3.1 Introduction

This chapter describes the development of the services required for the preferred HSR system (derived from an understanding of the travel market provided in Chapter 2) and how the system would be operated. It includes discussion of:

- **Transport products** – the types of HSR services to be delivered by the preferred HSR system. The services are defined by the journey time and frequency to be offered, the fares and other significant customer amenities such as WiFi access, business class, wheelchair accessibility and in-carriage luggage storage.
- **System requirements and technical specifications** – technical and/or performance specifications for infrastructure, equipment and systems capable (or likely to become capable, with anticipated technological developments) of delivering the recommended HSR transport products.

This chapter describes how the transport products, system requirements and technical specifications of the preferred HSR system were developed in response to the travel market assessment presented in Chapter 2. The process is illustrated in Figure 3-1.

This chapter describes:

- The key attributes of HSR products internationally and summarises the results of stated preference (SP) surveys undertaken for this study.
- A service pattern that provides sufficient capacity to serve the HSR demand forecast in Chapter 2.
- Requirements and technical specifications for track, power supply, train control, rolling stock including the required fleet size, depots and maintenance facilities that would deliver the service.
• The system-wide greenhouse gas and noise emissions that would arise from the operation of HSR.

The requirements and specifications for the HSR stations specifically are discussed in Chapter 5.

In developing the preferred system, this chapter seeks to answer the following questions:

• What types of services would best serve the forecast HSR demand?
• What is the expected journey time and frequency of services between HSR stations?
• What requirements – in terms of speed, reliability and availability – would deliver the desired journey time and frequency?
• What would be the technical specification of the infrastructure to deliver these requirements?
• How would the preferred system be operated and maintained?
• What would be the system-wide impacts of HSR in terms of greenhouse gas emissions and noise, and how could they be mitigated?

3.2 Transport products

The transport product is defined as the type and configuration of transport services, in planning terms, to be delivered by an HSR system, including market context, pricing strategy and level, the train service frequency/timetable to be offered, and other significant customer amenities.

The transport product translates the demand for HSR identified in the market analysis into the requirements for rolling stock and infrastructure, as shown in Figure 3-1.

Further detail on transport products is contained in Appendix 2A.

3.2.1 Market research and commercial considerations

Development of the market needs and commercial context of a potential HSR service on the east coast of Australia was based on market research in Australia for this study and previous studies of HSR, complemented by a review of international experience in countries where HSR is already operating.
Australian market research

To develop an appreciation of the likely response of the Australian customer to the introduction of an HSR service in a competitive east coast travel market, two sources of analysis were employed – research undertaken for the Speedrail study between 1993 and 2000\textsuperscript{1} and the SP survey undertaken for this study (described in Chapter 2 and Appendix 1D).

Speedrail was a major study of the feasibility of an HSR link between Sydney and Canberra operating at up to 320 kilometres per hour. The Speedrail study market research included in-depth interviews and focus groups to identify consumer preferences and perceptions of existing travel modes and HSR. This research indicated that the perceived advantages of the service included speed, convenience, reliability and the ability to work on the train. Potential disadvantages included fare levels, the need to ‘keep to a schedule’ and to travel in groups, and the need for a car at a destination to complete the journey.

The SP survey, and the initial focus groups that preceded it, investigated why people would or would not choose to use HSR and what they would value most about HSR. More than half the travellers interviewed in the SP survey (travelling by air, car and standard rail) did not consider that there were any current alternative modes possible for their present journey. However, given a journey in the study area that would be served by HSR, 81 per cent responded that they would consider using such a service. Most of those who would not consider HSR were car users, with inconvenience and the need for a car at the destination the main reasons cited. These findings were consistent with the Speedrail study.

International evidence on HSR transport products

Research undertaken by consultant SDG for the European Community (EC) in 2006 reviewed the effectiveness of HSR and its competitiveness with air travel on eight European routes, including London-Paris (distance approximately 500 kilometres), Madrid-Barcelona (distance approximately 620 kilometres) and Paris-Marseilles (distance approximately 780 kilometres)\textsuperscript{2}. This data suggested that the main determinant of market share, as long as HSR had a competitive service frequency, was the rail journey time. The time required for check-in and other procedures prior to departure was considered part of the journey time, and the considerably easier access to HSR services was perceived to be an advantage.

A study by Nash broadly concurred with the EC report\textsuperscript{3}. Nash found that journey time, reliability, accessibility of stations (particularly city centre stations), airport check-in times (and waiting times generally), competitive fares, yield management\textsuperscript{4} and seat reservations systems were all cited as factors influencing customer choice. A review of the competitive environment for HSR also found that journey times were critical\textsuperscript{5}. Business travellers on HSR sought an uninterrupted journey (with the ability to work on the train), quality of service and a service frequency that allowed passengers to ‘turn up and go’\textsuperscript{6}. Fares, accessibility and check-in requirements were also cited as influences on mode choice.

\textsuperscript{1} Sinclair Knight Merz, Technical Note 1, Speedrail focus group discussions, 1998.
\textsuperscript{2} Steer Davies Gleave, Air and Rail Competition and Complementarity, European Commission, 2006.
\textsuperscript{3} Nash, HSR Overseas experience report, High Speed Rail Study Phase 1, 2011.
\textsuperscript{4} In this context, yield management is the strategy by which the travel industry maximises profit by varying prices for the same product, e.g. offering discounts on seats when it appears they will otherwise remain unsold.
\textsuperscript{5} Segal, High Speed Rail – The Competitive Environment, European Transport Conference, 2006.
\textsuperscript{6} ‘Turn up and go’ refers to high frequency public transport services where passengers do not need to look up a timetable as waiting time between services is short.
Summary of required service attributes

Based on the Australian market research and international analysis, a successful HSR service would require:

• Competitive journey times.
• High standards of on-board comfort and convenience.

These service attributes would need to be complemented by:

• Convenient station access/egress arrangements.
• Convenient timetabling (frequencies and service patterns).
• An appropriate fare structure (including availability of discount fares on undersold services).

These service attributes defined the requirements of a successful HSR system, which in turn established the technical specifications to deliver a successful system. These are discussed in the following sections.

3.2.2 Service planning

A guiding principle of the HSR study is that HSR must be successful in meeting travel needs in Australia’s competitive transport market. The primary demand for HSR services would be for travel to and from the east coast capital cities. The 2065 HSR patronage forecast is 83.6 million passengers, of which:

• 18.8 million passengers per year would travel between Sydney and Melbourne CBD (22 per cent of total forecast HSR demand).
• 10.9 million passengers per year would travel between Brisbane and Sydney CBD (13 per cent of total forecast HSR demand).
• 5.2 million passengers per year would travel between Sydney CBD and peripheral stations and Canberra (six per cent of forecast HSR demand)7.

