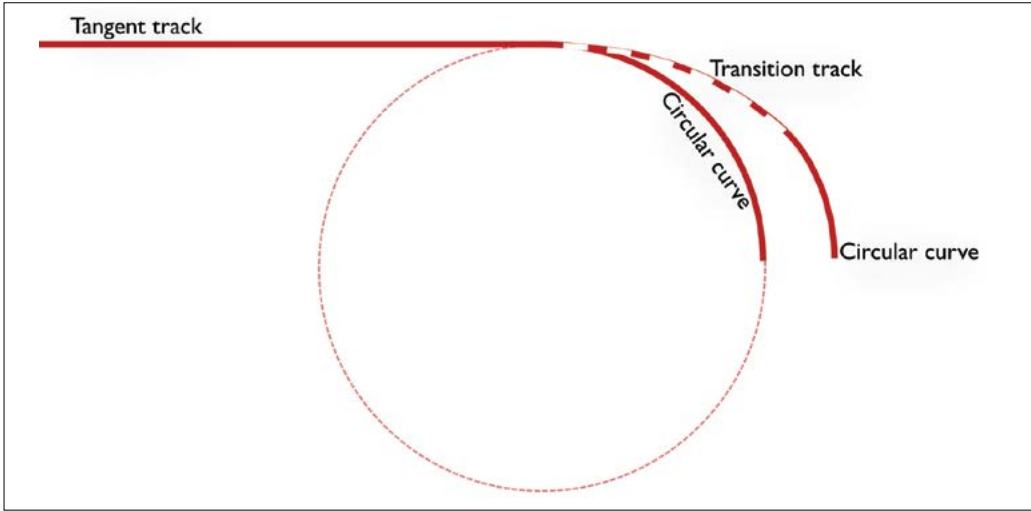
Speeds can also be enhanced by improving railway route alignments:

- reducing the extent of curved track and easing track curvatures; and
- reducing route lengths between any two destinations arising from historically-circuitous routes.

The curvature format is an important parameter that influences carriage stability and, thus, the maximum speed. In particular, a subtle, but important, element of curved track is the “transition curve”, which is the eased curve that lies between the straight track and the full curve around the corner. (The tighter circular curve in Figure 5 should be avoided; the transition track *gradually* increases the track radius from zero through to the desired radius). Thus, as Gostling notes, the “ultimate speed limitation is usually to do with irregularities in curves, in particular the transition which even when perfectly maintained provides a roll input to passengers which cannot be compensated...” (Gostling 1998, p. 701).

¹⁶ Lichtberger notes that it is essential to use heavy prestressed concrete sleepers if long lengths of welded track are to be introduced (Lichtberger 2005, p. 167). The weight of concrete over timber sleepers provides better resistance to movement, a tendency that can arise with train movements or with the impact of temperature changes on rails (which has a greater effect on continuously-welded rail than on short-length jointed rail).

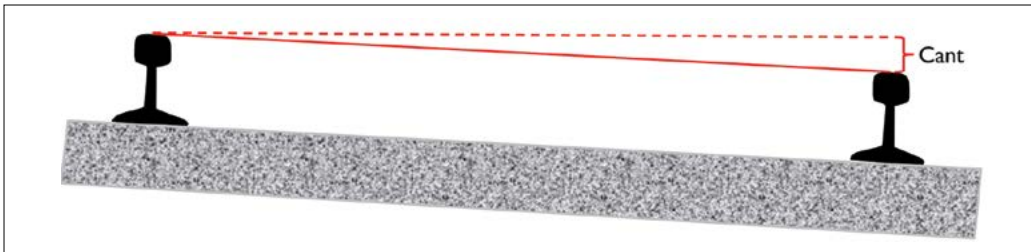
Figure 5 How transition track is used to ease train movement through curves



However, it can be very costly to ease track curvature and build more direct routes¹⁷. For example, 5 per cent of Victoria's *Regional Fast Rail* project's infrastructure budget was forecast to be absorbed in building one curve-easing/route-shortening deviation (the Bungaree Deviation on Victoria's Ballarat line) even though the deviation represented less than 1 per cent of the distance covered by the State-wide service-upgrading project. That said, the deviation saved almost 5 route-kilometres of distance and saved almost 5 minutes of travel time as well as adding line capacity¹⁸. That is, track- and route-alignment easing projects can deliver notable benefits but they also absorb substantial levels of project funding.

An alternative to building new alignments to replace tight curves is to “**bank**” (*cant, tilt, or “super-elevate”*) the railway track, meaning that the outer rail of the track is positioned higher (vertically) than the inside rail—see Figure 6. The banking provides a degree of offset to the train's centrifugal force in the curve with an offset in the carriage's centre of gravity¹⁹. Because the banking can reduce passengers' discomfort going through curves, the desired train speed can be raised.

Figure 6 Illustration of banking — or canting — railway track



For a given curvature of track, train speeds can be increased with rising banking (super-elevation), as shown in Table 1. This table shows a matrix of banking (super-elevation) versus

¹⁷ In any case, there may be limited opportunities for improving alignment without undertaking land purchase.

¹⁸ Transit Australia 2000 (for project distances); Hansard (Parliamentary Debates), 27 August 2003, for cost estimates.

¹⁹ Paraphrased from TEMS 2007, p. 3-28.

passenger train reference speeds. Clearly, the more curvature there is on a given route, the more it may be possible for track banking to allow trains to operate at higher speeds and, thus, reduce transit times.

Table 1 Passenger train reference speeds, with super-elevation (cant), km/h

| Banking (or “Super-elevation”), cm | Degree of curvature of track | | |
|---------------------------------------|------------------------------|-----|-----|
| | 1 | 2 | 3 |
| 0 | 149 | 104 | 85 |
| 2.5 | 160 | 114 | 93 |
| 3.8 | 166 | 117 | 96 |
| 5.1 | 171 | 122 | 99 |
| 7.6 | 181 | 128 | 104 |
| 10.2 | 192 | 136 | 110 |
| 12.7 | 200 | 142 | 115 |
| 15.2 | 210 | 149 | 122 |

Notes: Derived from TEMS 2007, p. 3-29. Data are converted from imperial units and rounded to one decimal point. Increased severity of line curvature is represented by higher degrees of curvature of track.

However, the application of track banking is circumscribed where the fast train shares the track with slower and heavier trains:

- A high degree of banking can be tailored to suit fast trains but that banking is unsuitable for slow local passenger trains as the banking would be too great for the train speed, resulting in passengers feeling discomfort as they would feel unbalanced.
- Banking that is optimised for fast trains will be excessive for slow freight trains and this creates the potential for top-heavy wagons to overturn. In addition, when traversing the banked track, the freight wagons would place undue pressure on the lower rail; this would cause extra wear on the rail and incites a shift of the track bed. Such consequences require additional maintenance; they have adverse safety consequences in extreme circumstances.²⁰

Because of these issues, on shared track the degree of banking that can be applied is constrained. (The similar application of **train** banking is considered below (page 25)).

Track capacity

Of the infrastructure components, track capacity is often the main impediment to service upgrading. There must be sufficient capacity to enable transit time reduction (by raising train speeds), to increasing service frequency, and to ensuring reliable services²¹. Capacity on railway tracks can be enhanced in a number of key ways:

- adding additional tracks;
- upgrading signalling systems;

²⁰ Soberman observes that “if high speed trains use a track that is not adequately banked, there is a safety hazard. If a slow freight train uses a track that has been banked for high speed, there is a tendency for the train to “fall off” the track or, at least, severely damage the lower rail” (Soberman 1995, p. 101).

²¹ Note that track capacity may constrain supplying extra train capacity through additional trains but, nonetheless, it may be possible to supply additional train capacity by operating longer trains.

- improving the efficiency of track layouts, especially at junctions and stations²²; and
- influencing the allocation of track capacity between trains of different operating characteristics.

Limited track capacity can often be the primary impediment to service upgrading.

Where land is available and where it is practicable, track capacity may be expanded within the existing land corridor by building additional passing loops or adding additional parallel tracks (such as expanding a single-track railway to a double-track railway). Alternatively, additional tracks may be added on newly-acquired land. Box 2 illustrates urban projects where track capacity has been added within existing corridors.

Box 2 Expanding capacity on existing railway corridor land

Recent Australian examples of track capacity amplifications within existing railway corridor land are:

- Track quadruplication on Sydney's **East Hills Line**, undertaken between 2008 and 2013. Two tracks were added to the 6.5 km twin-track railway within the existing railway land corridor between Kingsgrove and Revesby stations on the East Hills Line in suburban Sydney. The new track alignments passed around four intermediate passenger stations. The budgeted cost was \$774 million. One important benefit of the capacity enhancement is the ability to isolate stopping services, enabling express trains to continue unimpeded (Legislative Assembly NSW 2010, p. 23621).
- Additional freight line, southern Sydney. The 36 km single-track **Southern Sydney Freight Line** was constructed during 2009–12, costing \$1 billion. The line provides freight train access to inter-modal and port railway lines, unimpeded by freight train curfews during passenger train peak periods. The new track was added almost entirely within existing railway land. Complexities included issues with working around or shifting utilities; and fitting the line around 11 passenger stations.
- **Regional Rail Link** project, Melbourne, under construction since 2009. Part of this 47 km corridor project involves adding two tracks largely within the existing 12 km railway corridor between Melbourne Southern Cross station and Sunshine. Separate budget costs for this part of the project are not available. The locations for the new tracks are shown in Figure 16.

²² The Sydney Rail Clearways investment programme illustrates how changing layouts can improve track capacity. The stated aim of the programme is that it "will remove bottlenecks and junctions, reduce congestion and delays, and allow for simpler timetables for more reliable and frequent services". <www.transport.nsw.gov.au/projects-rail-clearways-program>.

Figure 7 Track capacity expansion, Watermark, NSW

Note: Construction of a new crossing loop, Watermark, NSW.

Source: Photograph courtesy of John Hoyle.

It is possible to enhance track capacity by revisions to the interface between slow and fast trains; revisions include changing track layouts to separate slow and fast trains and by re-scheduling services. Box 3 provides an illustration of capacity enhancement using reconfiguration of track layout. In general, operating trains at similar speeds involves less use of track capacity than where trains operate over a range of speeds. Major speed differentials between trains undermines capacity on the railway. The speed differences are accentuated where there is steeply-graded trackage because, while modern fast passenger trains have high performance²³ that enables them to ascend such tracks with ease, the older passenger trains and (especially) freight trains will operate over the grades at much slower speeds relative to their performance on flat alignments.

Box 3 Capacity enhancement by train separation: Sandgate, NSW

The flyover bridge at Sandgate, near Newcastle, NSW, was built in 2005–06. The flyover separates coal freight trains from other, principally passenger, trains. The flat junction between lines at this point had previously capped the potential coal throughput to the Port of Newcastle. The bridge removed conflicting movements of coal trains across the site, removing the track capacity constraint and improving train reliability (House of Representatives 2006, p. 13).

²³ High-performing passenger trains have high power-to-weight ratios, enabling sustained high speeds and high rates of acceleration.

Mixing fast passenger services with slower commuter and freight trains creates capacity, scheduling and reliability challenges that can stymie upgrade options.

Service rescheduling and re-prioritising is an operational approach to raising track capacity for specified trains. That is, fast passenger train capacity is achieved at the expense of other track users. In general, mixing fairly fast trains with (slower) commuter trains or freight trains creates capacity, scheduling and reliability challenges. The Federal Railroad Administration (FRA) in the USA has noted that its upgraded intercity train concept ("Accelerail") normally represents both the least costly High Speed Ground Transport (HSGT) option and "relatively high benefits" but its success normally relies upon using a private freight railway, requiring balancing the high-speed passenger priorities with the predominant slow, but time-sensitive freight usage²⁴ (Federal Railroad Administration 1997, p. 3-11).

Upgrading railway services normally requires upgrading of signalling systems.

There is a cost of fast train prioritisation. While freight and other track users impede efforts to accelerate passenger trains, it is worth inverting this issue: prioritising faster passenger trains, and absorbing track capacity with such trains, can adversely affect the productivity, reliability and viability of other track users (such as freight operators).

Faster passenger trains absorb track capacity and reduce freight priority, adversely affecting those operations.

Irrespective of railway working timetables, if the track manager is not the upgraded passenger service provider then *in practice* it may be that upgraded passenger services does not receive priority use of the track. Taking control of the allocation of track capacity may be a required strategy. For example, the US passenger train operator, Amtrak, has leased the "Hudson Line" in New York State from a freight railway company, CSX; this "ensures that passenger rail service has scheduling priority" and also enables infrastructure upgrades²⁵.

Signalling/communications and train control systems

Investment in upgrading conventional railways avoids much of the high construction costs in building new railways. However, as maximum speeds increase, the conventional railway needs to conform to the same high-specification signalling, communications and train control systems that apply to the high-speed railway. As noted above, these systems can also be important in expanding track capacity.

Two fundamental upgrades are required for signalling/communications and train control systems in order that train speeds be increased:

²⁴ See, in particular, Transportation Research Board 2009.

²⁵ Cuomo, A M 2012, "Governor Cuomo announces Hudson rail line lease", Press release of 4 December: <www.governor.ny.gov/press/12042012-hudson-rail-line-lease-announcement>.

- at high speeds the trackside signalling and signs are inadequate as a device for communicating information to the driver about authority to proceed and maximum required speeds; in-cab signalling becomes essential²⁶; and
- reliance on the driver to respond to the signalling directions shifts to external train control systems—ultimately, these over-ride and enforce train movement instructions if the driver fails to adhere to directions.

Oversight of train movements also increases in importance with rising speed differentials between the traditional and upgraded services.

In essence, railway signalling, communications and train-control systems are different aspects of the same overall safety task. For instance, line-side and in-cab signalling are forms of communication, conveying safety-related information to drivers from traffic controllers. At their simplest, train control systems advise drivers passively as to whether the train can proceed further along the track at pre-determined speeds for given track sections; increasing degrees of sophistication involve advising drivers as to the speed at which the track may be traversed at a particular time. Ultimately, advanced remote train control system can be set to include remote over-riding of drivers' controls. Some train operations (not high-speed) are, in fact, driverless, with the trains being driven remotely.

In a practical sense, then, upgrading railways to operate at higher speeds leads to the need — or requirement — that investment be undertaken in upgrading signalling systems that are little (or no) different from those used on high-speed railways. For example, raising maximum train speeds in the USA is conditional upon increasing the signalling standards; to operate speeds above 80 mph (128 km/h), trains must have Automatic Train Protection (where an electronic system overrides the driver when the latter is driving above authorised speeds or has ignored signals).

Systems of active train control (rather than passive situations which rely on the train driver to respond to all signals—which the driver may inadvertently not do) are increasingly required with increased passenger train speed and for all train operations where passenger and freight trains share tracks. The USA's *Rail Safety Improvement Act of 2008* requires most of the country's railways to install Positive Train Control, to actively prevent (enforce) trains from undertaking unsanctioned movements²⁷.

While such requirements are anything but low cost, the signalling upgrading can (but not necessarily will) lead to improvements in track capacity. Nash (2003, p. 61) notes that the advanced signalling is required to provide safety needed for the greater speeds, but that the advanced signalling specification is also required for the high capacity, flexibility and reliability that is demanded when providing high-speed services.

²⁶ As train speeds increase, systems necessarily need to migrate from trackside signalling to in-cab signalling because train speeds become too high for the driver to reliably read the signal as the train moves along the track. Shifting signalling from trackside to driver's compartment does mean, however, that in-cab signalling would then need to be applied to both the fast train and to all other trains on that track.

²⁷ See further discussion on Positive Train Control below, p. 136, footnote 121 and Government Accountability Office 2010, p. 2.

Rolling stock upgrades

Upgrading rolling stock is the second key input to increasing train performance, essentially complementing track upgrades. Trains can be built to operate on existing track at higher speeds than conventional trains. Raising speeds on conventional track requires more complex trains, but it has been recognised that upgrading has a role to play because “there will always be a threshold of passenger traffic below which it is simply not viable to build even a limited amount of new high speed line” (Potter 1993, p. 161).

Upgrading rolling stock — traction power and carriage handling — can facilitate trains operating at higher speeds on conventional track.

A range of train performance enhancement options have been developed. These include:

- **traction power upgrades**, such as shifting from diesel-electric propulsion to electric propulsion, increasing train speed and acceleration;
- **improved carriage handling** at speed through developments in bogies (carriage wheel frames), raising the maximum speed that can be safely reached; and
- **introducing innovative carriage-handling systems**, which further enhance carriage handling through changing train centrifugal forces on curves.

These are now reviewed.

Traction power upgrades

Higher average train speeds can be achieved through the use of propulsion that can achieve, and sustain, high speeds and accelerate quickly.

A key performance differential is between diesel-electric propulsion and electric propulsion. A typical maximum speed for diesel-electric trains is between 200 and 225 km/h. Modern electric propulsion can deliver much higher speeds, and which can be sustained over much longer distances — and with better acceleration. Across the world, electric trains are propelled by a range of different forms of electric power, although the 25 kV, 50 Hz AC power is regarded as providing the best overall performance.

Improved carriage-handling

Modern wheel-set and carriage designs can be used, with good maintenance, to facilitate high train speeds. Ultimately, whether the track is straight or curved, the train's design speed requires good riding performance and stable running.

Until the 1960s, there was a cap on higher train speeds because carriage-handling issues developed; these arose irrespective of track standards or route alignment (whether the track was straight or curved). As train speeds approached 160 km/h, railway carriages rapidly became unstable on the track. The condition arose because sideways oscillations of wheels between the rails (called “hunting”) increased with rising speeds.

A method for removing carriage-handling instability was identified by Alan Wickens at British Rail, involving improved suspension systems on the bogies. Modern railway carriage and wagon frames are normally attached to twin-axle wheel sets, known as bogies. Resolving this problem enabled train speed limits to be increased on conventional and high-speed railways, with speeds up to 515 km/h being achieved.

Innovative carriage-handling systems

Poor railway track alignments — at its worst, large proportions of tightly-curved track — is an important impediment to raising train speeds, irrespective of other beneficially-high standards. Innovative carriage-handling systems can deliver marked speed improvements on such railways without requiring route realignments.

Poor carriage (and wagon) handling on curved tracks constrains the safe speed of trains. Lower speeds are required:

- to ensure that the train does not roll over sideways off the track; *and*
- to reduce passenger discomfort arising from strong centrifugal forces that grow with increased speeds²⁸.

This issue does not arise on built-for-purpose high-speed railways because their track alignment is straight or has very shallow curvature (large curve radii).

As noted above (page 19), an option for reducing passengers' discomfort from the centrifugal forces is to **“bank” (tilt) the railway track**²⁹ — the outer rail of the track is positioned higher (vertically) than the inside rail. Where the degree of banking is designed for high speed movement through curves, however, it is less suitable, or is unsuitable, for trains operating at other speeds.

An alternative approach to banking the infrastructure is to **“bank” the train itself**, with the train leaning into the curve³⁰. This tilt is demonstrated in the photograph at Figure 32, p. 100. An instrument measures the lateral acceleration on curves and the required carriage body tilt is then calculated and applied. Trains can travel at higher speeds through a curve because the tilt reduces passengers' feeling of centrifugal forces on curves and so it moderates their discomfort. Speeds are also higher before entering the curve and after leaving the curve: trains are not having to slow down to the same extent before entering a curve nor accelerate after coming out of the curve. The potential speed enhancement is constrained, however, when curvatures are very tight or when the route has a lot of reverse curves (such as s-shaped or “reverse” curves)³¹.

A range of “tilt” trains have been introduced since the 1970s, with two basic tilt mechanisms³². With the passive tilt, the train tilts in response to moving into a curve; with an active powered tilt, the systems within the train anticipate the curve so the carriage tilts with the curve rather than in response to the curve. Passive tilt mechanisms deliver more modest speed gains,

²⁸ These centrifugal forces increase with tighter curves and higher train speeds.

²⁹ This is also known as “cant” or “superelevation”.

³⁰ In practice, where tilt trains operate the track infrastructure is often also banked.

³¹ As noted by Harris, et al (1998, p. 3), the “tilt calculation and actuation takes some time, producing some lag between [the train] entering the curve and forces being correctly compensated”. For this reason, the attributes of the “transition curve” (the eased curve that lies between the straight track and the full curve around the corner) is important. Transition curves may be poor; or absent, with reverse curves.

³² Pioneering tilt trains include (West) Germany's ET 403, British Rail's Advanced Passenger Train and the Spanish *Talgo “Pendular”*.

with up to 3 degrees of tilt to either side, compared with active tilt mechanisms with up to 8 degrees of tilt³³. For example, the Talgo Pendular tilt train uses the passive system while the Alstom Pendolino family of tilt trains and the Bombardier X 2000 train use active tilt technology³⁴.

The train tilt mechanism does not alter the top safe speed limit that a train can pass through a given track radii³⁵. However, trains can go through curves at higher speeds that are still below the safe speed. What the tilt mechanism does is to raise passengers' comfort threshold closer to the safe track speed limit (which are a function of vehicle stability and lateral track forces (Harris et al 1998, p. 3). See Appendix A for a further discussion of the principles of tilt trains.

Safe train speeds can be raised by using bogies with flexible steering. The bogie—the support frame for the wheels (and containing the carriage suspension system)—normally consists of two axles. The bogie normally sets the two axles in rigid formation, that is, running parallel; a consequence is that on curves the wheels on the axle can be cutting into the rail. Thus, “in a curve at high speeds, the conventional rigid structure increases the chances of wheels climbing over the rail”. By contrast, independently-steered axles—meaning that the axles are not necessarily parallel—provide better alignment of wheel and rail. As a consequence, the steering mechanism (applied to tilt trains such as the X 2000) “allows the train to be driven at 70 miles per hour [112 km/h] into curves that most trains round at 50 miles per hour [80 km/h]” (O'Connor 1993, p. 64). The manufacturer indicates that the self-steering bogie also allows “a substantial increase in operating speed on straight track”³⁶. Such systems can result in dramatic reductions in the wear of wheels and rail profile³⁷, reducing maintenance and renewal costs.

In essence, tilt train technology focuses on increasing average speed, not increasing top speed.

The benefits that a tilt train can deliver are very route-specific because of the specific limitations of the application of tilt mechanisms and because of varying route curvature. Net benefits are greatest when tilt trains are operated on routes with a high degree of circuitous track, *albeit not curves with very small radii or where there are large numbers of reverse (notably, s-shaped) curves or where there are poor quality transition curves.*

A range of time savings across tilt-train upgrade projects is illustrated in Table 2. As would be expected from the foregoing discussion, there is a wide variation in transit time reductions, ranging from 12 per cent to 33 per cent. It is very important to stress the authors' qualification that these reductions *may* include other (relative) forms of upgrade of train or track.

³³ Harris, et al (1998, p. 3) note that the benefits from tilt encounter diminishing returns as the angle of tilt increases. For example, on Britain's West Coast Main Line, an increase of tilt from 3 degrees to 6 degrees can save 45 minutes but an increase from 6 degrees to 9 degrees can save only a further 10 minutes.

³⁴ Talgo Pendular <www.talgo.com/index.php/en/pendulacion.php>; Alstom Pendolino <www.alstom.com/transport/products-and-services/trains/high-speed-train-pendolino/>.

³⁵ Lichtberger notes that tilt trains can permit train speeds in curves to be increased by up to 40 per cent — up to 40 km/h. Thus higher speeds can be achieved without new track alignments. Lichtberger notes, however, that increased maintenance is required as the tilt system brings increased stress on the track system. Tilt vehicles are also more costly (around 5 to 12 per cent) and their maintenance costs are increased (by 3 to 5 per cent) (Lichtberger 2005, p. 360). Note, however, that the tilt mechanism has no practical advantage over conventional trains where the alignment is straight.

³⁶ The axles are kept in a radial position to a curve. See Bombardier, web site <www.bombardier.com/en/transportation/projects/project.x200-sweden.html?f-region=europe&show-by-page=50&page=1&f-country=se&f-segment=all&f-type=all&f-name=all>; www.bombardier.com/en/transportation/projects/project.x200-sweden.html?f-region=americas.

³⁷ See Elia 1998, p. 9.

Table 2 Transit times for conventional trains and tilt trains, by route

| City A | City B | Distance (km) | Transit time (minutes) | | Qualified time difference* | | Type of tilt train |
|-------------|-------------|------------------|---------------------------|------|-------------------------------|------------|-----------------------|
| | | | Conventional | Tilt | (minutes) | Percentage | |
| Saarbrücken | Frankfurt | 221 | 177 | 150 | 27 | -15 | VT 611 |
| Stockholm | Göteborg | 453 | 285 | 190 | 95 | -33 | × 2 |
| Stockholm | Malmö | 616 | 370 | 260 | 110 | -30 | × 2 |
| Milan | Rome | 605 | 300 | 252 | 48 | -16 | ETR 460 |
| Milan | Domodossola | 125 | 92 | 71 | 21 | -23 | ETR 460 |
| Milan | Como | 46 | 38 | 30 | 8 | -21 | ETR 460 |
| Rome | Bari | 503 | 322 | 257 | 65 | -20 | ETR 460 |
| Helsinki | Turku | 200 | 120 | 88 | 32 | -19 | S 220 |
| Helsinki | Seinäjoki | 346 | 190 | 130 | 60 | -22 | S 220 |
| Nürnberg | Bayreuth | 93 | 72 | 57 | 15 | -21 | VT 610 |
| Nürnberg | Hof | 167 | 125 | 101 | 24 | -19 | VT 610 |
| Madrid | Burgos | 282 | 178 | 157 | 21 | -12 | Talgo Pendular |

Note: * EcoTrain state that “the reduction of travel time may include higher speeds of tilting trains (also on straight tracks) and other upgrading measures.

Miller (2012) estimates transit times for a range of destinations from Sydney, using existing rolling stock, tilt-train stock and tilt-train stock with track upgrades.

Source: Data extracted from Table 3 in EcoTrain 2010, p. 28. EcoTrain themselves extracted the data from a 1998 report.

Choosing tilt trains results in higher train capital costs and higher track and train operating costs than when non-tilt trains are used. Implementing and maintaining good track condition is necessary for tilt trains: “the introduction of tilting trains presupposes a strong track structure with perfect track positioning” (Kottenhahn 1998, p. 85). EcoTrain (2010) identified higher capital costs of the trains (around 15 per cent), additional train maintenance costs (around 8 per cent due to the tilting mechanism, plus 7 per cent for other additional train maintenance tasks) and additional track maintenance costs (unstated uplift).

While the train’s tilt is intended to facilitate passenger comfort as the train passes through curves, there have been some reports of passengers experiencing motion sickness on tilt trains. Reports of passenger discomfort on a tilt train trial between Sydney and Canberra — see page 54 — might arise in part to the fixed carriage seating, which prevented passengers from facing the direction of travel, which is the conventional format for NSW country trains.³⁸

Other rolling stock upgrades

Improved train braking systems is a further approach to enhancing rolling stock performance. Trains operating at higher speeds still need to be capable of stopping within the existing signalling distance; raising the braking distance requires costly alterations to signalling systems and reduces line capacity. Technology can be applied to rolling stock to ensure that the trains can be accommodated within the existing signalling system. The technology focuses on improved adhesion techniques (Gostling 1998, p. 703–04).

³⁸ See Persson (2010) for further discussion.

Finally, safety regulation may require higher structural standards for rolling stock that operate at given speeds or when sharing tracks with freight trains. This is particularly relevant to rail safety regulation in the USA, where passenger trains must be built to a very high structural form so that the integrity of the carriage is highly likely to be retained, even in the event of a collision with a freight train. This standard applies irrespective of the train's maximum intended operating speed. These standards are jurisdictional-specific and it is notable that the TGV-based *Acela Express* train (operating on the mixed passenger–freight railway between Boston and Washington) is twice the weight of the train operating in France. A former chairman of Amtrak, the operator of the *Acela Express*, has referred to the train as “the high-velocity bank vault”, in reference to its (over) sturdiness (Dao 2005).

Service upgrades

A third approach to enhancing passenger train services is to upgrade the train operations. As noted by Nash, it is not the speed of the train, *per se*, that is the key to customer interest in high-speed trains; instead, customer interest is in the door-to-door time (relative to other modes) (Nash 2003, p. 14).

Ultimately, travellers are interested in the door-to-door travel time, not the top speed of the train, *per se*.

Door-to-door time

Service upgrades that reduce that door-to-door time can involve:

- increased service frequency (reducing the average waiting time between services)³⁹;
- introducing/increasing express train services;
- closing/omitting stations with relatively low patronage; and
- altering train routes.

Financially, these may be relatively low capital-cost options but they can involve other obstacles. One reason why proposals for upgrading Canada's Quebec–Windsor line did not proceed was due, in part, to the reluctance to omit intermediate stations (Soberman, p. 97). Yet, as Nash notes, “trains that stop and start frequently never reach their maximum speeds or reach it only for a short period of time. For planning purposes, this means that [fast train] systems are not cost effective on lines with frequent station stops” (Nash 2003, p. 14). Thus, in physical terms, it may be possible to accelerate train schedules but a plethora of stations — whether well-used or not — can stymie upgrading plans.

Where trains *do* stop, time can be saved by ensuring that station dwell times are kept as low as practicable. The characteristics of train designs affect the dwell times. For example, the number of doors on a carriage influences loading and unloading rates as does availability and location of luggage-storage. Similarly, station dwell time with Britain's High Speed Train (HST) services are protracted because the train is equipped with manually-opened and manually-closed “slam”

³⁹ Other, *non-travel* time upgrades include higher rolling stock standards (such as more comfortable seating) and more comfortable seating.

doors; the door closing process can be protracted as passengers struggle to close the doors or, indeed, fail in their duty to shut the door on passing through it. Embarking passengers at French railway stations are provided with information showing where the carriage with their reserved seat is located; this reduces station dwell time by encouraging passengers to be at the correct location on the platform, cutting delays arising from passengers walking along the platform to locate their carriage.

Frequency

While service frequency is, in itself, not travel time, it does have close connections with travel time. The service frequency determines how long a passenger waits for a train, and how closely the train departure (or arrival) is to the passenger's preferred time. Passengers' perceptions of service frequency are therefore closely related to their perceptions of journey time.

Service upgrades should see frequency as a component in travellers' journey time.

“Good” service frequency is a cornerstone of the upgrading of conventional railways. In the case of Amtrak's Boston – New York – Washington service, for instance, the company sees service frequency as central to its strategy for the corridor. The objective is to triple the number of services between Boston and New York, while on the New York – Washington link services would be five times their current level (Amtrak 2012, p. 22).

Illinois has a similar emphasis on frequency for developing the Chicago – St Louis rail service to make it competitive with car travel—see the case study below, beginning on page 134. At present, car travel accounts for up to 97 per cent of all passenger travel on the corridor. In planning its high-speed service, the State authorities argue that a daily eight-train frequency is required so that the “typical traveler will think of being able to leave every two hours as similar to the auto's ‘anytime I want’” (Travis 2000, p. 7).

Reliability

Reliability — also described as “punctuality” — is a quality attribute that can be an important determinant of uptake of the service. As discussed by the International Transport Forum (2010, pp. 129–140), informing passengers of “live” delays and prevailing punctuality performance can enable them to mitigate against the worst of the personal impact of actual or potential delays. To this end, in recent years railway undertakings have published statistics on service punctuality. The statistics also provide a benchmark for the level of service-provider performance.

The publication of reliability statistics has, however, encouraged service providers to downgrade their services, by padding train schedules to provide a “reliable”, if “slow”, service. The operator has an incentive to degrade services in order to achieve punctuality thresholds and exceed benchmarks.

Thus it is important to note that upgraded services should be robust (reliable) but there should be concern when that comes at the expense of being slower.

Practical considerations for upgrades

Upgrading existing passenger railway services is a policy option, as too are building new lines or, indeed, in doing nothing at all. Upgrading can be seen as complementing sections of new railway or as a testing ground for establishing an economic or financial case for a new railway. That is, if modest investment in conventional track can achieve a given level of patronage then it provides good underpinning — reduces project uncertainty — for assessing the case for a new railway.

As outlined to date, there is a range of upgrading options. Foremost amongst the factors that determine the choice of upgrade arises where:

- there is relatively favourable call on funding and finance for an upgrade compared with new lines. Required complementary upgrades can be undertaken as funds are available (although this may postpone benefits until the package of those upgrades is completed);
- there is relatively easy political consensus for an upgrade compared with a new line's high finance costs and the adverse impact of corridor acquisition on constituents; and
- where the existing railways have adequate capacity⁴⁰, it may not be feasible to provide reliable higher-speed services when services are inter-weaved with (slower) freight and commuter trains, especially if access to train paths for those other trains is reduced.

In this context, it has been argued that Britain developed the Advanced Passenger Train (prototype of today's tilt trains) and the High Speed Train (hybridised in Australia as NSW Train's XPT train) because the country provided relatively low state support for railways and because of its legacy of over-capacity of trackage (Potter 1993, p. 147). Also, line upgrading has attraction where delineation of new corridors is challenging. This arises in Britain because of country's relatively high urbanised population centres are strongly affected by land acquisition and because of the aesthetic and environmental value placed on non-urban land.

In conclusion, working against railway upgrading policy can be the negative stances by the track owner, and track users, on the conventional track. Working in favour of railway upgrading policy can be the greater hostility to new line construction.

Upgrade packages

For benefits to flow, complementary upgrades may be required, e.g., higher train speeds may mean grade-separation of level crossings, new signalling and train control.

Upgrading can require multiple upgrade elements that are inter-dependent. Put another way, while some upgrades are stand-alone investments that deliver benefits, other benefits may flow only after a set of complementary upgrades has been undertaken. (This implies that evaluations need to be taken on a package of tasks when the benefits that flow from the upgrade are reliant on other upgrades being undertaken.) For example, following international safety practice, Britain requires in-cab signalling for trains operating in excess of 200 km/h; this signalling has not been installed on the London–Glasgow West Coast Main Line. Thus, the maximum line speed has been capped at 200 km/h even though the Pendolino tilt trains on the line are capable of 225 km/h, and the track has been upgraded for 225 km/h operation.

⁴⁰ That is, a new railway is not required in order to expand capacity.

Where existing track upgrades deliver benefits, they can underpin further investment (by providing support for the business case for further investment and reducing investment risk). For example, the staged upgrade of the Chicago – St Louis corridor enables authorities to assess the business case for further investment: “Full roll-out of the high speed rail plan will follow when market reaction — patronage response — to the first phase is assessed.” (Travis 2000, p. 5)

Concluding comments

In financial terms, there is rarely a case for investing in passenger railways as returns rarely cover outlays; however, there is often a stronger economic case for such investment (reflecting net economic benefits). If a decision has been made to consider service improvements, the option to upgrade services needs consideration first. One justification for upgrading railway services rather than adopting a radical approach of building new high-speed railways arises from the high construction and operational costs of those new lines. A second justification for upgrading, in the first instance, is that the market response to the service upgrading can build the case for subsequent incremental — or wholesale — high-speed line construction. The financial and economic risk of such line construction is greatly reduced because line upgrading demonstrates that there is a market for better railway services.

The case against upgrading options can be built from affected parties, such as road users (when level crossings are closed) and from railway entities (the track owners and train operators who fear that their own trains will be side-lined).

We have discussed different infrastructure, rolling stock and service upgrade options, although the options are not necessarily mutually exclusive. For example, introducing a higher-performance train may be an investment that is necessary to increase train speeds, but it may not be a *sufficient* investment — investment in additional track capacity, enhanced signalling and elimination of level crossings may also be required.

Because individual upgrades can be necessary but not sufficient upgrades, the individual service upgrade option is likely to be appraised within a bundle of complementary investments.

A consequence of this inter-dependence between upgrade options is that individual upgrade options are likely to be evaluated as part of a collection of investments. That is, achieving the benefits from incremental improvements requires multiple investments. This has implications for the overall budget required to achieve a given service upgrade. Investment appraisals would therefore require a number of upgrade bundles to be considered, against the “do nothing” base case.

CHAPTER 4

Market aspects of service upgrading

This report considers the broader travel market for service upgrading. In the first instance, the travel market can be described by the physical markets served:

- regional;
- intercity;
- commuter; and
- airport.

Railway services are aimed at a range of different travellers and population centres, travelling for various reasons. A service can carry any of those travellers but will have service patterns (speeds, timetables, station stops) that focuses on those specific travel markets. Operations serving overlapping markets are likely and, indeed, desirable from a revenue perspective⁴¹.

In the following sections, the role of service upgrading for each of these markets is discussed, together with the objectives underlying the desired shift to railway services.

Regional and intercity

The traditional role for fast train services is intercity travel. As time/distance between cities increases, the dominant public transport mode shifts from conventional rail to high-speed rail, to air services. This intercity travel *market* represents a range of different travel *purposes*, broadly described as business and leisure journeys, for activities including business meetings, visiting friends and relatives, and long or short-break holidays by local and international travellers.

In the Australian context, the regional travel market is subtly different from the intercity market, being based around modestly-sized provincial centres that are linked to a major city. Similar travel purposes and activities might be expected although a degree of commuting might be expected if there is only modest time–distance involved.

Objectives

Strong regional and intercity links are recognised as being vital for social and commercial activities. The role is provided by road, rail and air networks. Good rail links can be complementary to other modes as well as substitutes. In particular, rail services may be fostered when there is

⁴¹ An example of strongly overlapping markets are the proposals for a “Calgary–Edmonton “Bullet Train”, linking the two cities in just over one hour, making intercity/commuting journeys possible. Along that route between the cities lie Edmonton’s airport and Calgary’s airport; a rail service could therefore potentially also be aimed at airport users and employees. <www.hsl-canada.net/en/canada.php>.

limited capacity on the other modes, to the extent that it is regarded as more cost-effective to provide train services rather than road upgrades or air services.

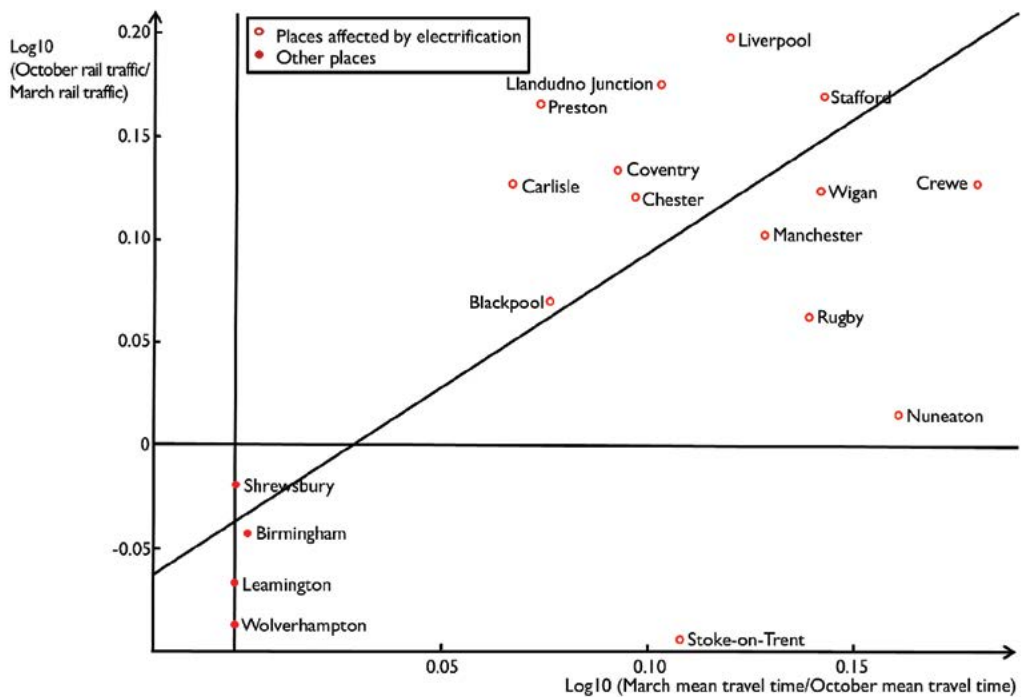
High speed rail is sometimes seen as a substitute for air services (and therefore releasing airport capacity for other, longer, services). It is less likely that slower train services can provide a similar role but, depending on the situation, the possibility should not be completely dismissed. For example, there are no scheduled flights between London Heathrow Airport and Birmingham (163 km); fast and regular rail (and coach) services operate. By contrast, there are regular flights between London Heathrow and Manchester (264 km) despite the substantial upgrading of the conventional railway between the two cities and the complementary introduction of tilt trains.

Competitiveness

The intercity and regional markets embrace an extensive range of travel needs. The specific service characteristics of an upgraded conventional railway will be determined by the nature of the alternative modes. The market response to upgraded services will depend on the relativities in time- and cost-competitive convenient modal options.

