

High Speed Rail Study

Phase 2 Report

Appendix Group 1 Travel markets

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Appendix 1A

Previous HSR demand studies in Australia and overseas

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Previous HSR demand studies in Australia and overseas

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March 2013

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March 2013

Quality information

Document	Appendix 1A
Ref	60238250-1.0-REP-0101-1A
Date	March 2013

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1.0 Introduction

This appendix reviews the previous studies of High Speed Rail (HSR) in Australia and overseas.

Section 2 reviews the three previous HSR studies of high speed trains along the east coast of Australia in the past two decades; the *Very Fast Train Study*¹ (1991), the *Speedrail* project² (1999) and the *East Coast Very High Speed Train Scoping Study*³ (2001). The characteristics of the HSR services and the demand forecasts for each project are outlined in this appendix.

The international evidence on the impacts of HSR projects is reviewed in **Appendix 1A** to provide broad international benchmarks for the assessment of HSR forecasts for the east coast corridor. Whilst overall journey time is an important factor in the success of HSR, evidence on other factors that contribute to the performance of HSR is reviewed in **Appendix 1A**.

2.0 History of High Speed Rail demand studies in Australia

2.1 The studies

There have been three studies of HSR in Australia:

- The Very Fast Train Study (1991).
- Speedrail (1999).
- East Coast Very High speed Scoping Study (2001).

2.2 The Very Fast Train study (1991)

The Very Fast Train (VFT) study identified a preferred HSR corridor between Sydney and Melbourne, along the Hume Highway (via Canberra). Inter-capital express service journey times were close to three hours between Sydney and Melbourne, two hours between Canberra and Melbourne and one hour between Sydney and Canberra (the service characteristics are given in **Table 1**).

¹ Access Economics, *Cost benefit study of the very fast train project*, 1990.

² SKM & VMA, *Speedrail Patronage and Revenue Forecasts*, supplement to final report, 1999.

³ Arup & TMG, *East Coast Very High Speed Train Scoping Study, Phase 1 Preliminary Study Final Report*, 2001.

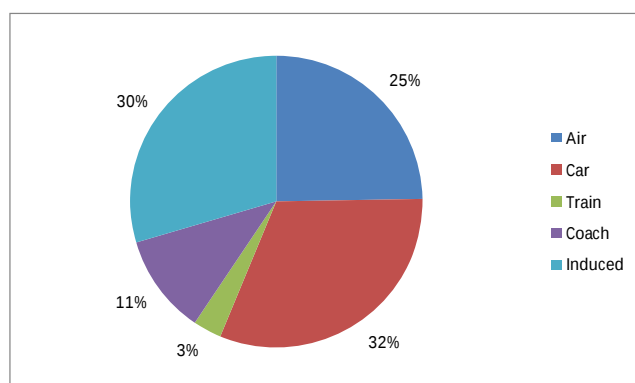
Table 1 The Very Fast Train service

		Fares	
Express services	Express journey times	Premium	Economy
Sydney-Melbourne	2 hrs 55 mins	\$217 (\$367*)	Full: \$130 (\$220*) Discount: \$87 (\$147*)
Sydney-Canberra	1 hr 5 mins	\$110 (\$170*)	Full: \$60 (\$102*) Discount: \$40 (\$68*)
Canberra- Melbourne	1 hr 58 mins	\$167 (\$282*)	Full: \$100 (\$169*) Discount: \$67 (\$113*)
Other stations			
Melbourne and Sydney Airports, Campbelltown, Bowral, Goulburn, Yass, Wagga Wagga, Wangaratta, Benalla, Seymour.			
Service patterns			
Three types of service: non-stop between Sydney and Melbourne, express also stopping at Canberra and about three other stations, and stopping services for other stations. In total 36 services per day in each direction.			

* Equivalent fare in today's prices, assuming base price for study fares is the year of the 1991 study.

The forecasting procedures used a logit mode choice model⁴ based on a stated preference survey. In 1995, 9.51 million passengers were forecast to use the VFT, of which 40 per cent were on business⁵. The sources of overall VFT patronage are given in **Figure 1**, which shows induced travel⁶ accounted for 30 per cent of VFT patronage, diverted car trips 32 per cent and diverted air trips another 25 per cent.

Figure 1 Source of Very Fast Train passengers (1995)



Note: Numbers do not add to 100 per cent due to rounding.

⁴ Most current Australian and international practice is to model the choice of transport mode using a particular model form referred to as the logit model. For aggregate application such as this it can be related to entropy-maximising concepts while in disaggregate models it arises from random utility theory.

⁵ *ibid.*

⁶ Induced travel is defined as journeys on the high speed rail service which were not diverted from other, existing modes of transport.

2.3 Speedrail (1999)

The Speedrail project identified a preferred HSR corridor between Sydney and Canberra via the Southern Highlands and Goulburn. The fastest inter-capital journey time was one and a half hours between Sydney and Canberra (the service characteristics are given in **Table 2**).