Sydney would be the hub of the HSR network serving the east coast of Australia to the north and south:

• 34 per cent of all HSR trips would have an origin or destination at Sydney North, Sydney or Sydney South stations.
• 21 per cent of all HSR trips would have an origin or destination at Melbourne North or Melbourne stations.
• 13 per cent of all HSR trips would have an origin or destination at Brisbane or Brisbane South stations.
• Seven per cent of all HSR trips would have an origin or destination at Canberra station.

In 2065, 72 per cent of all potential HSR trips originating in the north coast of New South Wales are forecast to have a destination in one of the four capital cities (Brisbane, Sydney, Canberra or Melbourne). For the regional communities between Canberra and Melbourne, 96 per cent of all potential trips would have a destination in one of the capital cities. The demand suggests the HSR system should facilitate:

• High speed travel between the capital cities on the east coast. This would be achieved through inter-capital express services. These would provide non-stop services between Brisbane and Sydney, Sydney and Canberra, Sydney and Melbourne, and Canberra and Melbourne. Some of these inter-capital express services may also call at city peripheral stations.
• High speed travel between regional communities and the capital cities. As the demand forecasts show, the capital cities are the primary destination for passengers using regional HSR stations and inter-capital regional services are primarily designed to provide regular high speed links between regional stations and at least two capital cities. Regional services would also facilitate travel between regional stations, although some inter-regional movements with low demand may require passengers to change from one service to another at an intermediate station to complete their journey.

7 These are station-to-station movements and vary slightly from the zone-to-zone movements presented in Chapter 2.
The service plans and frequencies (and assumed train sizes) were derived from the HSR demand forecasts. The plans were designed to ensure the average utilisation of each service was 90 per cent in the peak hours and at least 60 per cent over the operating day (these percentages are referred to as ‘loading factors’), while maintaining the supply of HSR capacity so that it matched forecast demand with attractive service frequency.

The HSR service pattern is expected to match the capacity profile in the corridor. For comparison, the 2011 inter-capital aviation market for three selected inter-capital air routes, drawn from Qantas profiles for scheduled domestic flights on a Friday, is shown in Figure 3-2, Figure 3-3 and Figure 3-4. These figures show the average weekday seat capacity (expressed as a percentage of the total seat capacity on the route that day) at hourly intervals over a year.

Figure 3-2  Brisbane-Sydney Qantas air services weekday capacity profile

Source: BITRE, 2011
Figure 3-3  Sydney-Melbourne Qantas air services weekday capacity profile

Source: BITRE, 2011

Figure 3-4  Sydney-Canberra Qantas air services weekday capacity profile

Source: BITRE, 2011
Along with departure times, the time of arrival at a destination is important to consider in a comparison of HSR and air travel. For HSR to be competitive, the arrival times need to be comparable between the two modes, so that an equivalent or shorter journey time by HSR is not undermined by less frequent services or a longer experience at the beginning or end of the journey, for instance to travel from an HSR station to a final destination.

The morning departure pattern in each case indicates peak arrivals in the destination CBD (after allowing for airport to city transfers) of 8am to 10am. The afternoon and evening profiles are slightly extended and differ between the routes shown, most likely as a result of airline passengers transferring between flights. In these three examples, the evening demand extends to destination city centre arrivals up to as late as 11pm.

Data was also collected on travel time for car trips in the corridor, using number plate matching at selected sites to identify the longer distance car trips in the market to be served by HSR. This information is discussed in Chapter 2.

Observations of northbound travel on the Hume Highway between Melbourne and Sydney show departure times from an overnight low of less than two per cent of daily traffic per hour, building up in the hours before 6am. Departures in each hour between 10am and 8pm are broadly in the range between five per cent and seven per cent of daily trips depending upon the trip length, implying destination arrivals up to midnight and beyond.

Given these market characteristics, the HSR operation would need to be available for approximately 18 hours per day, with services typically starting after 5am and finishing before midnight at the destinations. This would allow HSR passengers to arrive at the start of the working day, without having to start their journey unacceptably early in the morning, and provide a range of opportunities up to 8.30pm to leave after the business day and still arrive at their destination before midnight. The number of trains operated would vary between weekdays and weekends – and potentially also between days of the week – in response to day-to-day travel demand variations.

This pattern of operation is consistent with international experience. A review of the current timetables for HSR operations overseas (Eurostar between the United Kingdom and France, and Thalys between France, Belgium and Holland, and Taiwan) shows that:

- Eurostar (Paris/Brussels-London) journey times are typically two to 2.5 hours. Services are operated between 5:30am and 11.30pm. Friday is the busiest day of the week and weekend service levels are about 70 per cent of weekday service levels.
- Thalys (Paris-Brussels-Amsterdam) journey times are typically 1.5 to 2.5 hours, but some trips also operate to/from places off the HSR route with longer journey times. Services are operated between 6am and 11pm. Friday is the busiest day of the week and weekend service levels are about 80 per cent of weekday levels.
- Taiwan High Speed Rail (Taipei-Taichung-Zuoying) journey times are typically 1.5 to two hours. Services are operated between 6:30am and midnight. Friday is the busiest day of the week and weekend services are about 20 per cent higher than Monday to Thursday service levels.
- A shutdown period is needed every night in order to undertake essential maintenance and maintain the reliability targets.

To develop service plans for the east coast of Australia, the following assumptions were used based upon experience of HSR systems internationally:

- Average peak-hour loading factor (percentage of seats occupied) of 90 per cent.
- Overall average loading factor of 60 per cent.
- Load factors over individual sections of line not to exceed 100 per cent (i.e. no passengers are assumed to need to stand).
- Peak-hour demand of 1.5 times the average hourly demand.
Two standard train configurations have been assumed, to maintain operational flexibility for inter-capital express and inter-capital regional services.

Peak hour demand will be accommodated to some extent by a larger train capacity, so that expected service levels are only 1.3 times the daily average.

HSR services would operate for 18 hours per day, with a slightly shorter operating day on Sundays. Travel times between Brisbane/Gold Coast and Sydney and between Sydney and Melbourne are less than three hours for the inter-capital express services and up to 3.5 hours for the inter-capital regional service. This means that the last trains of the day travelling the full length of the northern or southern routes would need to depart by 8.30pm. Later trains could depart to terminate at an intermediate station, such as Canberra from Sydney or Melbourne.

There are 16 hours of the day during which HSR trains could depart Brisbane/Gold Coast, Sydney or Melbourne to travel the length of the HSR lines. HSR services to/from Canberra, because of their shorter trip times, could offer departures over 17 hours and still complete their trips before the end of the operating day.

**Indicative required service patterns**

The HSR service frequencies have been determined to match the forecast demand. Inter-capital express services would mainly operate non-stop between the CBD stations, although some services would make one call at one of the city peripheral stations to offer a non-stop service between the peripheral station and the destination capital.

Generally, two service patterns have been developed for inter-capital regional services between capital cities. A regional service would need to be operated at least once every two hours, so that the minimum level of service at any regional station would be an inter-capital regional train every two hours (travelling between two capital cities). For example, the minimum service level at Taree would be a regional train every two hours to Brisbane and every two hours to Sydney.