As noted in the introduction, there is a long history of railway service upgrading; the impact of one upgrade is shown with the impact of Britain's 1960s West Coast Main Line upgrading. In Figure 8, changes in patronage and journey times between London and provincial cities is shown for two half-year periods in 1966, relating to the period immediately prior to, and after, the completion of the railway upgrade. Amongst the impacts on other modes was a 25 per cent year-on-year decline in patronage for British European Airlines' (later part of British Airways) patronage between Manchester and London.

Figure 8 Change in volume of patronage in 1966, related to the change in mean travel time, 1960s upgrade of West Coast Main Line



Source: Extracted from Evans 1969, p. 78.

This example is location-specific; identified impacts of the upgrade are not transferable to other locations. Rail demand is strongly influenced by rail fares and travel time, by competition from other modes, by variations in economic activity and by seasonal variations. (Jones and Nichols 1983) The importance of travel-time and fares competitiveness is illustrated by the experience with high-frequency “Linx” services, Oslo–Stockholm (tilt-train) and Oslo–Göteborg–København, operated by the Norwegian and Swedish government railway operators from 2001. The services ceased in 2004, with times and fares being uncompetitive with services of the new low-cost airline operations that commenced operating from around 2003. Further, the Swedish railways also argued that Norwegian transit times were too long because the country’s tracks were not upgraded (Briginshaw 2005, p. 29).

Commuter

Through their impact on transit times, fast train services have a strong bearing on our options for where we live and work. A key component is the maximum commuting time that we are prepared to gouge out of our non-working time. “By making a return journey out from home and back again possible within a day, we open up all sorts of possibilities about where people choose to work and live” (Smith 2004, p. 445).

Train speed (or its corollary, journey time) is of particular concern for viable long-distance commuting from outer areas — and beyond. People reside in outer areas for a range of reasons,

including lifestyle and affordability. Once travel time reaches a threshold time (and a one-hour commute is often cited), the return daily journey time makes a disproportionate impact on the traveller's net hours available at home (after deducting travel and work time). McDonough established that “commuters tend to place greater emphasis on time-minimisation for peak-hour trips, which are generally work trips, than on the more occasional, leisure-oriented, off-peak-trip” (McDonough 1973, p. 142).

The typical focus of fast trains in the commuter market is therefore to reduce the transit time between those outer areas and the city centre. As elsewhere, the “time” is door-to-door time, with due consideration for service frequency and reliability.

Objectives

Fast commuter services are generally applied to trains operating between outer areas of cities and city centres; there is not normally a case that is articulated for that differential provision of such services. The outcome is clear, however: there is a reduced time differential of trains linking inner suburbs and city centres, and trains linking outer suburbs and city centres. For example, a person travelling from Sydney Central to Padstow (19 km from Central) may have identical travel time as a person travelling twice the distance, between Sydney Central and Rooty Hill (41 km from Central).

Plausible objectives for supplying fast commuter services with outer areas could include the desire to reduce the “remoteness disadvantage” incurred by outer-urban residents from the centre of a city's commerce. Similarly, with land near city centres attracting premium prices, it could be conceived that “affordable” residential locations would be impractical to live in as they would be prohibitively far from city centres; fast trains can make it practical. Investing in fast commuter services might also be seen as cost-effective relative to alternative strategies such as expanding road networks to reduce congestion.

Commuters' fares are almost always subsidised. Jackson (1975) considers that a better economic outcome may be achieved by subsidising the speed of the public transport vehicle rather than subsidising fares.

Countervailing policy may argue, however, that provision of fast (public and private) transport links encourages sprawling developments in outer fringes, and that long commuting journeys are therefore being encouraged. To the extent that the services require public funding and that users are relatively affluent, it is also argued that the operation involves subsidising passengers with high incomes who should not be subsidised.

Speed, frequency and reliability

Fast railway services are associated with long-distance commuting. There are a range of features of fast commuting services, which may include:

- infrequent train stops—long distances between stations and very few stops in inner urban areas (such as at major inner urban employment centres or at railway junction stations);
- electrified power source, for faster performance (especially acceleration from stops);

- segregated tracks—fast services can be separated from slower, stopping, services through provision of separate, parallel-running, tracks;
- consistent train service speeds (consistent station-stopping patterns) on the tracks; and
- high-performance trains.

Fast commuter services are provided typically on conventional railways. Many commuter services in Japan use the Shinkansen network. Similarly, some capacity on Britain's highly under-utilised High Speed 1 railway (as part of the Brussels/Paris–London Eurostar services) is used by “Javelin” commuter trains in Kent.

Depending on the context — and by contrast with other travel markets — it may not be necessary to offer high-frequency services, especially when speed and station locations are sufficiently central and accessible. For example, there are only five morning inbound, and afternoon outbound, services on the 64 kilometre “Northstar” (non-electrified) commuter train between Big Lake and Minneapolis; services operate at an average of 78 km/h, with six intermediate stops⁴². (The location is illustrated in Figure 45). Counter-peak flows in each peak time consist of one train only, while there are only three round trips in the inter-peak period.

While it is a new, rather than upgraded, conventional railway, the market response to Perth's Mandurah railway points to attributes that attract patrons (some of which can be adapted to existing railways). The railway has succeeded because:

- railway stations are more than six kilometres apart, by contrast with distances of one- to two-kilometres on other Australian urban lines⁴³; and
- trains are operating to the same service pattern: all trains stop at all stations, so trains are not inhibited by other trains operating at slower speeds—in this context, junctions with other railways are avoided;

Thus, the average train speeds on the 70 kilometre railway between Mandurah and Perth Central is 85 km/h. This operation is complemented by high reliability and excellent service frequency, offering a minimum of four trains per hour throughout the operating period, seven days a week; attracting commuter and other travellers. The well-located railway stations are served by coordinated bus and bicycle links and catered with large car parks. Patronage on the railway since its opening has exceeded forecasts (See BITRE 2012, p. 55).

There is a presumption that fast commuter trains will be reliable. The number of minutes of delay on long-distance commutes is commensurately greater than on short-distance commuting. Of course, the greater the distance traversed, the greater the likelihood of incurring delays. The incidence of delays and cumulative impact of the delays is greater than for short commuting distances. The longer-distance, high-speed commuting market is more vulnerable to perturbations, and the impact of perturbations is greater; that market therefore has a lower “tolerance” of unreliability.

⁴² <www.metrotransit.org/facts-funding.aspx> and <northstar.typepad.com/northstar_commuter_rail/>.

⁴³ See Bureau of Infrastructure, Transport & Regional Economics 2012, p. 11. Most railway services were introduced before private motorised transport became commonplace. As a consequence, stations were spaced more closely, increasing the catchment area for persons within walking distance.

Box 4 London commuting upgrade—Chiltern Railways

There are few recent examples of purely commuter-based railway upgrades. The railway between London and Birmingham via the Chiltern Hills provides an example of a major upgrade, dominated by medium-distance commuting travel and some intercity and regional traffic. Upgrading commenced in the late 1980s, with further upgrading continuing through to 2015, with upgrading projects called “Evergreen 2” and “Evergreen 3”.

A motorway running on the same corridor was opened in 1991. In principle, this new road should have siphoned off rail traffic but the road encouraged housing development along the line, increasing the travel market.

The rail upgrade delivered substantial service improvements. Upgrading on the line has raised maximum train speeds and track capacity, reducing transit times with service frequency more than doubling. Station car parks have been expanded substantially to improve accessibility.

A major obstacle to service expansion was the constrained terminal sight at London Marylebone Station; the land retained for the station was insufficient to expand platform capacity in the conventional way; the Evergreen 2 upgrade added two platforms in a staggered arrangement, often necessitating travellers walking longer distances to and from trains but averting a terminal capacity constraint that would otherwise have stymied increased service frequency.

In the ten years to 2007, patronage on the corridor more than doubled; this traffic growth was twice the pace recorded for the total London commuter market.

Conclusion

There is a long-established practice of catering for long-distance commuter markets; these fast rail services enlarge the catchment area of central-city employment. More generally, the services enhance links between outer urban areas and city centres for a range of journey purposes. As distance increases, speed and reliability become more important. Perth's Mandurah railway is an example of a fast, reliable long-distance commuting operation, achieved with electric propulsion, few station stops, consistent service patterns and minimal interaction with railway services on other routes. The *Regional Fast Rail* services in Victoria (see the case study below, from page 61) similarly provide fast, frequent and reliable services, for longer-distance commuters. Commuters have responded to these desirable features.

Airport services

A major travel market category for upgraded conventional railways is the airport railway, typically using an existing urban railway but involving construction of a new short spur to the airport terminal(s); this is the subject matter of this section.

Airport railways serve two primary travel markets:

- airport – city centre; and

- airport – regional, national, international locations, and to other airports⁴⁴.

Airport rail services can be favoured by travellers when they provide fast, frequent and *reliable* links⁴⁵.

Context

Policy focuses on developing good airport railway links for three core reasons:

- **City/airport viability.** Good public transport links encourage use of the airport, which is particularly important when seeking to bolster that airport over alternatives⁴⁶ and to encourage the city's commerce through a well-functioning airport;
- **Airport capacity.** In some cases, airport rail links can provide services that are substitutes for short-distance airline services. If this is possible, it can release airport capacity for other routes (where finding additional airport capacity is often a policy conundrum⁴⁷); and
- **Road congestion.** The rail service encourages airport access by public transport (reducing the impact on local roads by airport users who might otherwise drive and reducing the scarce airport land needed for car parks).

These factors apply to the *Gatwick Express* case study (page 104). It should also be noted that airports are also major employment centres; airline and airport staff share similar access mode requirements as airline passengers (and “meeters-and-greeters”).

Transport policy often uses the concept of integration within and between modes as virtuous, with integrated systems enabling use of each mode where the mode is particularly effective. In practical terms, this means integration between aircraft services operating over very long distances and trains operating at speed over shorter distances. Train services linking with Frankfurt (Main) Airport and with Manchester Airport arguably fulfil such roles—see Figure 10 and Figure 11, respectively.

London Stansted Airport presents an illustration of these policy issues. The airport has a dedicated city-shuttle rail service, the *Stansted Express*, which the airport company believes needs to be faster and more frequent in order to attract custom to the airport. The company argues that enhancing the railway will redirect airline traffic to Stansted, which has “significant spare capacity”; this would obviate the need for expanding capacity at other major London airports (particularly London Heathrow, which is capacity-constrained). The airport’s “Stansted in 30” campaign seeks government investment in track capacity that would reduce the Express’s transit time from 47 minutes (and sometimes more), to 30 minutes⁴⁸.

⁴⁴ There is also the potential (a) for the railway service to be used to link between airports, such as the “Thameslink” railway service that links Gatwick Airport and Luton Airport (Parkway) stations; and (b) for the railway service to provide a substitute for some airline services.

⁴⁵ The need for an especially fast railway service diminishes with the distance between airport and city centre. For example, the low-speed Docklands Light Railway that links London City Airport with the City of London (Bank) is arguably adequate for the situation; of more importance will be frequency, reliability and the city location of the terminal. See other discussion about London City Airport on p. 46.

⁴⁶ See the London *Gatwick Express* case study below, page 104.

⁴⁷ Lack of airport capacity also impacts on airline viability, constraining airlines’ ability to offer hub-and-spoke services. Manchester Airport Group, owner of London Stansted Airport, has submitted to the UK Airports Commission that reducing rail journey time between Stansted and London to 30 minutes (compared with 30 minutes for Gatwick and 16 minutes for Heathrow) will “enable fairer competition between London airports” (Local Transport Today 2013, p. 9).

⁴⁸ Current track capacity leads to the speed of fast trains being impeded by other, stopping services.

Airport railway services

Train speed, as a proxy for low transit time, is seen as a critical factor in airport railway competitiveness. Good transport links are required to reduce the effective distance between the airport and population, commerce and tourist centres in the city. However, the case for fast rail services is weakened where airports are located near city centres, or where the airport–city corridor has good road links or when the airport has only modest passenger throughput.

Airport railway services involve two major forms, often inter-related. Services can link directly between an airport and a city centre (and, sometimes, then beyond the “Central Station”). In other cases, rail services can be funnelled through, or to, an airport station, as with Frankfurt (Main) and Manchester airports, respectively (Figure 10 and Figure 11). Airport services were offered initially as city-centre links but, beginning with Zurich (in 1980), services have progressively been restructured to operate in, and integrate with, national rail services. When operated in these situations, dedicated airport services have been replaced with shared (non-exclusive airport) trains. (Transportation Research Board 2000, pp. 87–88). Table 3 illustrates the diverse offerings with airport railway stations in Germany.

Table 3 Rail access at German airports, 2009

| Airport | Daily train frequencies (number of trains) | | |
|-------------------|--|---------------|-------|
| | Local | Long-distance | Total |
| Berlin-Schönefeld | 202 | 1 | 203 |
| Dresden | 39 | - | 39 |
| Düsseldorf | 235 | 46 | 281 |
| Frankfurt (Main) | 215 | 143 | 358 |
| Friedrichshafen | 75 | - | 75 |
| Hamburg | 110 | - | 110 |
| Hanover | 40 | - | 40 |
| Köln-Bonn | 148 | 31 | 179 |
| Leipzig/Halle | 57 | 34 | 91 |
| München | 121 | - | 121 |
| Stuttgart | 111 | - | 111 |

Source: Grimme 2009, p. 8.

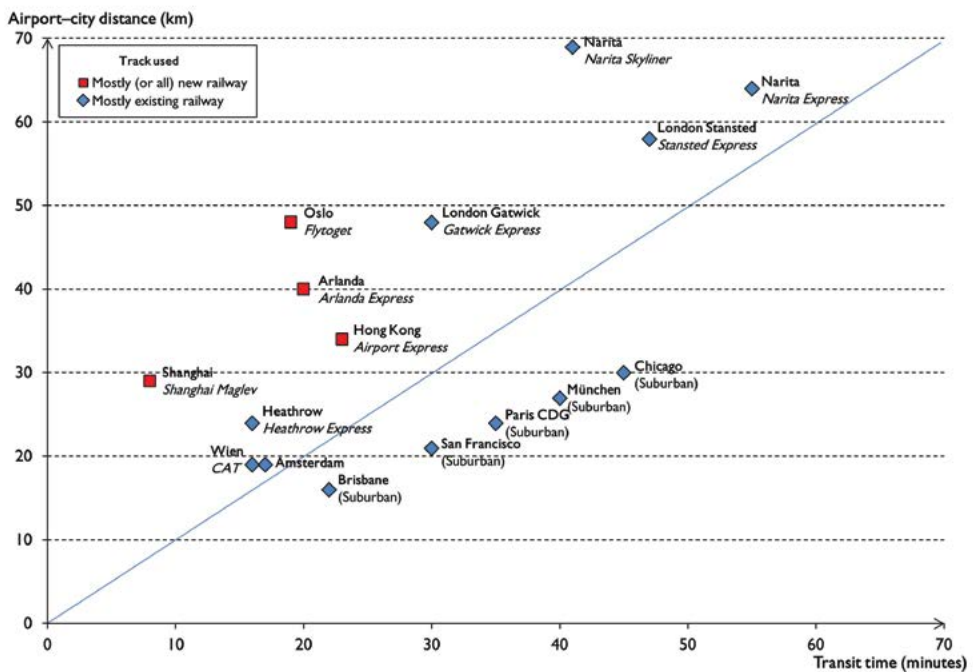
The potential for high-speed railway links to complement airports is strengthened when airports are located some distance from a city centre. New airports, in particular, are located some considerable distance from city centres by virtue of the large non-built space requirements. Fast trains serving Tokyo (Narita), Oslo (Gardermoen) and Hong Kong (Chek Lap Kok) are integral to the development of these new airports.

Provision of the services has been by upgraded existing track (with branches or spurs being built from main lines) and by new railway construction—the latter has been particularly applied with new airports. Figure 9 shows a range of airport railways, highlighting where services have been introduced using (essentially) existing track and the resulting journey times. Two aspects of the operations stand out:

- Where services use inherited high-standard track with reasonable spare capacity (such as the *Heathrow Express* using Brunel's high-standard Great Western Railway; and the Brighton Main Line for London *Gatwick Express* services), then low transit times can be offered; and
- Existing track is more likely to be used when airport–city distances are low—the airport is physically less remote.

The second aspect needs some qualification: if the policy objective is that the train serve the airport *and* offer a highly competitive transit time, then a “low” speed rail service may not suffice. For instance, Stockholm's Arlanda Express was funded on the basis that it would enable the airport to develop but without incurring road congestion and traffic emissions. For that reason, a new railway was constructed to provide capacity and route alignment to support fast and frequent services.

Figure 9 Airport railway characteristics



Source: Derived from data in Table 5.

For distant airports, then, train speed can be a crucial factor in ensuring the success of airport rail services. However, for the passenger, the speed — that is, the transit time — is a necessary, *but not sufficient* factor. This conclusion is illustrated by the relatively poor performance of Shanghai Airport's maglev train service, with its 6 per cent market share. As noted by the Airport Cooperative Research Program (ACRP), “a simple focus on line-haul speed of the vehicle does not produce a high mode share to public transportation, as revealed in Shanghai” (ACRP 2008, p. 5).

The Shanghai maglev airport service is undermined by very poor accessibility in the city. While the maglev train's speed (with an average train speed of 216 km/h and a top operational speed of 431 km/h) delivers very low transit time, this time saving is offset by other factors, not least the need to switch from the remote maglev terminal station to the underground metro system

in order to get to central Shanghai. The use of the maglev technology ensured that the airport service could not be integrated with existing conventional-rail metro services, thus requiring passengers to interchange between modes. Observation of the airport Shanghai mode characteristics (Table 4) reveals these deficiencies. As noted by Liu et al, Maglev+Metro is the only option that needs a transfer in the trip to the city centre. This is particularly unappealing because airline passengers with luggage have an aversion to modes involving transfers⁴⁹.

Table 4 **Characteristics of Shanghai airport – city centre modal options**

| Mode | Time (minutes) | Cost (RMB, ¥) | Mode share (%) |
|-----------------|--|----------------------------|----------------|
| Airport shuttle | 40–60 | 15 | 43 |
| Maglev + Metro | 21 (in vehicle, with Maglev time of 8 minutes) | 44–54 | 6 |
| Taxi | 40–50 | 80–90 | 19 |
| Private car | 40–50 | Fuel + ¥10 /hour (parking) | 29 |

Note: * Other modes have a 3 per cent mode share.

Source: Based on Liu, et al, 2008, pp. 228–29.

More generally, a number of factors come into play, *each* of which can be a crucial factor in a traveller's mode choice:

- **Speed:** Speed/transit time of the railway service relative to the alternative modes;
- **Frequency:** The (related) service frequency (or waiting time) of each mode;
- **Reliability:** Airline passengers are particularly sensitive to the reliability of surface access modes;
- **Location of station:** City-centre station and airport-station locations relative to journey origin–destination and airline gate, determining the number of transfers between services—airport travellers (with their luggage) are particularly averse to interchanges between or within modes;
- **Ultimate journey origin/destination:** The extent of other population centres (catchment area) that are served by direct (and, arguably, indirect) train services⁵⁰;
- **Train comfort:** For example, dedicated airport services segregate airport passengers from commuters;
- **Relative fares and costs:** Airport service uptake is influenced by the relative fares/costs of each mode; and
- **Luggage-handling:** Airport users are sensitive to the challenges and inconvenience of taking luggage on the surface access mode.

Thus, while speed is a necessary condition for the success of longer-distance airport railway services, the Maglev experience shows that it is not a sufficient factor. The implication of these conditions for achieving good uptake of airport railway services is that addressing train speed must be accompanied by addressing other factors.

⁴⁹ Liu, et al, expand the theme of this dislike: "Passengers dislike the time and cost required for transferring, but they also dislike the need for added trip planning, the possibility of a missed connection, the uncertainty of arrival time at their destination, exposure to weather and crowding, the need to find the next vehicle, difficulty of baggage handling and waiting in unfamiliar or hostile surroundings" (Liu, et al, 2008, p. 230).

⁵⁰ For example, it is argued that the growth in rail's market share at London Stansted Airport has risen because more Stansted Airport users are going to/from London; this, of course, can arise because the rail link makes the airport more accessible to London users.

Ironically, upgrading the conventional railway to an airport is likely to address some of the issues that arise with construction of a new high-speed railway (HSR):

- conventional railway speeds are lower than HSR lines;
- frequency is likely to be compromised relative to HSR lines due to more restricted line capacity;
- reliability is compromised by sharing track capacity with other, slower, trains;
- journey origin/destination are likely to be better because stations en-route are served and the existing centrally-located city railway terminal is more likely to be used;
- conventional trains can offer dedicated trains for airport users in the same way as HSR;
- conventional train services do not require recovery of considerable capital costs (Figure 9) and so the train fares can be set at levels that are more competitive with other modes; and
- systems can be implemented to reduce the adverse impact of luggage handling issues (which is common to all public transport forms).

The success, then, of fast airport services — which are particularly relevant to airports that are some distance from city centres — involves ensuring that each of a range of issues is addressed. These issues are discussed here.

Speed, frequency and reliability

Fostering strong links between airports and city centres — such as with the operation of fast rail links — has always been airlines' and airports' objectives. From the early days of commercial aviation operation, airlines provided airport–city bus services, to improve airport accessibility and so enhance air service attractiveness. Airports' desire for trains to fulfil that role has declined as airport users increasingly have ready access to a motor car (private or taxi) and because airport owners deriving considerable revenue from parking and taxi-access fees.

Where the distance between airports and city centres is relatively low, taxis can be cost-effective for travellers (ACR 2008, p. 54). The taxi can convey the traveller directly from their start point, or to their destination. The taxi has added appeal if road journeys are perceived to be reliable.

Over longer airport–city distances, however, fast rail services have become indispensable to airports. A number of major international airports have railway services. Table 5 presents a range of characteristics of airport railway services; the records are ranked by distance between airport and city centre. It is notable that the longer distance city-shuttle services are served by higher-speed trains and that these trains are generally dedicated, express, services.

Most of the train services shown in Table 5 operate on existing railways, albeit sometimes with capacity upgrading and usually with new branch line or diverted main line construction to link the existing network with the airport. Most airport stations have direct pedestrian access to the terminal, however, for example, Baltimore–Washington Airport's station requires a shuttle bus to access the terminal.

Table 5 Characteristics of airport direct railway services (ranked by distance between airport and city centre)

| Airport | Dedicated express service | Express trains per hour | Other services | Distance to city centre (km) | Time to city (mins) | | Average train speed (km/h) | Mode share (%) |
|------------------------|---------------------------|-------------------------|-------------------------------|------------------------------|---------------------|-------|----------------------------|----------------|
| | | | | | Rail | Road | | |
| Tokyo Narita | Narita Express (JR)◇ | 2 | | 64 | 55 | 90 | 70 | 14 |
| | Skyliner (Keisei) | 2 | | 69 | 41§ | | 101 | 10 |
| | - | | Transit | na | 80 | | na | 12 |
| London Stansted | Stansted Express | 4 | Regional | 58 | 47 | 70 | 74 | 24 |
| Oslo Gardermoen* | Flytoget | 6* | | 48 | 19 | 50 | 152 | 33 |
| | | | Regional | | | | | 7 |
| London Gatwick | Gatwick Express** | 4 | | 48 | 30 | 80 | 96 | 13 |
| | | | Regional | | | | | 4 |
| Stockholm Arlanda◇ | Arlanda Express | 4–5 | | 40 | 20 | 41 | 120 | 18 |
| Hong Kong Chek Lap Kok | Airport Express | 6+ | | 34 | 23 | 35 | 88 | 25 |
| | | | Suburban | | | | | 3 |
| Chicago O'Hare | - | | | 30 | 45 | 23+ | 40 | 5 |
| Shanghai Pudong | Maglev | 4 | | 29 | 8 | 50 | 216 | 6 |
| München | - | | | 27 | 40 | 35 | 42 | 31 |
| Paris CDG | - | | | 24 | 35 | 45 | 42 | 21 |
| | | | TGV | | | | | 6 |
| London Heathrow | Heathrow Express | 4 | | 24 | 16 | 45 | 96 | 9 |
| | - | - | Tube | 24 | 45 | 45 | 32 | 14 |
| San Francisco‡ | - | | | 21 | 30 | 20–40 | 42 | 7 |
| Amsterdam• | - | | city, regional, international | 19 | 17 | 30 | 67 | 35 |
| Wien | City Airport Train (CAT) | 2 | S Bahn | 19 | 16 | 25 | 72 | 14 |
| | | | | | 25 | | | 16 |
| Baltimore–Washington | - | 59 | | 16 | 20 | na | 48 | na |
| Brisbane | - | | Gold Coast | 16 | 22 | na | 43 | 8 |
| Zürich | - | | | 11 | 10 | 20 | 67 | 42 |
| København | - | | regional, international | 11 | 13 | 13 | 51 | 33 |
| Brussels | - | | regional | 11 | 17 | 20 | 48 | 16 |
| Frankfurt | - | | high speed | 10 | 12 | 20 | 48 | 8 |
| | | | regional | | | | | 8 |
| | | | local | | | | | 12 |
| Düsseldorf | - | | regional, international | 8 | 12 | 12 | 40 | 18 |
| Sydney | - | | | 8‡ | 13 | na | 37 | 11 |
| Genève | - | | regional, international | 5 | 10 | 10 | 29 | 21 |

Notes: * Oslo Gardermoen opened as the city's primary airport in 1998, supplanting Oslo Fornebu. The new airport was

opened with a new high-speed railway. The Gardermoen Line takes a more direct route from Oslo Central to the airport than a previous route that operates most of the length of the corridor between the airport and the city centre.

** Since 2008, some (peak-hour) *Gatwick Express* services have not been dedicated as the trains originate or terminate in Brighton (south, beyond — away from — London). Other, non-express, rail services operate to London Bridge and north to Luton Airport. See the *Gatwick Express* case study, beginning on page 104.

‡ International (T2) terminal.

† Distance between International Terminal and Sydney Central; distance between Domestic Terminal and Central is 6.6 km.

◇ Some Narita Express peak-period trains make additional stops for commuter traffic.

§ Journey time is between Narita Airport Terminal 1 and Tokyo Ueno station, the terminus of the service; travel to Tokyo JR station involves changing at Nippori (36 minutes from Narita) to the JR Yamanote Line, for an 11-minute journey. See <www.keisei.co.jp/keisei/tetudou/skyliner/us/>.

• 3 of the 6 hourly services extend beyond Oslo Central Station.

◆ The Arlanda Line is essentially a new railway in entirety between the airport and Stockholm Central, with a new route and track quadruplication on an existing route.

• Most trains between Amsterdam Schipol Airport and Amsterdam Centraal are express services.

Sources: ACRP, pp. 55, 60, 69, 79, 93, 95; rail service web sites; Booz & Company 2010, p. 1; London Stansted Airport 2013, p. 8. Kouwenhoven 2008, p. 10; UK Airport Consultative Committees 2009, p. 10. Johnson 2011, p. 10.

One exception to this incremental line construction is the Oslo Gardermoen airport line. The airport became the Norwegian capital's commercial airport in 1998, with a new railway being built to provide speed and capacity for the airport service, *Flytoget*. A consequence is that the service operates over a built-for-speed railway, with relatively high speeds that result in the 48 kilometres between airport and city centre being covered in 19 minutes. In addition, 3 of the 6 trains in each hour extends to other stations around the city network, increasing service coverage/accessibility to other parts of the city. As is evident from Table 5, the speed, frequency and accessibility of the service has resulted in a relatively high mode share.

Reliability is a key journey time attribute that is required for surface transport links with airports; airport users place great weight on reliable access modes. Rail has particular advantages where it delivers fast and reliable services, particularly when other modes have a high degree of *unpredictable* variability in travel times. In the USA it has been found that “many air travelers are willing to pay additional fares for the convenience offered by door-to-door services because they value travel time (particularly reliable travel time) more highly than travel costs” (ACRP 2008, p. 66). The same study found that because Chicago-resident travellers are familiar with the “very reliable” railway service between Chicago city and Chicago-O'Hare airport, the rail market share for residents is “far stronger” than for non-residents (ACRP 2008, p. 152, International Transport Forum 2010, pp. 41–42).

Station location and journey origin/destination

As the Shanghai maglev experience illustrates, the accessibility of the service to travellers' origin or ultimate destination can outweigh considerations of the train's speed/transit time. That is, is speed more important than the directness of the journey? London's crowded Piccadilly Tube railway to Heathrow Airport illustrates this point:

- the Tube's average train speed to Central London is 32 km/h (for a journey of, maybe, 40–50 minutes), compared with 96 km/h for the *Heathrow Express* for a 16-minute journey;
- the Tube carriages have no dedicated luggage area whereas the *Heathrow Express* has ample luggage capacity;

- the Tube's fare is £5 for a single paper ticket compared with £20 for the *Heathrow Express*); but
- the Tube route directly accesses a number of locations across London while the dedicated *Heathrow Express* terminates at Paddington station on the edge of central London⁵¹; and
- the Tube has a 14 per cent market share compared with 9 per cent for the *Heathrow Express*.

Thus, the Tube fare can be a major reason why travellers choose the mode over the much faster Express, but also the travellers may prefer the Tube route as it serves travellers' destinations better (without interchanges) than the Express. In any case, express routes may be of limited appeal if the catchment area (without the need for interchanging) represents only a minor portion of air passenger traffic. Similarly, despite the absence of express trains, Schabas found that 51 per cent of travellers going through London City Airport used the Docklands Light Railway; the railway provides good and reliable access to the City/Docklands (for business travellers) and to the south-eastern London railway network (Schabas 2013, p.81, 89).

Where city-shuttle services are not dedicated (express) operations, the station stops will incur time (speed) penalties but nonetheless may be attractive to travellers by being more direct for some travellers in accessing their ultimate destination or origin.

Journey comfort

Journey discomfort may be an important factor in travellers' airport access mode choice; this may prevail over speed as the determining factor for mode choice. Important comfort issues are the provision of dedicated city-shuttle trains (separating airport users from crowded commuting conditions) and the supply of facilities that streamline travellers' luggage-handling.

The provision of remote airline facilities in city-centre locations have been used to enhance public transport links with airports. The city-centre facilities may issue boarding passes and check-in of luggage and be the site for train or bus airport express services. However, while the terminals benefit some passengers, the luggage check-in remains an expensive service (labour and city-floor space) for airlines and it is generally not viable for airlines unless they receive a share of the revenue from the complementary rail-express premium service (Airport Cooperative Research Program 2008, p. 119). Kouwenhoven has reviewed the service and concluded that the remote check-in facility "does not appear to be seen as so important by passengers" (Kouwenhoven 2008, p. 22). In some cases, third-party operators have entered the market, charging for the service of taking luggage at remote locations; this is not necessarily linked to rail services (Airport Cooperative Research Program 2008, p. 125). Box 5 provides some examples of integrated airport–city transport (with luggage) services that have been undertaken.

⁵¹ Another example is the rail link that passes through London Luton Airport Parkway station; the link does not take the traveller to the airport terminal—a short bus ride is still required.

Box 5 Illustrations of integrated city–airport services

- British European Airlines (the European–domestic operations of what was to become British Air-ways) operated the West London Air Terminal in Kensington between 1957 and 1973, issuing board-ing passes, luggage check-in and an express bus service to Terminal 2 at London Heathrow airport; the demise of the service was precipitated by the opening of the Piccadilly Underground railway to Heathrow. BOAC (later subsumed within British Airways) operated a similar terminal from near London Victoria railway station to Heathrow (Terminal 3), connected by bus.
- British United Airways (later absorbed within British Caledonian) operated terminal and luggage check-in facilities at London Victoria railway station between 1962 and 1988, with a train service that connected to London Gatwick Airport. Other airlines established similar services at Victoria, com-plemented by the dedicated *Gatwick Express* rail service from 1984; these airline have ceased within the last decade.
- A number of airlines opened check-in facilities at London Paddington railway station in 1999, soon after the dedicated *Heathrow Express* train commenced at that station; there were 27 desks at that time (Sharp 2004, p. 12) but airlines had withdrawn from the facility by 2004.
- Integrated airline terminal facilities can also exist at cities away from the airport. For example, In conjunction with Deutsche Bahn (DB, German railways), Lufthansa have facilities at Köln (Cologne), Siegburg/Bonn and Stuttgart railway stations. Passengers receive their boarding passes at the remote city, then take a dedicated “AIRail” train service⁵² or a dedicated Lufthansa carriage on a DB train, to Frankfurt Airport. Passengers *retain* their luggage to Frankfurt (and when leaving Frankfurt by train), but effort is saved by taking the luggage to the AIRail terminal at Frankfurt railway station rather than to the adjacent airport terminal.
- Swiss Federal Railways accept luggage at a number of Swiss railway stations for flights departing from Zurich, Geneva and Bern airports; boarding cards are provided at the same time. The luggage must be checked-in on the day prior to the flight.⁵³
- In Moscow, the Aeroexpress dedicated airport service between Moscow Domodedovo Airport and central Moscow offered through-luggage facilities but this ceased in 2010, with the separate luggage van on the train being converted to passenger seating.
- In Wien (Vienna) there is a city-centre check-in at Wien-Mitte station, accepting luggage, issuing boarding passes, linked by the *City Airport Train (CAT)* express to the airport, a 19 km journey that takes 16 minutes⁵⁴. City-centre check-in is free but only a limited number of airlines accept luggage at the station.
- Some off-site through-luggage options still exist, albeit not linked to rail services, such as between Abu Dhabi’s National Exhibition Centre and the airport; and Etihad Airways’ city-centre terminals in Abu Dhabi, Al Ain and Dubai⁵⁵.

⁵² <www.bahn.com/i/view/GBR/en/prices/germany/airail.shtml>.

⁵³ <www.sbb.ch/en/station-services/services/baggage/check-in-at-the-railstation.html>.

⁵⁴ <www.cityairporttrain.com/Infos/City-Check-In-Wien-Mitte.aspx>.

⁵⁵ <www.tradearabia.com/news/TTN_237569.html>.

Fares

Airport rail links often provide a convenient, and comfortable link between airport and city centre, particularly when services are dedicated and fast. In such circumstances, there would be a presumption of premium fares, especially against a background of higher operating costs and infrastructure expenditure.

Kouwenhoven notes that where the rail service sets “a price premium over other modes [it] must be combined with superior journey times and product positioning” (Kouwenhoven 2008, p. 22). Some pricing up for faster, dedicated, city-shuttle services can be applied as air passengers have been found to be less price sensitive than other passengers (Kouwenhoven 2008, p. 22). Greater pricing up can be undertaken where business travellers form a substantial proportion of airport users (with a predisposition to city centre origin/destination and a lower price-sensitivity), although this may undermine the economic underpinnings of government funding if leisure travellers are priced off.

Kouwenhoven notes that the premium on the Oslo *Flytoget* service is around 30 per cent higher than the bus fare but rail still achieves a “very high” mode share (33 per cent for the express operation). By contrast, the similar Stockholm’s *Arlanda Express* service levies fares that are more than double the bus fare, with the result that price-sensitive passengers are lost to other modes (and the express records an 18 per cent mode share). Kouwenhoven notes similar low mode share for the *Heathrow Express*, which levies fares that are around four times that of the Tube service (p. 46) and achieves a mode share that is considerably less than pre-construction traffic estimates.

Ultimately, the levying of fares that are substantially higher than fares or costs of other modes can undermine the objective for funding the facility. In the case of the *Arlanda Express*, for example, the objective of reducing road congestion and road vehicle emissions has not been met because the fares are uncompetitive (even for such a fast, high-quality, service) and usage is lower than the underlying economic case for public funding⁵⁶.

⁵⁶ The economic case for the railway rested on the train service reducing road congestion and vehicle emissions. In 2006, the coach fare was SEK 90 while the Arlanda Express fare was SEK 200; journey times were “about 40 minutes and 20 minutes” respectively (Nilsson, et al 2006, p. 15).

Figure 10 Direct railway services linking with Frankfurt (Main) Airport (schematic network map)

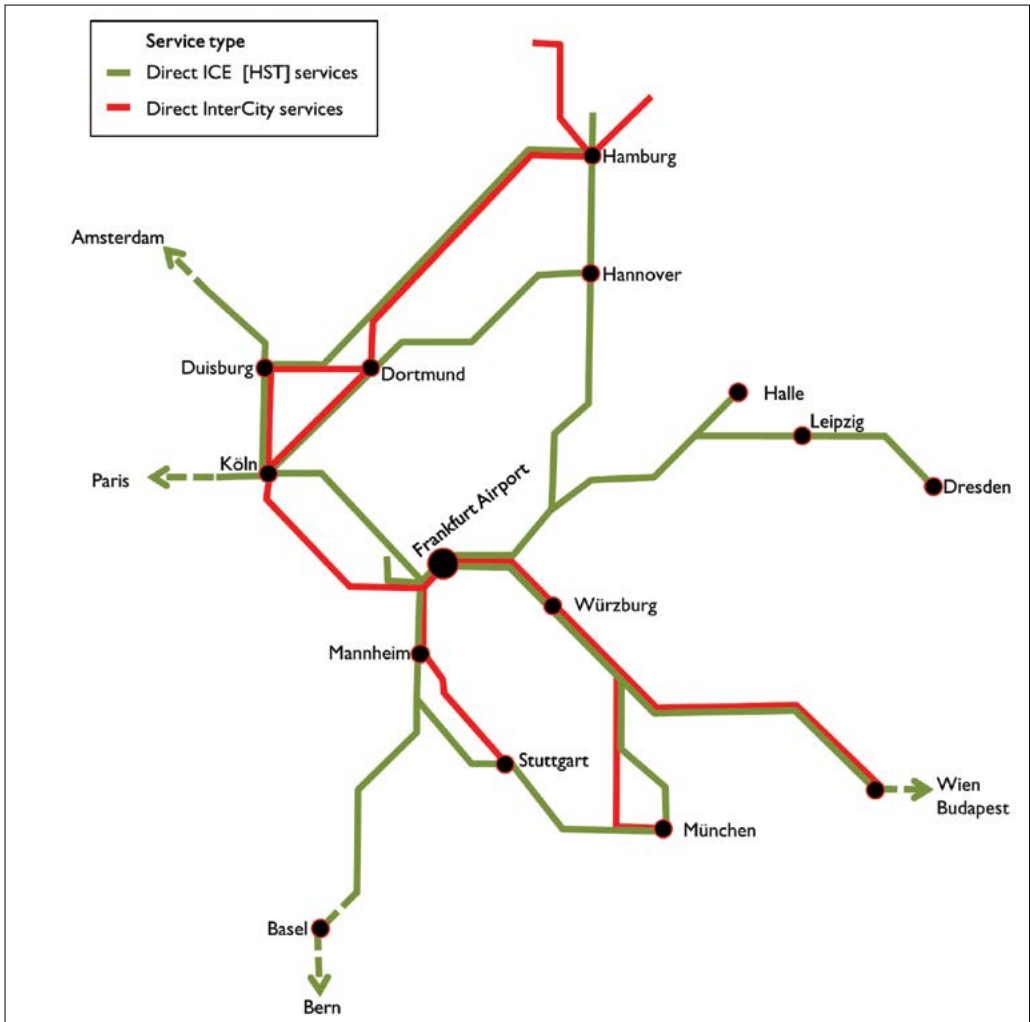
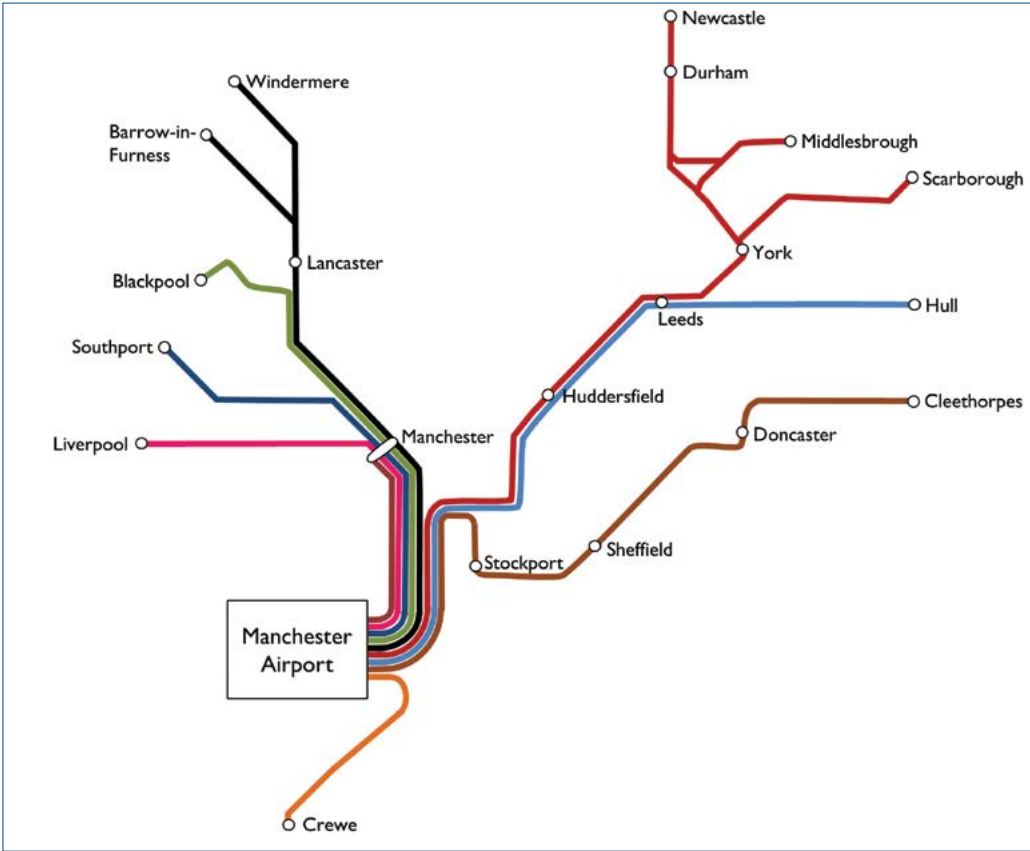


Figure 11 Direct train services linking with Manchester Airport (schematic network map)



Source: Derived from Nickel 2011, p. 33.

Conclusion

Fast airport railway services, grafted onto existing railway infrastructure, have been introduced in recent years where airports are located at some distance from the city centres. The primary role of the railway in those circumstances is to link with the city centre, although some railways are also used to extend the airport catchment (as with Manchester Airport) and also as providing substitute airline services (as with Frankfurt Main Airport).

Part of the attraction of the rail services lies in the speed of dedicated city-shuttle operation, albeit that the express operation means passing potential catchment areas. A dedicated service that penetrates the heart of the city reduces the likelihood of travellers' need to interchange—which loses time and is an inconvenience to which airline passengers are especially averse. Oslo's *Flytoget* service has regular airport trains that then continue beyond the city centre station, lengthening the operation and so broadening the catchment area where would-be travellers can use the service without the need to interchange. Airport users place a high value on the absence of interchange, on high reliability (which is usually a feature of dedicated city-shuttle rail services), and on dedicated rolling stock/services.

Where airports are close to city centres, the airport services generally use existing suburban trains and suburban track capacity. Train speed is not a priority although trains may nonetheless have a time advantage over road vehicles due to road congestion. Over short distances, however, taxi operations can become very competitive as taxis can offer door-to-airport service at competitive prices (especially when there are multiple passengers).

The relative fares/costs across modes are integral to the success of the service and use of existing tracks may result in a better outcome than entirely new tracks. A dedicated express service that connects with the city centre can be a financial failure if the rail fares are set too high. The challenge with new high-speed lines is that high construction and finance costs necessitate high fares but this is likely to undermine the financial and economic case for constructing the line. By contrast, where existing lines can be upgraded—infrastructure standards and line capacity—at relatively modest cost to provide fairly fast, and frequent, trains, then there is less pressure to raise fares. The viability remains challenging, nonetheless, because the rail service may not have sufficiently superior quality (train speed, frequency and accessibility) to attract travellers from other modes.

There is no clear-cut attribute that brings about success with airport railways. Fast, frequent and reliable services are essential, especially over longer distances. Dedicated (express) services are desirable, especially where airport travellers otherwise have to share a crushing journey with commuters on rolling stock that is not suitable for travellers with luggage. What is also required are good catchments, an absence of interchanges, conveniently-located stations in the city and the airport—qualities that justify a premium fare relative to competing modes.

Market responses to upgrades

The response to upgrades is very location-specific and depends, not least, on the markets being served. This chapter has presented an overview of the key regional, intercity and commuter markets for railway upgrades.

The upgrades produce a railway travel market constituting:

- pre-existing rail travellers;
- persons diverted from other travel modes; and
- people who are undertaking new journeys (that is, “generated” journeys).

Journey time/train speed is one element of service quality (with factors such as service frequency and reliability and seamless travel/journey interchanges between origin and destination). The attributes of other modes, their price/cost, and the transport and attractiveness of alternative (substitutable) destinations, are other aspects of competition.

CHAPTER 5

Case studies of service upgrades

This chapter reviews 12 service upgrades or proposals from a range of locations across the world. The case studies presented here are intended to illustrate the obstacles, challenges and outcomes of different service upgrades.

The case studies reviewed are:

| Study number | Railway line or corridor | Primary service attribute upgrade |
|----------------------|--|---------------------------------------|
| Australia | | |
| 1 | Sydney–Canberra | Tilt train trial—reduced transit time |
| 2 | <i>Regional Fast Rail</i> , Victoria | Increased service frequency |
| Europe | | |
| 3 | Stockholm–Göteborg | Reduced transit time |
| 4 | Berlin–Hamburg | Reduced transit time |
| 5 | Wien–Salzburg | Reduced transit time |
| 6 | Helsinki – St Petersburg | Reduced transit time |
| 7 | Paris/Tours–Bordeaux | Reduced transit time |
| 8 | London–Glasgow (West Coast Main Line corridor) | Increased service frequency |
| 9 | London–Gatwick Airport | Dedicated airport train |
| North America | | |
| 10 | Québec–Windsor | Proposal: Increased service frequency |
| 11 | Boston – New York – Washington (Northeast Corridor) | Reduced transit time |
| 12 | Chicago – St Louis | Reduced transit time |

Note that the degree of detail on each case study varies according to data availability.

Study I: X 2000 tilt train trial, Sydney–Canberra

Summary

- six-week trial of tilt train between Sydney and Canberra in 1995
- unspecified time savings achieved due to tilt
- timetable shows latitude for time savings without tilt
- most curves on Canberra branch were too tight to allow acceleration
- positive market response but patronage was probably attracted by service novelty

Background

In 1995 the NSW Government's long-distance train operator, Countrylink (a subsidiary of State Rail), undertook a trial of tilt train technology on the existing Sydney–Canberra passenger service. The service links the conurbation of Sydney (with a population in 2010 of 4.6 million) and Canberra (which, with Queanbeyan, has a population of 0.4 million), a distance of 329 km. See Figure 12. The railway is a two-track (or more) railway between Sydney and Goulburn (as part of the Brisbane–Melbourne north–south railway corridor) and a single-track branch line from near Goulburn through to Canberra. Outside of Sydney, the track is non-electrified; the Canberra services are therefore diesel-powered.

The trial was conducted on the route at a period when there were studies into the Sydney–Canberra corridor, with a view to a private-sector consortium (Speedrail) constructing dedicated new high-speed railway on the corridor.



Objective and goals

The trial of tilt train technology was undertaken to evaluate tilt technology and to assess customer reaction to the technology (Legislative Assembly 1998, p. 49).

Figure 12 Sydney–Canberra route, via East Hills



Description of project

State Rail undertook the trial on the basis that it had observed that tilt trains are “capable of significantly reducing journey times on existing infrastructure, as a result of their advanced bogie and tilting body designs” (Finnimore 1997, p. 34). The evaluation was undertaken to inform its rolling stock purchase strategy.

Countrylink invited tilt train manufacturers — all located overseas — to make a train set available for evaluation. Only ABB/Swedish State Railways⁵⁷ was able to supply carriages within Countrylink’s specified time scale. The model was the X 2000 train (now classed as the SJ 2000 or X2), which operates extensively through Sweden. The train has a top design speed of 210 km/h.

Three tilt train carriages were supplied from an electrical multiple-unit train (EMU). Powered-driving carriages were not supplied; the train itself would be evaluated on largely non-electrified track⁵⁸. In any case, as noted above (page 25), the objective of tilt mechanisms is to raise the speed at which a carriage can proceed through track curves while retaining passengers’ comfort level; this does not require the driving unit itself to be so-equipped with tilt capability.

⁵⁷ ABB’s train manufacturing became part of ADtranz (part of DaimlerChrysler) and then part of Bombardier Inc.

⁵⁸ Power specifications for NSW and Swedish electrified track are, in any case, different, so even where the train operated in electrified areas (essentially Sydney–Lithgow/Wollongong/Newcastle), a powered carriage would not have been able to draw the power as the systems would have been incompatible.

The propulsion for the trial was supplied by two of Countrylink's XPT diesel-electric power cars, with one unit at each end.

Implementation

The X 2000 trial was conducted on the Sydney–Canberra service, supplementing existing trains. The trial added two return journeys per day between the capitals, over a six-week period. Because the carriages were slightly wider than existing carriages at platform level, the platform edges had to be trimmed at stations between the two cities. The three carriages were fitted with generously-spaced seating with the one-class Swedish “First Class”; there was no second class.

The trial train services were operated with very limited intermediate stops — at Campbelltown and Goulburn, with Moss Vale also being served by some trains. By contrast, the regular Sydney–Canberra services additionally stop at Strathfield, Mittagong, Bowral, Bundanoon, Tarago, Bungendore and Queanbeyan.

During the trials, technical information was collected on the effect of the X 2000 carriages on the track. The carriages performed well, recording lower (i.e., less adverse) forces on the track than on the XPT trailer carriage that was assigned to the train; this arose because of the self-steering axles on the bogies—see the discussion above, p. 26. It was concluded that this was “attributed to the superior curving performance of the bogies and the fact that the X 2000 carriages were operating well below their design deficiency” (Finnimore 1997, p. 36).

It has been reported in the NSW Parliament that the cost of the trial was \$7 million⁵⁹.

Impact on service

It could be interpreted that virtually all time savings derived from the tilt were centred on mainline tracks rather than the Canberra branch. As is apparent in Figure 13, the line south from Goulburn has relatively slow speeds, particularly on the track south of Tarago, where the line incurs a considerable number of curves. It does not follow, however, that upgrading should be undertaken where speeds are slowest; the location and nature of upgrading depends on the relative costs and benefits of upgrading options along the track.

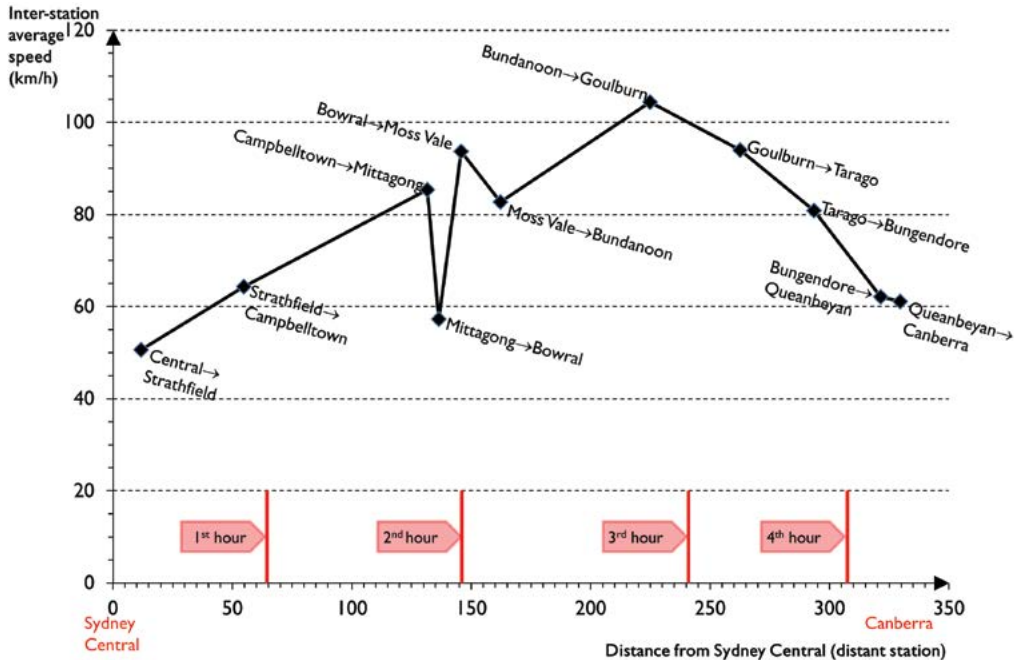
The trials did demonstrate that the X 2000 tilt could deliver train speeds up to 15 per cent higher than conventional trains when going through curves; and 10 per cent faster on other tracks, up to a maximum speed of 170 km/h (Finnimore 1997, p. 35).

The tilt mechanism was of negligible benefit on the branch line. Speeds could be increased only if curves are not tight: the minimum length for “optimal curve radius” for the X 2000 train is 800 metres (*Op. Cit.*, p. 36). However, on the Goulburn–Canberra line the radius of almost two-thirds of the curves (or one-third of the total kilometres) is tighter than 800 metres. The distribution of track curvature on the branch line is illustrated in Figure 14; the severity of curvature can be contrasted with a *similar* chart for the Stockholm–Göteborg line (for which the X 2000 was designed), in Figure 20. Train speeds on the branch were therefore constrained by this preponderance of tight curves, together with s-shaped (“reverse curve”, a form of “compound curve”) track alignment (which limit train speeds irrespective of tilt mechanism); in

⁵⁹ Legislative Assembly Hansard 2002, 27 June, p. 4121.

such circumstances “tilting vehicles yield little advantage over conventional rolling stock (Harris, et al 1998, p. 3)⁶⁰. Laird (1999, p. 115) described it as a “fast train on slow track”.

Figure 13 Sydney–Canberra service speeds, by timetabled station stops



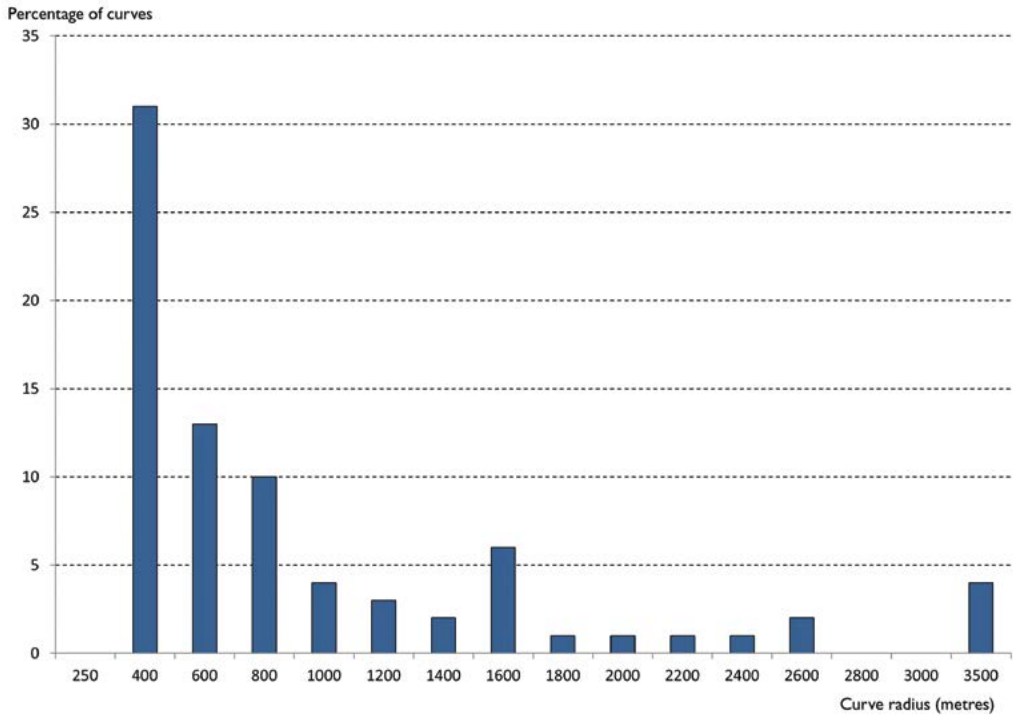
* Timings are for the 0658 train from Sydney Central to Canberra, using the timetable current at January 2013

Source: BITRE analysis of NSW TrainLink timetable.

The time savings from tilting on the branch were also limited because there were relatively few curves to which the tilt mechanism are suited; the benefits of tilting “diminish” when the radius is above 2 000 metres (Legislative Assembly 1998, p. 71) because the curvature itself with regular track cant is not an undue impediment to comfortable train speed.

⁶⁰ There are 79 curves separately identified on the 100 kilometre route between Joppa Junction and Canberra. Of the 37 left curves (away from Sydney), 23 curves are tighter than 800 metre radius; of the 42 right curves, 27 are tighter than 800 metres. Those tight curves (50 out of 79 curves in total) represent a conservative 33 kilometres of track and the X 2000 was unlikely to have negotiated such curves at a higher speed than that permitted by conventional trains. Analysis was made from data in the RailCorp “Curve and gradient diagrams” document and the RailCorp “Train operating conditions manual”. An additional factor, for which data are not available, is the extent of the “transition curves” on the route, that is, the nature of the curve that is built between the straight track and the full curve through which the track is aligned—see above, footnote 31.

Figure 14 Distribution of track curvature severity on the Canberra branch line



Note: The chart presented here is a BITRE analysis of RailCorp “Curve and gradient diagrams”—see Rail Access Corporation 1999. Radius figures have been aggregated, for instance, where the “400” metre represents curvature above 250 metres and up to 400 metres; the “600” metres represents curvature above 400 metres and up to 600 metres. The “percentage of curvature” is the percentage of the *number* of curves rather than the length of curves (contrasting with Figure 20).

At around 205 minutes, the overall scheduled transit time for the demonstration services was considerably faster than the conventional train service time of around 252 minutes. The tilt mechanism facilitated the faster transit time although its contribution to overall time saving is unclear. Other factors that contributed to the time savings included:

- fewer station stops than conventional services (as noted above);
- expedited process for exchanging “signal” tokens as authority for drivers to proceed along track sections. (On conventional trains, the driver had to leave the cabin to go to a facility on the platform to exchange a physical token [or staff]; for the trial, the driver returned a token to platform staff and received a new token from that staff member, all while the train was proceeding through the station at low speed.);
- the train was routed via the faster East Hills line in Sydney rather than via the conventional train route via Strathfield; and
- the train was given special priority over other trains in timetables and in practice. This priority is less likely to occur with conventional Canberra trains.

The X 2000 is known for its “good acceleration from both station stops and sections of track that require slower speeds” (O’Connor 1993, p. 65); the relative performance of the substitute

XPT diesel-electric power cars (used to propel the X 2000 carriages in lieu of the normal overhead-electric traction used in Sweden) is not known.

Overall, then, a range of adjustments were made to the operating practices and it is not possible to identify separately the time-saving contribution of the tilt technology. Put another way, a conventional train set, given similar signal, priority and station-stop adjustments, might achieve similar time savings to those achieved in the trial.

Impact on market

The X 2000 trial reportedly attracted good patronage, with a seat utilisation of 84 per cent (Legislative Assembly 1998, p. 49). It is not possible, however, to interpolate the long-term market response from the short trial, which attracted people who rode the train for the “experience” (Finnimore 1997, p. 35) and the novelty (Legislative Assembly 1998, p. 50). There were adverse views about the train’s seating which, by contrast with other NSW country trains, could not be reversed to face the direction of travel.

The Legislative Assembly’s report into the trial concluded, however, that the “time savings were not of the order to make rail competitive with either road or air transport” (Legislative Assembly 1998, p. 62).

Conclusions

On the available information, it seems that the tilt train trial gave inconclusive technical results. It is not possible to say how much time was saved due to the tilting. In any case, it seems that a majority of the curves on the branch line south of Goulburn are too tight to allow higher train speeds. Indeed, the NSW Legislative Assembly report into the tilt train concluded that “This evidence suggests that there is a bottom limit below which tilt technology will not provide an effective remedy to poor quality track” (p. 72).

What is notable from the trial, however, is that changes to operating practices themselves can deliver significant time savings. It remains to be seen whether the costs of those changes—such as routeing the train on the faster East Hills line or raising the priority of the service over other train services—is warranted⁶¹. Omitting station stops was also a significant source of time savings, though this is inevitably unpopular with bypassed population centres.

The Legislative Assembly concluded that the tilt technology could deliver “significant time savings” but that track quality in the trial impeded the extent of time that could be saved. In the case of the trial, the savings were insufficient to make the tilt train service competitive with air and road. Drawing conclusions from the Speedrail work, the Assembly also concluded that track improvements would be needed to make a service viable (Legislative Assembly 1998, p. 62).

The Legislative Assembly’s conclusions indicate the importance of identifying the objective of an upgrade: what is an upgrade seeking to achieve?

Since the trial, the tilt train technology has been applied to Brisbane–Rockhampton–Cairns passenger services, with considerable track upgrading being undertaken in the decade prior to the new trains—see Box 6.

⁶¹ It is notable that the time-consuming action of manual staff exchanges at Tarago, Bungendore and Queanbeyan were removed in 2012, however the passenger timetable remained unchanged.

Box 6 The Queensland tilt trains



Tilt train technology has been applied to intercity services in Queensland, using Hitachi's tilt technology. Tilt Queensland Rail train services were introduced from 1998, with electric-powered trains operating on 622 km between Brisbane and Rockhampton—see the map at left, showing the major centres served. The track on that link had been upgraded in the 1980s, including 128 km of deviations, with concrete sleepers laid on more than 95 per cent of the track and an 85 km extension of overhead electrification through to Rockhampton.

Diesel-powered tilt trains were introduced on the 1 680 km route between Brisbane and Cairns from 2003, with services benefitting from construction of 118 km of deviations to ease curves and gradients between 1992 and 1997. The introduction of the latter train reduced transit time from 31½ hours, to 25 hours. Complementary track upgrade work was undertaken, including some replacement of timber with concrete or steel sleepers, heavier rails (also benefitting freight operations) and upgraded

level crossings. This upgrading was focused on both freight and passenger traffic, hence the replacement or rebuilding of over 800 bridges to increase axle loads. Enroute a number of major centres are served, including Maryborough, Bundaberg, Gladstone, Rockhampton, Mackay and Townsville.⁶²

Figure 15 Queensland Rail electric tilt train



Note: Queensland Rail's electric tilt train, shown departing from Maryborough West, enroute from Rockhampton to Brisbane.

Source: Photograph courtesy of John Hoyle.

⁶² See Hammond 2003, p. 24; Laird 1999.

Study 2: Regional Fast Rail, Victoria

Summary

- simultaneous upgrade of four railway corridors linking regional centres with Melbourne, between 2000 and 2006.
- major infrastructure renewal, with upgraded and additional, higher-specification rolling stock.
- some peak-period trains had substantial transit time reductions.
- principal service upgrade was higher service frequency.
- completion of upgrade coincided with fare reductions.
- substantial growth in patronage on all corridors, up by 75 per cent since completion of the upgrade.

Background

The *Regional Fast Rail* project involved upgrading train services that operate along four population corridors that fan out from Melbourne (Figure 16); the adjacent table provides a snapshot of the corridors. Services are provided by publicly-funded V/Line Passenger operating over non-electrified railway (outside of metropolitan Melbourne).

| Four-corridor profiles | | | |
|------------------------|--------------------------|-----|-----------------------------|
| Terminus city | Minutes from Melbourne** | Km | Corridor Population* ('000) |
| Geelong | 60 | 73 | 180 |
| Ballarat | 70 | 119 | 245 |
| Bendigo | 110 | 162 | 160 |
| Traralgon | 120 | 158 | 125 |

Notes: * Populations include multiple population centres including, respectively: Urban Geelong; Ballarat with Bacchus Marsh, Melton/Rockbank, Deer Park/Ardeer; Bendigo with Castlemaine/Kyneton/Woodend and Macedon/Gisborne/Riddells Creek; Traralgon with Moe and Morwell.

** There is a wide range of transit times; these times represent good timings, with some limited stopping.

As part of planning *Regional Fast Rail*, it was recognised that additional infrastructure was needed in metropolitan Melbourne. However, following changes to project funding arrangements, the *Regional Fast Rail* upgrade project focused on nonurban operations. Funding had originally been intended to be achieved through a public–private partnership (PPP), with the State government contributing \$550 million of the-then cost estimate of \$810 million. In the event, the PPP did not eventuate and the proposed upgrades were scaled back, to a budget of \$556 million (Auditor-General Victoria 2006, pp. 26–27). Subsequently, after consideration of a range of upgrade options, the *Regional Rail Link* project (shown in Figure 16) was initiated

to address the underlying urban capacity and reliability issues in the Melbourne metropolitan area. That project includes provision of a new double-track railway throughout the urban area. These new tracks shift regional services away from the tracks used by suburban services, enhancing track capacity and service reliability for regional and metropolitan trains.

Objective and goals

In 2000, the Victorian State government introduced its “Linking Victoria” policy. One aspect was the upgrading of country rail services between Melbourne and population centres in the Geelong, Ballarat, Bendigo and Latrobe Valley (to Traralgon) corridors.

The objectives of the upgrade were:

- **Market:** to achieve a substantial and sustained increase in patronage, attracted by shorter express transit times and comfortable and affordable travel.
- **Supply:** to deliver these upgrades within the allocated finances, within a specified time, to transfer risk to the private sector where appropriate, to ensure probity, and to “minimise the long-term costs to the taxpayer” (Auditor General, Victoria 2006, pp. 27–28).

For the market, the patronage growth objective would be achieved by increasing the market size and by diverting commuters from cars. Making Melbourne more accessible (by more frequent, and faster, trains) would enlarge the practical commuting area, stimulating population growth in regional areas. Making rail services more attractive relative to driving would encourage a switch to trains.

For the supply of upgrades, the government set goals that reflected the available budget. Thus it ruled out highly-ambitious upgrades that would result in transit times from Ballarat, Bendigo and Traralgon being under one hour (and below 45 minutes from Geelong) as this would have doubled the funding required (Transit Australia 2000, p. 251).

The basis for funding the upgrade project was argued by the-then State Premier that “there is significant economic benefits associated [sic] reducing travel times between Melbourne and the four provincial centres” (Auditor-General Victoria 2006, p. 52). Benefits cited included enhancement of local economic and employment opportunities, improved suburban and freight train speeds and reliability, improved trade and communications functioning, and reducing reliance on cars (Transit Australia 2000, pp. 251–52).

Description of the upgrading project

The service upgrades involved six key elements:

- **track condition.** Track was upgraded on the non-metropolitan parts of the four corridors, including relaying track with concrete sleepers and heavier rails⁶³.
- **level crossings.** There was considerable level crossing upgrading or elimination.

⁶³ Victoria’s (then) Department of Infrastructure “identified that maintenance costs associated with timber-sleepered track were almost 3 times those for concrete-sleepered track at fast rail operations of 160 km/h” (Auditor-General, Victoria 2006, p. 69).

- **signalling and communications systems.** A fibre-optic cable network was laid, for upgraded communications and new signalling, which was almost entirely renewed and modernised, including a train protection and warning system⁶⁴.
- **enhanced rolling stock performance.** During the negotiation of the contract for the first batch of 29 two-car “VLocity” Diesel-Multiple Units (DMU), the specification was revised so that their maximum service speed was increased to 160 km/h for operation on *Regional Fast Rail* corridors.
- **additional rolling stock.** An additional 11 two-car “VLocity” trains were ordered in 2002 to meet the anticipated demand resulting from the project. Traffic growth following the success of the project led to additional orders in 2006 and 2008 for a further 22 intermediate carriages in two batches, to lengthen existing two-car VLocity trains to three cars. A subsequent batch of 32 cars (10 three-car units and 1 two-car unit) were ordered at the end of 2008, with the last of the cars entering service in 2011⁶⁵.
- **enhanced service frequency.** The additional rolling stock enabled much higher service frequencies to be provided.

The track and rolling stock enhancements facilitated the introduction of some faster, limited-stop services, particularly in peak periods.

The upgrading also focused on improved accessibility to the rail services. These efforts included improvements to connections between trains and coaches (Auditor General, Victoria 2006, p.28).

Aspects of the upgrade are presented in Table 6.

Table 6 Aspects of the Victorian *Regional Fast Rail* upgrades

| | Section-km | Crossing upgrades (no.) | New signals | New turnouts/ points |
|----------------------|------------|----------------------------|-------------|-------------------------|
| Werribee–Geelong | 48 | 17 | 129 | 41 |
| Sunshine–Ballarat | 107 | 57 | 127 | 31 |
| Watergardens–Bendigo | 138 | 37 | 162 | 49 |
| Pakenham–Traralgon | 100 | 26 | 174 | 29 |

Source: Hope 2004, p. 841.

The upgrading was based on the existing corridors in non-urban areas, although a significant new alignment was adopted at Bungaree on the Ballarat line (shown in Figure 16), resulting in a new, more direct, 8.2 km route alignment, saving four minutes in running time (RTSA 2009)⁶⁶. (Apart from being 4.9 km longer, the old alignment has a number of small-radius curves, slowing the trains down.) The Bungaree deviation had an estimated cost of \$30 million, out of a then-estimated \$573 million project for the four corridors.

As with other upgrading projects in other countries (such as Chicago – St Louis), the higher speeds led to work to raise protection at, or eliminate, level crossings. On the Bendigo line, 35 of the 36 level and pedestrian crossings were provided with warning/protection devices (bells,

⁶⁴ The key safety aspect of the train protection and warning system (TPWS) is that it operates by applying a train's brakes should a train pass a stop signal or if the train exceeds the maximum designated track speed. The State's rail safety regulator required that all trains using the four corridors must have TPWS fitted.

⁶⁵ Maximum train lengths are seven cars, formed from a three-car DMU and two, two-car DMUs. To accommodate these longer trains, work has had to be undertaken to extend platforms at some stations.

⁶⁶ This was at Bungaree, south-east of Ballarat. There were four other, relatively modest, deviations on the line.

flashing lights or boom gates); similar work on the Geelong line eliminated all passive crossings. The level of crossing protection on the Traralgon line was increased. On the Ballarat corridor, 32 passive level and pedestrian crossings were upgraded (Hansard, Victoria 2006, p. 1451).

Upgrades inevitably involve compromises. In this case, to save upgrade costs, one significant action was to convert 49 km of the 72 km of double-track section between Kyneton and Bendigo to single track; also the Sunbury–Kyneton section was retained but not upgraded to allow for 160 km/h running. The track singling with passing loops⁶⁷ between Kyneton and Bendigo was implemented as the capacity provided by two continuous double tracks was in excess of what was needed to operate the proposed services. The singling lowered the cost and risk of the project as it limited the works needed on heritage bridges and on tunnels on the line section⁶⁸ (Auditor-General, Victoria 2006, p. 68).

Figure 16 Victorian Regional Fast Rail project* routes, 2004–06



Note: *The map also shows the alignment of tracks being added as part of the *Regional Rail Link* project; the new lines are between Melbourne (Southern Cross) and west side of Sunshine; and Deer Park and Werribee.

Note: Services were upgraded on the lines shown in this figure. However, some Bendigo services operate on to Swan Hill and Echuca; some Ballarat services go on to Ararat or to Maryborough; some Geelong services go on to Warrnambool; and some Traralgon services go beyond, to Bairnsdale.

⁶⁷ A passing loop is a short section of double track that is used to enable two trains moving in opposite directions to be able to pass each other.

⁶⁸ Hope (2004, p. 842) states that “it is claimed that the additional gauge clearance required for 160 km/h cannot be found without rebuilding [heritage masonry arch bridges]”.

Implementation

The main physical tasks on the four corridors commenced from late 2003 and were completed between March and September 2006. In essence, the lines were upgraded simultaneously, and the upgrade timetable benefits were implemented within one timetable revision. The full benefits of the upgrades were implemented in timetable changes in September/October 2006 (Auditor General, Victoria 2006, p. 90).

Impact on service

The principal service upgrade was the increase in service frequency. This is illustrated in Table 7, which shows the number of weekly services by corridor. The frequency change ranged from 13 per cent additional services on the Geelong corridor, to 83 per cent additional services on the Ballarat corridor. Improvements varied from station to station; for instance, there were no significant frequency enhancements for Bacchus Marsh (Ballarat corridor) or Kyneton (Bendigo corridor).

Table 7 V/Line service frequencies, pre-upgrade and post-upgrade

| Station | Weekly services between station and Melbourne Southern Cross | |
|-----------|--|--|
| | Before completion of upgrade, July 2004 | At completion of upgrade, September 2006 (change) |
| Geelong | 274 | 310 (+13%) |
| Ballarat | 98 | 179 (+83%) |
| Bendigo | 119 | 203 (+71%) |
| Traralgon | 111 | 177 (+59%) |

Source: Data from communication with Public Transport Victoria.

Frequency enhancements catered for serving week-day commuters and other markets such as leisure travel. The total week-end services on the Geelong corridor rose from 30, to 35; services on the Ballarat corridor rose from 15, to 27; on the Bendigo corridor the number of services increased from 13, to 27; and on the Traralgon corridor, from 10 to 21 services (Australian Association of Time Table Collectors 2006, p. 4).

Transit time enhancements were a high-profile objective of the investment programme (as suggested by the “*Regional Fast Rail*” title), though service frequency is arguably a more pervasive enhancement. The journey-time improvement was focused on individual peak-time “Flagship” services, with excellent transit times that were not representative of other service transit times. Best-time transits were marked: the Geelong “Flagship” achieved 45 minutes (compared with a previous best of 51 minutes), the Ballarat best transit was 64 minutes (compared with 82 minutes), Bendigo’s best transit was 84 minutes (compared with 101 minutes) and the Traralgon transit was 116/120 (to/from Melbourne) (compared with 117 minutes) (Auditor General, Victoria 2006, p. 27).

The flagship travel times catered for a portion of the overall rail travel market. More generally, describing the time aspects of the *Regional Fast Rail* service upgrades should recognise the very wide dispersion in journey times across individual services. This is illustrated by a review of the week-day transit times and frequencies on the Ballarat corridor—see Table 8. Transit times were reduced markedly, although there is a very broad dispersion of transit times around the average—for instance, that the 2013 week-day transit times from Melbourne averaged 82 minutes, but could be as low as 67 minutes or as high as 110 minutes.

Table 8 **Week-day transit time and frequency, V/Line Melbourne–Ballarat services, 2004 and 2013**

| | 2004 | | 2013 | |
|----------------------------|----------------|--------------|----------------|--------------|
| | From Melbourne | To Melbourne | From Melbourne | To Melbourne |
| Number of trains | 10 | 12 | 17 | 16 |
| Average transit time (min) | 94 | 93 | 82 | 83 |
| Slowest transit time (min) | 103 | 115 | 110 | 102 |
| Fastest transit time (min) | 88 | 82 | 67 | 73 |

Source: BITRE analysis of April 2013 V/Line timetable; Australian Association of Time Table Collectors 2005, p. 4.

As illustrated in Table 8, a key impact of the upgrades on the services was that the fastest of the trains on each line became faster. This was consistent with the government-stated benchmark that was set when the upgrading was announced—that the target transit times were met on a one-train per week-day return “flagship” service on each corridor (Australian Association of Time Table Collectors 2006, p. 3). However, the growth in demand reduced the emphasis on these “flagship” services: the consequence of flagship services was heavy loadings, which reduced reliability of these, and other, services. In general, it was a constraint that made it harder to balance the overall service offering across the corridor. Instead, V/Line has broadened the service-improvement focus across the range of peak and counter-peak services, shifting and encouraging demand on those services. That is, V/Line refocused the service enhancements to accommodate the needs of a wider spectrum of users with frequency improvements and some transit time reductions.

The following elements of service changes on the corridors are notable:

- On the Geelong corridor, the proportion of stopping trains increased relative to semi-express trains, resulting in minimal transit time improvements. At the time that the new service was introduced, the majority of the trains were powered by locomotives and therefore unable to be operated at higher speeds.
- The Ballarat corridor received the most time saving due to the track re-alignments and because most services are operated by the high-performance VLocity DMUs. Average week-day transit time was reduced by around 10 minutes, but there is wide dispersion in transit times, ranging from 67 minutes to 110 minutes (comparing 2004 and 2013). Table 8 presents a snapshot of week-day transit time and frequency for the V/Line Melbourne–Ballarat services in 2004 (before the upgraded service was implemented) and in 2013.
- A reduction of a few minutes was achieved on the Bendigo corridor in 2006, with faster running times partly offset by an increase in the average number of stops made by trains.
- On the Traralgon corridor, only two of the VLocity services were operated with VLocity units; with an additional station stop being included, the result was a minimal improvement in transit time in 2006 (Australian Association of Time Table Collectors 2006, p. 3).

The increase in patronage has led to the purchase of additional VLocity trains—the VLocity fleet has increased from the original 80 carriages in 2006, to 134 in 2013, while the basis for the multiple-unit trains is shifting to three-car rather than two-car. A further 40 carriages are being constructed, for delivery from 2014. Some of the vehicles have been used to lengthen

the train sets: the original trains were based around the two-car VLocity train (for instance, a coupling of two, two-car VLocity DMUs to form a single four-car train). In 2006 it was decided to order additional carriages that would be inserted in the middle of two-car DMU units; these cars were delivered from 2008.

Figure 17 Regional Fast Rail, showing VLocity DMUs



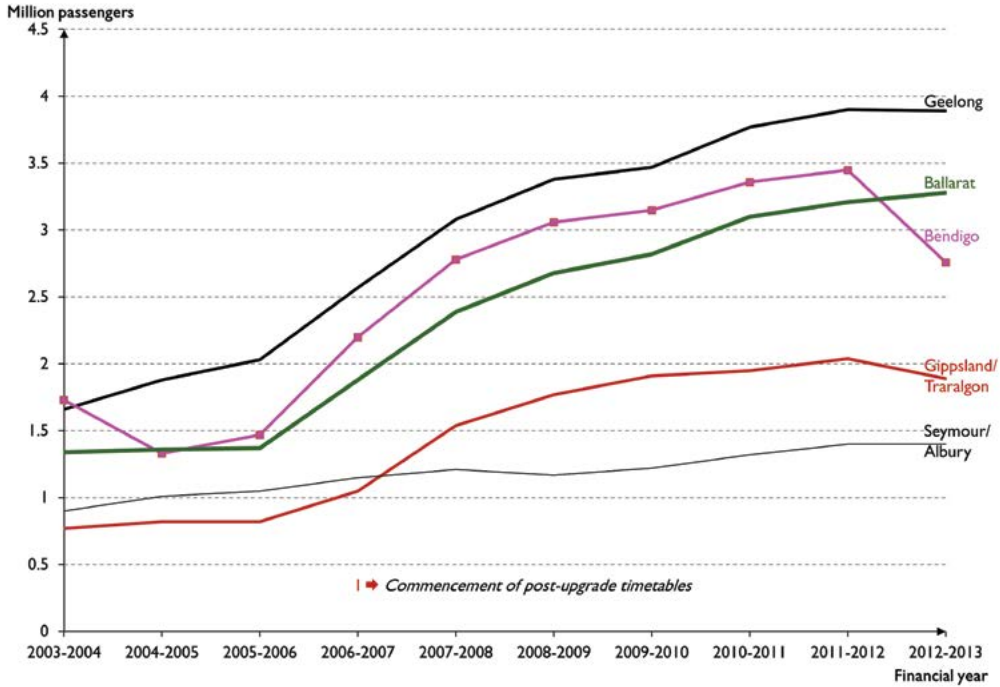
Source: Photograph courtesy of V/Line.

Impact on market

The travel markets (commuting and leisure activities) have responded strongly to the broad package of improvements—notably, substantially increased frequency, a general reduction in transit time and enhanced reliability, complemented by the introduction of modern trains giving excellent ride quality on renewed track. Patronage rose by 75 per cent between 2006–07 and 2011–12, from 7.2 million to 12.6 million users.

Figure 18 charts V/Line's rail patronage by the four corridors; notable influences on patronage that lie beyond the Fast Rail project are summarised below the chart. The Albury corridor (including Seymour, and Shepparton from 2004) is also included in the figure; the patronage on that service cluster provides a benchmark as it benefitted from the fare reduction but not the service upgrades. That is, the Albury corridor's lower patronage growth in the initial period after the 2006 provides some guidance to the marked effect of the upgrade on patronage. From December 2008, however, the Albury services have been either suspended (for conversion of the track from broad, to standard, gauge) or disrupted/delayed due to ongoing and protracted track work. That is, the Seymour/Albury operation patronage provides only a limited-value benchmark against which to assess the Fast Rail programme's success.

Figure 18 V/Line rail patronage by corridor



Notes: In general, patronage on the corridors benefitted from incremental traffic growth arising from supplementary services from other destinations served, such as Ararat (2004–05) and Maryborough (2010–11) on the Ballarat line; Bairnsdale (2004–05) on the Gippsland/Traralgon line; and Echuca (beyond Bendigo). In 2004, V/Line also resumed responsibility for the Melbourne–Seymour trains, through to Shepperton (services previously provided by Hoys, for the State government) and Warrnambool (beyond Geelong).