One intermediate station between Brisbane and Sydney and one between Sydney and Melbourne would be served by all inter-capital regional services. This would allow passengers travelling between regional stations to do so with, at most, one change of train. South of Sydney, the selected station could be Wagga Wagga, so a passenger wanting to travel from the Southern Highlands to Shepparton could change trains at Wagga Wagga with only a short wait between services. The equivalent station north of Sydney could be Coffs Harbour. Although the demand forecasts suggest that the number of passengers making such trips will be comparatively small, the facility could be offered without significant impact on the trips between regional stations and capital cities.

No HSR trains would operate non-stop through Sydney. Passengers travelling from stations north of Sydney to stations south of Sydney would have to change trains at Sydney Central.

The actual timetable to be operated for inter-capital express and regional services would be determined by the operator on a commercial basis. However, it is assumed that a regular interval service of HSR trains would run at the same time each hour of the trip pattern’s operation. This has operational advantages and would also make the HSR service easier to market to prospective passengers. The timetables for Eurostar, Thalys and Taiwan HSR all show these regular interval characteristics.

The indicative stopping patterns between Brisbane-Sydney and Sydney-Melbourne are shown in Figure 3-5 and Figure 3-6 respectively.
The typical 2065 service patterns shown in Figure 3-5 were developed to provide sufficient capacity to accommodate the forecast peak period demand and comprise:

- Two one-stop inter-capital express services per hour for Brisbane-Sydney, calling at either Brisbane South or Sydney North city peripheral stations.
- One or two non-stop inter-capital express services per hour for Brisbane-Sydney.
- An hourly inter-capital regional service calling at Brisbane South, Coffs Harbour, Port Macquarie, Taree, Newcastle, Central Coast and Sydney North.
- An hourly inter-capital regional service calling at Brisbane South, Casino, Grafton, Coffs Harbour, Newcastle and Sydney North.
- Two regional services per hour for Gold Coast-Sydney calling at Coffs Harbour, Port Macquarie, Taree, Newcastle, Central Coast and Sydney North.
- Two regional services per hour for Gold Coast-Sydney calling at Casino, Grafton, Coffs Harbour, Newcastle and Sydney North.

Some regional services between Gold Coast and Sydney would be extended to start from, or terminate at, Brisbane.
The typical 2065 service patterns shown in Figure 3-6 were developed to provide sufficient capacity to accommodate the forecast peak period demand and comprise:

- Two non-stop inter-capital express services per hour for Sydney-Melbourne.
- Three one-stop inter-capital express services per hour for Sydney-Melbourne, calling at either Sydney South or Melbourne North city peripheral stations.
- An hourly inter-capital regional service calling at Sydney South, Wagga Wagga, Albury-Wodonga, Shepparton and Melbourne North.
- An hourly inter-capital regional service calling at Sydney South, Southern Highlands, Wagga Wagga and Melbourne North.
- One inter-capital express service per hour, calling at Sydney South, for arrival in Canberra between 8am and 10am.
- Two inter-capital regional express services per hour for Sydney-Canberra, calling at Sydney South and Southern Highlands.
- One inter-capital express service per hour for Canberra-Melbourne, calling at Melbourne North to provide Melbourne arrivals between 8am and 10am.
- At least one inter-capital regional service for Canberra-Melbourne, calling at Wagga Wagga, Albury-Wodonga, Shepparton and Melbourne North.

The mix of business and leisure travellers on the HSR services would be determined by the service pattern and also by the pricing strategy adopted by the operating company. For this analysis, it has been assumed that the peak services match the business arrival and departure times and that off-peak service levels are broadly constant over the operating day. Peak service hourly demand is assumed to be 1.5 times the average hourly demand.

### Table: Sydney-Melbourne indicative stopping patterns in 2065

<table>
<thead>
<tr>
<th>Service Group</th>
<th>Express</th>
<th>Regional</th>
<th>Express</th>
<th>Regional</th>
<th>Express</th>
<th>Regional</th>
<th>Trains/day per direction</th>
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<td>Sydney South</td>
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<tr>
<td>Canberra</td>
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<tr>
<td>Wagga Wagga</td>
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<tr>
<td>Albury-Wodonga</td>
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<tr>
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<tr>
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</tbody>
</table>

**Express services call at the peripheral stations in the AM peak (outbound) and PM peak (inbound).**

**Off-peak frequency (trains/hour per direction):**

- Sydney: 4 trains/hour
- Southern Highlands: 0.5 trains/hour
- Canberra: 0.5 trains/hour
- Wagga Wagga: 1 train/hour
- Albury-Wodonga: 1 train/hour
- Shepparton: 0.5 train/hour
- Melbourne North: 0.5 train/hour
- Melbourne: 0.5 train/hour

**Peak frequency (trains/hour per direction):**

- Sydney: 5 trains/hour
- Southern Highlands: 1 train/hour
- Canberra: 1 train/hour
- Wagga Wagga: 1 train/hour
- Albury-Wodonga: 2 trains/hour
- Shepparton: 1 train/hour
- Melbourne North: 1 train/hour
- Melbourne: 0.5 train/hour

The typical 2065 service patterns shown in Figure 3-6 were developed to provide sufficient capacity to accommodate the forecast peak period demand and comprise:
demand, but in the peak hours, service levels are only 1.3 times the daily average hourly service levels, reflecting the higher load factors assumed to apply to peak train operations.

The HSR service would build up in stages to the 2065 service pattern, as described in Chapter 6 and as shown in Figure 3-7:

- In 2035, with HSR services operating between Sydney and Canberra and still in the ramp-up phase, total forecast HSR demand is 2.3 million passengers per year, of which 1.3 million (57 per cent) would be travelling from Sydney Central to Canberra or vice versa. In 2035, HSR services would be operated between Sydney and Canberra on an hourly basis throughout the day with additional inter-capital express services in the peak period to accommodate this demand – a total of 38 trains per day.

- In 2050, with HSR services operating Newcastle-Sydney, Sydney-Canberra, Sydney-Melbourne and Canberra-Melbourne, total forecast HSR demand is 39.2 million passengers per year, of whom 11 million would be travelling between Sydney and Melbourne CBD stations (28 per cent of total forecast HSR patronage). The 2050 service pattern would be:
  - 66 trains each way per day between Sydney and Melbourne, of which 48 would be intercapital express services.
  - 34 trains each way per day between Sydney and Canberra.
  - 19 trains each way per day between Canberra and Melbourne.
  - 28 trains each way per day between Newcastle and Sydney.

The demand at regional stations is also predominantly focused on travel to the capital cities. For example, the 2065 forecasts show:

- For Grafton, 38 per cent of passengers would be travelling to Sydney and 44 per cent to Brisbane/Gold Coast.
- For Newcastle, 47 per cent of passengers would be travelling to Sydney and 25 per cent to Brisbane/Gold Coast.
- For the Southern Highlands, 59 per cent of passengers would be travelling to Sydney, 23 per cent to Melbourne and two per cent to Canberra.
- For Albury-Wodonga, 69 per cent of passengers would be travelling to Melbourne, 12 per cent to Sydney and six per cent to Canberra.