Notable factors that impacted on patronage in 2012–13 include:

- Gippsland/Traralgon patronage being adversely affected by two major temporary line closures. From late March 2013 (until the end of October 2013) trains did not operate between Traralgon and Bairnsdale, awaiting safety-related track repairs. In addition, the line between Moe and Morwell was closed between late-August 2012 and mid-October 2012 as a result of flood damage.
- V/Line Bendigo patronage was adversely affected by the shift of most Sunbury station patrons from the V/Line services to Metro Trains services when the latter operator's electric trains were extended to that well-used station.
- Patronage on Bendigo and Ballarat train services was adversely affected when the corridors' rail services were replaced by road coaches for periods of up to three weeks (enabling *Regional Rail Link* construction work to be undertaken). Longer, and less reliable, transit times dampened ridership.

Source: V/Line annual reports, various.

When considering traffic growth after the completion of the upgrade, it is important to note the adverse effect of engineering works on patronage during the upgrade. V/Line reported that patronage on the Geelong, Ballarat and Traralgon corridors fell by between 17 and 35 per cent during 2003–04. The works also involved “extended shutdowns” during 2004–05, with an inevitable dip in patronage at that time⁶⁹. Similar service disruptions have been affecting patronage adversely since the commencement of *Regional Rail Link* works in 2011—this is *part* of the reason for the check in patronage growth evident since that time (Figure 18).

⁶⁹ V/Line 2004, *Annual Report 2003–04*, p. 16; V/Line 2005, *Annual Report 2004–05*, p. 11. For example, the Werribee–Geelong line was closed for six weeks from January 2004; the Pakenham–Traralgon line was closed for nine weeks from February 2004; and the Ballarat line was closed between April and July 2004 (Hope 2004, p. 841).

Patronage levels rebounded after the completion of the Fast Rail project, importantly, continued to grow strongly. It is notable that V/Line reduced its fares by 20 per cent in March 2007 (around six months after the new services were introduced); this, too, will have stimulated rail traffic. V/Line indicated that the “new timetable and the 20 per cent fare reduction have played major roles in attracting more customers” (V/Line 2007, p. 3).

External factors have fuelled the upgrade stimulus to patronage. Growth in population and, especially in Melbourne employment, were additional factors that influenced V/Line’s strong growth after the completion of the upgrade work. As discussed in BITRE 2011 (p. 195) and in BITRE 2012 (p. 18), the City of Melbourne Local Government Area employment grew by 3 per cent per annum between 2002 and 2006 while between 2006 and 2008 the employment grew by 7 per cent per annum.

Note, however, that part of the observed population growth in the corridors is a consequence of the *Regional Fast Rail* project itself. In extending the area that falls within the reach of a practical daily commute, the project has boosted new housing development trends in those areas⁷⁰. For example, the Melton–Bacchus Marsh statistical area (straddling the Ballarat corridor) grew by one-third (from 100 thousand, to 134 thousand) between 2007 and 2012 (Australian Bureau of Statistics 2013). Thus, those new residents have expanded the travel market, stimulating rail patronage, especially for commuting purposes.

While the project enhances regional links to the city it also improves links for travellers to, or between, regional centres. This will include tourists from Melbourne as well as commuters *into* the main regional centres. Data from the 2011 Census indicates a growth in commuting between regional centres (excluding Greater Geelong) from 2006 although this trend was evident between 2001 and 2006 on the Ballarat and Bendigo corridors (Australian Bureau of Statistics 2012).

Against a background of strongly growing travel markets, Census data suggest that the *Regional Fast Rail* travel mode share to the Inner Melbourne Statistical Local Area has generally risen in the decade 2001 to 2011:

- from Ballarat it increased from 57 percent to 68 per cent and from Moorabool Shire (including Bacchus Marsh) it increased from 59 per cent to 64 per cent.
- from Greater Geelong it remained at 68 per cent;
- on the Bendigo corridor; the rail mode share from the Mount Alexander Shire area (including Castlemaine) rose from 60 per cent to 65 per cent and from the Macedon Ranges Shire area (including Kyneton and Gisborne) the rail share rose from 50 per cent to 52 per cent.

In summary, while it is not possible to separate travel market trends that would have happened without the upgrade, from the observed trends, the services have complemented and stimulated rail travel and economic activity along the corridors.

Conclusions

The *Regional Fast Rail* project sought to facilitate development in regional centres, enhancing the attractiveness of those centres as residential, commuter and tourist centres by strengthening links with Melbourne (for employment and services). There have been substantial patronage

⁷⁰ Note the existing, ongoing trend for the development of outer city areas and near-city townships.

and regional development responses. The V/Line operations have witnessed strong patronage growth since the completion of the *Regional Fast Rail* upgrades. Rail has generally grown its mode share while the travel market itself has grown strongly, complementing—and being complemented by—strong residential market establishment. Other factors have also driven this traffic growth, notably Melbourne employment growth and the fillip of a one-off fare reduction.

The completion of the upgrades provided key service improvements. Patronage rebounded after the upgrade work disruptions, responding to the much greater service frequency, as well as to some transit time reductions and greater comfort (new trains giving good ride quality, complemented by new high-standard track). Upgrade benefits extended beyond patronage growth. In particular, level crossings were upgraded, protecting passengers and reducing the incidence of road vehicles failing to stop when required.

The upgrade work illustrates compromises that arise from budget limitations. In particular:

- Early analysis demonstrated that upgrading to achieve transit times below one hour (45 minutes on the Geelong line) was not feasible within a realistic budget.
- The transit time upgrades were initially targeted at commuters/peak time travel—with notable “flagship” services—rather than the wider travelling public. The growth in demand reduced the emphasis on those services; instead, V/Line has broadened the transit time improvements across the service period.
- The initial upgrade work was also scaled back when it became evident that private sector funding could not be secured; such funding would have enabled track upgrade (additional capacity) in the metropolitan area.

In retrospect, there were upsides to the failure to secure funding for the metropolitan upgrading. The successful patronage uptake of the VLocity services provided strong evidence for the economic case for the subsequent *Regional Rail Link* upgrade work. The demonstrated strong demand for the regional services also provided a case for augmenting the urban project, notably in complete separation of regional and suburban services.

What is clear from this study is that there has been strong patronage growth since the completion of the upgrade. The strong response to the upgrade stems from a range of service quality enhancements, notably the improved service frequency, better reliability and enhanced rolling stock. In the absence of ex post evaluation, it is not possible to assess whether the upgrade met its cost–benefit criteria.

Study 3: Introduction of X 2000 train, Stockholm–Göteborg

Summary

- objective was to increase rail share of rail–air traffic.
- service upgraded in 1990, Stockholm–Göteborg, and then to other Swedish cities.
- curved track was major impediment to higher speeds.
- journey time savings achieved through use of tilt train, incorporating self-steering axles.
- average train speeds rose through higher speeds around curves.
- rail's market share with air rose from 42% to 60%.

Background

Sweden's population is relatively small and dispersed; traffic volumes are too small to make it practical to build a dedicated high-speed railway. At the time that Sweden introduced its X 2000 train, there was adequate spare railway capacity. From the 1970s, the manufacturer, ABB, in co-operation with the Swedish State Railways, developed a tilt train to provide faster rail services on existing track in lieu of building a high-speed railway (See Flink and Hultén 1993, pp. 89–103).

The debut for the train was on the 456 km double-track “West Main Line” electrified railway⁷¹ between Stockholm (with a population of 1.3 million) and the country's second city, Göteborg (with a population of 1 million). Services commenced in 1990. The train is now widely operated in Sweden and to the Danish capital, København. Patronage in 1996 was around nine million⁷².

The agent for the service upgrade was the above-rail government-owned Statens Järnvägar, succeeded by SJ AB, and now SJ. Below-rail (infrastructure) ownership was a government agency, Banverket, succeeded by Trafikverket, the Swedish Transport Administration.

Objective and goals

At the heart of the work in the important Stockholm–Göteborg corridor was the concern over the patronage decline, with traffic being lost to other modes (especially, to air). The investment in the corridor was aimed at reversing that decline.

To achieve this goal, it was decided to improve rail service competitiveness by development and introduction of a tilt train that would reduce transit times on existing tracks. This strategy was adopted in lieu of incurring what was regarded as prohibitive expenditure in building a dedicated high-speed line.

⁷¹ In Swedish this name is “Västra stambanan”. Note, also, that small sections of the railway around Göteborg and around Stockholm have four tracks.

⁷² <www.railway-technology.com/projects/sweden/>.

Figure 19 X 2000 Stockholm–Göteborg and Stockholm–København route



Description of the upgrading project

The tilt train that would deliver faster transit times did not exist at the time that the Swedish State Railways adopted the upgrade strategy; the development of the train thus became part of the upgrade process⁷³. The development of the X 2000 tilt train was a protracted process. In 1982 the first tender request was issued to undertake the development; after a second tendering process in 1985, the final contract negotiation occurred in 1986. The train commenced commercial operations in late 1990 (Edquist, et al 2012, p. 13).

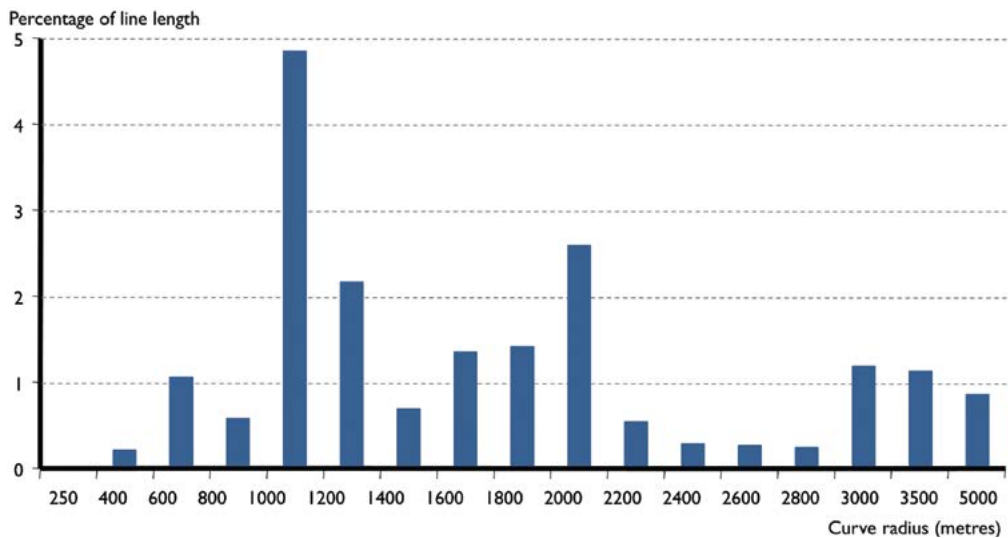
The X 2000 trains are equipped with a carriage tilt mechanism together with independently-steered axles. These features enable the trains to pass through curved track at higher speeds, with a reduction of lateral forces on passengers and reduced forces on the track, respectively (Nelldal 1998, p. 103). Further, the carriages are of a lightweight design and, with powerful traction motors, provided a high power-to-weight ratio that enables good acceleration from stops and away from slow-speed track sections. The top train speed was also higher than conventional trains, with a top commercial speed in service of 207 km/h and an average speed of 147 km/h between the two cities.

⁷³ The Pendolino train did exist, however, having been in operation since 1976. The Pendolino is based on traction motors in each vehicle whereas the X 2000 uses traction in a locomotive at one end of the rake of carriages.

The track between the cities has a number of curves—Figure 20 shows the extent and severity of the curves. The X 2000 can pass through curves at higher speeds than conventional trains, specifically when the curve radius lies between 800 metres and 2 000 metres. As can be seen in the figure, a large proportion of the track curvature lies in this radius where X 2000's tilt and bogie mechanisms deliver relative speed enhancements. (The pattern of these curves should be compared with that on the Canberra branch—see Figure 14).

The rolling stock upgrade was associated with a range of upgrades of the infrastructure on the Göteborg line. The track standard was raised. Level crossing standards were raised. New signalling was introduced; it was not necessary to invest in Automatic Train Protection because the system was already a standard feature for Swedish trains (O'Connor 1993, p. 64; Nelldal 1998, p. 103).

Figure 20 Stockholm–Göteborg line—distribution of curves below 6 000 metres, as a proportion of total line length



Note: The curvature length percentage is the length of that curve radius classification relative to the total line length.

Source: Derived from Persson 2010, p. 514.

Implementation

The X 2000 train was introduced to the Stockholm–Göteborg route in 1990, at a later date to the Stockholm–Malmö route (Figure 19) and then to other destinations in Sweden. The Malmö services were extended to København when the Öresund fixed link between Sweden and Denmark opened in 2000.

There is no information on changes to service frequency between the cities following the train's introduction. Current service frequency is approximately one train per hour in each direction.

Experience with the train in operation showed that rail wear and maintenance were reduced following the train's introduction. This arose because the self-steering mechanism reduced forces on the track.

Figure 21 Swedish X 2000 train



Source: Photograph courtesy of SJ.

Impact on service

When the X 2000 services commenced, transit time between Stockholm and Göteborg fell by one-third. Transit time is now just over 180 minutes, compared with 55 minute flying time. The introduction of the X 2000 to the Stockholm–Malmö route reduced the transit time by 30 per cent. Flink and Hultén (1993, p. 101) note that one reason why transit times were reduced was because some train services no longer stopped at some of the smaller population centres between the two cities.

The introduction of X 2000 services was accompanied by an increase in service frequency (Nelldal 1998, p. 108).

Initially, the X 2000 service was focused on attracting business travellers. As a result, only first-class carriages were provided, with premium-only seating (Keefe 1992, p. 6). Services now have two classes of accommodation.

Impact on market

The X 2000 upgrade enhanced the services offered by Swedish State Railways, winning travellers from other modes and reversing the recent earlier substantial decline. In 1980, rail's

market share of the rail–air market on the Stockholm–Göteborg route was 67 per cent it had fallen to 42 per cent by 1990 (Nelldal 1998, p. 105)⁷⁴.

From 2001 to 2007, the rail share of the rail–air market rose from around 48 per cent to 60 per cent. (Löfving (2012, p. 4) Rail's market share of all-mode travel on the Göteborg route is 35 per cent⁷⁵.

It is not possible to establish a clear perspective on fares during this time, albeit that the route has an active low-cost airline market (which developed from 1993).

Fröidh notes that despite achieving an estimated 40 per cent growth in rail traffic, the impact could nonetheless be regarded as modest in that the pre-upgrade market share was already relatively good: “the trains had a larger market share to begin with” (Fröidh 2003, p. 66). This observation should be remembered when comparing the impact of upgrades across the different corridor studies: the impact of the upgrade on patronage depends on the starting point of the service upgrade.

Conclusions

Details on the expenditure undertaken on the X 2000 are not available nor is there any information on important aspects of the extent and nature of service enhancements (such as service frequency). Nonetheless, the service is notable for having achieved its objectives of recovering mode share through a reduction in transit time. Higher average speeds have been achieved with trains passing through curved tracks at higher speeds. The train itself is suited to the track conditions it faces, with curvature being not too sharp nor too shallow for the technology.

The current transit time is five to ten minutes longer than has been achieved in the past; this slowdown is attributed to capacity constraints that have developed on the Göteborg corridor. Löfving (2012, p. 3) indicates that there are longer-term plans for high-speed railway construction to relieve the capacity constraints; the preferred option is a new route to the south of the current West Main Line.

While the service upgrade has reversed the mode share decline and led to an estimated 40 per cent traffic growth, it is notable that the upgrade was undertaken from services with a relatively high standard and so, arguably, the incremental traffic growth was therefore relatively modest.

⁷⁴ The coach service between the cities takes around 7 hours.

⁷⁵ In 1996, two-thirds of the rail passengers travelled by X 2000 and one-third by conventional trains (Nelldal 1998, p. 105).

Study 4: Berlin–Hamburg Ausbaustrecke (ABS)

Summary

- comprehensive rehabilitation of infrastructure between 1994 and 2004, restoring line standards and line speeds.
- restoration of capacity.
- large increase in service frequency.
- cessation of air services on route.
- underlying restoration of social and economic links propelled overall travel market growth.

Background

The 286 km Berlin–Hamburg railway links Germany's two largest cities: Berlin (population 3.4 million) and Hamburg (1.8 million). The railway and passenger train services are operated by the government railway company, Deutsche Bahn (DB)⁷⁶.

By contrast with other parts of the East and West German rail networks, the Berlin–Hamburg railway deteriorated in the years prior to the country's reunification: the corridor operated through both countries but, with restricted passenger flows, the railway languished. Reunification restored the leisure and commerce links between the east and west, raising the importance of the corridor. In 1999, Berlin was restored as the unified country's federal capital.

Objective and goals

The impetus for the railway upgrade lay in the German Unity Transport Projects, announced in 1991. This bundle of corridor enhancement projects recognised the importance of good transport links in eastern Germany, including links between Berlin and western areas. With Berlin–Hannover being the principal corridor linking Berlin with the west, the corridor was enhanced with the construction of a largely-new railway⁷⁷—see Figure 22. For the Berlin–Hamburg corridor, construction of a dedicated high-speed line was rejected on costs grounds; despite this decision, a more-costly Maglev high-speed concrete guided trackway was proposed, together with upgrading of the existing railway to speeds of 160 km/h — project “VDE No. 2”. The track upgrade was completed in 1997⁷⁸.

In 2000, further upgrading of the conventional line was triggered subsequently because the *Transrapid* Maglev proposal was abandoned following a review of the patronage forecasts that underpinned that relatively expensive project. The further upgrading work focused on raising maximum train speeds to 230 km/h. The work was completed in 2004.

⁷⁶ Most of the railway corridor east of Hamburg and to the west of West Berlin (that is, the East Germany area) was owned by Deutsche Reichsbahn (of East Germany) until 1994.

⁷⁷ The German term for these new railways is Neubaustrecke, NBS; upgraded railways are designated as Ausbaustrecke, ABS.

⁷⁸ Verkehrsprojekte Deutsche Einheit, VDE.

Figure 22 Berlin–Hamburg corridor and Hannover HSR route



As with other European corridors, the railway's role was elevated with the economic and social binding of European Union countries and the eastwards expansion of that federation's membership; and growing trade with members of the Commonwealth of Independent States (such as Russia).

Description of the upgrading project

While the corridor had a sound railway alignment, the division of the country and the economic circumstances in the east had impeded corridor development. The railway was inherently capable of higher speeds than those that prevailed in the lead up to reunification. For instance, in 1933, the *Fliegender Hamburger* train commenced operations between Hamburg and Berlin, with an average speed of 122 km/h, a top speed of 160 km/h (Ebeling 2005, p. 37) and transit time of 138 minutes compared with 243 minutes in 1990.

The first phase of the upgrading work (1992–1997), therefore involved renewal and enhancement work that had long been applied to other parts of the network. These first-phase enhancements included:

- electrification;
- enhanced capacity, through the restoration of double-track⁷⁹; and
- introduction of the InterCity Express (ICE) train in 1997.

This work enabled train speeds to be raised up to 160 km/h.

⁷⁹ There had previously been a second track, which was dismantled as part of post-war reparations to the USSR.

The cancellation of the Maglev plan in 2000 led to considerably more substantive upgrading than the earlier works, such as:

- **Capacity.** Capacity enhancement through the provision of new tracks in the Hamburg area, enabling the separation of the Berlin trains from the local S-Bahn trains;
- **Signalling, communication and train control.** Automatic train control, in-cab signalling and protection were introduced (Zugbeeinflussung, LZB);
- **Crossings.** All level crossings were removed on the route (of which there were 57)—this involved constructing 56 grade separations (Der Spiegel 1999, p. 115);
- introduction of platform barriers, separating people from trains speeding through stations;
- **Condition of infrastructure.** Extensive track, overhead wiring and bridge replacement was undertaken;
- **Tilt trains.** Siemens ICE-T tilt trains were introduced (using Alstom–Pendolino tilt technology).

For safety regulation reasons, the removal of the level crossings was a necessary step in order to increase speeds above 160 km/h. No information is available on the costs for each component.

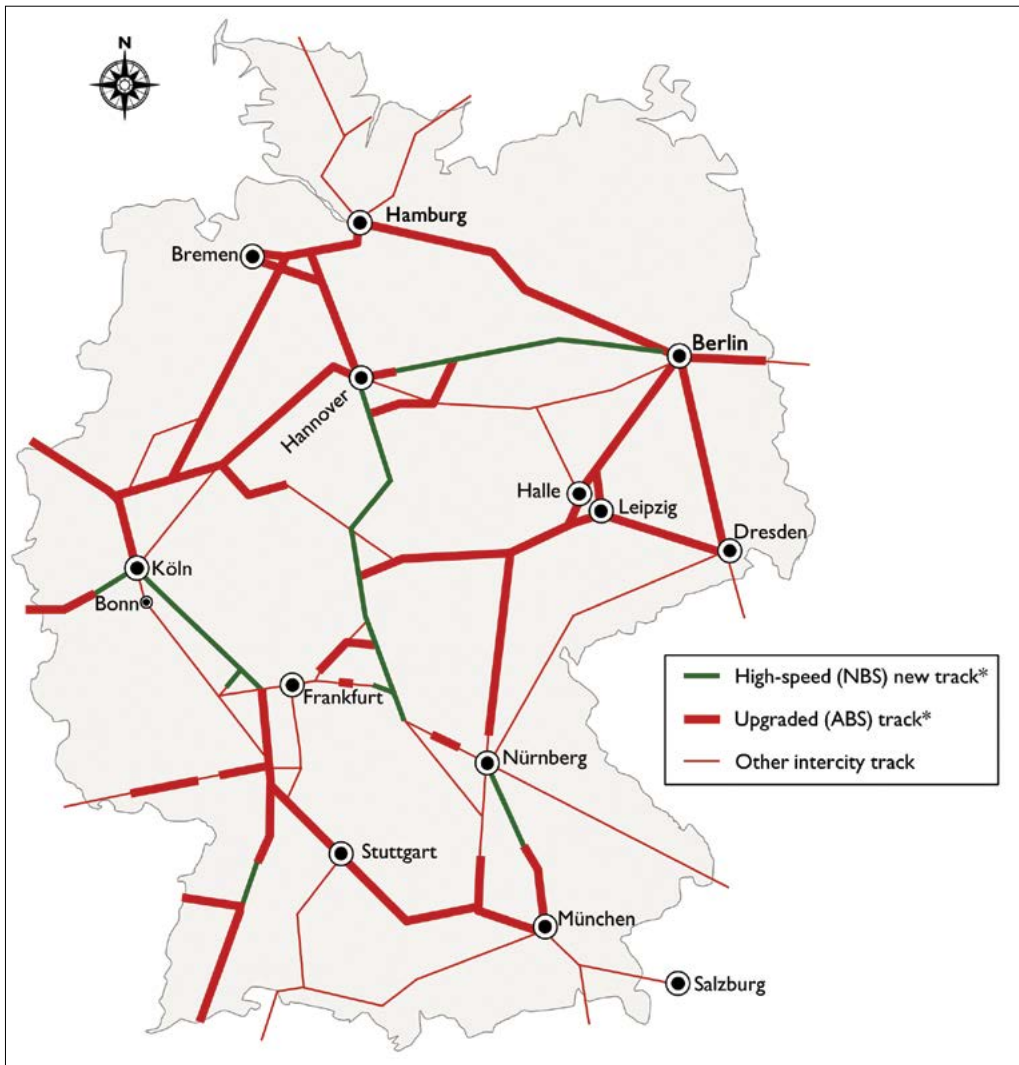
The passenger train operator, Deutsche Bahn, had intended to have a higher proportion of express services than are actually run but their plans were over-ruled by a government minister (Die Welt 2007).

Box 7 German upgraded and new railway policy

The provision of high-standard German railway passenger services is based on the philosophy of line upgrading rather than new railway construction. New sections of railway are constructed where capacity is constrained, where track alignments provide a severe speed constraint or where much higher speeds are desired. As is evident in Figure 23, the upgraded railway services dominate the network, with high-speed operations forming only a relatively minor role.

The upgrade policy is encouraged by the country having a legacy of good track and route alignments and relatively dispersed cities. The dispersed German cities contrast with French demographics centred on Paris; in the latter case, the development of a several radial high-speed lines is a relatively cost-effective strategy that could not be applied to providing (non-radial) high-speed links connecting the complex web of German cities.

The German philosophy of mixed passenger and freight traffic on upgraded track is based on scheduling freight traffic to operate during evenings and nights, when few passenger trains run; this ensures that there is minimal scheduled timetabling, and real-time prioritisation, issues between the different train types. This then ensures that each mode's reliability is protected.

Figure 23 German upgraded and other railway services (schematic map)

Note: * NBS, Neubaustrecke; ABS, Ausbaustrecke.

Implementation

The upgrading work was undertaken in two phases, between 1994 and 1997; and between 2000 and 2004. Track speeds were then raised, in the first phase to 160 km/h and then to 230 km/h. Work was completed subsequently in the Berlin area, with new central station facilities and U-Bahn and S-Bahn connections.

The extensive engineering works had a marked impact on services at various stages. For example, transit time in 1995–96 was increased from 179 minutes to 220 minutes to expedite track work (Deutsche Bahn 1996, p. 30). The need for extensive renewal of track along the route led to the closure of the railway for 11 weeks in 2003.

Impact on service

The removal of the country border and the upgrades have brought substantial reductions in transit time, to intercity times that are competitive with road. In 1990, the transit time was 243 minutes, falling to 204 minutes after reunification. In 2000, after the initial corridor upgrade, the transit time was around 138 minutes. The completion of the second stage of the upgrade in 2004 reduced transit time by a further 30 minutes. By August 2013, the lowest transit time was 98 minutes (for express operations), with several minutes added for each additional station stop, to an average of about 102 minutes. To place these transit times in context, it has been reported that transit time by car is around 140 minutes; the Bundesautobahn 24 between the cities is a high-speed motorway, about two-thirds of which has no upper speed limit (Der Spiegel 1998, p. 78).

Following the upgrade, service frequency was increased substantially. Before reunification, there were two trains per day on the route, increasing in 1993 to a train every two hours; by August 2013 there was one train per hour.

The enhancement to the route was complemented by extension of services to destinations beyond Hamburg. This has the effect of broadening the corridor's market and catchment area. For example, some services were extended to Munich in 2006 and to København in 2007.

Rolling stock upgrades were also implemented, first with the introduction of the InterCity Express (ICE) train in 1997 followed by the introduction of the ICE-T tilt trains. The track is relatively straight on the route but the tilt mechanism is of value on lines beyond Hamburg.

Impact on market

There is little evidence on the impact of the service on patronage although, with service frequency rising from two trains a day, to an hourly service, it could be surmised that there has been strong growth. It is notable that the first upgrade alone led to the withdrawal of competing airline services on the route (Spaven 2006, p. 12). (Given the relatively short corridor length—286 km by rail—it is a mark of the underperformance of rail that air services between these two large cities could have been sustained over that distance.) It was reported in 1997 that “due to heavy demand”, an hourly rail service frequency was introduced (Deutsche Bahn 1997, p. 23).

The second upgrade has led to notable gains in patronage. In 1997, daily patronage averaged 6 000. In 2003, patronage was 6 575 per day (Stern 2004 quoting 2.4 million per annum). Daily ridership was 10 000 in 2007, with traffic in the twelve months after its completion, to May 2007 rising by 47 per cent (Die Welt 2007). DB identified reasons for growth as including new fare offers, shorter travel times and improved connections to local and longer-distance routes (Deutsche Bahn 2007). Longer-term traffic growth will have occurred with advent of free social and economic movements across the former border.

Conclusions

The political realignment of Germany with reunification, and the growth of the European Union have driven the case for the upgrade of the Hamburg–Berlin railway, paralleled by new traveller patterns across the reunited country and neighbouring countries.

As with other case studies, the extent of upgrade work depended on the starting position. From being “fast” double-track railway across the country before the Second World War, by 1989 the service had declined to an infrequent operation on a slow, single-track railway operated by two organisations across two countries.

The first upgrade phase essentially redressed the considerable infrastructure renewal backlog. This enabled restoration of the earlier track speeds, complemented by electrification and, with added capacity (double-tracking), introducing frequent services.

The second upgrade phase completed renewal work and removed obstacles to achieving higher speeds. These obstacles included the need for in-cab signalling and advanced train protection, and the removal of a large number of level crossings.

The limited patronage information indicates strong growth along the corridor, with services aligned to link with cities beyond the core Berlin–Hamburg axis.

Study 5:Wien–Salzburg (Westbahn) upgraded railway

Summary

- comprehensive upgrade of the railway between Wien and Salzburg, aimed at a higher-performance railway, not higher speeds.
- the focus has been on enhanced capacity, enabling a range of additional passenger and freight services to operate.
- additional enhancements include some new track alignments (with eased curves) and a more accessible new city centre station in Wien,
- increased service frequency and higher-performing rolling stock have also improved service quality.

Background

Wien (Vienna), in eastern Austria, has a population of 3 million. Westbahn (Western Railway), is a 317 km line that links the city with Salzburg, (population 145 000). The corridor is an important connection across the country and across the European Union.

Trains and tracks are managed and operated by state-owned Österreichische Bundesbahnen — Austrian Federal Railways, ÖBB. Since 2011, a private operator (called Westbahn) has operated a competing passenger train service on the Westbahn.

Objective and goals

The investment in upgrading the railway had its roots in the Austrian Federal Railways' 1987 policy statement for the "New Railway" concept, with the objective of reducing transit times (Schönbäck, et al, 1990, p. 219). Following this strategy the Austrian government decided in 1989 to upgrade the Westbahn corridor to 200 km/h operation as a proclaimed "high performance route" (ÖBB Infra 2009, p. 4). The railway company's philosophy is based on "building a high performance railway rather than simply developing a high speed line" (Hainitz and Koller 2002, p. 192).

The corridor's role increased after Austria's accession to the Union in 1995 and subsequent entries of other eastern European countries, bringing additional passenger and freight flows across the country. The railway also became a link in the European Union's Trans European Network (transport) as designated by the European Commission—the corridor between Paris, Strasbourg, Stuttgart, München, Salzburg, Linz, Wien and Bratislava ("Priority axis No. 17") and, at Linz, a link to Praha (Prague) ("Priority axis No. 22")⁸⁰.

The heightened role of the railway as an international corridor reinforced the emphasis of the upgrading as a high-performance and high-capacity route rather than just reducing transit time.

⁸⁰ See <ec.europa.eu/ten/transport/maps/doc/axes/pp17.pdf>.

Figure 24 Wien–Salzburg line upgrade



Description of the upgrading project

The upgrading programme has been underway since the early 1990s, with the first project being completed in 1994.

New or upgrading work covers 284 of the 317 route-kilometres. As noted above, the key elements of the upgrading have been to expand track capacity. This has involved upgrading the number of tracks for much of the distance from two to four. However, with fewer trains operating west of Wels (where Nürnberg traffic diverges) there is less emphasis on capacity expansion (Figure 24); the emphasis on that line segment remained with reducing transit times and this includes new track alignments.

Capacity amplification has provided the opportunity to reduce transit times. The track quadruplication has provided an opportunity to ease curves on the supplementary tracks, to enable trains to operate at higher speeds on those new tracks.

It was not always possible to implement upgrades on the existing alignment, requiring entirely new alignments to be built. To add capacity and speed on the section Wien and Sankt Pölten (Figure 24), two tracks were added on an entirely new 56 kilometre alignment (Hainitz and Koller 2002, p. 191). Trains using these tracks can cross the section in 25 minutes rather than 41 minutes on the earlier alignment. (Reidinger 2013, p. 26). Two other, less-curved supplementary railway alignments that are well away from the older line can be seen in Figure 24.

Improved city accessibility is a major undertaking. Work is continuing on developing a new Central Station in Wien. This work includes building a new railway to enable Salzburg trains to access the station rather than at the relatively-remote Wien Westbahnhof (western station)

that is the current terminus. The new station will give better access to the city centre and to long-distance and local rail and tram services.

Rolling stock was purchased for the new *Railjet* services operated on the corridor. The *Railjet* services operate between München and Zurich in the west and Bratislava and Budapest in the east. The new locomotives used with the new passenger carriages are capable of the higher speeds.

Implementation

Work on the upgrading has been undertaken over a period of more than 20 years, with further work planned through this decade and beyond. The major capacity amplification between Wien and St Pölten was completed in 2012. *Railjet* services, with new rolling stock, have been operating since 2008–09. Works around the new Central Station in Wien are yet to be completed. The quadruplication of tracks is continuing.

Impact on service

As noted above, the emphasis of the upgrade has shifted from transit time to capacity enhancement. However, the additional two tracks between Wien and St Pölten has reduced transit time on that section by 16 minutes. It is unclear, however, what improvements in service frequency have been achieved.

Train services on the corridor have increased in that an additional train operator, Westbahn, commenced operations in December 2011 in competition with ÖBB.

Figure 25 ÖBB *Railjet* train



Source: Photograph courtesy of ÖBB.

Impact on market

There are no data available on the impact of the upgrade. It was noted that, prior to the upgrading work, that long-distance transport within Austria had declined in favour of car travel. In 1984, the rail share of long-distance passenger travel was 17 per cent (Schönbäck, et al, 1990, p. 219). There are reports of strong passenger traffic growth (Reidinger 2013a) but there is insufficient information available to clarify the data (such as whether the *Railjet* services recorded a disproportionate level of traffic growth).

Conclusions

The upgrade of the Wien–Salzburg railway corridor has been undertaken over a protracted period (more than 20 years) and upgrade work continues. The focus has been on enhanced capacity, which then enables higher service frequency on the route. New alignments, easing the curved tracks, allow higher speeds; new city centre station in Wien improves service accessibility. New rolling stock has been introduced, with 230 km/h operation.

Study 6: Helsinki–St Petersburg *Allegro* service upgrade

Summary

- comprehensive upgrade of infrastructure—track renewal, curve-easing and a major new section of track
- substantial work on expanding capacity, notably by diverting much of the freight traffic to other upgraded tracks
- introduction of tilt trains
- pooling of Finnish and Russian services and doubling service frequency
- undertaking custom/immigration activities on the train
- strong market response to upgrade

Background

The cities of Helsinki (with a population of around one million) and St Petersburg (with a population of around five million) are linked by a 415 kilometre electrified railway⁸¹. Until 2010, separate train services between Helsinki and St Petersburg were operated by the Finnish, and Russian, State railways (VR Group and RZD) respectively. Finnish railways ran its *Sibeli* train between Helsinki and St Petersburg and the Russian railways operated its *Repin* train. The trains had a transit time of 342 minutes or longer (Finnish Rail Administration 2008, p. 16).

Objective and goals

Since the 1980s, the national governments of the two countries have resolved to improve land links between the cities, with a Soviet passenger service (*Repin*) being supplemented by a Finnish operation (*Sibeli*) in 1992. In 2001, the Finnish and Russian presidents formally committed to upgrade the services⁸². This top-level accord led to the respective State-owned railway entities reaching agreement over the technical and funding aspects of the upgrade of the system and the revenue-sharing between them.

The decision to upgrade services based on existing lines rather than build a dedicated line reflected the countries' common practical solution to service provision on other routes. With large, dispersed populations, Finland and Russia have used service upgrades as a way of delivering cost-effective, attractive passenger train services. In Finland, the tilt train technology has been applied on four corridors, using the Pendolino train. In Russia, the *Sapsan* [Peregrine Falcon] high-speed train service has linked Moscow and St Petersburg over a 650 kilometre upgraded railway since 2009, operated at speeds up to 250 km/h.

⁸¹ The railways of the two countries have different track gauges, but the variation is small enough (1 524 mm for Finland; 1 520 mm for Russia) to be accommodated within the wheel spacing.

⁸² There is no evidence that the countries have ever considered seriously that the link should be a dedicated new railway (notwithstanding that the success of the upgrade could be a proving ground and, thus, a precursor to a policy for such an investment).

Figure 26 Line upgrade and freight diversions, Helsinki – St Petersburg

Note: Single track is shown as a thin line; the freight route is shown in green. Only lines that are directly relevant to the analysis are shown; thus, for example, Lahti and Luumäki are major railway junctions.

Description of the upgrading project

The average train speeds of the pre-upgrade services were retarded by a large number of physical and procedural factors. For example, the two railways used different power systems, requiring locomotives to be changed at the border. In addition, throughout the corridor service reliability was undermined by the diverse use of the track by a range of freight and passenger trains. Finally, the two railways provided independent services, operating at irregular times and undermining would-be patrons' perceptions of service frequency.

There are five key areas where the upgrading enhanced the services, taking place between 2006 and 2011:

- **Infrastructure.** Infrastructure work that improved transit times included construction of a new 63 kilometre alignment (between Kerava and Lahti, Figure 26) that shortened the route by 26 kilometres and bypassed tightly-curved tracks; a number of curve-easing track realignments (Lahti–Luumäki); and track renewal that upgraded the track standard, enabling trains to operate at higher speeds (Lahti – St Petersburg⁸³). Signalling enhancements were also undertaken.
- **Capacity.** Transit time and reliability was improved by reducing capacity utilisation on the corridor. Differential speeds of (fast, short) passenger and (slow, long) freight trains absorbs a lot of capacity and increases the potential for unreliability. To avoid these issues, some of

⁸³ For example, the maximum speed on the Lahti–Luumäki section was raised from 140 km/h to 200 km/h (Ruohonen 2010, pp. 11–12).

the freight movements were moved to an alternative route. The diversion, on the Russian side — between Vyborg and St Petersburg (Figure 26) — involved construction of a 64 kilometre electrified line and the electrification, track upgrade and track duplication of other parts of the freight line (in particular, Petyayarvi – St Petersburg). This separation of trains resolved what had been “an acute issue for a long time” (Baltic 2009).

- **Rolling stock.** New rolling stock contributed to transit time improvements. The *Allegro* service uses Alstom's Pendolino EMU (electric multiple unit) tilt train which (for example) raised the maximum speed on the Luumäki–Vainikkala line from 120 km/h to 140 km/h (Ruuhonen 2010, pp. 11–12). It is not known how much of the route has curved track that could be traversed at higher speeds due to the tilt mechanism. The train has dual voltage, removing the time needed to change locomotives at the border.⁸⁴
- **Administration.** The customs and immigration processing switched from being undertaken while the train was stationary at the border, to being undertaken on the moving train. Anecdotal evidence — the previous dwell time at Vyborg station (near the border) — suggests that this change has saved at least 30 minutes.
- **Service frequency/service pattern.** Combining the separate *Sibelius* and *Repin* services as a single, co-ordinated *Allegro* train (with modern interiors and ride-quality) on a structured timetable has enhanced the comfort and the perceived service frequency.

There is no information available on the impact of the individual upgrades on the transit time improvement.

Implementation

The implementation of the upgrades involved three phases. In the first phase, the Kerava–Lahti “Direct Line” was opened in 2006. The *Allegro* service was launched in December 2010 following extensive track work, the development of an independent Russian freight route and delivery of the Pendolino trains. Initially, the service was two return trains per day, rising in 2011 to four return trains per day.

⁸⁴ The Finnish electrical system operates to 25 kV AC through the catenary, while on the Russian side the voltage is 3 kV DC. See also VR Group 2010.

Figure 27 *Allegro* tilt train, between Helsinki and St Petersburg



Source: Photograph courtesy of VR Group (Finnish Railways).

Impact on service

The track upgrading phase inevitably had an adverse impact on transit times, reliability and the level of service cancellations of the *Sibelius* and *Repin* services. Commuter services on the St Petersburg – Vyborg line were also affected severely⁸⁵.

The inauguration of the five key upgrades had a marked impact on service transit time and frequency. Transit times were reduced by more than two hours, to 216 minutes. The pre-upgrade service frequency probably underperformed because railways' services were separately marketed and operated⁸⁶. The current four return trains have departure times that are staged across the day, with identical transit times⁸⁷. The number of intermediate stops remained as six stations.

There is no information available on levels, or changes in levels, of reliability of the service. It is presumed that reliability will have been improved with the removal of many of the freight train interfaces, and the customs and immigration clearance in Vyborg.