The regional stations to be served by HSR are described in Chapter 4.
3.3 System requirements

This section describes the key system requirements, namely system operating speed, reliability and availability\(^a\).

3.3.1 Speed

The demand forecasts presented in Chapter 2 indicate that, internationally, HSR can achieve a 50 per cent or higher share of the air/rail market when journey times are about three hours or less. Achieving this journey time for HSR trips between the capital cities on the east coast of Australia would therefore be a principal factor in defining the required operating speed of the railway. This definition is necessary as it determines the design speed, which in turn determines the geometric parameters of the system.

To achieve a journey time of three hours between Sydney–Melbourne and between Brisbane–Sydney would require operating speeds of up to 350 kilometres per hour. This would enable the train to attain an average speed of approximately 300 kilometres per hour for the overall journey, after allowing for negotiation of the terrain and operating environment between these cities. This capability would be consistent with the latest practice for HSR systems being planned and implemented, for example, in the USA, Italy and China.

The design speed for the HSR system infrastructure would exceed the maximum operating speed, to allow for later improvements in rolling stock that may be able to operate safely at higher speeds. The maximum design speed for this system would be 400 kilometres per hour.

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\(^a\) A fuller description of the requirements is provided in Appendix 2B.
3.3.2 Reliability and availability

The infrastructure will, during its whole life cycle, need to meet requirements concerning reliability, availability and maintainability.

International benchmarking experience suggests that 99.7 per cent of planned journeys are achievable on a closed HSR system, as demonstrated for the Taiwan HSR, which has services that achieve departures within one minute of the timetabled schedule, and within five minutes on arrival 9.

Conversely, where HSR services share infrastructure with conventional passenger and freight trains, the service availability diminishes considerably, due to a variety of operational, reliability and maintenance factors.

The existing rail infrastructure in and around Brisbane, Sydney and Melbourne is currently operating close to capacity. The option to superimpose the HSR train requirements on top of the predicted services anticipated to be operating in future on the existing infrastructure is considered impractical. The geometry of existing infrastructure would require very significant modification to allow HSR operational speeds to be attained. This is discussed in Chapter 4.

To achieve the required journey times and reliability, the HSR system would require dedicated infrastructure for the entire system. A system mixing HSR services with conventional passenger and freight rail services on shared infrastructure would not be capable of delivering competitive HSR journey times at the required level of service reliability.

Freight services have not been included in the service planning. International experience demonstrates that the only freight carried on dedicated HSR networks is transported in vehicles similar to high speed passenger rolling stock. ‘Light freight’ trains carrying items such as high-value, parcel-type goods may have some potential, although there would be some additional cost involved to cater for these services. Additionally, freight services on the HSR line would have ramifications for speed and also for track wear from heavy haulage. Overall, this opportunity is minor when compared to the HSR passenger services and has not been considered as part of the preferred HSR system. The removal of any conventional passenger train services due to the introduction of HSR could, however, relieve capacity on the conventional rail network for additional freight operations.

3.3.3 Safety

The entire railway would need three metre-high security fencing on both sides to prevent access by persons and animals. Provision for this, and its electronic surveillance, has been made in the costs. Suitable track crossings for stock and fauna, either by underpasses or bridges, are also provided for in the costs. Specific crossings for fauna, including for arboreal mammals such as gliders, would be designed at the detailed stage when accurate information on fauna corridors would be available.

3.4 Technical specifications

3.4.1 Technical components

An HSR system comprises a number of technical components that combine to determine system performance. These components include:

- Track infrastructure.
- Tunnels.
- Power supply and transmission.
- Train control and communications systems.
- Rolling stock.
- Stations.
- Operations and maintenance facilities.

In selecting the technical components for a potential HSR system on the east coast, proven wheel-on-rail technology, which is already in service internationally, has been specified to ensure that the system achieves the defined requirements. Magnetic levitation, or ‘maglev’, technology is not proposed for the Australian east coast HSR. The text box below presents the arguments considered.

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9 The recently completed HSR railway in Taiwan reports achievement of reliability targets of 99.7 per cent and above (Taiwan High Speed Rail Annual Report 2011).
Magnetic levitation (maglev)

Maglev is a rail system that uses magnets to suspend, guide and propel vehicles along a fixed track, rather than the mechanical methods used for conventional and HSR train systems. The first commercial system began operating at Birmingham International Airport (United Kingdom) in 1984, running at 40 kilometres per hour, but it closed 11 years later due to maintenance problems and costs. More recently, two new prototype systems operating at higher speeds have been commissioned in Japan and China. The Chinese system (opened in 2004) operates at up to 400 kilometres per hour (and is designed for 500 kilometres per hour) over a 30.5 kilometre shuttle line between Shanghai and Pudong Airport. The base system cost about US$1.2 billion to build – approximately twice the anticipated average capital cost per kilometre of wheel-on-rail HSR.

While maglev could potentially offer greater speeds and therefore shorter journey times for HSR than conventional systems, it has a number of disadvantages, including:

• Construction: No existing maglev routes are over 30.5 kilometres long and the challenges of building a 1,700 kilometre route are likely to be significant. Maglev is almost certainly more costly to build than a conventional HSR system, with total costs very difficult to estimate with precision.

• Maintenance: The long-term maintenance issues and associated costs are also largely unknown. While the mechanical aspects of maintenance have improved in recent years, the civil and general infrastructure maintenance and repair costs will only materialise after a minimum operating period of 20 years.

• Practicality: A study commissioned by the British Government (United Kingdom Government White Paper, Delivering a Sustainable Railway, 24 July 2007) rejected maglev for future planning, concluding that maglev is not proven for anything other than short-distance ‘airport people-mover’ or shuttle-type operations, and that when development risk is taken into account, it could cost between four and five times more than conventional HSR.

• Operations: Maglev cannot currently be used at multi-platform stations, which would be required at all major city stations, as it cannot run on conventional rail tracks.

There are clearly major technological and cost risks in adopting maglev and it was not considered as part of the preferred HSR system.

3.4.2 Track infrastructure

Track geometry

HSR requires a specific and demanding set of parameters governing track geometry and track type. The geometry needs to maintain the comfort of passengers while enabling the train to travel at high speed. This is ensured by restricting the degree of horizontal and vertical curvature of the track and limiting how much vertical acceleration/deceleration is permitted. A comparison of the geometries required for conventional rail and HSR is provided in Chapter 4.

Parameters and track types for existing HSR systems in Europe, China, Taiwan and Japan as well as for proposed HSR systems in the United Kingdom, California and Norway were considered in the system selection process. The standards adopted are described in Appendix 2B. The alignment would generally be twin track, except at stations where additional tracks will be required.