Impact on market

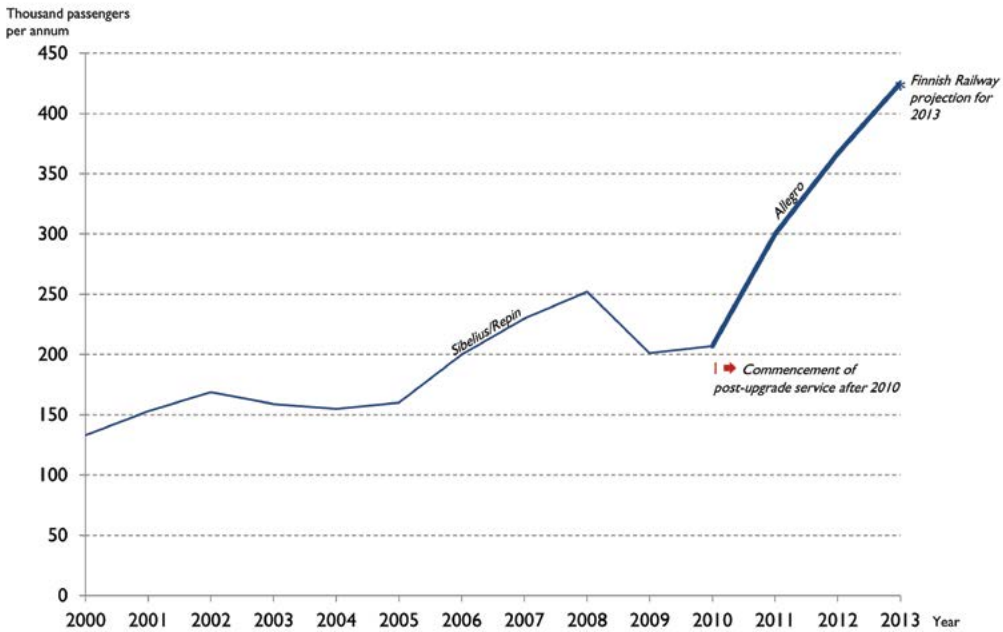
Prior to the commencement of the *Allegro* service, in 2008, patronage had peaked in 2008, with 252 000 passengers (Ruohonen 2010, p. 33). With substantial upgrade disruptions, *Sibelius*/*Repin* patronage had fallen to 200 000 in 2010. See Figure 28.

⁸⁵ Baltic (2009) reported that “the reconstruction became a real disaster for inhabitants of Leningrad area and St Petersburg who use the local trains going in the direction of Vyborg”. There were “extreme” train cancellations and extended travel times.

⁸⁶ There is also an overnight sleeper each way between Helsinki, St Petersburg and Moscow; this service lies beyond the subject area of this report.

⁸⁷ There is a one-hour time zone difference between the cities: Eastern European Time and Moscow Time.

Figure 28 Passenger volumes on the *Sibelius/Repin* and *Allegro* services*



Note: * The patronage figures here exclude riders on the Helsinki – St Petersburg – Moscow *Tolstoi* overnight sleeper train.

With the commencement of *Allegro* and the completion of upgrade works, patronage of 300 000 on those services (that is, excluding the *Tolstoi* overnight train) was recorded in 2011, followed by 367 000 in 2012. In the January–May 2013 period, patronage was up 31 per cent, on the corresponding period in 2012; that suggests an patronage of 425 000 in 2013 (VR Group 2013).

As is evident in Figure 28, there has been a rebound after the upgrade disruptions and strong growth subsequently. Before the service commenced, the predictions were that patronage would be 1.5 to 2 times the pre-*Allegro* level after five years⁸⁸. The annualised patronage estimate for 2013 suggests that the lower end of that forecast will have been exceeded by the end of 2013. Press reports suggest that business travel is being attracted as well as leisure; business travel is being diverted from air.

In considering the patronage patterns, the fares should be considered. The *Allegro* operation was introduced with higher fares. At the time that the new service commenced, second-class fares were around €70 (replacing a €50 fare) and business-class fares were around €110 (replacing a €90 fare). Subsequently, fares have been adjusted according to the popularity of individual trains.

Other passenger markets have benefitted from the upgrade programme and upgrading work is being undertaken to improve service connections between this corridor and other parts of Finland and Russia (Lehtipuu 2012, p. 12). The Kerava–Lahti Direct Line added important capacity to the route, and also provided a more immediate benefit to travellers between, and beyond, Lahti and Helsinki (including new regional Pendolino services). Patronage in that corridor rose significantly as a result of the faster, direct line.

⁸⁸ Baltic Go-ahead Elephants Analytical Group 2009.

Figure 29 *Allegro* tilt train, Helsinki Central Railway Station

Source: Mr Andrew Grantham, Railway Gazette International.

Conclusions

A range of investments have been undertaken in this corridor to renew and upgrade the track and expand the capacity. These investments, complemented by service upgrades (higher service frequency and new rolling stock) and procedural changes (crossing the customs and immigration border; multi-voltage trains that obviate the need to change locomotives), have resulted in a transit time reduction of more than two hours.

The enhancements that culminated in the introduction of the *Allegro* service dealt with a broad range of travel time and capacity issues. The infrastructure renovation is not just a benefit to the *Allegro* service, with commuter and freight services also benefitting. Nonetheless, as with other case studies, there is no evidence of cost-benefit analysis to underpin the investment decisions.

The substantial capacity enhancements on the corridor have been an essential upgrade expenditure to enable the amplification of services and to ensure that the services can be provided reliably. Such capacity works do not necessarily deliver time saving benefits but they underpin the delivery of faster and more frequent services.

The travel market has responded strongly to the upgrades. With considerable time savings achieved, a city-centre-to-city-centre operation, and on-board customs and immigration, the new service can now offer some travellers a door-to-door time that is competitive with air services.

The traffic growth resulting from the upgrades has supported the case for further investment. Further upgrade work is planned, with transit time reduced at least 30 minutes, to a three-hour journey. Further studies are underway for ways to achieve that time reduction (Lehtipuu 2012, p. 12).

Study 7: Paris/Tours–Bordeaux upgrade⁸⁹

Summary

- from the 1970s there was an upgrade of the Tours–Bordeaux railway
- the upgrade was built on the existing high technical standard of the railway, enabling a high performance service to be implemented.
- a high-speed railway was grafted onto the northern (Tours–Paris) section in 1990, enabling a very competitive transit time to be offered between Paris and Bordeaux.
- higher service frequencies have brought traffic levels to the upgraded track that has triggered the construction of a dedicated high-speed railway to supplement the upgraded railway.

Background

Passenger trains link the French cities of Paris (metropolitan population of 12.2 million) and Bordeaux (population of 1.1 million) along a 584 kilometre railway. Passenger services are provided by French National Railways, SNCF, a government agency using RFF (Réseau Ferré de France, a government agency) tracks⁹⁰. The track is doubled, with some sections of quadruple track closer to Paris. The route of the “classique” link between Paris and Bordeaux is via Orléans and Tours (Figure 30).

The essential feature of the railway is that it was built to a very high track alignment standard. This high standard was reinforced by electrification in the 1930s. By that time, services between Paris and Bordeaux took 355 minutes—that is, an average speed of around 98 km/h.

⁸⁹ The assistance of Michel Leboeuf, from SNCF; and Alain Bonnafous, Professeur émérite de l'Université de Lyon, is acknowledged.

⁹⁰ Société Nationale des Chemins de fer Français — National society of French railways. The French government intends that on 1 January 2015 SNCF and RFF would be brought back together under SNCF.

Figure 30 Paris–Bordeaux *classique* and high-speed routes

As a result of the upgrading work from the late 1960s, the transit time was reduced to 235 minutes for the *Aquitaine* express train, so averaging around 149 km/h.

A high-speed railway (Ligne à Grande Vitesse, LGV, *Atlantique*) was opened between Paris and Tours in 1990 (Figure 30). Paris–Bordeaux services shifted from the *classique* route via Orléans to the high-speed route between Paris and Tours, with services being operated by TGV trains. With this new high-speed section, the best express transit times are around 180 minutes, so averaging around 195 km/h.

The electrical current on the route is 1.5 kV DC, which was standard for the French system before the 1950s. That DC current contrasts with modern 25 kV AC that is used on high-speed track, including Paris–Tours. Dual-voltage (1.5 kV DC and 25 kV AC) TGV trains operate on the route.

The success of LGV *Atlantique/classique* route services has led to capacity issues on the *Tours–Bordeaux* *classique* line. Resolving that capacity issue and also improving regional links beyond Bordeaux—such as to Toulouse and to northern Spain—has led to the construction of a new LGV line between Tours and Bordeaux (also shown in Figure 30).

Objective and goals

The upgrade was designed to arrest the decline in market share, with traffic being lost to airlines.

Description of the upgrading project

The high standard of alignment meant that relatively modest work was required to upgrade the route for higher speeds. The railway has large-radius curves and gentle gradients. The focus of the works were:

- track renewal;
- reinforced electrical power;
- removal of all level crossings on sections where trains would operate at speeds of 200 km/h;
- a new signalling system; and
- introduction of *Grand Confort* carriages that could be operated at the higher speed of 200 km/h⁹¹.

A result of the track, power, signalling, crossing and rolling stock work, the maximum speed of 200 km/h could be realised from 1971. TGV trains were introduced on the route when the Paris–Tours LGV was opened; those trains could be operated on the Tours–Bordeaux section at speeds up to 220 km/h.

Implementation

The upgrading work was undertaken from the late 1960s into the 1970s. The upgrading work enabled the introduction of the express “*Aquitaine*” *Trans-Europ-Express* (TEE) train in 1971.

Impact on service

The completion of the upgrading works and new rolling stock led to substantial reductions in transit time in 1971, particularly on the express service. The *Aquitaine* express offered a transit time of 235 minutes while semi-express services (with one or two intermediate stops) offered transit time of 245–255 minutes.

The subsequent diversion of the fast services to the LGV Tours–Bordeaux route in 1990 led to further transit time reductions, to around 180 minutes (an average of 195 km/h). The service also benefitted from the introduction of the modern, comfortable TGV trains. There is no information available to establish if there were any changes in service frequency; at present there are around 21 direct TGV trains each way per day. By contrast, there are around 18 Air France week-day flights between the cities (Zembri 2009, p. 10).

An adverse impact of the new express services between Tours and Bordeaux from 1990 was that other passenger and freight services were (literally) side-lined in order to give priority to the expresses (Chapulut 2001, p. 9).

⁹¹ The trains were designed for subsequent modification for a tilt mechanism but this update was not implemented.

Impact on market

The upgrade arrested the decline in traffic, which had been lost to airlines. However, the service frequency of the express (*Aquitaine*) train was limited to one return service per day and seating was provided only for first-class ticket-holders. Semi-fast trains were provided also, with two seating classes.

However, with a four-hour transit time, services were still uncompetitive with airlines and airlines retained their dominant market position. Thus the upgrade provided only a temporary respite, with further market share declines in the 1980s. This trend was not reversed until 1990, when the services were further enhanced with the introduction of the TGV trains and the LGV Paris–Tours route reducing transit time by around one hour. At the time that the TGV service commenced in 1990, the corridor had around 20 million passengers per annum.

It was estimated that in 2005 rail had a 65 per cent share of the rail–air market between Paris and Bordeaux (Steer Davies Gleave 2006, p. 9); the rail market share in 2008 was 68 per cent (Zembri 2009, p. 14). It was reported that the air routes in direct competition with the train had had “a significant reduction in traffic” while motorway traffic on the route had had a “slow-down in growth” whereas other motorways “continue to grow” (Arduin 1994, p. 31). Chapulut reported that it was difficult to assess the extent of the transfer of traffic from roads. (Chapulut 2001, p. 19) While the route also saw the introduction of low-cost air operations in the 1990s, by 2003 only Air France services remained (Zembri 2011, p. 7).

There is limited information available on rail fares following the 1990 upgrade but “an important increase in prices and more complex marketing procedures” has been reported⁹². The fare increase had a marked impact on shorter distances, with diversion to car (Houee and Klein 1998, p. 6).

The patronage growth after the TGV operation commenced has been sufficiently great as to justify the construction of a new high-speed line (Figure 30) to relieve congestion on the classique route and to develop links beyond Bordeaux (to Spain and Toulouse)⁹³. Because the existing railway is already operating at up to 220 km/h, the time savings on the new line will be only around 50 minutes for the (approximately) 350 kilometres between Tours and Bordeaux.

Conclusions

The Paris–Bordeaux route was built to a very high standards (route and track alignments), maintained to a high standard, provided with electric power in the 1930s, and developed with high capacity (with three or four tracks in places). Level crossings on high-speed sections were removed in the first (1960s/70s) upgrade.

The high route alignment and track standards made it possible to make relatively modest upgrades to the infrastructure, offering conventional train speeds of 200 km/h and TGV train speeds up to 220 km/h. The current good transit time on the corridor undoubtedly also owes much to the “leg-up” provided by the complementary investment in the LGV route between the Parisian suburbs and Tours. New (TGV) trains and a high service frequency (for a route that is almost 600 km in length) have been applied. The combination of the LGV link grafted onto the upgraded railway has provided a service that is competitive with airlines, despite the long distance involved. The third major investment in the corridor is the current (2013) construction of an LGV that will provide much-needed additional capacity.

⁹² The application of the then-new *Socrates* yield management system led to some traffic losses.

⁹³ The new railway would also enhance links between Paris and intermediate cities such as Poitiers.

Study 8: London–Glasgow corridor upgrade

Summary

- protracted and extensive infrastructure renewal to the railway corridor, involving some upgrading.
- extensive service disruptions were recorded during the renewal and upgrading work.
- upgrading and introduction of tilt trains have reduced transit times.
- capacity enhancements have enabled doubling of service frequencies.
- against a background of strong patronage growth on the British network, the corridor has experienced a doubling of patronage.
- concerns about future capacity constraints have triggered plans for construction of a new, high-speed, railway.

Background

The 642 km West Coast Main Line (WCML) railway links London (with a metropolitan population of 12 million) and Glasgow (2.9 million). As Figure 31 illustrates, the key cities of Birmingham (3.7 million), Manchester (2.6 million) and Edinburgh (0.8 million) are served by links along or from the main railway trunk. The railway is essentially four tracks north to Stafford and then two tracks beyond. Where the route is quadrupled, one set of twin-tracks is designed for fast trains (and upgraded to 200 km/h speeds) and the second twin tracks are designed for slow trains (upgraded to 160 km/h).

The route carries a diverse range of mixed passenger and freight traffic, including Anglo–Scottish (London–Glasgow) intercity trains; regional trains along and across the Midlands and North-West regions of England; commuter trains into London; and diverse intermodal and bulk freight traffic. The most intense passenger traffic on the line is at the London end; in 2009–10, almost 32 million journeys started or ended at London Euston station (Network Rail 2011, p. 45). The line carries 43 per cent of Britain's rail freight (Oliver 2005, p. 20).

With very diverse passenger travel markets, it is not possible to make a generalisation about rail's task performance relative to the other modes. However, in the urban London commuting market, rail performs well as it does with near-London intercity traffic; in the medium-distance intercity link between London and Manchester, rail had 76 per cent of the market in 2009; there are no flights between London and Birmingham (HS2 2011, p. 14). Rail performs less well in the long-distance intercity Anglo-Scottish market, with rail having just 17 per cent of the rail–air market in 2009.

The complexity of the route is rooted in its origins. The corridor was formed from linking more than one dozen independent railways that were built in the nineteenth century. The Railways Act 1921 completed the amalgamation of railways on the corridor, forming the London, Midland and Scottish Railway, which was nationalised in 1948 to form part of what was to become British Rail.

With a single entity owning the railway, there was additional impetus for strategies to develop the route. In the inter-war years, competition for Anglo-Scottish passenger traffic from the East Coast railway encouraged track and service enhancements. The 1955 British Railways Modernisation Plan heralded the first major upgrade of the Line; the upgrade included electrification and re-signalling. This programme of work commenced in 1957 and was completed in 1974. This brought about reduced transit time, such as time reductions of between 20 and 30 per cent for London–Manchester passenger services.

Much of the WCML has curved alignment, but the curves are sufficiently shallow as to be suitable for raising speeds with tilt trains. From the mid-1960s, British Rail undertook engineering research to develop what was to be called the *Advanced Passenger Train*, a tilt train that was intended to reduce transit time. Trials of the prototype train were undertaken on the line but funding was terminated and the train withdrawn before the significant technical problems could be resolved⁹⁴.

By the early 1990s, the railway was losing market to road and air; it was also overdue for renewal. However, the initiation of renewal and further upgrades was delayed by the vertical separation and privatisation of British Rail and the bankruptcy and renationalisation of the infrastructure owner, Railtrack (with assets then taken over by the government-guaranteed company, Network Rail). In addition, the 1990s franchising of the government's British Rail passenger train services increased the complexity of processes required to deliver the upgrades.

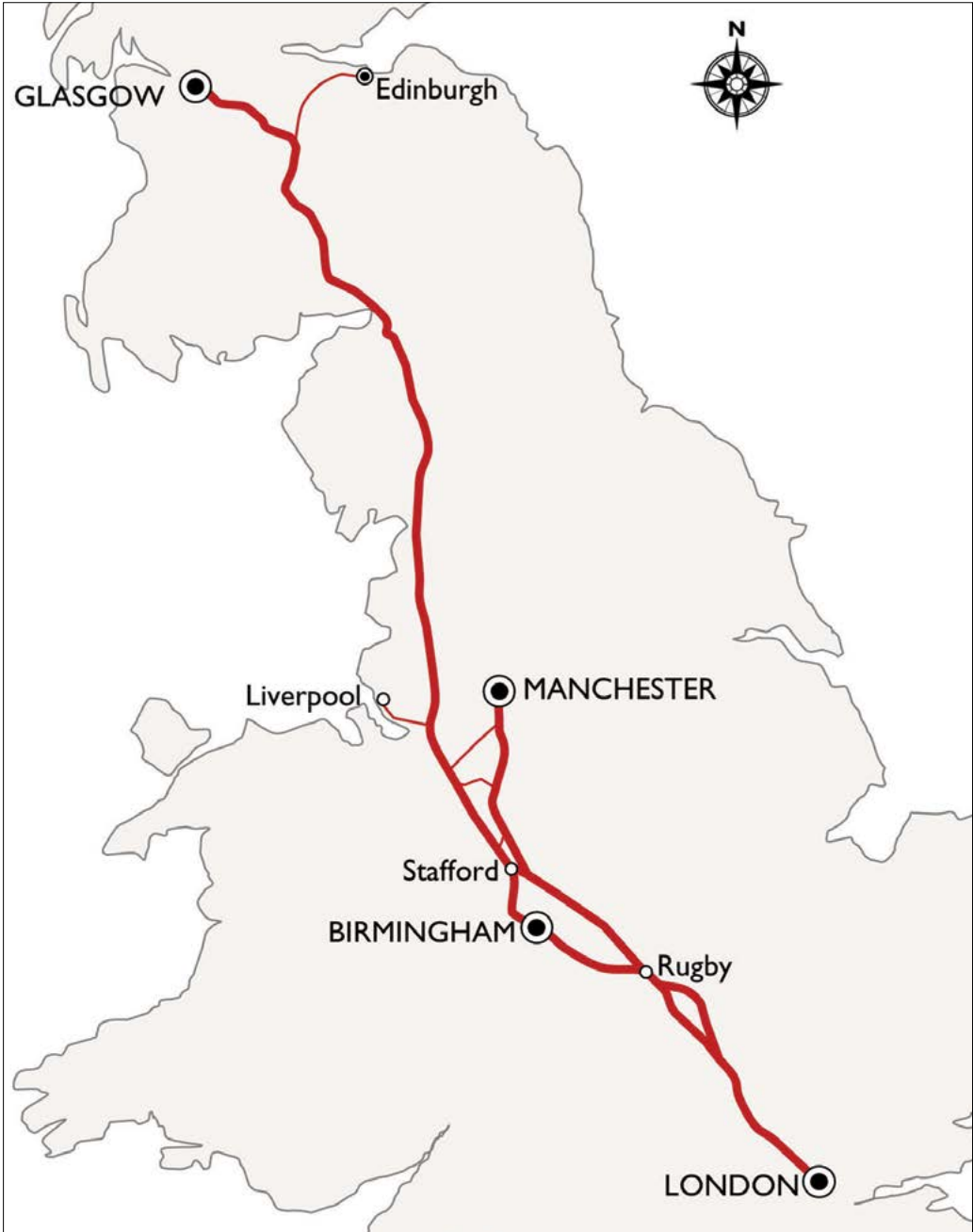
Objective and goals

The impetus for public funding of the route modernisation was, first and foremost, that the railway required renewal; government policy takes it as given that the railway is an integral part of the national transport system. The route is also part of the European Union's Trans-European Network for transport (Priority Axis No. 14). (See, for example, the Salzburg–Wien case study, also a Priority Axis, page 82.)

The decision to upgrade the infrastructure reflected the government's desire to expand track capacity to handle growing traffic and take advantage of new (tilt) technology to improve intercity transit times between the country's major cities. The government awarded the passenger train franchise to a company, Virgin Trains, that committed to introducing tilt-train services.

⁹⁴ See Potter (1993) for a review of the project. See also Nash (1993).

Figure 3I Upgrade, London–Glasgow West Coast Main Line* (network)



Note: *The West Coast Main Line is, in reality, a network rather than an individual line. This map shows connecting lines for Liverpool and Edinburgh. There are twin tracks north of Stafford while it is mostly quadruple track south of Stafford (via the eastern line to Rugby). Numerous lines link with the network; these other lines are not shown.

Description of the upgrading project

Infrastructure rehabilitation was the predominant component of the Route Modernisation that commenced in the late 1990s. Rehabilitation included long-overdue track, electrical and signalling system renewals. Renewal formed 85 per cent of the cost of the first phase with upgrading being 15 per cent (Oliver 2005, p. 20).

Given an out-turn budget in excess of £10 billion, however, the upgrade work is a major project. The government's Strategic Rail Authority stated that "A high proportion of total expenditure and activity is devoted to the renewal of much of the track, signals, and electrical equipment, together with the replacement of much of the foundations of the railway" (Strategic Rail Authority 2003, p. 11). Track and infrastructure standards were enhanced with this renewal work. For example, some structures and embankments were strengthened to accommodate the additional dynamic load arising from the operation of tilt trains.

During the upgrading the original 1960s electrical catenary was replaced as it was life-expired but it, too, was replaced with higher-specification equipment (such as higher-tensioned wires) to cater for the higher track speeds and more trains operating at higher power-to-weight ratios. In this context, additional electrical feeder stations were needed because the modernisation foresaw more trains operating.

The focus of upgrading work was to enhance capacity and reliability, to enable service frequency to be increased. Four forms of capacity and reliability enhancement were undertaken:

- **additional tracks.** Additional tracks were laid within the existing railway lands—notably, quadruplicating on 36 km of track (between Rugby and Stafford, Figure 31);
- **capacity expansion through signalling upgrades.** New signalling (and train control) systems were introduced;
- **electrical system upgrade.** Operating additional trains, and faster trains drawing more power required additional electrical power capacity; and
- **removal of bottlenecks.** Changes were made to the configuration of all 13 major junctions on the route, and for the layout of London Euston station. The work increased capacity by reducing conflicting train movements within and across the network.

Most of the upgrading work was undertaken on the track north of Rugby (Figure 31); important components of the infrastructure south of Rugby have yet to be upgraded.

The WCML work provides an illustration of how planners need to decide how much provision will be made for future traffic growth. The initial plans for upgrading the electrical system between London and Rugby involved a power boost that would "almost double the power available for traction, leaving a substantial margin for future growth" (Hope 2000, p. 738).

A range of other tasks that were undertaken included fencing off the fast line platforms and closing the few remaining level crossings.

Figure 32 Virgin Trains' Pendolino, West Coast Main Line



Source: Photograph courtesy of Virgin Trains.

Implementation

The upgrade of the WCML has its genesis in British Rail's network Modernisation Plan, which led to electrification and re-signalling of the route between 1957 and 1974. The later upgrading work was undertaken mostly between 1999 and 2009, although some upgrade work has occurred since then and is scheduled to occur through 2014–15. Other upgrade work (focused on signalling) has been proposed, with the objective of raising maximum tilt train speeds to 225 km/h.

The upgrade work was overly ambitious⁹⁵, however, akin to the 1970s service upgrade attempt using the *Advanced Passenger Train*. The plan to use radio transmission-based moving block signalling was abandoned after it was concluded that the technology was not sufficiently proven to be applied on the corridor. While it had been applied in small and urban railway settings, it had not been applied on a large scale or for a network of the complexity of the WCML. The abandonment of moving-block signalling had a number of consequences:

- **budget.** The upgrading plan had assumed that a lower-cost software-based moving-block in-cab signalling system could be implemented, obviating the need for wholesale physical signalling replacement. Reverting to the more traditional lineside signalling meant that the budget needed heavy upwards revision.

⁹⁵ The House of Commons Committee of Public Accounts noted that "The original aim to upgrade the line in two phases, in 2002 and 2005, using untried signalling technology, proved overly ambitious and the programme quickly ran into difficulty" (2007, p. 3).

- **upgrading delay.** The work programme involved a protracted process of upgrading, ultimately being more than three years late relative to the original schedule (Hope 2003, p. 561). The delay arose as signal replacement (rather than operating old and new technologies side-by-side) made it harder to replace the assets while retaining regular services.
- **scaling back the upgrade.** The reversion to lineside signalling, rather than the in-cab signalling that would have come with moving-block technology, led to a reduction in the maximum allowable line speed that would be permitted: down from 225, to 200 km/h.

The renewal and upgrading work disrupted passenger and freight services severely over the primary upgrading period. For example, 19-week closure of 77 km of track south of Manchester from May 2003. The train operating companies — but not the passengers who suffered the delays — were compensated more than £500 million for the disruption during the works programme⁹⁶ (Preston 2010, p. 12).

Impact on service

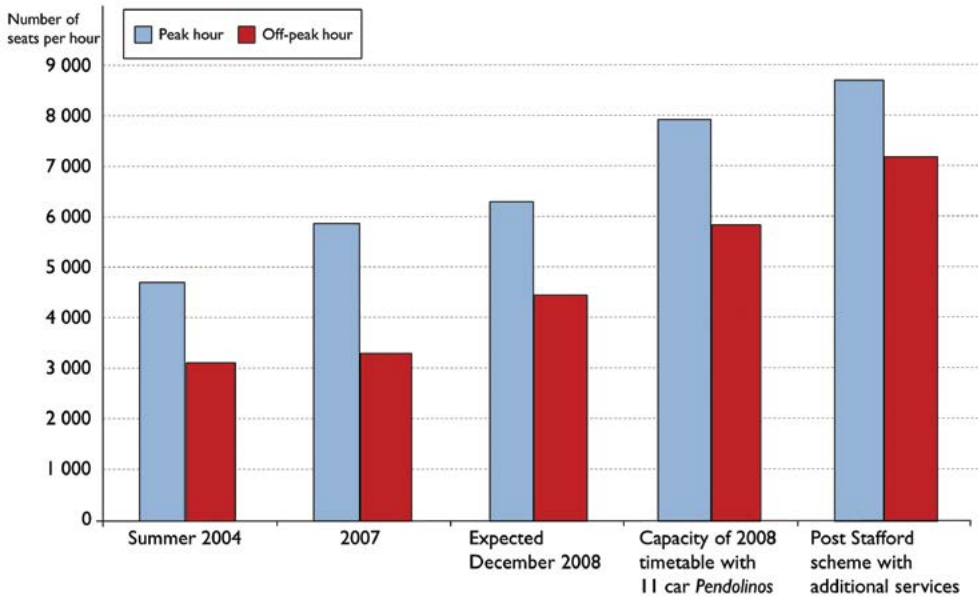
The maximum route speed was raised (from 177, to 201 km/h). This, together with the introduction of the Pendolino tilt train (enabling higher speeds through curves), brought about a reduction in transit times. For example, transit time between London and Manchester for the fastest train was reduced from 156 minutes to 124 minutes (House of Commons 2011, p EV 37; Strategic Rail Authority 2003, p. 44).

The Pendolino train was introduced to intercity services on the corridor from 2004, with additional capacity added subsequently. Pendolino trains were originally eight carriages in length, subsequently lengthened to nine carriages. Strong ridership levels, particularly in off-peak periods, led to the ordering of additional carriages in 2007, bringing some trains to an eleven car length.

The end of the major upgrading work in December 2008 triggered a major expansion in infrastructure capacity, enabling a substantial increase in service frequency. As is evident in Figure 33, the number of available passenger seats for peak periods almost doubled while off-peak seating more than doubled; this reflected infrastructure and train capacity enhancements.

⁹⁶ The House of Commons Committee of Public Accounts has suggested that the compensation may be excessive. (2007, p. 6).

Figure 33 Capacity expansion on the West Coast Main Line from infrastructure and train upgrades (as planned in 2007)



Source: Derived from House of Commons Committee of Public Accounts 2007, p. 14.

Impact on market

The corridor consists of strong flows of commuter, inter-regional (Midlands) and Anglo-Scottish passenger traffic. The upgraded railway is a network, with strong traffic flows based on segments, rather than between the extremities. London–Manchester and London–Birmingham are key shorter-distance flows that dominate over the London–Glasgow termini flow.

It had been expected that the service improvements would bring 15–25 per cent more passenger journeys between London and the major cities than if renewals alone was undertaken. It was “expected” that around 60 per cent of the additional passenger journeys would be transferred from road journeys (Strategic Rail Authority 2003, p. 44).

The upgrade work was completed at a time of strong patronage growth elsewhere on the network. The line recorded a very strong recovery of riders as works disruptions eased and as service frequency increased. Patronage on the corridor doubled from 1999 (All-Party Parliamentary Group for High-Speed Rail 2012, p. 7).

Conclusions

As with Northeast Corridor upgrading in USA (page 118), the work undertaken on the London–Glasgow route was primarily a comprehensive programme to rehabilitate the condition of the infrastructure. With expenditure that is well in excess of £10 billion, however, it is important to stress that the upgrade elements were still very substantial. The upgrade

provided more robust railway track and power systems that would support new tilt trains and raise line speeds. Remodelling of station yards and junctions relieved bottlenecks and, with additional running tracks, led to substantial increases in capacity on the network and inherently better reliability. These enhancements enhanced the quality of passenger services by enabling significant increases in intercity service frequencies.

These higher service frequencies — with passenger traffic growing in tandem — and a surge in freight (especially port–inland terminal intermodal services) have absorbed much of the additional capacity generated by the upgrade. With the prospect of further traffic growth, government has faced the likelihood that the upgrade is a victim of its own success and that only the construction of an entirely new — *fast* — line will ensure that there is sufficient capacity to handle higher levels of traffic in the future.

Debate continues on whether building an entirely new railway (the planned *High Speed 2* line) is more cost-effective than a *further* upgrade, especially when set against a background of high, protracted levels of disruption to the existing services⁹⁷. On this extremely busy network, the disruptions arising from the engineering works were substantial and occurred over a very protracted period. Thus supporters for *High Speed 2* (which would supplement line capacity at the southern end of the corridor), have challenged the recently-completed upgrade, arguing that building a new line would have been more cost-effective and would have avoided service disruptions. It is the extent of those disruptions that has been put forward as one of the main reasons that the Transport department adopted a strategy for building a new railway rather than pursuing further upgrading (Engineering the Future Alliance 2011, p. 6; Department for Transport 2013). This ignores the fact that most of the work was undertaken for renewal, not upgrading, and this renewal was required if the railway was to continue to operate. In any case, the upgrading work essentially doubled passenger capacity (Figure 33). Nash notes that the upgrade had “bought us some time at least”. (House of Commons 2011, *passim*, and p. Ev 4)

Line capacity rather than line speed has been the focus of the upgrading work. While track upgrading work supports tilt-train speeds of 225 km/h, the abandonment of in-cab signalling constrains the top speed to 200 km/h. In essence, the level of investment in signalling has not matched the potential of the tilt train, the business case of which was that it would operate at 225 km/h. As has been noted regarding conventional railway upgrades, “The railway is a technically integrated system, and every one of the many technical issues must be identified, understood and overcome. Failure in any one area results in failure of the whole” (Gostling, 1998, p. 701).

⁹⁷ Network Rail reviewed proposals for further corridor upgrades, in lieu of the construction of the dedicated HS2 line. The review identified the following issues that worked against the further upgrade idea: (a) that proposals would still not meet forecast London suburban commuter demands (b) that additional off-peak passenger trains would prevent freight trains operating (c) that London Euston station would require further redesign (d) that services would be severely disrupted due to protracted line closure (e) that the fast tracks would be highly-utilised, reducing performance (f) while some long-distance connections would be improved, it would worsen connections for some intermediate traffic flows. (Network Rail 2011a, p. 2).

Study 9: *Gatwick Express* airport train service

Summary

- rail services between London and its second airport at Gatwick were steadily enhanced from the late 1950s, notably with the introduction of a dedicated airport train in 1984.
- removal of a track layout bottleneck enabled high-frequency services to be introduced from 1979.
- regular services, dedicated rolling stock and platforms, on-train ticketing and marketing of the *Gatwick Express* enabled the train to maintain its market share against rapidly expanding airport throughput.
- Competition for track capacity has led to downgrading of the service, with withdrawal of dedicated bespoke rolling stock, peak period trains no longer being dedicated airport services and with the withdrawal of on-train ticketing.

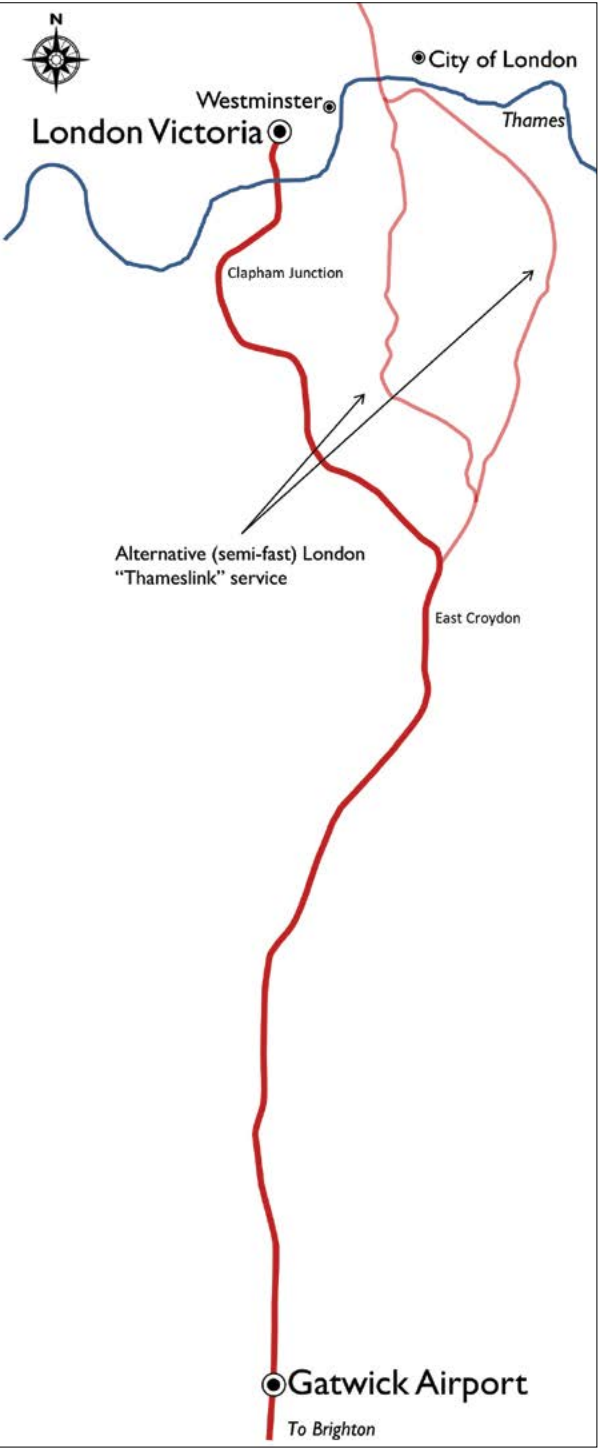
Background

London's second-largest airport (after Heathrow) is Gatwick Airport, located just over 40 kilometres south of Central London. The airport caters for around 34 million passengers per annum; a considerable workforce also commutes to the airport.

A 43 kilometre four-track railway links a railway station at Gatwick Airport with Central London (London Victoria station). The railway is electrified, using a third-rail electrical pick-up that supplies 750V DC power; this power source is relatively inefficient by modern standards, thereby restricting train performance. The route is shown in Figure 34, together with the alternative (bifurcated) "Thameslink" railway service that serves the City of London (and further destinations north). The route is part of a wider network of railways to the south of the Thames, many of which connect with the Gatwick route. The route is part of a longer key corridor; between the terminating station at Victoria, and Brighton on the south coast.

The *Gatwick Express* is the non-stop passenger train service between London Victoria station and the station at Gatwick Airport. Services operate for 21 hours of the day, with four trains per hour in each direction over the core business hours and lesser frequencies at other times. Semi-fast and stopping trains also run over the route.

Figure 34 Route of the Gatwick Express, London



Objective and goals

There is no single, definitive, stated objective for the *Gatwick Express* service. A common objective of the private airport operator and central government is to make the airport a viable alternative to Heathrow Airport. With Heathrow being around one-half of the distance that Gatwick is from Central London, it is essential that the airport be accessible. The airport owner states that “to maintain and continue to attract new, direct, high-value routes to and from the UK, improved rail links to Gatwick are crucial” (Gatwick Airport Ltd 2013).

To these ends, an attractive, fast train service facilitates that accessibility goal while deflecting travel from potentially/actually congested roads from the airport's main catchment areas. The railways between the airport and central London offer faster transit times than alternatives, enhanced by express operations. The airport operator seeks to increase public transport use to the airport (for travellers, non-travellers and employees) and particularly to maximise railway use on Central London journeys, where railways can be especially time competitive on door-to-door trips.

While central government seeks to maximise airport efficacy and public transport usage, it is also concerned to ensure that there is sufficient commuting capacity on the line; as discussed below, this has led to some degradation of the *Gatwick Express* service in order to provide additional commuting capacity.

Description of the upgrading

The principal forms of train service upgrade involve:

- the introduction of express (that is, reduced transit time) services;
- high-frequency operation (with a core four trains per hour);
- dedicated, bespoke and clearly branded trains, providing suitable on-board luggage facilities and ensuring travellers are not competing for space with commuters;
- ticket purchases could be made on the train, rather than queuing at the ticket office or machine; and
- an airport–railway station that is an integral physical element of the airport terminal, ensuring seamless transfer between station and airport facilities. Dedicated platforms were instituted at the London Victoria station.

Special fares were introduced for the *Gatwick Express*, with a premium being levied. The current premium for “standard class” travel is around 50 per cent above the fares levied for non-*Express* trains.

There were no substantial infrastructure issues, with good track alignment and condition, no level crossings and with minimum four-track provision that could be used to separate fast trains (on two of the tracks) from slow trains (on the other two tracks). In spite of this capacity, however, it has been argued that a conscious decision was made to minimise costs by using existing tracks and that this has resulted in an unreliable service due to congestion (Vetrovsky and Kanafani 1994, p. 10).

Implementation

As with other upgrades, the initial phases of the upgrade were modest, namely with the construction of a station in the airport environs, opening in 1958. The station was enhanced in 1980, providing clearer and easier links to integrate the railway with the airport.

The summer 1979 timetable revision introduced a four-trains-per-hour service frequency between London and Gatwick. Rolling stock for the branded “Rapid City Link” service was attached and detached from trains coming from or going to destinations beyond Gatwick. The services between London and Gatwick stopped at intermediate stations. The Rapid City Link carriages were modified to provide extra luggage space and included removing the at-seat tables that were features of other stock on the line.

Reorganisation of track and signalling layout in the East Croydon area (Figure 34) enabled the introduction of the express services in 1984. This reorganisation removed a capacity bottleneck that had hitherto prevented the introduction of additional trains. Because the new service did not stop at Clapham Junction, the transit time was reduced from 37 minutes to 30 minutes (Perren 1984, p. 247).

The branded *Gatwick Express* trains operated only between London Victoria and Gatwick Airport. New sets of renovated dedicated train sets were provided; carriages were modified to provide good internal circulation and luggage space. The service operated four times per hour through core business periods of the day, seven days a week.

New, built-for-service train sets were introduced over the protracted period between 1999 and 2005, providing the extra luggage and easy, wide-door access required for airport travellers burdened with luggage.

A downgrading of the service commenced in 2008, when some peak-period services were extended beyond the airport station, to Brighton. A consequence of this change was that airport passengers would have to compete for seat (and standing) space with Brighton commuters. The bespoke airport operation was further degraded from this time, with the progressive withdrawal of the purpose-built/designed train sets. On-board ticket purchasing was also withdrawn.

The issue at the heart of the service downgrading was the growth in passenger traffic on the Brighton line. The government's transport department and its infrastructure company, Network Rail, concluded that the line and train capacity used by the *Gatwick Express* could provide some relief to the overcrowding occurring on the commuter trains. Inevitably, the airport owner disagreed with this quality reduction. Network Rail has proposed at least one intermediate station stop [at Clapham Junction] for the service (Gatwick Airport Ltd 2013, RF12).