Regional and city-peripheral stations would have two additional tracks to serve platforms. This would improve the safety and amenity of these stations by allowing non-stop trains to bypass the station itself. Approaches to terminal stations would have extra tracks to provide sufficient capacity and access to all HSR platforms (for illustrations see Chapter 5).
**Track gauge**

The proposed gauge (1,435 millimetres) is the standard used on HSR networks throughout the world. Using a standard gauge would enable procurement of standard rolling stock and other equipment, thereby minimising the risk and additional cost associated with new prototypes.

**Track type**

There are two generic choices of track structure type: ballast and slab track. Traditionally, a track structure consists of the rails and sleepers with top and bottom ballast (typically crushed stone). With slab track, the track structure comprises a series of concrete slabs with the rails either embedded in it or fastened to it, instead of fastened to sleepers embedded in ballast.

Ballasted track has the advantage of being relatively quick to install and can be maintained by a fleet of specialist plant. However, the nature of ballast track means that the track can and will move under load, which results in the need for ongoing maintenance to restore the line and level and for the ballast to be cleaned or replaced. There is some experience (French TGV) where the use of ballast at high speed (more than 300 kilometres per hour) has been found to produce fine particles which are deposited on the rail surface and cause damage to train wheels.

With concrete slab track systems, the ballast is replaced by a rigid concrete slab track, which transfers the load and provides track stability. Slab track systems require little routine maintenance. Consequently, fewer possessions of the track are required, increasing the availability of the track for running trains. An inspection regime is necessary, but, because the track is fixed in position, there is no requirement for regular realignment of the rails. Concrete slab track is used by the Japanese HSR network and increasingly throughout mainland Europe as well as in China.

Many slab track systems require less construction depth than the equivalent ballasted system. Embedded rail systems and resilient base plate track types require the least depth. The reduced construction depth means reduced dead load on structures such as bridges, making their construction less costly. Slab track is fixed in position and will not move out of line or level under load. Concrete slab track also offers a greater degree of track bed stability than ballasted track, meaning that higher running speeds are achievable. Resilience is introduced into the track system by means of pads, bearings or springs, depending on the type of slab system.

Slab track can be designed to suit particular requirements and to meet the required performance criteria in terms of noise and vibration. Within each generic system, the resilient components can be selected to optimise the balance between acoustic performance and rail stability.

An estimate of design life for traditional ballasted track is around 15 years, after which the ballast requires renewal. This is a noisy and time-consuming activity if performed during non-operational hours and, given the long lengths of track involved, would require a large labour force working continuously. A concrete slab track is typically constructed with a design life of at least 60 years and can be designed to withstand a temperature range of −10 to 50 degrees Celsius.

Although the capital cost of slab track systems is usually higher than the equivalent ballasted track (about 20 to 30 per cent higher initial outlay), the long design life and minimal maintenance requirement for slab track systems means that overall their whole life cost is lower than that of traditional ballasted track.

Slab track has been used successfully on a number of HSR projects around the world, as shown in Table 3-1.
Table 3-1 International examples of slab track use

<table>
<thead>
<tr>
<th>Project</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shinkansen</td>
<td>Japan</td>
</tr>
<tr>
<td>High Speed Line HSL-Zuid</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Cologne-Frankfurt High Speed Line</td>
<td>Germany</td>
</tr>
<tr>
<td>Nuremberg-Ingolstadt High Speed Line</td>
<td>Germany</td>
</tr>
<tr>
<td>Taiwan High Speed Railway</td>
<td>Taiwan</td>
</tr>
<tr>
<td>Eje Atlantico</td>
<td>Spain</td>
</tr>
<tr>
<td>TGV Méditerranée</td>
<td>France</td>
</tr>
<tr>
<td>Channel Tunnel Rail Link Phase II</td>
<td>United Kingdom</td>
</tr>
</tbody>
</table>

3.4.3 Tunnels

Chapter 4 contains a summary of the rationale for tunnelling on sections of the alignment. This section discusses the various configurations and construction methods that could be applied, although the actual configuration of each tunnel would only be determined at a more detailed stage of design.

Tunnel configurations

HSR tunnel configurations are commonly:

- Single bore double track tunnels (e.g. Japan, Taiwan, shorter tunnels in Spain).
- Twin bore single track tunnels (e.g. Germany, and longer tunnels in Spain and the United Kingdom).

The use of a third tunnel for services/emergency egress has also been adopted on some systems (e.g. Brenner Base, Channel Tunnel), but is more relevant to tunnels without practical locations for intermediate access.

The following components need to be accommodated within a tunnel:

- Rail track form.
- Rolling stock structure gauges.
- Emergency egress (i.e. walkways).
- Emergency and operations access.
- Traction power supply.
- Signalling and communications.
- Tunnel utilities (including the possibility of utilising tunnels for non-HSR services).
- Tunnel ventilation.
- Tunnel lining/support.

In addition to the above space-proofing considerations for HSR, the tunnel would need to be sized to meet aerodynamic pressure requirements.

Recently constructed tunnels in Europe and Asia show a strong correlation between the free tunnel area and train speed. As the speed increases, so does the tunnel area required to minimise adverse pressures and shockwaves. These effects are calculated from what is termed a free area ratio. In order to minimise the impacts of pressure (comfort, train structural strength and fatigue) and energy consumption (friction), tunnels are built progressively larger to accommodate increases in operational speed. The free ratio is the proportion of the unfilled, or ‘free’, tunnel cross-sectional area relative to the occupied (train cross-sectional profile). Other effects associated with changes in free area ratio include noise, heat generation and energy efficiency.

For the purposes of this study, the various types of tunnel were developed for costing before establishing an average cost per kilometre for use in the alignment model (Quantm) and the capital cost estimate (see Appendix 4B).
**Tunnel construction**

Tunnels would normally be constructed by tunnel boring machines or mined tunnel techniques, depending on ground type. Because of their disruptive effects at ground level (requiring any structure above to be demolished and land to be occupied for long construction periods), cut-and-cover tunnels would only be constructed in exceptional circumstances, for example at the final approach to Central station in Sydney, as the tunnels emerge to the surface.

Tunnel boring machines would achieve faster production rates and economies of scale in longer tunnels compared with the other techniques, but are restricted to circular tunnel shapes of constant size. While the relatively high capital cost and long manufacturing time of tunnel boring machines makes them expensive and impractical over short lengths, they are well suited to the full range of ground and groundwater conditions expected throughout the study area.

Shorter tunnels are usually more economical when constructed by mined tunnel techniques, due to the lower capital costs of plant. Over longer tunnels, the additional work cycles required in these methods make them less competitive unless multiple excavations can be established.

### 3.4.4 Power supply and transmission

The traction power supply system is the railway electrical distribution network used to provide energy to high speed electric trains. It comprises three types of traction power facilities – traction power substations, switching stations, and paralleling stations, in addition to connections to the overhead contact system and to the traction return and grounding system.

A 2 x 25 kilovolt (KV) autotransformer feed configuration has been proposed for the traction electrification system. Although 1 x 25kV traction power supply systems have been used successfully for electrified main line railway for many years, 2 x 25kV autotransformer feed systems have become the modern standard for main line electrification, especially for HSR.

In total, there are more traction power facilities required for a 2 x 25kV autotransformer feed system than for a 1 x 25kV system, but there are fewer substations, with their associated HV utility circuits, HV transformers and HV switchgear. The electromagnetic interference emitted due to the load current in the catenary system and running rails is considerably reduced. For the Australian HSR, for the purpose of cost estimation it has been assumed that the track power supply would be provided by two 25 kilovolt 50 hertz autotransformers every ten kilometres with traction power feeder stations typically every 60 kilometres.

All trains have been assumed to use regenerative braking to reduce traction power requirements by eight to ten per cent. This is shown and quantified in Appendix 2B.

### HSR power demand from the national power grid

It is estimated that HSR power demand would progressively increase from approximately 540 megawatts in year 2035 to approximately 820 megawatts in year 2050, and would require approximately 1,800 megawatts from the national power grid along its length by 2065. The 2035 HSR power demand of 540 megawatts compares to the current total national generation capacity of 72,000 megawatts, in effect less than one per cent of the current grid capacity. A similar percentage is estimated by 2065. While the HSR system would be a significant user of electricity, it is estimated to consume a small overall percentage within the likely growth of the national electricity supply system.

### 3.4.5 Train control and communications systems

A bi-directional transmission-based train control system would be specified throughout the length of the route, providing the ability for trains to continue to operate at full line speed, in either direction, on either track without having services interrupted by unscheduled disruptions. The operation of the railway would be controlled from an operations control centre, with an identical standby control centre located in close proximity.
to allow for the transfer of operational staff if required. As Sydney would be at the hub of the HSR operation, it has been assumed that both control centres would be in Sydney. There is no need for the centres to be physically located on the railway so precise locations have not been specified.

### 3.4.6 Rolling stock

A large number of high speed trains are in service around the world. Several well known international suppliers of rolling stock have trains in their current product range that meet the requirements of a 350 kilometre per hour operational speed for the express services.

There are a number of high speed trains designed to provide a variety of customer amenity options, such as a choice between business class and economy, catering and WiFi. Business class would offer more space and a higher level of comfort and amenity to the passenger, including ‘at seat’ catering.

Trains would be typically 200 metres long at the commencement of operation, increasing over time in accordance with market requirements\(^\text{10}\). The longest train set envisaged for the east coast market in this study is 300 metres, and all city terminal stations have been specified to accommodate trains of this length. Table 3-2 lists some of the items required for the rolling stock.

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\(^{10}\) Different suppliers have different configurations and number of cars to create a train set. The passenger capacity has therefore been specified, not the number of cars.

### 3.4.7 Operations and maintenance facilities

**Operations facilities**

The HSR would be operated from one of two management control centres (one main and one standby) located in Sydney. The control centre would contain all the operational functions including:

- Management of train operations.
- Signalling and train movement control.
- Electrical control.
- Management of service disruption.
- Management of operational incidents.
- Management of customers (and other members of the public) and operational staff.
- Management and maintenance of fleet.
- Management of infrastructure, the infrastructure controller, plant and premises.
- Management of accidents, major incidents, emergencies and other reportable incidents.

The operation of the main and standby control centres is not analysed in this study. There are options for the use of these facilities to be used in dual operating mode (i.e. one line operated from each centre) with the ability for competitive operation of the two lines and possibly to provide better continuity in the event of an emergency transfer of control.
Table 3-2  High speed express rolling stock specification

<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design life</td>
<td>30 years</td>
</tr>
<tr>
<td>Standards</td>
<td>European Technical Specification for Interoperability or equivalent(^{11})</td>
</tr>
<tr>
<td>Recyclability</td>
<td>98% of train to be recyclable following disposal</td>
</tr>
<tr>
<td>Modular design</td>
<td>Facilitating future-proofing for layout flexibility</td>
</tr>
<tr>
<td>Maintainability</td>
<td>A design that facilitates ease of maintenance</td>
</tr>
<tr>
<td>Train reliability</td>
<td>200,000 km/technical breakdown</td>
</tr>
<tr>
<td>Fleet size</td>
<td>2035 – 6 x 200 m sets&lt;br&gt;2050 – Combination of 34 x 200 m sets and 25 x 300 m sets (59 in total)&lt;br&gt;2065 – Combination of 72 x 200 m sets and 56 x 300 m sets (128 in total)</td>
</tr>
<tr>
<td>Maximum operating speed</td>
<td>350 km/h</td>
</tr>
<tr>
<td>Braking system</td>
<td>Electrical regenerative braking to improve energy efficiency</td>
</tr>
<tr>
<td>Configuration</td>
<td>Business and economy class&lt;br&gt;Comfortable seating for all classes&lt;br&gt;Catering facilities&lt;br&gt;Toilet in each carriage&lt;br&gt;Wheelchair-accessible carriage entrance on each train set&lt;br&gt;WiFi and power sockets available for all classes&lt;br&gt;Luggage storage in each car&lt;br&gt;Passenger information provided in all cars</td>
</tr>
<tr>
<td>Train length</td>
<td>200 m and 300 m</td>
</tr>
<tr>
<td>Seating capacity</td>
<td>520 seats (200 m sets) and 780 seats (300 m sets)</td>
</tr>
<tr>
<td>Security</td>
<td>In line with current operational domestic HSR railways, no specific security measures are assumed at the stations. Passenger assistance and CCTV in all cars</td>
</tr>
<tr>
<td>Seat reservation</td>
<td>Automatic system to be provided for each seat</td>
</tr>
</tbody>
</table>

**Maintenance facilities**
Based on the current evaluation of maintenance stabling for the train fleet, it has been determined that the following facilities are required:

- Two main maintenance depots and stabling yards located close to both the Newcastle and Canberra stations (at Lenaghan and Goulburn respectively), capable of undertaking heavy maintenance activities and each with adequate stabling for the respective stations.
- One stabling yard close to each of the Brisbane, Sydney and Melbourne stations (at Greenbank, Holsworthy and Craigieburn).

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\(^{11}\) Specifications adopted by the European Commission to ensure interoperability of the trans-European rail system. They relate to infrastructure, energy, rolling stock, control and signalling, and maintenance and operation.
The configuration for maintenance depot and stabling yard locations has been established and addresses the productivity, reliability and availability of the HSR fleet. A segmented approach to the system has been taken to accommodate the distribution of trains on the network during peak service operation. These segments are:

- Brisbane-Newcastle (including Gold Coast).
- Newcastle-Sydney.
- Sydney-Canberra.
- Canberra-Melbourne.

The busiest segments would be Sydney-Canberra and Newcastle-Sydney. Locating a depot close to the segment with highest service frequency would reduce the movement of empty trains and provide increased operational flexibility in managing the fleet to return trains to the depot for maintenance. 

Figure 3-8 shows the location of depots and stabling facilities.
3.5 System-wide environmental impacts during operation

The construction, operation and maintenance of the preferred HSR system would generate greenhouse gas and noise emissions. This section describes how estimates of these emissions were derived and the measures available to mitigate their impact.