While the express route to Central London (the West End) has seen degradation, the expansion of infrastructure capacity that is being built on the Thameslink routes to the City of London (Figure 34) will result in additional train services on this alternative. The services do not have premium fares but they generally involve multiple stops while the current rolling stock is very deficient for luggage and overall spare seating capacity.

Impact on service

The upgrade was essentially a staged service and station upgrade, culminating in the introduction of dedicated express operations that were achieved through the removal of a track and signalling bottleneck. The express operation reduced transit times. Improved station design enhanced the perception—and the reality—of integration between the airport and the railway service.

The tracks were not dedicated to the service but while the rolling stock was dedicated, it meant that branding and train designs were conducive to passengers' needs.

Impact on market

The mode shift to rail that resulted from the upgrade is not known. A 1984 survey — the year that the express service commenced — found that 32 per cent of all traffic using the airport was coming by rail, with a 57 per cent share for Central London traffic (Vetrovsky and Kanafani 1994, p. 10). Survey data for 2006 suggested that rail had a 29 per cent market share, with the *Gatwick Express* having a 13.4 per cent share of the total⁹⁸.

Assessing the impact of the express service over a longer time period also requires acknowledgement of other major changes. It is notable that traffic through the airport has grown substantially in the intervening period (with 2013 throughput being more than three times the number of 1984) and improved road links (such as the completion of the M25 motorway feeding the M23 motorway that serves Gatwick) have enhanced the private transport options.

Trends in non-express rail patronage between London and the airport are notable, not least because these other services do not attract a fare premium. The non-express traffic has risen from 10.4 per cent of total traffic in 2000 to 15.6 per cent in 2006. (UK Airport Consultative Committees 2009, p. 9) Much of the rest of this rail market was achieved by “Thameslink” services between the City of London (and further northern locations); and stopping services between London Victoria and Gatwick. With *Gatwick Express* service having a 50 per cent fare premium, the 15.6 per cent non-express train mode share (that is, greater patronage than the express) is unsurprising.

Early survey data (Vetrovsky and Kanafani 1994, p. 10) suggest, however, that service reliability was a greater concern amongst *Gatwick Express* passengers than the fare. That is, those travellers choosing the express will do so because of the (perceived higher) service reliability and airline travellers' own demand for “high” reliability (International Transport Forum 2010, p. 41).

Conclusions

The service-based upgrade of passenger trains between London and its second airport at Gatwick has been achieved through using existing high-quality track, with enhancements achieved by improved station–airport links and the introduction of dedicated frequent express trains (achieved by removing a capacity bottleneck).

⁹⁸ It was estimated that 11 per cent of employees travelled by train in 2006 (UK Airport Consultative Committees 2009, p. 10).

Subsequent downgrading of the service—the loss of bespoke, dedicated carriages and introducing competition for seating capacity with commuters—will have undermined the premium market. The growth of commuting traffic has increased the opportunity cost of dedicating specific capacity to serving airport traffic. That is, achieving the goal of high-standard express airport services competes with the goal of accommodating commuter traffic.

Study 10: Québec–Windsor corridor proposal

Summary

- study proposals undertaken in 1995, updated in 2010, to upgrade services.
- the Québec to Windsor corridor encompasses Canada's most-densely-populated region, including the string-of-pearls of Québec City, Montréal, Ottawa and Toronto.
- upgrading rail links between these travel markets is founded on increasing service frequency by providing additional tracks within existing railway alignments and increasing speeds with some new alignments.
- apart from capacity amplification, the largest cost item would be grade separation between railway tracks and roads.

Background

The 1 200 kilometre Québec–Windsor corridor (Figure 35), in the Canadian provinces of Québec and Ontario, encompasses the country's most densely-populated region. From the north-east end of the corridor to the south-west, there are major population centres: Québec City (0.8 million), Montréal (3.8 million), Ottawa (1.2 million), Kingston (0.2 million), Toronto (5.6 million), London (0.5 million) and Windsor (0.3 million). These cities alone constitute more than one-third of Canada's population. Directly to the north-west of Windsor, across the (Detroit River) border with USA, lies the city of Detroit (5.2 million).

There are at least two railway corridors at any point along the corridor: Canadian National (CN), Canadian Pacific Railway (CP) and Les chemins de fer Québec-Gatineau (CFQG); VIA Rail Canada owns some of the designated corridor to the east of Ottawa. The railways are non-electrified outside of urban areas.

Objective and goals

Because railways connect Canada's major population centres, policy attention has been directed to the nature of the links as a vital national transport artery. In particular, the objective has been to give a more prominent role to train services; these are provided by the Canadian government's passenger train operator, VIA Rail Canada, which carries around 3 million passengers in the corridor.

Previous upgrade has been based on modest infrastructure upgrades, and new rolling stock. High-performance passive-tilt trains (*Turbotrans*) were introduced between Montréal and Toronto in 1967 for the (world) *Expo '67* international event; in that instance, the train "failed almost entirely to live up to its performance claims" and the trains were withdrawn. (Soberman 1995, p. 96) A similar high-performance train (but with active tilt), the LRC (*Léger, Rapide, et Confortable*) train was introduced in 1981, with deactivation of the self-propelled/tilt equipment in 2000.

Again, in the early 2000s VIA Rail proposed a high-performance "JetTrain" but this was abandoned when government funding was not forthcoming. The train was considered as part

of the unpublished “VIAFast” study that was undertaken in 2002. The study examined corridor enhancements with signalling upgrades, the removal of bottlenecks and improvements to train performance.

Government studies were undertaken in 1987 and in 1989–91 followed by a major report that was published in 1995, updated in 2010. The studies put forward options for enhancements based on the dual-corridor approach (see page 16).

The transport goals of the 1995/2010 studies are focused on intense shorter-distance traffic between key cities within the corridor than on traffic between the end points of the corridor. A key aspect of the 1995/2010 corridor analyses considered the needs of the corridor but the 1 200 kilometre corridor length places the markets (and the services that need to be considered) into distinct groups. These groups (with distances, VIA Rail trains per day (tpd) and best recent transit times), include:

- Québec City–Montréal (260 km, 5 tpd, 189 minutes);
- Montréal–Ottawa (195 km, 7 tpd, 110 minutes);
- Ottawa–Toronto (400 km, 7 tpd, 239 minutes);
- Montréal–Toronto (550 km, 8 tpd, 278 minutes);
- Toronto–London (195 km, 7 tpd, 127 minutes). (EcoTrain 2010a, p. 19, S-8); (VIA Rail Canada 2013).

The objective of the upgrades is to offer services that are more than time-competitive with road on the city-centre-to-city-centre journey times. At present the transit times on the key city pair (Montréal–Toronto) are comparable with road times but the studies have concluded that lower times are required if the service is to attract erstwhile car drivers⁹⁹.

⁹⁹ This conclusion reflects that it is door-to-door that matters, not main-mode time; access mode time undermines or weakens the time advantage of the main (regional/intercity) mode.

Figure 35 Québec–Windsor corridor (with schematic routeing)



Note: Other railway lines in the corridor are omitted. Note, for instance, there is a direct route (owned by Canadian National) following the St Lawrence River between Kingston and Montréal.

Description of the upgrading proposal

The crux of the 1995/2010 upgrading proposals was to increase line capacity, to enable more trains to run, unencumbered by slow-moving freight trains. This would be achieved largely through the construction of additional (twin) railway tracks within, or adjacent to, current railway rights-of-way. (The principle is outlined above, on p. 16, as ‘dual-corridor’ operation.) The essential aspect of this is “dedicated tracks” for passenger trains, but not on a “high-speed” alignment. There are few exceptions to this principle; the intercity trains would share tracks with other trains in urban areas only. The higher-capital-cost option of electrifying the line was rejected because the options involved a top speed of 200 km/h, which lies within efficient and practical diesel-electric locomotive performance (EcoTrain 2010a, pp. 13–14).

While higher speeds, unimpeded by freight, was an objective, the strategy involved ensuring that costs were contained, particularly when benefits were modest. In particular, “Significant capital cost savings were achieved by accepting design speed reductions in a few locations where they did not significantly increase travel time” (Transport Canada, et al, 1995, p. 11).

There were a number of reasons put forward for adding rather than sharing capacity. In particular, the existing railway owners (Canadian National and Canadian Pacific) expressed concern about capacity on their already heavily-used freight corridors between the cities. This implied that it would be difficult to reduce transit time and increase service frequency on the existing tracks.

The alternative was obviously to consider a new railway on a new alignment; 200 km/h and 300 km/h speed options were considered. With the 300 km/h option it was suggested that a new alignment would actually be cheaper than trying to increase existing railway-corridor capacity. “VIA Rail’s 300 kph proposal attempted to avoid existing rights-of-ways, arguing that

the, costs of land acquisition would be lower than the costs of improving existing track.” (Ontario/Québec Rapid Train Task Force 1991, p. 17) Soberman puts another angle on this pro-high-speed track idea, suggesting that the “TGV proponents” argued that eliminating level crossings would be more costly than building an entirely new railway on a new right-of-way. (Soberman 1995, p. 124). There was no evidence provided to underpin these views, nor have subsequent studies pursued the strategy. The later (1995/2011) studies expressed the environmental and agricultural concerns about constructing a new railway corridor and the strategy predominantly adhered to the existing rights-of-way. It was argued that use of existing corridors would minimise the environmental impact (Transport Canada, et al, 1995, p. 17).

The upgrading proposal, then, is a hybrid concept, based around use of existing right-of-way rather than existing trackage. Crucially, it was concluded that existing rights-of-way are “generous” — a corridor of at least 30 metres — and can often readily accommodate additional tracks (EcoTrain 2010a, p. 23, pp. 34-35). In the 2011 study, the 200 km/h option for the corridor would have involved a blend of existing right-of-way (for 379 km); using land that adjoins the existing right-of-way (482 km); and using new right-of-way (361 km). In part, the latter alignment component relates to situations where existing railway alignment has undue curvature. In urban areas, the existing city centre railway stations and tracks would be used, but supplemented by some new suburban or small city stations (EcoTrain 2010a, p. 39). The 1995 study also assumed that some of the railway land that is currently used in urban areas would be rationalised and would therefore be available for new tracks. (Transport Canada, et al, 1995, p. 79) Similarly, in rural areas it was considered that “freight traffic relocation” could be undertaken, that is, that freight could be shifted onto other railway corridors (Transport Canada, et al, 1995, p. 17).

A specific feature of the upgrading proposals was the consideration given to the harsh winter climate in the region. This factor influences the strategies being considered (Transport Canada, et al, 1995, p. 9).

An important requirement for raising train speeds was a need to remove all level crossings—this would be undertaken entirely by grade separation, not by road closures (EcoTrain 2010a, p. 67). As is evident in Table 9 and Figure 36, the largest single cost component in the upgrade is the removal of level crossings.

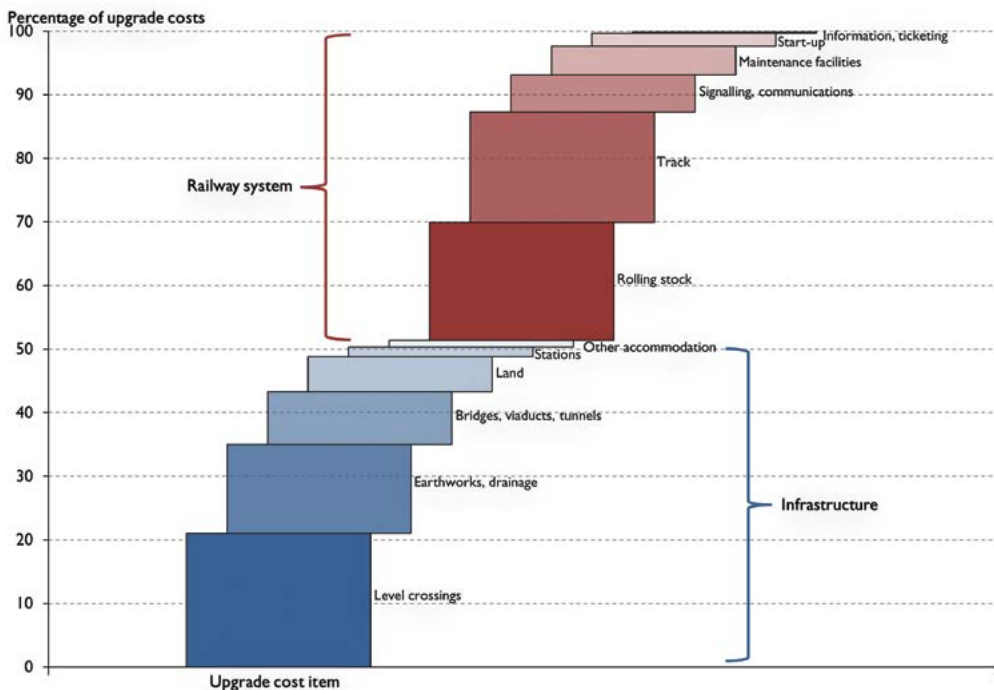
Tilting trains were rejected as an option due to their higher capital and operating costs and because “only minor reductions in travel time” would be achieved as new route alignments would divert away from circuitous sections (EcoTrain 2010a, p. 11).

Table 9 **Québec–Windsor corridor — estimated upgrade costs to 200 km/h system**

| Component | Cost (Canadian Dollars, '000) | Percentage of total |
|-------------------------------------|-------------------------------|---------------------|
| Infrastructure | | |
| Right-of-way acquisition | 1 043 | 5.5 |
| Earthworks and drainage | 2 652 | 14.0 |
| Bridges, viaducts and tunnels | 1 562 | 8.3 |
| Level crossings (grade separations) | 3 979 | 21.0 |
| Other accommodation works | 209 | 1.1 |
| Stations | 277 | 1.5 |
| Sub-total — infrastructure | 9 723 | 51.4 |
| Railway systems | | |
| Track | 3 298 | 17.4 |
| Power systems | 9 | 0.0 |
| Signalling and communications | 1 102 | 5.8 |
| Rolling stock | 3 506 | 18.5 |
| Maintenance facilities | 844 | 4.5 |
| Information and ticketing | 46 | 0.2 |
| Start-up | 400 | 2.1 |
| Sub-total — railway systems | 9 205 | 48.6 |
| Total | 18 927 | 100 |

Source: Data extracted from table in EcoTrain 2011, p. 70.

Figure 36 Allocation of estimated upgrade costs (to 200 km/h) on Québec–Windsor corridor



Source: Data extracted from table in EcoTrain 2011, p. 70.

Implementation

The findings of the studies have not been implemented¹⁰⁰. The 2010 study concluded that an upgrade of the full length of the corridor would not generate a positive net economic benefit but that the section between Montréal, Ottawa and Toronto could do so.

As is evident in Table 9, level crossings form a major cost component. It has been suggested that it was “probably the single most important impediment to increasing speed on existing track”. (Soberman 1995, p. 101) Similar issues arise with other North American upgrades—see the Chicago – St Louis case study (p. 136). The legacy condition of the infrastructure—the starting point for upgrading—therefore has a strong influence on what cost-effective actions can be done to enhance the service.

Impact on service

Upgrades would involve service based on three shuttle operations, with increases in service frequency: Québec–Montréal, Montréal–Toronto (via Ottawa and Kingston); and Toronto–Windsor (EcoTrain 2010a, p. 37). There would be “significantly increased frequencies” (Transport Canada, et al, 1995, p. iii). Depending on the city pair, the daily service frequency

¹⁰⁰ This does not mean that services have been bereft of more piecemeal upgrades (see discussion above, p. 13): over 70 kilometres of third-trackage was added to the Montréal–Toronto section between 2009 and 2012, with the objective of reducing transit time by 30 minutes. See <www.viarail.ca/en/about-via-rail/capital-investment/project/kingston-subdivision>.

in 2025 would be between 8 and 22 trains (EcoTrain 2010a, p. 83). This is a greatly increased frequency compared with current frequency of between 5 and 8 daily trains (page 111). For example, Montréal–Ottawa frequency would increase from the 7 daily trains in 2013, to 20 trains in 2025.

The study found that the proposal was feasible but, as at early 2014, no further planning had been done.

Figure 37 Adding capacity: a third-main line being added near Kingston, Ontario, 2010



Source: Photograph courtesy of ViaRAIL Canada.

Impact on market

VIA Rail's share of the public transport travel in the Québec City – Windsor corridor in 2006 was estimated to be 38 per cent of business travel and 62 per cent of non-business travel. Air dominated the business public-transport travel, with a 59 per cent share but 7 per cent of the non-business travel (EcoTrain 2010a, p. 43). The 2010 study estimated that in 2031 the 200 km/h option would result in rail having 57 per cent of the business public-transport travel and 67 per cent of non-business public-transport travel; the equivalent business air share would fall to 39 per cent and non-business air share would be 0 per cent.

Looking more generally at travel in the corridor (that is, not specifically city-to-city), the current travel market is based on car travel (82%) with equal share for rail, air and bus (each of 6%) (EcoTrain 2010a, p. 46). In 2031, the 2010 study predicts a car mode share increase (to 86%) and a rail share increase (8%) (EcoTrain 2010a, p. 56).

The 2010 study estimated that, in 2031, 59 per cent of the rail travel would be diverted from car; 10 per cent from air and 28 per cent from conventional rail; 4 per cent would be diverted to coach and 6 per cent of the rail travel would be induced (EcoTrain 2010a, p. 46).

Conclusions

The upgrade strategy focuses on increasing track capacity, essentially by adding lines to the existing railway alignment (within, or adjacent to, the existing right-of-way). Apart from this capacity amplification, the single largest cost item is grade separation between railways and roads. Railway re-alignments would bypass the worst of the curved tracks.

With the passenger trains having use of the track that is unimpeded by freight trains, services would have lower transit times, would operate more frequently and reliably.

Study 11: Boston – New York – Washington, D.C.: Northeast Corridor

Summary

- the extensive Northeast Corridor, linking USA's premier north-eastern cities, has been upgraded over a very protracted period.
- a range of higher-performance rolling stock (such as the *Metroliner* and *Acela*) have been introduced over the years but their contribution has been undermined by under-funding of infrastructure renewal.
- a major upgrade on the northern (Boston – New York) section has been the completion of electrification, bringing about transit time reduction by removing the need for changing locomotives.
- as an extremely busy corridor that is shared with commuter and freight trains, running reliable and more frequent services remains the key issue.
- with congestion issues on competing road and air modes, the package of service upgrades have led to strong patronage growth
- despite the presence of low-cost airlines and strong air markets, rail's mode share has increased dramatically and it now dominates Boston – New York and New York – Washington, D.C. city-pair travel;
- corridor patronage trends partly reflects the cycle of service upgrades *and* downgrades.

Background

The use of existing railway corridors is seen as underpinning efforts to provide more attractive passenger train services in the USA. Extensive road networks and good air public transport, together with long distances between cities, weaken the case for building dedicated high-speed railways. Upgrading of existing railway has thus been the default action although growing rail patronage and train congestion has increased analysis of, and planning for, development of a new, high-speed, railway¹⁰¹.

As with virtually all regional and passenger railways across the world, the USA's passenger trains are publicly-funded. Regional and long-distance rail passenger services in the USA are almost entirely provided by the publicly-funded National Railroad Passenger Corporation, trading as Amtrak. Apart from the Northeast Corridor, Amtrak operates its trains mostly over third-party tracks that are owned and operated by private freight railway companies. The Federal policy on fast passenger train service provision is sketched in Box 8.

The Northeast Corridor railway links Boston, New York and Washington, D.C..¹⁰² When discussing intercity passenger services, the corridor can be divided into two main travel segments:

- the Northern Segment, Boston – New York (372 route kilometres), with key intermediate cities enroute at Providence and New Haven; and

¹⁰¹ See, for example, Federal Railroad Administration 2012 ("NEC future") and Amtrak, 2012 ("The Amtrak vision for the Northeast Corridor").

¹⁰² The railway also includes branch lines to Springfield, Massachusetts; Albany, New York; and Harrisburg, Pennsylvania. This report will focus on the mainline.

- the Southern Segment, New York – Washington, D.C. (363 route kilometres). Important city-pair markets within the Southern Segment are New York – Philadelphia (145 route kilometres) and Philadelphia – Washington, D.C. (214 route-kilometres).

The railway runs through the most densely populated conurbation in the United States. Approximately 53 million people (17 per cent of America's population) live in the corridor (Vacca and Galloway 2012). The principal cities are New York City, Washington D.C., Philadelphia, Boston and Baltimore. The corridor is shown in Figure 38. As befits such a long and densely-populated corridor, air travel is strong; the Boston – New York airline patronage is the seventh busiest in the Union.

In total, the Corridor is 735 route-kilometres in length between Boston and Washington, D.C.. Apart from being a long railway, the corridor involves substantial infrastructure. It is electrified throughout. The corridor also has very substantial trackage: with important exceptions, the northern segment is characterised by double-track while, again with important exceptions, the southern segment is dominated by four-track railway infrastructure¹⁰³.

The railway is operationally complex, with track capacity shared by over 2 000 trains daily including intercity (Amtrak) services, commuter services and third-party freight trains. The intercity Amtrak services carry around 12 million passenger trips per annum; there are more than 200 million commuter trips.

Figure 38 Northeast Corridor



¹⁰³ With a number of important exceptions (involving fewer or more tracks), the Boston – New Haven track is largely 2 tracks; New Haven – New York City, 4 tracks; New York City – Newark, 2 tracks; Newark–Philadelphia, 4 tracks; Philadelphia–Baltimore, 4 tracks; and Baltimore–Washington, D.C., 2 or 3 tracks. Further details on infrastructure provision can be found in Northeast Corridor Infrastructure and Operations Advisory Commission 2013.

The track is owned by one Federal and three State passenger-service agencies:

- The National Railroad Passenger Corporation, trading as Amtrak, a Federal government agency; Amtrak owns over 79 per cent of the route-kilometres of the Corridor;
- New York State's Metropolitan Transportation Authority (MTA);
- Connecticut Department of Transportation (ConnDOT); and
- the Massachusetts Bay Transportation Authority (MBTA).¹⁰⁴

The corridor includes the country's fastest passenger services — Amtrak's *Acela Express* — which, on short sections of track, reaches speeds of 240 kilometres per hour; and the *Northeast Regional*, which is slower, cheaper and stops more frequently than the *Acela Express*. Transit time between Boston and New York on the *Acela Express* is approximately 210 minutes and around 250 minutes on the *Northeast Regional*. Transit times between New York and Washington, D.C., is 170 minutes on the express and 205 minutes on the stopping service.

¹⁰⁴ Amtrak is the primary agency, with ownership of the entire line between Washington, D.C. and New York as well as 24 kilometres between New York Penn Station and New Rochelle and 190 kilometres between New Haven and the Massachusetts state line. The MTA owns 16 kilometres between New Rochelle and the Connecticut state border. The ConnDOT owns 75 kilometres between the Connecticut state border and New Haven (but with the track being operated and maintained by MTA's Metro North Railroad). The remaining 61 kilometres, between the Massachusetts state border and Boston, is owned by MBTA which contracts out maintenance to Amtrak (Mathur & Cerreno, 2006, p. 90).

Box 8 USA Federal policies on passenger trains and development of faster trains

The development of fast passenger train services in the USA should be seen in the context of a not-uncommon hostility by some Federal politicians to funding the publicly-owned national passenger train operator; Amtrak (which took over responsibility for intercity services from the private railways in 1971). However, there is stronger support for some of the Amtrak services, notably the fast, frequent, operations on the Northeast Corridor between Boston, New York and Washington. Indeed, the service represents an important example of upgraded passenger rail services and was an early recipient of funds for service enhancements.

Peterman, et al, notes that “The first high speed rail act, in 1965, contributed to the establishment of the nation’s fastest rail service, the Metroliner, on the Washington, DC, to New York City portion of the Northeast Corridor (NEC), when that line was still under private ownership” (Peterman et; al. 2012, p. 2).

Service upgrading appears somewhat partisan, with the Clinton and Obama administrations being more disposed to funding enhancements than the Republican administrations.

Facilitated by the Swift Rail Development Act of 1994, the Next Generation High-Speed Rail Program commenced in 1995; it supports the development of research development and demonstration projects. This programme “was designed to support the availability of modern, cost-effective technology enabling rail passenger service at speeds up to 150 mph (240 km/h) on existing infrastructure” (Nash 2003, p. 20).

In 2009, President Obama announced a programme for funding fast passenger trains, incorporating both dedicated new high-speed track and upgraded existing track. Apart from the construction of some new high-speed railway along the San Francisco – Los Angeles corridor, funding has focused on upgrades in five corridors: Seattle–Portland; Chicago – St Louis; Chicago–Detroit; the Northeast Corridor; and Charlotte–Washington, DC” (Peterman et. al. 2012, p. 2).

The predominantly private ownership of railways forms an important parameter of USA and Canadian railways that influences the reception to upgrade proposals. It is paramount for freight protecting (and their shareholder interests) to reserve existing and future infrastructure capacity and service standards (including reliability) for freight operations. Freight traffic on the railways has responded very positively to the deregulation measures adopted through the *Staggers Act of 1980*; this reversed a long-term decline in the industry, leading to increased track utilisation. The *Act* facilitated the availability of track for use by passenger trains but increased freight operation also means that there is less capacity available for the passenger trains.

Objective and goals

USA has a long history of passenger service upgrades by its private-railway companies. The railways have a heritage of private ownership; until the formation in 1971 of the Federal government’s National Railroad Passenger Corporation, trading as “Amtrak”, the non-commuter passenger rail services were essentially privately-owned and operated. Initiatives for upgrades

date from the 1930s, meeting the growing threat of car and aeroplane; in common with European railways at that time, the emphasis was on achieving superior services by high-performance rolling stock. The “streamliner” trains in the 1930s introduced diesel-powered (replacing steam) locomotives, together with lightweight carriages using new metal alloys. The battle to retain passengers and, thus, private railway interest, was lost by the 1950s—see, for example, the seminal *Trains* magazine review from 1959, “Who shot the passenger train?”. Experiments in cost-saving new technology, such as that offered in the mid-1950s by General Motors with its *Aerotrain*, continued to a small degree.

The *High Speed Ground Transportation Act* of 1965 was a landmark in Federal government involvement in passenger train upgrading. In signing the *Act*, President Johnson noted that “an astronaut can orbit the earth faster than a man on the ground can get from New York to Washington... [but] the same science and technology which gave us our airplanes and our space probes, I believe, could also give us better and faster and more economical transportation on the ground” (Johnson, 1965). Some public funds then went to track upgrades¹⁰⁵ between New York and Washington, D.C., and to the purchase of *Metroliner* trains on that line segment, introduced by the Pennsylvania Railroad’s *Metroliner* and the New York, New Haven and Hartford Railroad’s *TurboTrain*.¹⁰⁶

The demographics and the transport infrastructure legacy define the role for the railway corridor. The Northeast Corridor is exceptional in the United States in the extent to which it links a series of large cities. These conditions contribute to high inter-city and regional travel demand, but accompanied by limited capacity-enhancement opportunities on air and road infrastructure:

“What made the Northeast Corridor so marketable was a combination of economic and geographic circumstances. Because the Northeast Corridor lacked the space to add the highway and air capacity needed to match growing travel demands, it was a good candidate for enhancing existing infrastructure” (Cerreño, Evans and Permut 2005, p. 21).

The progressive upgrades have had numerous service quality goals to make rail services more competitive:

- a reduction in transit time, to be competitive with air services (especially in the Boston – New York and New York – Washington, D.C. markets), through capacity enhancements and timely infrastructure maintenance and renewal;
- increased service frequency; and
- improved reliability.

What is a competitive time? As illustrated in Table 10, city centre – to – city centre rail times remain somewhat above airport-to-airport times on the two main city-pair markets, but airport access/egress times provide rail with a competitive advantage for city-centre-based travel movements.

¹⁰⁵ The higher electrical power requirements required for the *Metroliners* to perform at high speeds required improvements to the catenary system.

¹⁰⁶ The names of the train sets came later while the two railways became part of Penn Central.

Description of upgrading projects

The railway was upgraded incrementally from the late 1960s. Some impetus for upgrading came from the *High Speed Ground Transportation Act* of 1965. Upgrades focused on high-performance rolling stock and track infrastructure and works were generally separated into northern (Boston – New York) and the southern (New York – Washington) projects.

A key additional service enhancement on the corridor was the consolidation of Amtrak's long-distance operations within New York. Until 1991, key trains ("Empire Service") from the north/north-west of New York State (including Chicago) terminated at the city's Grand Central Terminal. Onwards journeys on the Northeast Corridor required a bus, taxi or metro transfer to Penn Station. This interchange resulted in poor accessibility and reliability concerns for the corridor in a key market. The shift to Penn Station brought one million Amtrak passengers directly to the Northeast Corridor interface, greatly reducing the interchange issue¹⁰⁷.

The four main stock and infrastructure upgrade phases were:

1. Rolling stock quality enhancements, 1969–1976

Southern segment. The upgrading during this period built on the legacy of the country's highest-engineered track infrastructure, on the southern corridor segment (New York – Washington, D.C.). The electrification of that segment had been completed in 1933. New electric multiple-unit (EMU) rolling stock was developed and introduced for the southern segment, with a *Metroliner* service commencing in 1969. The *Metroliner* operated between New York and Washington, D.C. in 150 minutes, compared with 210 minutes on previous services.

Northern segment. Also in 1969, the *TurboTrain*, a gas turbine train was introduced for the largely-non-electrified northern, Boston – New York, segment (electrified only south of New Haven); the *TurboTrain* featured a passive tilt mechanism, potentially valuable given the considerable amount of curvature on this segment¹⁰⁸. *TurboTrain* was designed to round curves 40 per cent faster than conventional trains. The objective of the stock upgrade was to reduce Boston – New York transit time by 60 minutes but, technical deficiencies with the new technology limited the time saving to 30 minutes. Despite having attracted extra patronage, the *TurboTrain* was withdrawn from service in 1976 (Mathur and Cerreño 2006, p. 95).

The stock upgrades were undermined progressively in the 1970s by downgrading of the infrastructure. The financial difficulties, and subsequent bankruptcy (in 1970), of the private track owner, Penn Central, led to the decision to defer track maintenance. In response to this, train speeds were reduced and reliability declined (U.S. Department of Transportation 1978, p. 6). As a result, on the New York – Washington, D.C. segment the and transit times were increased by 30 minutes, to 180 minutes. With such timings, the service lost its decisive advantage over air travel (Perl, cited in Mathur and Cerreño 2006, pp. 93–4). Similarly, transit time was lengthened on the Boston – New York segment as track standards deteriorated.

¹⁰⁷ To some travellers, "New York City is seen as intimidating, and the transfer is not popular" (Scully 1991, p. 16).

¹⁰⁸ The passive tilt mechanism is discussed on page 23.

2. *Infrastructure renewal and enhancements (1976–84)*

The upgrade climate changed in the 1970s with two significant events. Most long-distance private passenger trains were taken over by the Federal agency, Amtrak, in 1971; in 1976, most of the bankrupt Penn Central-owned Northeast Corridor was sold to Amtrak. These actions provided the foundation for subsequent Federal government upgrade programmes.

In 1976 the *Northeast corridor improvement project* was approved by Congress.¹⁰⁹ The overarching aim was to establish “regular and dependable” passenger services with the fastest trains offering trip times of 160 minutes between New York and Washington, D.C.; and 220 minutes between Boston and New York (Mathur and Cerreño 2006, p. 111).

The first phase of the programme focused on reducing levels of deferred maintenance, and renewals, although important upgrades were proposed. These included significant curve realignment, bridge upgrades and replacements, and completion of corridor electrification (between Boston and New Haven). However, over time the budgetary constraints led to the scaling back of the programme, notably with the cancellation of the electrification.

3. *Electrification, infrastructure upgrades and new rolling stock (1992–2000)*

Apart from the perennial issue of long-overdue asset renewal, the key element of the second phase of the *Northeast corridor improvement project* sought upgrades in order to achieve reductions in transit time on the northern (Boston – New York) segment. The goal of electrifying the remaining un-electrified section (Boston – New Haven) was restored to the programme. The 1992 *Amtrak Authorization and Development Act* sought “regularly scheduled, safe and dependable” services between Boston and New York, with a travel time of 180 minutes or less (Mathur and Cerreno, 2006, p. 114).

With electrification came a range of complementary infrastructure upgrades. The most significant infrastructure works related to bridge improvements/replacements, new signalling and elimination of level crossings. The first limited high speed service between Boston and New York commenced in January 2000 using refurbished *Metroliner* EMUs.

The full scope of infrastructure works, however, was never realised. According to the United States General Accountability Office, by 2004 only 21 of the 72 work elements designed to improve infrastructure and enhance capacity were completed under the programme (Mathur & Cerreno, 2006, p. 137).

To reduce transit time on the curved track route between Boston and New York, Amtrak tested trains from 1993. This led to the introduction of the *Acela* tilt train from October 2000, with *Acela Express* services being introduced.¹¹⁰ The service is aimed at airline passengers, with competitive travel times and carriage interiors designed for passenger comfort.¹¹¹ See Figure 39.

¹⁰⁹ The improvement project was approved under the Railroad Revitalization and Regulatory Reform Act (“4R Act”). The Act made Amtrak the primary owner of the Northeast Corridor right of way by purchasing it from Penn Central at the time the latter was being restructured into Conrail (Mathur and Cerreño, 2006, p. 97).

¹¹⁰ Amtrak also trialed Swedish X2000 and German Intercity Express (ICE) trains. Bombardier – Alstom was eventually chosen because they were willing to amend existing models to the design and safety specifications of Amtrak.

¹¹¹ Amtrak felt increasing passenger comfort would create a competitive advantage over airlines. (Johnston 1999, p. 1)

Figure 39 Acela train service on Amtrak's Northeast Corridor

Source: Photograph courtesy of Amtrak.

4. *Infrastructure maintenance and enhancement (2003-ongoing)*

Following the introduction of the *Acela* service, works have focused on bringing the corridor into a "state of good repair". The aim of the project is to address a backlog of basic infrastructure and maintenance works (Amtrak, 2010).

Impact on service

Over time, the standard of express services have varied with the realisation of dividends of specific infrastructure investments, with the rolling stock programmes and with the vagaries of the infrastructure maintenance budget. At one stage the government's General Accountability Office expressed concern that the tight budget was being directed excessively to the upgrades at the expense of the ongoing maintenance, resulting in infrastructure deterioration¹¹²—a practical example of "robbing Peter to pay Paul".

The factors of upgrade and maintenance works, and rolling stock investments, underlie the prevailing transit times and reliability. Thus, with reference to Figure 40 for Boston – New York:

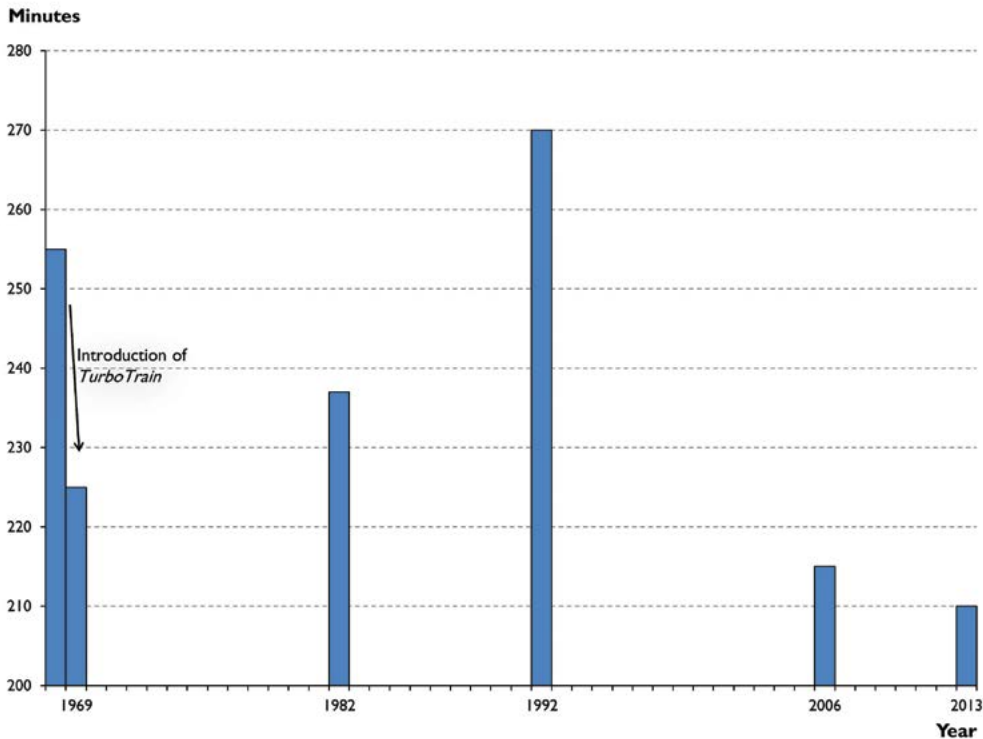
- transit times fell by 30 minutes (to 225 minutes) in 1969 when the *TurboTrain* was introduced;
- technical problems with *TurboTrain* led to its withdrawal in 1976 with a consequent increase in transit times (not shown in the chart). However, by 1982 there was some improvement in transit times as the operation of the high-performance *Metroliner* trains (operating on the corridor's southern segment) was extended to the northern segment; the completion of the first phase of the Northeast Corridor improvement project also brought down transit times.
- by 1992, with very little infrastructure maintenance being undertaken over successive years, transit times were extended markedly; and

¹¹² General Accountability Office 1996, p. 17.

- subsequently, the completion of electrification, the introduction of *Acela Express* and the reduction in the maintenance backlog have reduced transit time to around 210 minutes. The transit time impact of the *Acela's* tilt mechanism — useful on the curved track north of New Haven — is not known.

The 180 minute transit time goal that was set under the second phase of the Northeast Corridor improvement project is yet to be achieved.

Figure 40 Express train transit times, Boston – New York



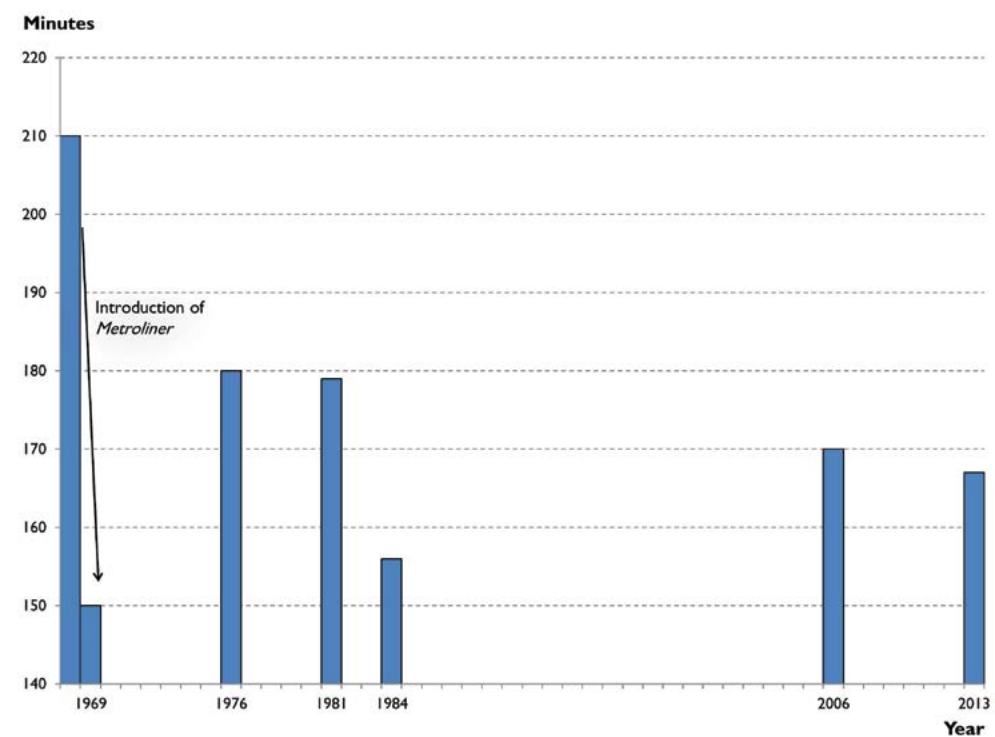
Sources: Nashua Telegraph 1968; Matur and Correño 2006.

Transit times for the New York – Washington, D.C. (southern) segment varied for similar underlying reasons:

- Transit times decreased substantially with the introduction of the *Metroliner* in 1969¹¹³ — see Figure 41. Indeed, the 150 minute transit time are yet to be bettered, with 2013 time being around 15 minutes longer.
- Transit times gradually increased, to around 180 minutes in the 1970s; this arose from a lack of adequate maintenance work (that is, deferred maintenance).
- The completion of the first phase of the *Northeast corridor improvement project* in 1984 restored much of the lost track condition.
- Transit time has subsequently increased, again, it is argued, mainly as a result of deferred maintenance (Mathur and Cerreño 2006, p. 132).