3.5.1 Greenhouse gas emissions

According to the Greenhouse Gas Protocol\textsuperscript{12}, the Intergovernmental Panel on Climate Change (IPCC) and Australian Government GHG accounting and classification systems, GHG emissions are reported as tonnes of carbon dioxide equivalent (t CO$_2$-e), categorised into three ‘scopes’:

- Scope 1 emissions, also called ‘direct emissions’, are generated directly by the project, e.g. emissions generated by the use of diesel fuel by construction equipment onsite.
- Scope 2 emissions, also referred to as ‘indirect emissions’, are generated outside the project’s boundaries but provide energy to the project, e.g. the use of purchased electricity from the grid.
- Scope 3 emissions include all indirect emissions, other than those included in scope 2, associated with upstream or downstream activities, e.g. emissions associated with the extraction, production and transport of purchased construction materials.

This study has considered all emissions, although scope 3 estimates were derived through benchmarking of other studies as some of the information necessary to calculate them was unavailable. Scope 1 and scope 2 emissions associated with the construction of HSR and subsequent infrastructure renewal (through the use of electricity, fuel and materials and the clearance of vegetation) amount to 11.4 million tonnes of CO$_2$-e. The majority of this is attributable to the diesel fuel consumed by construction vehicles associated with earthworks, together with the power consumed during tunnelling operations. Further detail is provided in Appendix 5G.

Benchmarking of scope 3 emissions suggests they usually account for 50 to 80 per cent of overall construction emissions. This would mean total construction emissions of 22.8 to 57.1 million t CO$_2$-e.

Operation and maintenance of the preferred HSR system would consume energy and generate GHG emissions over the life of the infrastructure, primarily in relation to the consumption of electricity to run the trains. However, the HSR system would also enable passengers to switch from more GHG-intensive modes of transport (e.g. air travel), which would produce countervailing reductions.

To determine the actual GHG impacts of HSR, the initial step was to derive emission factors for electricity and each fuel type used by the non-HSR modes from which trips are diverted. These were derived for this study using energy and carbon content parameters from the Australian Treasury\textsuperscript{13} and the National Greenhouse Accounts (NGA) Factors\textsuperscript{14}, taking into account projected changes in the parameters over the study period. Full details are provided in Appendix 5G.

\textsuperscript{12} World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI), 2004, Greenhouse Gas Protocol.

\textsuperscript{13} Australian Treasury, 2011, Strong Growth, Low Pollution - Modelling a Carbon Price, Commonwealth of Australia, Canberra.

\textsuperscript{14} DCCEE, 2012, National Greenhouse Accounts Factors July 2012, Canberra.
The emission factors were then combined with forecast fuel consumptions and occupancies for air, road and rail to derive unit emissions per passenger kilometre over the evaluation period. Table 3-3 shows the average emissions per passenger kilometre of each mode, calculated from the total operational emissions and passenger kilometres for each mode over the operational period. It illustrates that coach and HSR travel have the lowest emissions per passenger kilometre, while aviation and business car use have the highest emissions. Note the emissions totals for HSR include the operation of both the infrastructure and trains, whereas the emissions for other modes comprise only the operation of the vehicles (aircraft, coaches, trains).

The extent to which HSR would change the level of GHG emissions was then calculated by combining the number of passengers expected to divert from each of the non-HSR modes with the unit emission rates included in Table 3-3.

Table 3-4 and Figure 3-9 compare the difference in emissions between the base case (without HSR) and the reference case (with HSR). The reduction in emissions as the result of modal diversion are shown in green in Figure 3-9, while the new emissions associated with HSR construction and operation, and from suppressed aviation demand in Sydney, are shown in red. There is a net increase in emissions in the reference case of approximately 22 million tonnes of CO$_2$-e over the assessment period from 2035-2085. The costs associated with these emissions are included in the economic appraisal provided in Chapter 8.
### Table 3-3  Operational emissions per passenger kilometre 2035-2085

<table>
<thead>
<tr>
<th>Transport Mode</th>
<th>Emissions (Mt CO$_2$-e)</th>
<th>Passenger km (billion)</th>
<th>Emissions per passenger km (tonnes CO$_2$-e / 1000 pkm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation$^{(1)}$</td>
<td>197</td>
<td>1,765</td>
<td>0.112$^{(2)}$</td>
</tr>
<tr>
<td>Coach</td>
<td>3</td>
<td>171</td>
<td>0.018</td>
</tr>
<tr>
<td>Car – business</td>
<td>18</td>
<td>186</td>
<td>0.097</td>
</tr>
<tr>
<td>Car – leisure</td>
<td>93</td>
<td>1,613</td>
<td>0.058</td>
</tr>
<tr>
<td>Rail</td>
<td>6</td>
<td>166</td>
<td>0.036$^{(3)}$</td>
</tr>
<tr>
<td>HSR</td>
<td>56</td>
<td>1,981</td>
<td>0.028</td>
</tr>
</tbody>
</table>

$^{(1)}$ Doubling of aviation emissions (due to radiative forcing) applied.

$^{(2)}$ Includes allowance for impact of non-CO$_2$ gases released at altitude (see Appendix 5G).

$^{(3)}$ Estimate for non-urban rail services which would be directly affected by HSR.

### Table 3-4  Total emissions over evaluation period (million tonnes CO$_2$-e)

<table>
<thead>
<tr>
<th>Emissions source</th>
<th>Base case (No HSR) (Mt CO$_2$-e)</th>
<th>Reference case (with HSR) (Mt CO$_2$-e)</th>
<th>Change (Mt CO$_2$-e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation</td>
<td>232</td>
<td>116</td>
<td>-116</td>
</tr>
<tr>
<td>Aviation – additional emissions due to suppressed demand in Sydney</td>
<td>-</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>Coach</td>
<td>4</td>
<td>3</td>
<td>-1</td>
</tr>
<tr>
<td>Car – business</td>
<td>21</td>
<td>18</td>
<td>-3</td>
</tr>
<tr>
<td>Car – leisure</td>
<td>97</td>
<td>93</td>
<td>-4</td>
</tr>
<tr>
<td>Rail</td>
<td>9</td>
<td>6</td>
<td>-3</td>
</tr>
<tr>
<td>HSR – transferred</td>
<td>-</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>HSR – induced</td>
<td>-</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Construction</td>
<td>-</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>362</td>
<td>384</td>
<td>22</td>
</tr>
</tbody>
</table>

Notes: Totals may not sum due to rounding differences.
Figure 3-9  Savings in GHG emissions arising from the operation of HSR in the reference case

Note: Positive numbers denote a reduction in emissions, while negative numbers denote an increase.
The impact of assuming additional aviation capacity in Sydney is shown in Figure 3-10. Under this scenario, it is assumed that there is sufficient aviation capacity within the Sydney region to meet demand, i.e. there is no suppressed demand. The emissions in this scenario, without HSR, are therefore higher, as there is more travel by air than in the constrained scenario. The overall outcome is a net reduction in GHG emissions of approximately 55 million tonnes of CO₂-e over the assessment period from 2035-2085, due to travel shifting from air to HSR. Emissions per passenger kilometre are lower with HSR than in the additional aviation capacity base case.