¹¹³ The *Metroliner* was a high-performance Electric Multiple Unit (EMU) using new electric propulsion technology and lightweight carriages.

Figure 4I Express train transit times, New York – Washington



Sources: Nashua Telegraph 1968; Matur and Correño 2006.

Apart from enhancing competitive transit times, Amtrak has sought to achieve higher frequencies and reliability. Thus, the upgrades have included goals for service times and frequencies. These goals, and the standards achieved, are listed in Table 10. As is evident from the table, while northern-sector frequency in 2013 falls short of objectives, it is a considerable enhancement on earlier levels.

Table 10 Travel time and frequency, objectives and current service levels

| | Northeast corridor improvement project—Phase I objectives (1978)* | Northeast corridor improvement project—Phase 2 objectives (1994)** | Current service level (2013)‡ | |
|-----------------------------------|---|--|-------------------------------|-----|
| | | | Rail | Air |
| Boston — New York | | | | |
| Travel time (minutes) | 220 | 180 | 210 | 75 |
| Service frequency (two-way total) | 22 | 54 | 38 | |
| New York — Washington, D.C. | | | | |
| Travel time (minutes) | 160 | na | 167 | 80 |
| Service frequency (two-way total) | 76 | na | 76 | |

Source: Derived from Mathur & Cerreño, 2006, p. 134; Amtrak, 2013; Nixon 2012.

Notes: * Specified in the projects' Final Programmatic Environmental Impact Statement (1978).

** Specified in the *Northeast Corridor Transportation Plan: New York City to Boston (1994)* (Mathur & Cerreno, 2006, p. 117).

‡ These numbers are comprised of regional and express services. They are approximations only, taken from random weekdays selected on Amtrak's website.

The objectives for service reliability were not as clearly defined as for travel time and service frequency. It has been noted (Mathur and Cerreño 2006, p. 134) that the goal for the first phase of the *Northeast corridor improvement project* was 75 to 80 per cent on-time performance for the Southern end and “somewhat higher” for the Northern end¹¹⁴.

Available data for the *Acela Express* shows that on time performance (within 10 minutes of schedule), has improved in the last decade. The poor reliability of the service in its early years was partly because of technical problems with the new fleet. Interference caused by other trains, together with signal and track malfunctions, cause more than one-half of the delays¹¹⁵. Amtrak's reliability exceeds that of airlines on the New York – Washington, D.C. route, with Delta Airlines' punctuality in 2012 being in the “mid-80s” and US Airways' indicating that its record was “a little higher” (Nixon 2012).

¹¹⁴ In 2007, *Acela's* Boston – New York punctuality was 73 per cent, compared with air; Boston – New York LaGuardia of 67 per cent, Boston – JFK of 61 per cent and Boston–Newark of 51 per cent (Demerjian 2008).

¹¹⁵ See Northeast Corridor Infrastructure and Operations Advisory Commission 2013, p. 8.

Box 9 Capacity constraints on the Northeast Corridor: the Trans-Hudson Tunnels

While much of the key Northeast Corridor in the USA is four-track, the central, *busiest*, corridor section, entering New York Penn Station from New Jersey, is limited to two tracks in tunnels under the Hudson River.

The Trans-Hudson Tunnels are therefore the major pinch point on the corridor, constraining service frequency, no matter what capacity expansion is undertaken elsewhere on the corridor.

The “Gateway Project” has been proposed by Amtrak and New Jersey senators; the project would add a second tunnel to the crossing, providing two extra tracks. The estimated expenditure, however, is US\$13.5 billion (Railway Track & Structures 2011, p. 6). Preliminary work on new tunnels was halted in 2012 due to State budgetary issues.

Figure 42 Trans-Hudson Tunnels, linking New Jersey and New York



Source: Photograph courtesy of Amtrak.

Ongoing development of passenger services has impacted on other track users, with one freight operator being particularly downbeat about the mixing of traffic: “We operate day-to-

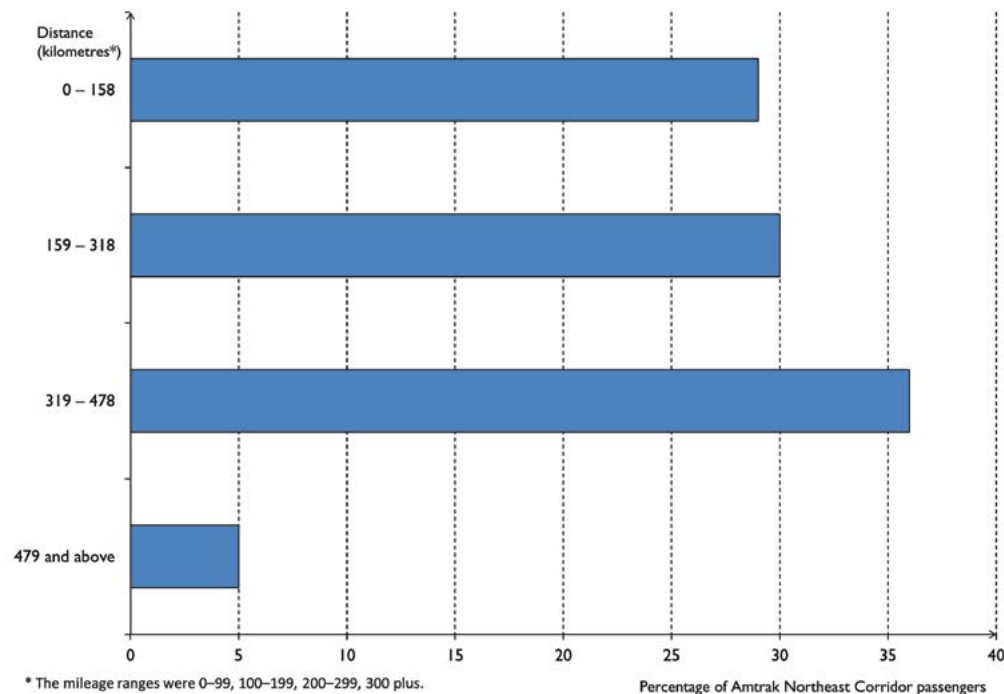
day in the NEC, the only high speed corridor in the country. If this is a vision of the future, it doesn't work.” (Vantuono 2000, p. 49, quoting a director from Norfolk Southern)

Impact on market

The Northeast Corridor caters for a range of travel markets, anchored on the principal cities of New York, Washington D.C., Philadelphia and Boston. The completion of electrification on the northern segment and the introduction of the *Acela Express* from 2000 marked key upgrade milestones for the Corridor. An early report from 2000 indicated that the transit time saved on the northern segment had achieved a 40 per cent increase in patronage in the first year—and this involved existing passenger carriages and high-performance locomotives, for the now-named semi-fast *Regional Express* services. (Railway Age 2000, p. 26)

The Corridor serves a conurbation throughout its length, but its primary role is the city pairs within the Corridor rather than between the end-points. This point, and rail's lack of competitiveness on the longest journeys (relative to air), is illustrated by rail's low market share on the (390 minute transit) Boston – Washington, D.C. market. (Congressional Research Service, 2012, p. 22) As shown in Figure 43, the rail services cater for a broad range of journey lengths but there is relatively little travel for the longest distance-bracket. Short city pairs have relatively high rail shares (e.g., in 2001 it was 95% for New York – Philadelphia; 82% for Philadelphia–Washington but 23% on the Boston–Philadelphia pair and 12% on the Boston–Washington, D.C. pair) (General Accounting Office 2002, p. 6).

Figure 43 Northeast Corridor, distribution of rail passenger trip lengths



Source: Derived from National Association of Railroad Passenger, 2013. Journeys relate to both *Acela Express* and *Regional Express* patronage.

As shown in Table 11, air/rail market share data that are available for the end-point city-pairs of the segments suggests that the upgrades have had a marked effect on air/rail mode share—and also on overall air travel¹¹⁶. Rail is now the dominant mode for each of these markets.

Table 11 Northeast Corridor rail share of the air/rail market, by city pair

| Route | 1999 | Share in 2010 | Share in 2012 |
|-----------------------------|------|---------------|---------------|
| Boston – New York | 20 | 51 | 54 |
| New York – Washington, D.C. | 37 | 69 | 76 |
| Boston – Washington, D.C. | 12* | 5 | na |

Note: * Boston – Washington, D.C. figure is for 2000.

Sources: Amtrak, 2009b, p. 19, Congressional Research Service, 2012, p. 22, Amtrak 2013a, p. 2; General Accounting Office 2002, p. 6.

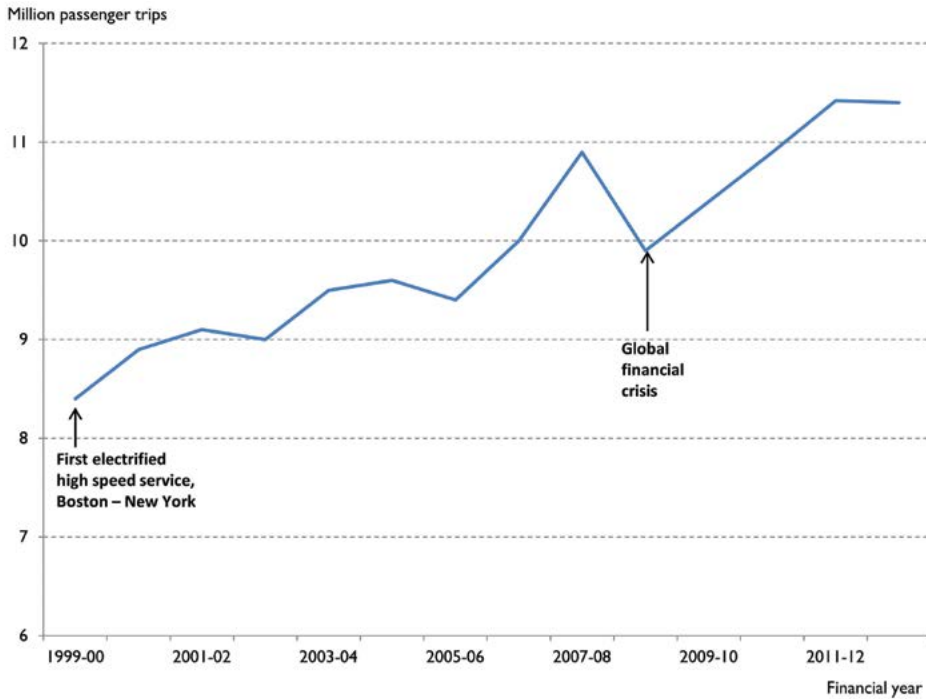
The upgrade work has achieved a substantial shift to rail but not all the mode shift to rail can be attributed to the upgrading; deterioration in other modes is a factor. A transport correspondent suggests that the air passengers were being “pushed” to Amtrak. Deterioration in the attractiveness of air services included factors such as high fares, lengthening airport security (following the 2001 terrorist attacks), “frequent flight delays” and an airline process that does not encourage use of new technology (Wi-Fi and the absence of workstation amenities) (Nixon 2012).

Patronage has increased since the completion of the *Northeast corridor improvement project* and the introduction of the *Acela Express*. Figure 44 shows Amtrak patronage on the *Northeast Corridor*.¹¹⁷

¹¹⁶ Boston – New York airline patronage fell by nearly 30 per cent between 1999 and 2009 (Johnston Chase 2010).

¹¹⁷ Amtrak patronage is mainly made up of the *Acela Express* and *Northeast Regional*. Separate long time series patronage data are unavailable for the separate services. In 2011–2012 financial year, *Acela Express* patronage was 3.4 million passenger trips, or 30 per cent of total Northeast Corridor patronage. The *Northeast Regional* is the most patronised with 8 million passenger trips, or 70 per cent of the corridor’s patronage (Amtrak 2012b).

Figure 44 Northeast Corridor Amtrak patronage



Notes: Patronage data are for all Amtrak regional services; contracted commuter service patronage are excluded. Patronage in 2005 was adversely affected by technical issues with *Acela* train braking systems leading to a four-month total withdrawal of the fleet. There is limited longer-term data. US Department of Transportation (1978, p. 6) indicates Washington – New York/Newark patronage of 1.218 million and Boston – New York patronage of 1.813 million, in 1976. The NEC Master Plan Working Group cites 2009 patronage for the same city pairs as 1.740 million and 0.664 million, respectively. There is no apparent definitional differences between the years, leaving unexplained the drop in the Boston traffic. General Accountability Office (1996, p. 6), suggests Amtrak's corridor patronage was about 11 million in 1995. It is also known that there were periods of intense competition in the airline industry, with marked fare reductions.

Sources: Amtrak, 2010b, 2012a

Patronage has grown at an average annual rate of almost 2.5 per cent since 1999–2000. In the 2008–09 financial year, passenger trips declined at the time of the global financial crisis, accompanied by decreases in the cost of competing travel—falling airline fares and petrol prices (Amtrak, 2009a, p. 34). Nevertheless, patronage subsequently recovered.

Further patronage growth may be capped somewhat by the high load factors experienced on the *Acela* (63 per cent) — but 48 per cent on the Regional (Archila 2012, p. 7). Amtrak will lengthen its trains by 2015, increasing *Acela* capacity by 40 per cent. Additional trains will be introduced by 2020 (Nixon 2012).

Since 2008, new coach services have operated between New York and Washington, D.C.. The companies, BoltBus and Megabus, offer much slower transit times (270 minutes, compared with 167 minutes on the *Acela Express*) but much lower fares¹¹⁸. With seven operators, coach services between Boston and New York also provides strong competition for rail and air.

¹¹⁸ Megabus and Amtrak argue that the characteristics of the rail and coach operations makes it difficult to compare the two modes. Megabus argues that its main competitor is other consumer goods such as air conditioners or flat-screen televisions, not Amtrak. The contention is that not many passengers switch between the modes (Craghead 2014, p. 8).

The *Acela Express* was introduced as a key upgrade element to deliver premium services targeted at airline passengers. Table 11 demonstrates the service has significantly raised rail's share of the air/rail market for the Boston – New York and New York – Washington, D.C. routes.

Conclusions

The incremental upgrade of the *Northeast Corridor*, including track work, electrification and new rolling stock has improved service transit times, frequencies and reliability; on the key city-pair traffic, rail has achieved a substantial mode-share shift from air.

The very high-performance rolling stock—the *Metroliner* (and later derivatives found in the *Regional Express*), the *TurboTrain* and the *Acela*—have been central to the upgrade strategies. The corridor has experienced strong patronage growth and the premium service, the *Acela Express*, offers services with time, frequency and reliability that compete strongly with air on key city pairs.

Despite considerable upgrade work, however, in 2013 the transit time between New York and Washington, D.C., was 20 minutes greater than it was in 1969. Maintenance deferral has contributed to lengthened travel times. Amtrak notes that sections of the track have deteriorated to the extent they are now 'overwhelmed' (Amtrak, 2010, p. 1). Their current works programme is aimed at renewing infrastructure so that the corridor is in a 'state of good repair'.

Further service frequency upgrades are stymied by a significant bottleneck that will be very costly (at least US\$14.5 billion) to resolve. The least capacity on the corridor is the twin tracks at the Trans-Hudson Tunnels between New Jersey and New York; this is also where the passenger demand and train service provision is at its highest.

The *Northeast Corridor* demonstrates the potential for incremental upgrades to tracks and trains to improve service levels, patronage and market share; for the key markets, the shift in mode share from air has been very marked.

However to maximise the potential benefits, upgrades need to be supported by ongoing infrastructure maintenance. The case study thus also illustrates that, to achieve desired goals, sufficient resources are required on an ongoing basis to ensure that service upgrades do not lead to downgrades.

Study 12: Chicago – St Louis service upgrade

Summary

- ongoing service upgrading from 1993, to encourage shift to rail, to provide more balanced use of modes.
- speed improvements through track standard enhancements, raising track capacity and improving level crossing safety.
- incremental improvements have been implemented, notably since 2006, but more substantial work is required to achieve higher service standards that could impact on the market.
- from 2006 patronage has more than doubled, spurred by service frequency upgrading.
- timescale is protracted and, in the case of double-tracking, it is subject to funding so timing is open-ended.

Background

In the USA the National Railroad Passenger Corporation — Amtrak — has identified patronage levels on a number of medium-distance corridors where upgrading can deliver services that provide a competitive product. Unlike the largely single-corridor in the northeast, a number of passenger train corridors fan out from Chicago, under the umbrella term “Midwest High Speed Rail”. Two such corridors are shown in Figure 45: the Chicago – St Louis corridor and the Chicago–Detroit/Pontiac (Michigan) corridor. The St Louis corridor is considered here—Box 10 provides insight into differences between the two corridor upgrades. A study conducted in 1974 concluded that it was not feasible to construct a dedicated new railway on the corridor (Cerreño and Mathur 2006, p. 18).

Chicago is a conurbation of around 9.5 million while St Louis has a population of 2.8 million; there are relatively modest population centres between these cities. The current Amtrak route between the cities is 454 km, along a non-electrified railway. Amtrak journey time is around 330 minutes. Amtrak has a one per cent share of the 35 million travellers on the corridor, which is dominated by car travel (Sneider 2013, p. 21). The rail share of the air/rail market is 29 per cent (Amtrak 2012d, p. 2).

Objective and goals

One objective of public funding of the upgrading is to enhance the service to give “a more balanced use of the modal components”. The project web site suggests that “A more balanced transportation system in the corridor would provide travelers with greater mobility options”. A range of benefits to users and non-users is set out in Quinn (2010, p. 52–63). Federal commitment to rail upgrades is provided on the basis that it will “provide faster and more energy-efficient means of travel”¹¹⁹; improved traveller safety in the corridor is seen as a benefit along with a “reduction in air pollutant emissions and energy consumption” (FRA 2014).

¹¹⁹ Illinois High-Speed Rail, Chicago to St Louis, <www.idoths.org/faqs/>. The White House, www.whitehouse.gov/high-speed-rail Funding has also come from the *American Recovery and Reinvestment Act of 2009*, which was a response to the economic downturn arising from the Global Financial Crisis.

Figure 45 Chicago – St Louis (and other) line upgrades*



Notes: The map shows the upgraded lines (including the Minneapolis – Big Lake commuter line upgrade, p. 37) discussed in this report. Only the intermediate stations between Chicago – St Louis that are mentioned in the text are shown.

Chicago is a hub of a number of railways that are targeted for upgrading. These lines radiate to a number of cities in nine Midwest states. The Midwest Regional Rail System is described at www.dot.state.mn.us/passengerail/mwrrri/

The institutional and political framework for this corridor upgrade has a bearing on USA upgrade projects. The USA generally has a less interventionist stance to public transport provision than European countries and its railways are mostly privately-owned. As a result, it is particularly important to appreciate the funding and sources of support of services and service upgrades. The US Transportation Secretary designated the corridor under the *Intermodal Surface Transportation Efficiency Act of 1991*. The agents for the St Louis upgrading are the Illinois Department of Transportation with the Federal Railroad Administration. The upgrading is funded by the USA Federal Government's High-Speed Intercity Passenger Rail Program; and a grant under that Program. State funding has come through the Illinois Capital Bill, from the State's Department of Transportation, from local governments and from the Union Pacific Railroad (UP)¹²⁰. UP has co-operated on the corridor "because the route does

¹²⁰ The corridor consists mostly of UP track (Joliet – south of Alton) but also segments where track is owned by Canadian National (Chicago–Joliet), Kansas City Southern and the Terminal Railroad Association (the latter operators' tracks being from south of Alton through to St Louis).

not have heavy freight traffic” but has not co-operated on the St Louis – Kansas line, which is “very busy” (Cerreño and Mathur 2006, p. 46).

Uniquely amongst the case studies, the Chicago – St Louis upgrade is also being undertaken to *prevent* subsequent worsening of the prevailing service standard. It was stated in 2006 that the line has “very low freight traffic” (Cerreño and Mathur 2006, p. 29) but that the freight railway owners expect to handle substantial increase in freight traffic. This means that not upgrading would increase capacity constraints that could further lengthen transit time, undermine reliability and efforts to increase service frequency.

Description of the upgrading project

The upgrading project is ongoing, with major improvement in service frequency from 2006; major infrastructure works have been undertaken around Springfield (completed in 2004), with a later concerted programme commenced in 2010. This latter work is geographically-phased, with Springfield–Alton work in 2010 followed by Dwight–Lincoln and Alton – St Louis work in 2011.

Another important upgrade has been enhancement to station accessibility, with the development of the St Louis Multimodal Transportation Center. The facility opened in 2008, replacing a temporary station that had been used since 1978; the station is well-sited in the city, and in addition to Amtrak it caters for coach operations and is adjacent to St Louis MetroLink (light rail) station.

The immediate objective of the upgrade on the Chicago – St Louis corridor is to achieve 176 km/h [110 mph] top speed for passenger trains. The maximum track speeds in the USA are regulated by the government agency, the Federal Railroad Administration according to specified route infrastructure standards. Thus, to achieve these higher track speeds requires that the infrastructure meets the “Class 6” track standards, which include:

- the requirement for installation of Positive Train Control¹²¹ or in-cab signalling;
- higher track standards, including higher-specifications of rails, sleepers and rail–sleeper fasteners and high-speed turnouts;
- tighter track geometry tolerances—for instance, the 1 435 mm track gauge must not vary by more than 19.05 mm over a distance-length of 9.5 metres¹²²; and
- level crossings must be fully-gated across the road to prevent road vehicles ignoring signals and passing around half-barriers.¹²³

¹²¹ Positive Train Control is a signalling system that includes active enforcement of movement. The system actively constrains train movement in a range of situations, notably where the train exceeds stated-maximum speeds or where the train driver fails to respond to approaching stop signals. The system has been mandated for most US railways (effective from end-2015) and is required for all lines where trains operate at or above 144 km/h (90 mph).

¹²² See Federal Railroad Administration 2013, p. 16 074.

¹²³ “Safety improvements will include new train signal systems, four quadrant roadway gates, improved roadway geometry, pedestrian gates, and fencing. This work also may include the installation of new concrete crossing panels and/or temporary/permanent approach improvements.” (<www.idothsr.org/2010_const/details.aspx>). General Electric Transportation’s Incremental Train Control System has been installed on the 176 km/h track; the System is an in-train monitoring system that confirms the operation of the four-quadrant gates and that no vehicles are within that gated area. <www.getransportation.com/its/signaling-train-control/automatic-train-protection-control-systems/itcs-incremental-train-control>.

The higher infrastructure standards lead to higher operating costs as ongoing inspection and maintenance must be conducted more frequently.

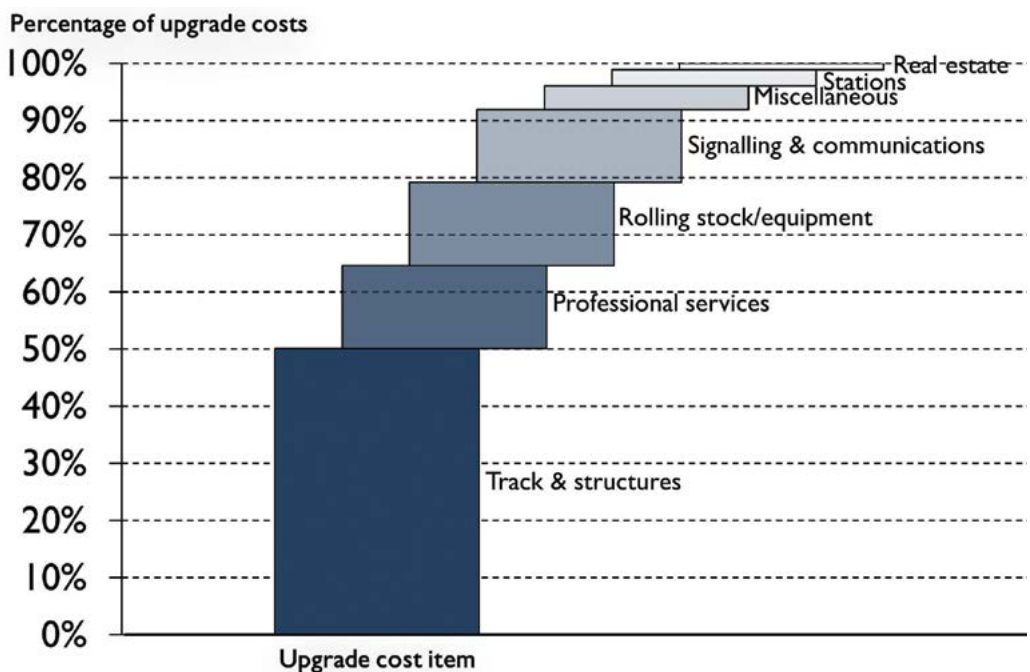
Capacity expansion is also a major upgrade task. In particular, the aim is to expand the largely-single track railway to double-track throughout. This is required to provide sufficient capacity to expand passenger services and the projected expansion of freight on the route (with 7 daily freights in 2001 but projected to rise to 20 per day)¹²⁴. Signalling systems are also being upgraded (Johnston 2009, p. 23).

The upgrading programme also involves the introduction of new (conventional) rolling stock.

The “Tier I” study initiated by the Illinois Department of Transportation in 2010 assessed the strategy for future upgrades such as the track doubling, the service frequency goals and also the determination of the preferred railway routes out of Chicago (to Joliet), out of St Louis (to Alton) and through Springfield; the presence of multiple freight railways in these sections enables this consideration (Illinois High-Speed Rail, nd.).

The cost apportionment of current programme upgrade work is illustrated in Figure 46; the total costs for the current upgrade programme is USD 1.45 billion.

Figure 46 Upgrade cost apportionment, by category



Source: Derived from data in Pasterak 2012.

Implementation

With an extensive package of upgrade plans and limited funding, the upgrade programme is protracted. In 2006, the number of return trains per day was increased from three, to five. In 2012, the upgrade of the line between Dwight and Pontiac (Illinois) was completed, raising the

¹²⁴ Frailey 2011, p. 38; Trains 2001, p. 87.

line's standard to Class 6, enabling the top speed to be increased to 176 km/h; a major element of the work involved raising standards, or elimination, of level crossings.

Train speeds between Dwight and Alton will be raised by the end of 2015, to 176 km/h (110 mph) as a result of work that will improve the track condition that currently checks the train speeds. The completion of this work will reduce transit time by one hour (Sneider 2013, p. 22).

Impact on service

The current transit time between the cities is 330 minutes. The intention is that the upgrades will lead to a future transit time of 210 minutes (Bowen, 2012, p. 35). Service frequency is five trains per day each way, with four trains being the Chicago – St Louis *Lincoln Service* and one train being the Chicago – St Louis – Los Angeles *Texas Eagle*.

Box 10 Chicago–Detroit [Pontiac] (Michigan) enhancements

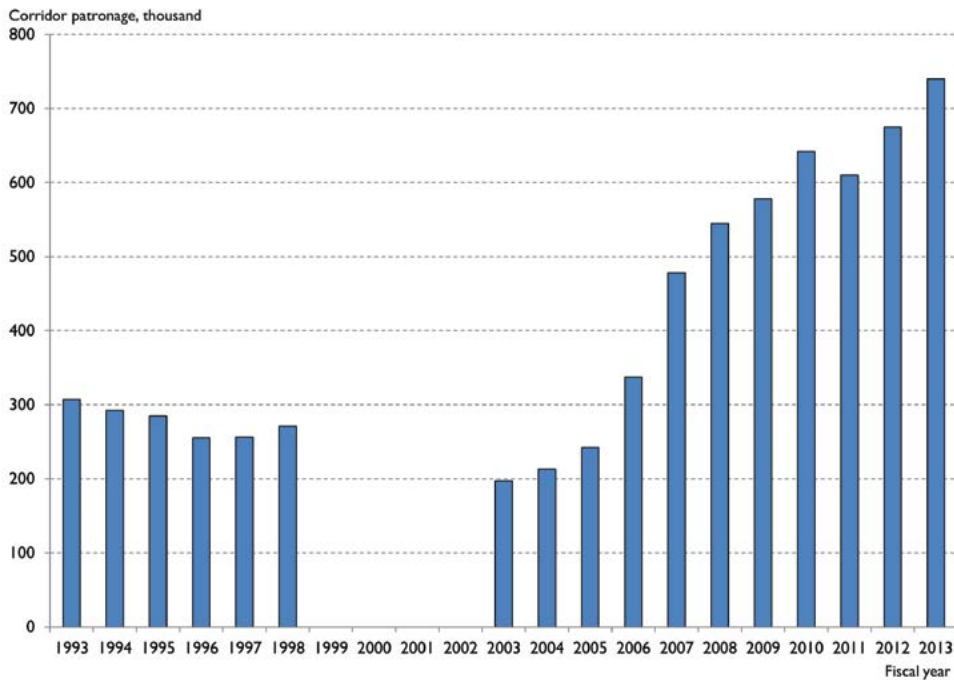
The upgrade of the Detroit corridor (Figure 45) has similarities to the St Louis corridor. The objective is 176 km/h speeds on three-quarters of the track, taking 100 minutes off the 330 minute transit time. To achieve this, there is a need to rebuild 180 level crossings. The corridor is a similar length (489 km), a similar level of patronage (around half-million passengers per annum) and frequency (three trains per day). Authorities are predicting a four-fold increase in patronage. Current air/rail market share (12 per cent) is less than one-half that of the Chicago – St Louis route (29 per cent) (Amtrak 2012s, p. 2).

Arguably, however, the Detroit corridor has fewer challenges in implementing the upgrade. In particular, there are fewer railway agencies involved and those that are involved have an active goal of passenger rail enhancements and own more than three-quarters of the route. While the St Louis corridor has five railway owners, the Detroit corridor has four; where two are passenger rail proponents rather than freight-based railways. These two entities, owning adjoining sections of the corridor, are Amtrak (owning 156 route-km) and the State of Michigan (with 217 route-km, owned primarily for the purposes of facilitating the passenger operations, purchased from a freight railway company, Norfolk Southern, in 2013). The freight operators, owning 116 route-km, are Norfolk Southern (immediately east of Chicago) and Conrail Detroit Shared Assets (on the west side of Detroit). The service beyond, to Pontiac, are tracks owned by Canadian National (which also owns 3 km of track within the Michigan State-owned route) (Johnston 2014, pp. 22–23).

Train operations should also face fewer scheduling and reliability challenges. The Detroit corridor also generally has less interface with freight operations, for instance with very little freight on the Michigan-State-owned track.

Impact on market

In 2013, patronage on the Amtrak services (the *Lincoln Service* and the *Texas Eagle*) on the corridor was 740 thousand, having risen by 10 per cent over the previous year. As is evident in Figure 47, there have been marked increases in patronage since 2006 after languishing for many years. It is notable that the step-change in patronage is associated with the increased service frequency in 2006—which is some time prior to the benefits of track condition upgrades beginning to be realised.

Figure 47 Patronage on Amtrak's Chicago – St Louis corridor

Source: Amtrak 2013c; Sneider 2013, p. 24, St Louis Post-Dispatch 2013, Cudahy 1994, p. 46; General Accounting Office 1998, p. 37.

Notes: Data are not available for 1999–2002. Earlier data indicates some growth through to 1993, with 182 000 passengers being recorded in 1977. (General Accounting Office 1978, p. 4).

Projections published in 2010 pointed to patronage of 716 thousand in 2014 (exceeded in 2013) and 844 thousand in 2023 *without the double-track*. When double-track is provided, the service frequency would rise from six trains, to eight trains; in this scenario, the projections would be two-thirds higher (to 1.4 million) in 2023 (Quinn 2010, p. 46). Such figures point to the relatively high importance of frequency in this study as an important upgrade attribute. The double-track will also enhance service reliability, an important factor in attracting patrons.

There are no figures on mode-share diversion arising from the implemented upgrades. In the year 2000, the road share for intercity journeys in the corridor was estimated to be 98 per cent, with two per cent for public transport—which was split with 12 per cent rail¹²⁵, 67 per cent air and 21 per cent bus. The projections for 2025 suggest a road share of 94.6 per cent, with 5.4 per cent for public transport—split with 41 per cent rail, 51 per cent air and 8 per cent bus. The scenario points to overall traffic growth in the corridor, with diversion to rail being principally from road travellers. Amtrak sees that its new customers should be coming from road more so than short-haul air services (Judge 2003, p. 36).

¹²⁵ General Accounting Office (2002, p. 6) estimates rail having around 3 per cent of the rail–air market.

Figure 48 Chicago – St Louis Amtrak “*Lincoln Service*” operation



Note: The photograph shows Amtrak’s *Lincoln Service* north of Springfield, Illinois, running adjacent to the Interstate-55. Photograph courtesy of Amtrak.

Conclusions

An important feature of this case study is that the upgrading task depends on the inherited infrastructure standard. Thus, while it generally does not incur terrain that involves curved tracks that impair train speeds, the corridor does have a range of other challenges and obstacles:

- The defined corridor is owned by four separate private entities; negotiating access and terms of upgrading is a planning and funding challenge.
- The condition of the track may be fit-for-purpose for freight operations but this is well below the standard required for high-speed operations.
- Signalling upgrades are required, although the Federal Government’s mandating of Positive Train Control signalling (see footnote 121) would, in any case, have led to its installation.
- The large number of level crossings—often situated in the centre of towns—require substantial upgrading of crossing systems or, indeed, grade separation.
- Finally, additional route capacity is seen as essential for accommodating freight growth and for raising service frequency and reliability.

The upgrade efforts must be seen in context, however, of overall mode share. The corridor has excellent roads, albeit especially congested in urban areas. The goal of the upgrade is to achieve of “a more balanced use of the modal components” and if rail patronage projections are realistic, then rail would achieve 41 per cent of the public transport market in 2023 following

the completion of the full line upgrading. Note, however, that with strong use of the car, this market share represents just 2 per cent of the corridor's total travel market.

Finally, the step-change in patronage that followed the increased service frequency in 2006 is notable: service frequency can be a potent upgrade tool.

Summary of case studies

This section draws together the threads of the range of experiences, summarising the upgrades and market responses.

Application

One overarching motivation for service upgrades is to modernise and improve service quality to match rising customer expectations or simply to increase (or maintain) rail's share of traffic relative to airlines and land transport. Conversely, services often exist in a policy vacuum, where standards are maintained, not modernised.

Upgrades can also be spurred by economic–political realignments, such as arising from European Union integration, the end of the Iron Curtain/CoMEcon¹²⁶ and the re-unification of East and West Germany. Upgrading can also be undertaken to prevent service deterioration, such as with Chicago – St Louis, where the growth in non-express/freight train services would increase capacity constraints that would stymie efforts to increase intercity service frequency and trigger service deterioration (longer transit times and lower reliability).

The investment programmes require a conscious decision to establish the extent of upgrading. The case studies include three such illustrations:

- Electrical system capacity on part of the London–Glasgow corridor was expanded to leave a “substantial margin” for future growth in demand for power.
- The proposed construction of a Maglev high-speed system on the Berlin–Hamburg corridor tempered the corridor upgrade programme that was triggered by the expansion of the European Union and the German reunification. When the Maglev project was cancelled, the railway upgrade programme was extended.
- The degree of, and the pace in, upgrading is also a function of project budgets, so projects such as Victoria's *Regional Fast Rail* was focused on non-urban upgrading; the *Regional Rail Link* in the Melbourne environs was developed subsequently as a later upgrade project.

The policy strategy for upgrading railways or building new railways has received vigorous debate in Great Britain. The southern end of the London–Glasgow corridor has received considerable rehabilitation *and* upgrade of performance and capacity. Traffic levels and projections suggest, however, that the capacity may be exhausted in future years. One option is further upgrading but it has been suggested that this will involve what could be interpreted as unacceptable levels of disruption to week-end (off-peak) services. The policy response to this has been that a high-speed railway is the only practical option for supplying additional capacity. This is the approach adopted for Tours–Bordeaux.

Rail service upgrades can be integral to other policies, such as the dedicated airport express services for London's Heathrow, Gatwick and Stansted Airports (as discussed in the *Gatwick Express* case study and in the discussion on airport service, from page 38). That is, these express services enhance the attractiveness of an airport relative to other international airports (notably, for Heathrow) and enhances the substitutability of an airport for a capacity-constrained airport (as with Gatwick and Stansted as substitutes for Heathrow). The airport rail services also

¹²⁶ Council for Mutual Economic Assistance.

relieve pressure on road capacity links to the airports. Ultimately, the complementary airport and rail service enhance the commercial attractiveness of the city.

Policy is not necessarily always benevolent towards rail services. Passive or active policy development, driven by capacity and financial pressures can also lead to service downgrading. This is illustrated with recent developments with the London *Gatwick Express*, and with Northeast Corridor services.

In the context of the Northeast Corridor it is important to stress that the service downgrading also reflects, in part, the extent of resources required on an ongoing basis when a long railway corridor is involved. Further, resources are required to catch up on deferred maintenance and renewal on this very lengthy, 735 route-kilometre, railway—and then additional funding for upgrade operations for new high-performance rolling stock to deliver fast, frequent services.

Nature of upgrades

The four key elements of infrastructure upgrading are condition of infrastructure, capacity, curvature of track and road crossings; these are complemented by rolling stock upgrades (with complementary electrification) and service upgrades.

Condition of infrastructure

It is notable that much of the service upgrade work that is reviewed in this report relates simply to rehabilitation of track—it is not the application of new technology. While un-renovated track might be “fit-for-purpose”, it is unsuitable when the purpose is to operate high-performance trains. As noted in Table 13, the condition of the infrastructure is a significant element of the work required to upgrade services.

Track rehabilitation is often required simply to bring track back to a previous standard that has been lost for a range of reasons; track enhancements are a bonus. For instance, in 1936 Chicago–Detroit services included 285 minute transit times, but a best time in 2013 is 318 minutes. Similarly, the pre-war Berlin–Hamburg best-time transit of 138 minutes was not equalled until 2000. In both these cases, double-track infrastructure had been singled and infrastructure standards lowered to meet new market and budgetary circumstances.

The cost involved in these upgrades—coming from a low-standard base—can be very substantial. Extensive deferred maintenance, renewal and modernisation on railways such as the USA’s lengthy Northeast Corridor (stemming back from well before the railway bankruptcies of the 1970s) has cast a long budgetary challenge over bringing infrastructure up to the standards that are commensurate with modern trains. Similarly, the fall of the Iron Curtain and the European Union membership of Eastern European countries has refocused the main transport arteries on that continent, again changing the status of railway lines from fit-for-purpose to inadequate.

The advent of high-performance trains, be they Austria’s *Railjet* locomotives or tilt trains, has elevated the required infrastructure standards where those trains run. There is a synergy between that infrastructure performance and the train performance. Thus, infrastructure standards may need not just renewed, but also modernised and raised where high-performance trains are operated.

Capacity

Raising service frequency—and raising reliable operation—is a common service upgrade objective. This amplification requires the availability of track and station capacity. Similarly, additional track capacity is required when the passenger train speeds are raised: the speed differential between upgraded trains, and other trains, absorbs capacity.

In that context, then, most of the case studies considered here required capacity expansion (Table 13). Constructing additional capacity is a major cost component. For long-term upgrade projects, such as Boston–Washington, the severe capacity constraints remain dominant obstacles to service enhancements. In the case of Québec–Windsor, it was argued that it would be more cost-effective to build new railway tracks on existing or adjoining land than to amplify capacity on the existing tracks. In the case of Wien–Salzburg, some new railway alignments were chosen to expand capacity; this had the advantage of bypassing the severe curves of the historical alignment.

Other approaches to enhancing capacity include raising permitted speeds on slower freight and local trains (as has been done on parts of the London–Glasgow route); or by diverting some of those slower services to other routes (such as the new Russian freight route that obviates the need to use the Allegro route).

As with the Chicago – St Louis, London–Glasgow and *Gatwick Express* upgrades, securing capacity for *existing* traffic does not secure the capacity when other traffic grows. For example, the growth of non-express train traffic (i.e., commuting) on the London – Gatwick Airport route has undermined the case for the providing train capacity exclusively for airport users; commuting traffic has grown to the extent that additional commuting seating can be acquired only by making express train seats available. In this context, where the passenger service provider operates over a freight railway, it may lead to pre-emptive actions: a North American freight railway may forestall upgrading where it perceives later demands for additional track capacity that would undermine its own traffic expansion objectives.

Curvature

Service enhancements focus typically on reduced transit times and this is achieved normally by track rehabilitation and enhancements. This was the case, in particular, with the well-aligned Berlin–Hamburg line, where track rehabilitation and reinstatement of the second track were the major tasks required to restore the pre-war “race track” speeds. Similarly, the Tours–Bordeaux railway was built to a very high standard.

However, when there is poor railway alignment (poor curvature), transit times are impeded even when track is in good condition. The primary solutions are to construct new alignments (such as on sections of the Wien–Salzburg track) and introducing tilt trains (such as on the London–Glasgow and Stockholm–Göteborg routes) and/or canted tracks.

Tilt technology cannot enhance speeds when track curvature standards are severely deficient, such as on the tightly-curved Canberra branch line between Bungendore and Queanbeyan. Also, tilt technology offers minimal time savings when the route has a relatively low amount of curved track.

Crossings

Level crossings place an upper limit on train speeds through those intersections, in order to protect train operations from wayward road vehicle movements. Each case study upgrade has involved varying degrees of work to improve level crossing standards or to remove the crossings entirely. This issue is particularly pertinent on the Chicago – St Louis route, where there are a large number of crossings. Grade separation tends to be particularly challenging where roads intersect railways in townships, as the built-up location can place constraints on bridges or underpasses to separate the networks.

The presence of untreated level crossings influences the sequencing of the upgrade programme. Transit time can be reduced by removing line sections where the train is having to brake and accelerate through speed restrictions. Removing a contiguous cluster of level crossings on the St Louis route now permits the train to achieve higher average speeds. By contrast, piecemeal treatment of crossings across a corridor results in irregular speed limits, which affects transit time, and capacity because trains lose momentum when passing through untreated crossings.

Service, rolling stock and accessibility upgrades

Service quality (notably, frequency), rolling stock performance, and station accessibility upgrades provide complementary or alternative upgrades. Examples from the case studies include:

- **Accessibility.** In 2014, the Wien terminus for *Railjet* services will shift from a relatively remote western station to the Central Station in the city centre. This will improve service accessibility, reducing door-to-door times and enhancing the city-centre links to other public transport modes. Amtrak shifted its New York Grand Central services into its Penn Station, a more central station with better links to Northeast Corridor and commuting services. The failure of the Shanghai maglev airport service, remote from the city centre, (page 41), illustrates the importance of accessibility.
- **Station standards.** Amtrak reported that the transfer of its Washington services back into its restored Union Station, from a very poor terminal behind the Union Station, led to a 15 per cent increase in throughput.
- **Operational and procedural changes.** The introduction of *Allegro* services was accompanied by streamlined procedures that reduced transit time. New dual-current locomotive traction reduced transit time by removing the need for a locomotive change at the Finnish–Russian border. The border crossing was also used for customs and immigration border checks; checks are now made while the train is in-transit, removing the need for a lengthy station stop at the border. Changes to operational procedures on the Sydney–Canberra tilt train trial provided some of the transit time savings.
- **Station stops.** A common strategy for reducing transit times is to reduce the number of intermediate station stops. This was adopted on the Sydney–Canberra tilt train trial and was applied to the enhanced Berlin–Hamburg services. In making such changes, passengers at those stations are disadvantaged, while recognising that the station stop imposes a modest time penalty per person that is very substantial when aggregated across all patrons.

Enhancing service reliability is a key service quality attribute that is achieved by a range of factors. Expansion of track capacity is especially important: reliability improves when track utilisation is below practical capacity limits. Another key factor that facilitates reliability is where

the upgraded service provider also manages the track; this ensures that the upgraded services are given priority over other track users. See footnote 25, for example.

Another important factor that can be used in achieving higher rail traffic is simply to reduce fares; where yield management systems are used effectively or where traffic is very price-elastic, this does not necessarily lead to lower revenue. Lower fares on *Victoria's Regional Fast Rail* services are regarded as being one factor that has complemented the effect of service upgrades in increasing patronage.

Finally, when an upgrade programme is undertaken, it must be coherent and consistent: the abandonment of in-cab signalling on the London–Glasgow route meant that while track and trains were built for 225 km/h operation, the reversion to lineside signalling meant that trains would be limited to 201 km/h. Cost-effective upgrades recognise the technically-integrated nature of the railway.

Market response

The success of service upgrades depends ultimately on achieving the goals of the upgrade, and those goals being relevant to passengers. Irrespective of any technical achievements, we argue that a robust market response is necessary for success.

Table 12 Case study market characteristics

| Primary corridor population centres | Market classification | Corridor distance (km) | Target market | Principal quality upgrade |
|--|-----------------------|------------------------|---------------|---------------------------|
| 1. Sydney–Canberra | intercity | 329 | n/s | time |
| 2. Melbourne – regional towns (four corridors) | regional | 73–162 | n/s | frequency |
| 3. Stockholm–Göteborg | intercity | 456 | air | time |
| 4. Berlin–Hamburg | intercity | 286 | n/s | time |
| 5. Wien–Salzburg | intercity/regional | 317 | n/s | time |
| 6. Helsinki – St Petersburg | intercity | 415 | n/s | time |
| 7. Paris/Tours – Bordeaux | intercity | 584 | air | time |
| 8. London – Birmingham/Manchester – Glasgow | intercity/regional | 642 | car | frequency/time |
| 9. London – Gatwick Airport | airport | 43 | car | frequency/time |
| 10. Québec – Montréal – Ottawa – Kingston – Toronto – London – Windsor (Detroit) | intercity | 1 200 | car | frequency/time |
| 11. Boston – New York – Philadelphia – Washington | intercity | 735 | air | time |
| 12. Chicago – St Louis | intercity | 454 | car | time |

Note: n/s, not stated.

Table 12 summarises some of the market characteristics of each case study. In some cases the corridors are long—such as Boston–Washington—but these corridors usually entail multiple markets (such as Boston–Providence, New York – Philadelphia – Baltimore). Those population-centre clusters act to enlarge the rail-competitive market.

Where pre-upgrade rail service already has a prominent role on a corridor, the upgrade can generate strong growth, but not necessarily a revolutionary change. For example, the Stockholm–Göteborg train service had a relatively good market share prior to the upgrade; the upgrade generated an estimated 40 per cent traffic growth; the growth was arguably still “modest” because the pre-upgrade train service already captured a relatively good share of the traffic.

It can be difficult to assess the market response to upgrades because of the typically protracted period of work—for instance, there has been a near-continuous renovation and upgrade of the Boston–Washington corridor since the 1970s (and arguably even earlier) and the London–Glasgow corridor from the 1990s. Similarly, however, it is difficult to assess short time periods, such as the Sydney–Canberra six-week tilt train trial, because ridership is likely to be influenced strongly by the novelty of the experience.

In considering the studies it is important to appreciate the level of transit time involved because there are non-linear effects of transit time savings: an upgrade may or may not provide enough improvement to divert or generate traffic. More specifically, it is not the speed, per se, that is important but the transit time: as Chen and Hall note, the transformative nature of good rail links depends on the numerical level of transit time, enabling (for instance) day returns for Paris–Lille or Paris–Le Mans due to transit times of 1 hour, or a 3-hour transit time, such as Paris–Bordeaux, which makes it far easier to consider an irregular business trip but less easy to commute on a daily basis (Chen and Hall 2012, *passim*); “The time-space effect of HSR has great potential in bringing closer major cities within critically important time zones” (Chen and Hall 2012, p. 5).

In summary, the outcomes were:

- **Sydney–Canberra tilt train trial.** The goal was to test the technical capabilities of the tilt but it was concluded that “time savings were not of the order to make rail competitive”. In market terms, the trial’s novelty attracted high interest (84 per cent utilisation) but market response was not an objective.
- **Regional Fast Rail, Victoria.** The goal was to increase patronage in response to reduced express transit times and comfortable and affordable travel. Patronage has grown very strongly, probably spurred more by the “comfortable” VLocity trains, by “affordable” lower fares and by much higher train frequencies—arguably more so than in response to the few faster peak-period trains.
- **X 2000 train, Stockholm–Göteborg.** The goal was to reverse rail’s mode share loss without incurring the prohibitive cost of building a new high-speed railway. The X 2000 tilt train reduced transit time by one-third while rail–air mode share increased from 42 per cent to 60 per cent. Traffic growth has spurred plans for a dedicated high-speed line.
- **Berlin–Hamburg upgrade.** The goal was to restore infrastructure links between eastern and western parts of re-united Germany and to strengthen links across the European Union. There was minimal operation and, thus, patronage prior to re-unification; the initial return of services led to the withdrawal of airline services.
- **Wien–Salzburg upgrade.** The goal was to develop the railway as a high-performance railway, not just a high-speed railway, that is, a railway providing higher speeds and higher throughput (through increased line capacity); this work has been undertaken. The impact on patronage is not known.

- **Helsinki – St Petersburg service upgrade.** Finnish and Russian governments sought to improve land links between the respective cities. Transit time was reduced by around two hours and service frequency was doubled. Since late 2010, patronage has more than doubled.
- **Paris/Tours–Bordeaux upgrade.** The upgrade of the Tours–Bordeaux railway enabled the railway to compete more effectively with the increasingly more competitive airlines; and 20 years later complemented the construction of the Paris–Tours high-speed railway, enabling French Railways to offer a three-hour transit time between Paris and Bordeaux. The traffic generated ultimately led to capacity constraints on the upgraded line, resulting in the (current) construction of a new high-speed railway between Tours and Bordeaux.
- **London–Glasgow (West Coast Main Line) upgrade.** The railway corridor required rehabilitation; this provided an opportunity to modernise the infrastructure, expand capacity to handle growing traffic and to improve reliability. Time savings of up to 20 per cent were achieved with a near-doubling of service frequency. Planners aimed for 60 per cent of the additional traffic to be diverted from road. Strong traffic growth has been recorded although upgrade disruptions had held back growth, and against a background of strong traffic growth on other parts of the network. Continuing exogenous traffic growth underpins plans for a dedicated high-speed railway.
- **London–Gatwick Airport service upgrade.** High-quality railway services between Gatwick and Central London enhance the attractiveness and, thus, competitiveness of Gatwick Airport as a substitute for the capacity-constrained Heathrow Airport. The availability of high-quality capacity on the route meant that a good/frequent service could be achieved by introducing an express train with bespoke rolling stock, and modifying the terminal stations. The growth of non-airport traffic, competing for capacity, has undermined the strategy.
- **Québec–Windsor corridor upgrade proposal.** The goal on this Canadian corridor has been for train services to have a more prominent role. Early efforts to upgrade services through new high-performance trains failed due to the trains failing to live up to expectations. Traffic projections assume that traffic would be diverted primarily from car travel. The case study provides an interesting hybrid on the concept of upgrading because it focuses on using the existing right-of-way, not the existing tracks—the ‘dual-corridor’ model.
- **Boston–Washington (Northeast Corridor) service upgrade.** The corridor provides an important mode option, against a background of congested roads and airways. It has undergone extensive rehabilitation over decades, electrification has been completed and new rolling stock introduced. Upgrade benefits have not been sustained, however, due to deferred maintenance instituted arising from budgetary constraints. On major segments market share has been won from air.
- **Chicago–St Louis service upgrade.** The goal is to encourage a more balanced use of modes, particularly with shifting from car (rather than air). Extensive upgrading is continuing but patronage rose by over 40 per cent in the five years to 2012, precipitated by the upgrade in service frequency.

The case studies illustrate how market response to upgrades vary, not least because of the relative competitiveness of each service prior to the upgrade; and due to the extent of the upgrade.

Practicalities of upgrade programmes

Other key practicalities of the upgrade programmes include:

- **Protracted programme.** Projects can be very protracted, especially on busy and long corridors (e.g., Wien–Salzburg and Chicago – St Louis, over 20 years; Boston–Washington, over 45 years; London–Glasgow, over 15 years);
- **Disruption to existing services.** Projects usually involve severe disruptions to existing traffic (such as on Russian track between Helsinki and St Petersburg, on Victoria's corridor upgrades, and as has been suggested would arise with any further upgrade to London–Glasgow line—indeed the extent of disruption is given as rationale for building a new line instead¹²⁷); and
- **Upgrading can broaden future service enhancement options.** Once an upgrade achieves competitive transit times, then (depending on how much the market is geographically clustered around the railway terminals) goals may be reached by other upgrades (frequency, in particular), as illustrated by Victoria's *Regional Fast Rail*.
- **The number of entities involved.** The greater the number of agencies, track owners and train operators, the more challenging the upgrade task, particularly where the goals of individual entities diverge.
- **Ownership of assets.** It is easier to implement an upgrade when the service provider owns or manages the assets. For example, the Chicago–Detroit upgrade is arguably easier to implement than the Chicago–St Louis upgrade because Amtrak owns/operates most of the track and the goals of the entities converge on increasing passenger traffic; on the St Louis upgrade, there are more entities, the track is not owned by Amtrak and the track owners naturally seek to protect current and future freight movements.

There are also major challenges for upgrade programmes:

- **Project funding required.** Justifying the political case for the call on public funds;
- **Other railway users may be adversely affected.** Accommodating upgraded services on tracks that are shared with freight and other (lower-speed) passenger traffic (as experienced on Chicago – St Louis, Boston–Washington and London–Gatwick) and noting that giving priority to express services then downgrades those other services (as experienced between Tours and Bordeaux). The Québec–Windsor studies avoided this issue by proposing additional capacity on adjacent land within or beside the railway corridor rather than sharing capacity. German railways avoid scheduled- and real-time prioritisation by operating freight trains in evenings and during nights (as far as possible), when few passenger trains operate although this does not mean that those operating periods are optimal.
- **Not all passenger train users will benefit from upgrades.** Where higher speeds are achieved by rationalising services that stop at smaller intermediate railway stations (as experienced on Berlin–Hamburg line, Stockholm–Göteborg and during the Sydney–Canberra tilt train trials).

A practical aspect of an upgrade programme is the safety regulation stance. The regulatory environment is an important difference between the case studies; this can be a major factor in upgrading. For example, where passenger trains share tracks with freight trains, the USA's

¹²⁷ Department for Transport 2013.

Federal Railroad Administration's (FRA) safety regulations require very high structural standards for the carriages. To meet the FRA's safety standards, the weight of the Northeast Corridor *Acela* train has been increased considerably relative to French TGV trains¹²⁸. Regulations can therefore play an important part in the practical application of service upgrading.

Finally, the chequered experiences with services on the Northeast Corridor; and with the *Gatwick Express*, indicate that while efforts are required to achieve service *upgrading*, other issues—such as financial constraints and other demands on capacity—can bring about service *downgrading*.

¹²⁸ An *Acela* train of around 203 metre length weighs around 565 tonnes compared with a TGV (Sud-Est) 200 metre train weighing 385 tonnes (that is, around 68 per cent of the *Acela* weight). Note that some of the extra weight on the *Acela* arises from the tilt mechanism. Bogie systems differ between the trains, with *Acela* having additional bogies and so reducing the axle loads; nonetheless, the train has higher axle loads than the TGV, with consequently higher track wear-and-tear (and, thus, maintenance).

CHAPTER 6

Improving regional passenger rail services

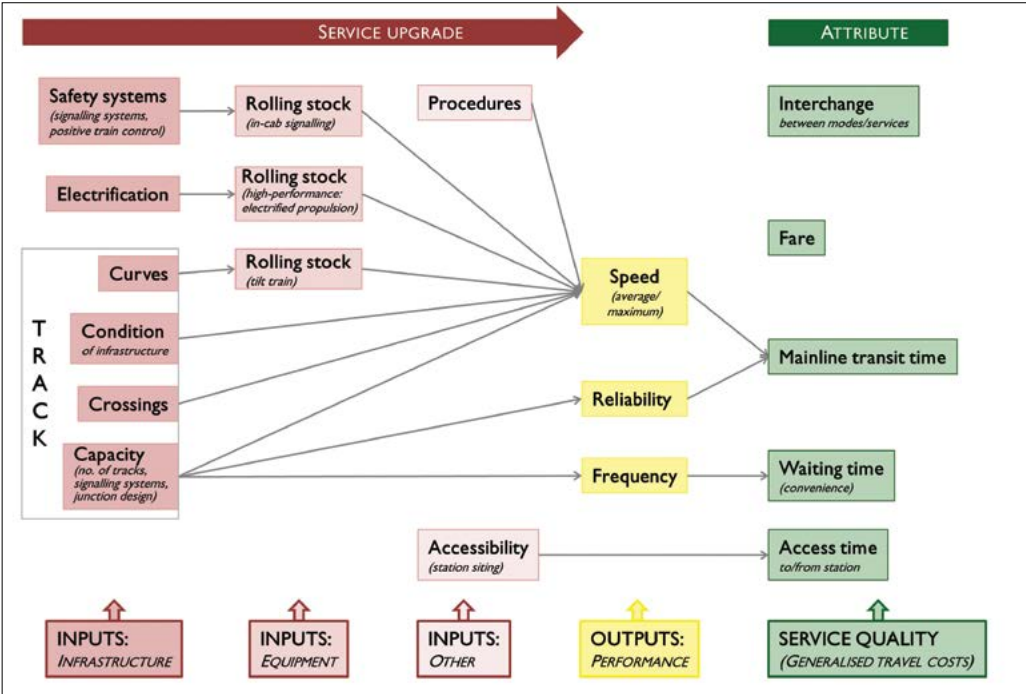
This report has reviewed passenger train service upgrades as a cost-effective strategy for delivering better regional passenger trains. Upgrades may provide a low-cost substitute **or** complement **or** precursor to the radical option of construction of a dedicated high-speed railway. The lead time in introducing better services can be much less than for new construction, depending on the nature and extent of upgrading. Thus upgrades may deliver corridor improvements earlier, and also cheaper, than building a new railway; in this way the upgraded services can be valuable proving-ground for the case for a new line.

As illustrated by the case studies, the merits of upgrades must be considered on a case-by-case basis so it must be stressed that a proposed upgrade may not deliver sufficient service quality benefits to warrant even relatively-modest investments. This arises, in particular, because of high upgrade costs and/or an inadequate market response.

Matching upgrades to market needs

Figure 49 (reproducing Figure 3) encapsulates the principal service upgrades and service quality attributes as perceived by travel market individuals. Upgrades to infrastructure and equipment systems, and accessibility and procedural inputs bring speed, reliability and frequency enhancements to railway services. For the traveller, these service enhancements mean better access and mainline transit time and waiting time (or convenience time) relative to competing modes.

Figure 49 Simplified chart of service upgrade and market product relationships*



Note: * Some product attributes, such as carriage comfort, are not considered here but may be important factors in travellers' choice of mode.

Input costs and existing service quality characteristics influence the upgrade strategy (assessed through cost–benefit analysis). For instance, if a service already has relatively good transit time, then improving service frequency may be more effective than a transit time enhancement.

This study has identified a range of service upgrades that may attract travellers. In economic terms a successful upgrade will depend on (a) the extent of the upgrade required, (b) the market response and (c) the resulting upgrade strategy. These are now summarised.

Nature of upgrades

The railway's service upgrades can be considered as “output-based” performance measures such as:

- higher average train speeds, applied to a robust (reliable) timetable;
- more frequent trains; and
- modern trains.

Service frequency amplification is likely to require investment in additional rolling stock (which may include higher-performance vehicles such as tilt trains).

The cost of upgrades is strongly levered by four key elements:

- **Condition.** Infrastructure in poor condition or which is obsolete;

- **Capacity.** Constrained infrastructure capacity (especially when there are great speed differentials between different train types), together with challenging impediments to its expansion;
- **Curvature.** Severe and poor track curvature geometry; and
- **Crossings.** Presence of road level crossings.

To enhance speed and frequency performance standards, input standards must be raised. For example, trains must operate on high-standard infrastructure, with sufficient track capacity and with matching high-standard signal and communications systems. Depending on the pre-upgrade infrastructure quality, raising those standards can be prohibitively expensive.

These four “c” expenditures can be major elements that undermine the economic case for funding upgrades and which create budgetary obstacles to financing the upgrades.

Market response

The market response to the upgrade depends on the characteristics of the upgrade, notably:

- door-to-door and terminal-to-terminal **transit time**;
- service frequency, that is, **convenience/waiting time**;
- service **reliability**;
- changes in **fares**; and
- service comfort and accessibility.

The growth in patronage following an upgrade depends on key travel market characteristics:

- the level of travel on the corridor;
- the types of travel (such as business/leisure, international tourism, day tripping); and
- rail's existing market share.

Thus the market size and market characteristics underpin the potential for cost-effective service enhancements.

Finally, the market response depends on what responses or changes in service attributes are undertaken by other modes—for example, changes in air fares strongly influenced rail patronage on USA's Northeast Corridor; and led to the demise of the *Linx* service in Scandinavia (p. 35). Similarly, deterioration in airline reliability on the Northeast Corridor has complemented Amtrak's service upgrades.

Upgrade strategy

Upgrade strategies should reflect the market characteristics that the rail service seeks to serve. For example, where the catchment area around rail terminals is very dispersed, it can result in long (and costly) access/egress times, exacerbated by situations where there are poor or costly access/egress modes linking with the terminals. Thus, an upgrade strategy can focus on reducing mainline transit time to offset this weakness.

The situation differs, however, if there is a large travel market clustered near to the rail terminals (or with good links to those terminals), and thus with low access/egress times. When the travel market is structured thus, rail's mainline time competitiveness may suffice for rail to have a significant market share. Focusing on other service quality attributes—notably, train frequency—then become more relevant.

Table 13 outlines the input and market aspects of the case studies, showing where the specific inputs were upgraded in order to address specific market deficiencies.

Table 13 Case study strategies

| Case study | Primary upgrade input component | | | | | Primary market deficiency | |
|--|---------------------------------|----------|--------|-----------|-------|---------------------------|-----------|
| | Condition | Capacity | Curves | Crossings | Train | Journey time | Frequency |
| 1. Sydney–Canberra (trial) | ✗ | | ✗ | | | ✗ | ✗ |
| 2. <i>Regional Fast Rail</i> , Victoria* | ✗ | ✗ | | | ✗ | | ✗ |
| 3. Stockholm–Göteborg | | | ✗ | | | ✗ | |
| 4. Hamburg–Berlin | ✗ | ✗ | | | ✗ | | ✗ |
| 5. Wien–Salzburg | | ✗ | ✗ | | | ✗ | |
| 6. Helsinki–St Petersburg | ✗ | ✗ | | | ✗ | ✗ | ✗ |
| 7. Paris/Tours–Bordeaux | | | | ✗ | | ✗ | ✗ |
| 8. London–Glasgow | ✗ | ✗ | ✗ | | ✗ | | ✗ |
| 9. London–Gatwick Airport | | | | | ✗ | | ✗ |
| 10. Québec–Windsor (proposal) | ✗ | ✗ | | | | ✗ | ✗ |
| 11. Boston – New York – Washington | ✗ | ✗ | | | | ✗ | |
| 12. Chicago–St Louis | ✗ | ✗ | | ✗ | | ✗ | ✗ |

Note: * As originally conceived, the *Regional Fast Rail* would have incorporated substantial urban capacity enhancements; these were omitted with the scaling back of the project. The subsequent *Regional Rail Link* project focuses on that urban capacity amplification.

Underpinning issues

There are three key issues for service upgrades. First, there is the presumption of government funding of investment and ongoing service support. Secondly, there is the strategy that is adopted to upgrade the corridor rather than build a new railway. Finally, there is the treatment of the interface between freight and passenger train services. These aspects are reviewed by reference to the case studies.

Goals of upgrading

The service upgrade case studies illustrate the range of different goals for service upgrades. A range of reasons is given for public funding of railway passenger services. At the extreme, it has been argued that the USA's Northeast Corridor is funded in part because alternative road and air corridors are highly congested, with severe difficulties in expanding their capacity; a well-functioning railway corridor is seen as offering capacity and mobility relief to travellers in the

region. The case for funding the Chicago – St Louis corridor has been made on the basis that it would lead to a more balanced use of modes and shift use to more energy-efficient trains, thereby reducing air pollutant emissions and energy consumption. Nonetheless, that country's Government Accountability Office has called for the establishment of well-defined, measurable goals associated with upgrading¹²⁹ (GAO 2009, p. 44–5).

Public funding of European railway corridors is seen as having merit because the corridors are designated critical arteries in the trans-European transport network.

What the case studies here illustrate, however, is that in practical terms, the upgrading policies are often remedies for replacing obsolete infrastructure, or infrastructure in poor condition. That is, the upgrades represent **coherent** modernisation strategies rather than erstwhile piecemeal replacement work. Modernisation lies at the heart of most of the upgrade projects, whether it be rehabilitating track, signals, communications, capacity or rolling stock.

Corridor strategy

The key decision to upgrade a railway is often determined by the poor economics of the alternative—building a new railway. In most of the case studies, the decision to upgrade services rather than build a new railway inevitably hinged on poor demographics or—its flipside—poor economics for a dedicated new railway. The populations being served are too small and dispersed—this was the basis for upgrading the Stockholm–Göteborg, Salzburg–Wien and Helsinki–St Petersburg corridors. It is implicit in the rehabilitation and upgrade of the Chicago–St Louis corridor.

Environmental concerns also influences corridor strategies. The upgrade of the London–Glasgow line provided some transit time enhancements (aided by tilt trains) and a near-doubling of service frequency. Crucially, the upgrade avoided the need for developing a new railway, a decision which hitherto had been avoided because of the high draw on the taxpayer and the adverse impact on the physical environment. The adverse reaction to the subsequent decision to build a new high-speed railway at the southern end of that corridor supports the reticence to develop new corridors.

Train prioritisation

Inherently, service upgrades that deliver more and faster trains will increase the conflict between upgraded services and other track users. Upgrades therefore require a range of strategies depending on track ownership/management, regulation and obligations.

Train prioritisation or physical strategies are required for accommodating upgraded and local and freight trains. The interface issues can be reduced where it is possible to reduce the speed differential between passenger and freight trains (that is, by speeding up freight trains). Because European freight trains are typically shorter and faster than North American counterparts, the interface issue is less pronounced in Europe than North America. (Vantuono 1994, *passim*.)

¹²⁹ “specific, measurable, achievable, and outcome-based goals that are in turn based on identified areas of federal interest, improve the foundation for allocating federal resources and optimizing the results from the investment” (GAO 2009, p. 45).

Some freight commodities, such as perishables (see Burns 2013, for example) need such speeds and so upgraded railways would complement those freight services. Irrespective of this, freight customers no longer tolerate low freight service (priority, speed and reliability).

In some cases, the upgrade strategy involves removing the freight-passenger interface—this is the proposal for the Québec–Windsor corridor (by placing passenger tracks that are parallel to the existing freight tracks: the ‘dual-corridor’ model). The Helsinki – St Petersburg passenger services no longer share tracks with freight trains in Russia as freight operations have been diverted by developing an alternative freight corridor. In Germany, freight services are operated at night to avoid scheduling issues with passenger trains and adversely affecting passenger train reliability.

Capacity remains at the heart of resolving potential conflicts between prioritising upgraded passenger over other trains. Where freight trains take priority over passenger trains—such as over the freight railways between Chicago and St Louis—then key passenger service upgrade characteristics (speed, frequency and reliability) can be achieved only by ensuring that capacity is expanded sufficiently to enable co-existence of the services. Additional capacity was introduced on the Helsinki – St Petersburg corridor by some construction of diversions, notably a diversion that provided a direct route for passenger trains and an alternative route for some freight trains.

Decision-making also needs to address the issue of balancing calls on capacity between regional/intercity and commuter trains; sometimes the issue has been resolved only by separating the trains. In the case of Victoria’s *Regional Fast Rail* project, the supplementary *Regional Rail Link* in Melbourne is a project that shifts the regional trains onto dedicated tracks. In Hamburg, the Berlin trains have been shifted onto tracks away from the S-Bahn suburban services. The co-existence of commuter and intercity services on Amtrak’s North East Corridor is a major operational challenge that is met essentially by capacity expansion.

Upsides and downsides of service upgrading

This report is focused on the policy attraction of service upgrading as a substitute for constructing a dedicated new high-speed railway. Total travel time, service quality and accessibility matter more than “speed” per se, and certainly more than a headline maximum speed.

There are other reasons for upgrading that we do not consider here—in particular, upgrading (or “modernisation”)—which is merely keeping pace with the productivity and service quality attributes available in the transport mode and in the alternative modes and the higher standards that travellers expect.

There is a range of arguments for and against service upgrading when seen as an alternative to building a new railway:

- it is much cheaper, and so requires less call on public funding, than a new railway (although note that the Canadian case study suggests otherwise);
- an upgrade can buy time by introducing better rail services long before the alternative (a new line), although (for various reason) some upgrades have been protracted;
- an upgrade reduces market risk associated with constructing dedicated track—the existing track is a proving ground for the market;

- incremental (staged) upgrading can be undertaken, enhancing services as required;
- an upgrade provides some substitute, if not the best option when high costs and small market make it uneconomic to undertake new railway construction—such as underpins the various tilt train services considered here, however the upgrade may be too inadequate to make a significant impact on the market or the desired policy goal;
- upgraded services adversely affect other uses of track capacity—slower freight and passenger services;
- during upgrading there can be long periods of disruption to services, as illustrated with the London–Glasgow and (Finnish–) Russian case studies; it might only be possible to truncate the length of the upgrade project by having complete possession of track sections (that is, running no trains) for extended periods;
- upgraded services adversely affect population centres that become bypassed by express trains; and
- investment may be wasted if it is required to construct a new railway before the benefits of the upgrade are realised.

Ultimately, determining if a line upgrade has been successful depends on the goals set out—and these are often not defined in financial or economic (cost–benefit) terms or in terms such as mode share, congestion relief or regional activity.

Options for Australia

This study has examined the concepts, opportunities and impediments to enhancing regional passenger train services as a cost-effective way of stimulating rail travel. Typically, much can be done to infrastructure and trains to enhance train services—but does it deliver enough market stimulus to warrant the expenditure? Put another way, can an upgrade project pass a financial investment test or a cost–benefit analysis?

Australia, like North America, has opportunities for upgraded regional and intercity passenger train services, but these are relatively few compared with Europe. This arises because of the relatively large distances between Australian/North American cities, the good road links and because of the relative dispersion of populations/travel markets within those cities—aided and abetted by relatively weak radial public transport links from those city centres.

It is worth considering three major types of railway service that could be considered for Australia:

- the population-centre clusters along a corridor (such as Boston – New York – Washington; Québec–Montréal–Toronto–Windsor; London–Birmingham–Manchester–Glasgow);
- the strong medium-distance city-pair or region–city pairs (such as Wien–Salzburg; the *Victorian Regional Fast Rail*; Berlin–Hamburg); and
- the airport market-specific dedicated airport train (such as the *Gatwick Express* reviewed here).

Australia lacks the “string-of-pearls” of major population centre clusters along a linear corridor. Long-distance high-speed rail systems “perform best along corridors passing through clusters of high-density-population centers with significant economic activities” (Ashiabor

and Wei 2013, p. 210). The Boston– New York – Philadelphia – Washington and London – Birmingham/Manchester – Glasgow case studies illustrate corridors of a “string of economic pearls” that create excellent travel sub-markets within the corridor extremes. In both cases, the US and British case studies point to historical under-performance of rail services on their “string-of-pearl” corridors simply because of a failure to maintain the infrastructure standard—let alone to enhance the infrastructure to reflect modern, productive technology.

It is not possible to perceive Australian demographics with “long-distance” city pairs that can have their railway service upgraded sufficiently to make a significant impact on the travel market. Despite this, in 1981, the National Committee of Railway Engineering proposed the development of a higher-speed railway network to enhance links between Brisbane, Sydney, Canberra, Melbourne and Adelaide. The proposed “Bicentennial High Speed Railway Project” was based on upgrading existing railway infrastructure, apart from very limited track realignments and targeted additional capacity. The project envisaged that traffic would be diverted from car and air (both of which had lower infrastructure and service standards than today). It is difficult to envisage that these long-distance upgrades would be cost-effective given that Canberra–Melbourne transit time would have been 6½ hours, and Sydney–Melbourne transit time would have been 9 hours. In any case, intercity roads have been upgraded in the three decades since that study, making road movements faster and safer.

Australia’s demographics are better for medium-distance upgrading. Australia has some regional–city pairing, with good rail links—the Victorian case study presents an excellent application of service upgrading to four city–regional centre pairs. The experience with the Victorian *Regional Fast Rail* programme (and, arguably, the electric Rockhampton–Brisbane tilt trains, not considered here) illustrates the potential for medium-distance regional — or commuter — corridors. The introduction of high performance services on the four regional Victorian corridors has generated considerable traffic growth. Infrastructure and rolling stock renewal, higher service frequencies and lower fares have been applied to “medium-distance” regional corridors, attracting business, leisure and commuting travel between the regional centres and Melbourne.

Medium-distance corridors of Newcastle–Sydney, Sydney–Canberra and Albury–Melbourne have similar regional and commuter travel markets to the current Victorian regional services. In working out the in-principle case for given upgrades, it can be useful to identify high-level characteristics of upgraded rail services and what might be perceived to be close Australian equivalents.

Superficially, corridors such as Sydney–Canberra and Berlin–Hamburg can be compared, particularly because the city-centre distances are similar: 329 km versus 286 km, respectively. Setting the Berlin route as a benchmark, can we draw conclusions about the potential of upgrading Canberra services? Box 11 provides an outline of similarities and differences between the two corridors.

The Berlin route has become again a major corridor between Germany’s two largest cities. There would be significant infrastructure hurdles to be surmounted in upgrading the Canberra corridor to deliver service improvements akin to those achieved in Germany. Further, the structure and size of the Canberra travel market is relatively small. Nonetheless, this study has illustrated that a range of upgrades and modifications—in infrastructure (transit times), service quality (reliability and waiting times), operational processes and terminal accessibility—can bring about attractive train services that appeal to the prevailing travel market.

The third upgrade category is airport rail links, for which Australian capital cities offer varying opportunities. In some circumstances, the airport links are central to the overall airport capacity provision; the rail links provide the appeal of the airport. As discussed earlier, services can be incorporated within suburban operations or, especially on longer-distance links, operated as separate, dedicated services. At present, major capital city airports are located relatively closely to city centres and so are conducive to grafting onto suburban railway links. A second Sydney airport at Badgery's Creek would be some distance from the city centre and to appeal to travellers would therefore require good rail services, based on long-distance dedicated services, much in the same way as London's *Gatwick Express*. The ability to gouge sufficient capacity from within existing railway corridors would determine the feasibility of such an operation.

Concluding comments

The experiences with rail services in this country and overseas—in regional, intercity and airport links—illustrates the potential that may come from upgrading.

This study does not provide definitive answers on implementing successful train service upgrades but the study does point to types of upgrades that can be considered, it points to where upgrades have made a marked effect on travel markets, and it points to service upgrading as an option — or, indeed, a stage — in developing passenger rail services.

Box 11 Comparing the Berlin and Canberra corridors

Applying the concepts discussed in this report we can make the following conclusions:

Infrastructure

- the Berlin route had to be electrified; the Canberra route is not electrified;
- the German track is on relatively straight alignment whereas the Canberra route—particularly on the branch line—has considerable curvature, often very severe;
- the Berlin route had track in very poor condition or set to a low performance standard; the same could be concluded for the Canberra route;
- there were a large number of level crossings on the Berlin route that had to be removed; there are relatively few crossings on the Canberra route;
- to provide sufficient capacity, double-track had to be restored to the Berlin route; this is primarily an issue in the Sydney metropolitan area;

Equipment

- Berlin-route trains now have in-cab signalling and train protection controls; these are not present on Canberra-route trains;
- electric-propulsion rolling stock provides high performance (better acceleration) on Berlin services; Canberra services are not electrified;
- Hamburg and Berlin terminals are located centrally, with good U-Bahn and S-Bahn connections; Canberra's terminal is located in a city suburb, with infrequent bus connections—predominantly to the city centre;

Market

- Berlin and Hamburg have better market characteristics, being large, densely-settled cities with good public transport networks; Sydney is a large, predominantly low-density city while Canberra is a small, low-density city.
- both routes have good, competing road links, with at least dual-carriageway standard.
- after the initial upgrade phase, the Berlin route lost its airline service. Current Canberra route airline services on a week-day are around 29 services each way.

This analysis illustrates how seemingly similar corridors can have important differences that need to be appreciated. In terms of the market, the size of Canberra's population and related modest economic activity, Canberra's poor terminal site and access network to largely dispersed origin–destination undermines train traffic potential. Relative to the Berlin route, the historical track alignment on the Canberra branch (in particular) and Sydney capacity issues can limit transit time improvements and service frequency amplification. This Australian upgrade, then, is unlikely to achieve the impact of the Berlin route—and certainly not the cancellation of airline services—but modest market gains may be achieved.

APPENDIX A

Principles of tilt trains

The following is an excerpt from the report by Australian Transport Safety Bureau and the Queensland Transport Rail Safety Investigation (2005, pp. 43–44)

When a vehicle is driven around a curve at speed, any occupant will feel a lateral/centrifugal force. The philosophy behind 'Tilt Train Technology' is to reduce the lateral component of this force and convert this into a vertical component. Generally, people are more tolerant of vertical forces (gravity) than lateral/centrifugal forces and accordingly if passengers can be made to feel more comfortable they can travel around curves at higher speeds, provided the design limits of the train/infrastructure are not exceeded.

Cant is the cross level angle of track on a curve. It is used to compensate for the lateral/centrifugal forces generated by a train as it passes through a curve. For mixed traffic railways (a combination of freight and passenger services) the degree of cant is often a compromise between the slowest and fastest train types and rarely compensates fully for centrifugal loads. The difference between the equilibrium cant, that is the theoretical value of cant that will fully compensate for the centrifugal load, and the actual track cant is known as cant deficiency.

As centrifugal force is proportional to vehicle speed, and if not fully compensated by track cant, passengers will begin to experience a lateral/centrifugal force, which in the extreme becomes uncomfortable. In most cases, passenger discomfort arising from cant deficiency is the limiting factor precluding the running of passenger trains through curves at higher speeds, rather than the safety considerations imposed by the train/infrastructure design. This often implies that there is scope for increasing the speed of a train through curves without compromising on safety.

Tilt train technology takes advantage of this phenomenon by providing higher levels of passenger comfort by tilting the train body. The technology does not have any significant [effect] on rail forces or safety. That is to say, for two identical trains one with tilt train technology and one without each can generally traverse a curve at the same speed, it is only passenger comfort that becomes the real issue. This is evident in the design of the CTT [Cairns Tilt Train] in which the diesel power car is not equipped with tilt capability whereas the trailer/passenger cars are.

So why does a tilt train have a quicker journey time than a conventional train? The acceleration and deceleration of trains is relatively slow. For example, it can take several minutes for a train to get to its top speed. If there are frequent speed restrictions as a result of curves, and the train speed is slower through curves than technically necessary, for passenger comfort reasons, then the train is rarely going to approach its top speed capability. As tilt trains can travel around curves at a higher speed than conventional trains without causing passenger discomfort then it stands to reason that the train can maintain a higher average speed over the entire journey and thereby reduce the overall journey time. What must be recognised is that it is the engineering design standards that generally dictate the safe speed that a train can traverse a track. Generally these standards are quite conservative as is the case with the 'Cairns Tilt Train'.

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Abbreviations and terms

| Term or abbreviation | Meaning |
|-------------------------|---|
| ABS | Ausbaustrecke. German upgraded railway. |
| Amtrak | Amtrak is the trading name of the USA's Federal Government entity, The National Railroad Passenger Corporation. |
| ATP | Automatic Train Protection. This is a safety system on the train that applies the train brake in situations where a driver ignores speed or signal instructions. |
| Dual-corridor operation | This term refers to the addition of independent passenger train trackage within a railway corridor; see Welty 1995. |
| FRA | Federal Railroad Administration |
| HSGT | High Speed Ground Transport (a term used in USA) |
| HST | High Speed Train (a generic term that also applies to a British name of the same term) |
| LGV | Ligne à Grande Vitesse. French high-speed railway |
| NBS | Neubaustrecke. German high-speed railway. |
| Northeast Corridor | Railway linking Boston and Washington, via New Haven, New York, Philadelphia and Baltimore |
| PTC | Positive Train Control. This is a signalling system that includes active enforcement of movement. The system actively constrains train movement in a range of situations, notably where the train exceeds stated-maximum speeds or where the train driver fails to respond to approaching stop signals. |
| Shinkansen | Japanese high-speed railway |
| Tangent track | Straight track |
| TGV | Train à Grande Vitesse. French high-speed train. |
| Transition track | This is a short section of track that links curved track and straight track. With increasing distance along the transition track from the straight [or tangent] track, the radius of the curvature increases until it reaches the track radius of a curved section of track. |
| WCML | West Coast Main Line (the corridor/network linking London and Glasgow, including side-routes to Birmingham and Manchester) |
| X 2000 | Swedish Tilt Train (which is also known as the X 2) |
| XPT | eXpress Passenger Train (operated by NSW Trainlink in eastern Australia) |



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