Appendix 5G outlines 13 sensitivity tests in addition to the aviation capacity test, and documents their estimated impact on GHG emissions. These show that HSR only results in reduced overall GHG emissions compared with the base case where aviation capacity in Sydney is assumed to be unconstrained.

There would also be emissions associated with the construction of additional aviation capacity in the unconstrained aviation sensitivity tests, but these would apply both without and with HSR and were not included in the calculations.
3.5.2 Noise

An individual HSR train would be slightly louder than an existing passenger train operating on Australia’s rail network today, although given its greater speed the duration of the noise impact of a single HSR train would be shorter. However, the frequencies of HSR trains described in section 3.2 are significantly greater than current service levels, leading to a potentially greater noise impact overall. An assessment of the noise that would be generated by the HSR service was therefore undertaken to establish the mitigation that would likely be required. The cost of the mitigation is included in the commercial and economic appraisals provided in Chapter 7 and Chapter 8.

Two types of operational noise generated by HSR were assessed:

- Airborne noise emitted by moving trains across open space.
- Groundborne or regenerated noise transmitted through the ground arising from the passage of moving trains on the trackform.
**Airborne noise**

Recent research reviewing the noise sources associated with high speed rail defined the following components, all contributing to the overall noise levels:

- Bogie noise, created by the wheel/rail interaction.
- Aerodynamic noise from the front of the train.
- Aerodynamic noise emitted from the pantographs providing electrical power to the train.

**Figure 3-11** illustrates how the different types of noise contribute to the overall noise levels for a train travelling at 350 kilometres an hour in a rural area. The calculations are based on the slab track design assumed for the preferred HSR system, and the noise levels are those received at a point 25 metres from the centre line of the HSR track.

Airborne noise is measured in dB(A) units. $L_{A_{eq}}$ is the equivalent continuous noise level. For HSR airborne noise, the noise peaks arising from all the trains in a given period are combined to define an $L_{A_{eq}}$.

The period used for assessment of daytime noise in Australian noise standards is 15 hours. The $L_{A_{eq}(15h)}$ standard in NSW and Victoria is 60dB(A) and this was adopted for the assessment of mitigation requirements on the high speed rail study.

HSR trains are assumed to operate between 5am and 11pm and within that the 'daytime' period for noise assessment was assumed to be 7am to 10pm. The assessment was undertaken using train frequencies between Sydney and Canberra, the most intensively used section of the HSR system, which would carry the highest number of HSR trains per hour.

Noise emissions from HSR trains were plotted against distance from the track with and without mitigation. The assessment was repeated for urban areas, assuming a lower operational speed of 250 kilometres per hour, and also for 'urban' and 'transitional' areas on the approaches to towns and cities.

The results are provided in **Table 3-5**, which shows the distance from the centreline of the railway at which compliance with the adopted standard is achieved.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Compliance offset distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural area</td>
<td>230 m</td>
</tr>
<tr>
<td>Transition area with 2 m mounding</td>
<td>70 m</td>
</tr>
<tr>
<td>Transition area with 3 m mounding</td>
<td>51 m</td>
</tr>
<tr>
<td>Urban area with 2 m noise wall, 7 m from track centreline</td>
<td>25 m</td>
</tr>
<tr>
<td>Urban area with 2 m noise wall, 4 m from track centreline</td>
<td>21 m</td>
</tr>
<tr>
<td>Urban area on viaduct with 2 m noise barrier</td>
<td>21 m</td>
</tr>
</tbody>
</table>

Note 1: Rural areas have been assumed to comprise predominantly single storey receivers (e.g. dwelling, office, school).
Note 2: Urban areas have been assumed to comprise predominantly two storey receivers.
Note 3: Viaduct has been assumed to be predominantly elevated, resulting in a similar height as a second storey receiver.

The results summarised in Table 3-5 indicate that the indicative offset distances at which receivers would be affected range from 21 metres to 230 metres, depending on the location and noise mitigation provided. Noise barriers would be required for all built-up areas to ensure that receivers were not adversely affected. Mitigation for receivers in sparsely populated areas would generally comprise architectural treatments such as mechanical ventilation, upgraded doors and window seals. While further investigation of specific measures would be required at a later stage if an HSR were progressed, this assessment shows that appropriate noise mitigation could be included in the design to ensure that impacts comply with adopted standards. The measures required to achieve this outcome are included in the HSR capital cost estimates provided in Chapter 7.

3.6 Conclusion

The east coast travel market that HSR would attract is heavily influenced by the capital cities, which would be either the origin or destination of the majority of HSR travel. Furthermore, travel between the state capitals would be particularly strong and with the continued growth forecast over the evaluation period, would require trains 300 metres long operating four to five times during peak hours by 2065.

This leads to the definition of two types of product. Inter-capital express services would connect the state capitals with journey times less than three hours, which as shown in Chapter 2, internationally has led to HSR attracting market shares in the region of 50 per cent. These services would stop only at peripheral stations on the outskirts of metropolitan areas to pick up the outbound city resident market. Additionally, inter-capital regional services would connect the state capitals with more frequent stops at regional population centres.

The required journey times and frequency of these services could be provided through a twin-track wheel-on-rail system using technology proven on other HSR systems currently in operation overseas. This would assist with managing system cost and enable procurement of components from currently available sources. It would not, however, rule out adoption of further developments, for instance in the next generation of signalling technology, during the period of further planning that would be required for an Australian HSR program.

The preferred HSR system between Brisbane and Melbourne would be a substantial operation that would require a fleet of some 128 trains by 2065. Sydney would be the hub of the preferred HSR system and would be the location of the HSR operations centre. With services operating to the north and south, maintenance facilities would be required to serve both lines. Locations at Lenaghan (near Newcastle) and Goulburn (between Sydney and Canberra) have been identified as suitable for these facilities.
HSR would generate lower GHG emissions per passenger kilometre than other modes from which demand would divert, i.e. aviation and the private car. In the reference case, the circumstances of ‘no expansion of airport capacity in the Sydney region’ result in a preferred HSR system that would generate an overall net increase of 22 million tonnes of CO₂-e over the period from 2035 to 2085. In the aviation capacity sensitivity test there is less potential for aviation capacity released through diversion of some journeys to HSR to be taken up by aviation demand not previously catered for. The outcome of the sensitivity test is a net reduction in GHG emissions of about 55 million tonnes of CO₂-e over the period from 2035 to 2085, associated with the introduction of HSR.

The impact of noise emissions from HSR operations has been considered to develop noise mitigation for an HSR system that would be compliant with the adopted noise criteria. Adequate mitigation for both noise and vibration could be included in the design of a future HSR program to ensure that compliance is achieved for affected receivers. The mitigation has been included in the capital cost estimates.