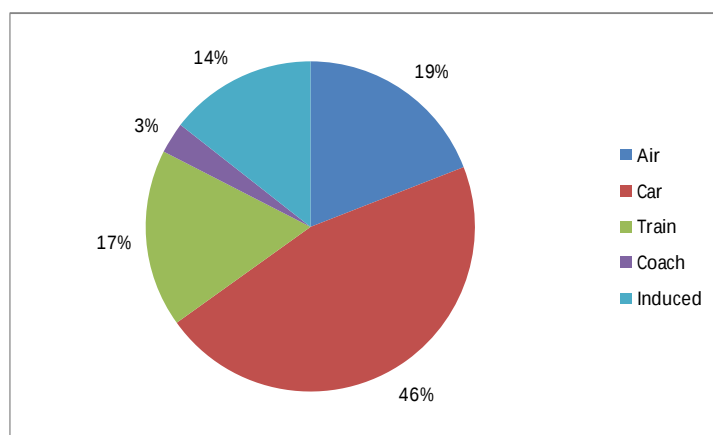
Table 2 The Speedrail service

		Fares	
Inter-capital service	Journey time	Business class	Economy
Sydney-Canberra	1 hr 30 mins	\$163 (\$240*)	Full: \$94 (\$138*) Discount: \$70 (\$103*)
Other stations			
Sydney Airport, Macarthur, Southern Highlands (Bowral), Goulburn.			
Service patterns			
All trains stop at Sydney Airport and Macarthur, with a more limited service to Goulburn and the Southern Highlands. In total 18 services per day in each direction in 2011 (this is the year for which detailed forecasts are reported – the first year of operation was anticipated to be 2007).			

* Equivalent fare in today's prices, assuming base price for study fares is the year of the study.

The forecasts also used a logit mode choice model based on a stated preference survey. Speedrail annual patronage was forecast to be 4.3 million in 2011, with business travel accounting for approximately 39 per cent of Speedrail passengers⁷. The sources of Speedrail patronage are given in **Figure 2**; diverted car trips comprised the majority (46 per cent) of Speedrail passengers, diverted air and rail trips another 19 per cent and 17 per cent respectively, while induced travel was forecast to be just 14 per cent of patronage. The forecasts allow for some train capacity constraints at peak times.

Figure 2 Source of Speedrail passengers (2011)



Note: Numbers do not add to 100 per cent due to rounding

⁷ SKM & MVA, op. cit., Tables 4.1-4.3.

2.4 East coast Very High Speed Train Scoping study (2001)

The Scoping study investigated a series of very high speed train (VHST) routes using train technologies providing speeds between 160 kilometres per hour and 500 kilometres per hour. **Table 3** gives the details of the 350 kilometres per hour service for a route following the coast north of Sydney and then, south of Sydney, an inland route through Canberra to Melbourne. Journey times of between four and four and a half hours between Brisbane and Sydney and between Sydney and Melbourne were assumed.

Table 3 The Very High Speed Train service

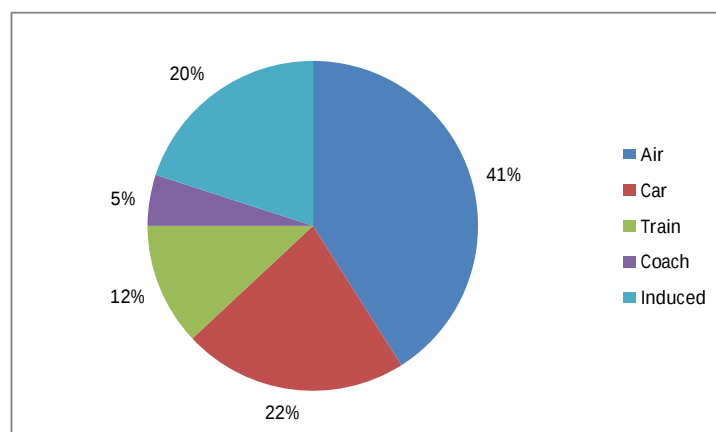
		Fares	
Service	Limited stop service journey time*	Business	Non-business
Sydney-Melbourne	4 hrs 7 mins to 4 hrs 30 mins	\$143 (\$193**)	\$119 (\$161**)
Brisbane-Sydney	4 hrs 24 mins to 4 hrs 33 mins	\$151 (\$204**)	\$108 (\$145**)
Sydney-Canberra	1 hr 48 mins	\$64 (\$86**)	\$47 (\$63**)
Canberra-Melbourne	3 hrs 18mins	\$129 (\$174**)	\$98 (\$132**)
Other stations			
Beenleigh, Robina, Coolangatta, Ballina, Grafton, Coffs Harbour, Port Macquarie, Taree, Broadmeadow, Warnervale, Gosford, Hornsby, Strathfield, Sydney Airport, Glenfield, Bowral, Goulburn, Canberra airport, Yass, Cootamundra, Wagga, Albury, Shepparton, Seymour, Melbourne airport.			
Service patterns			
Limited stop and all stop services. 16 services each way (an hourly service overall).			

*Times varied by the length of the route.

** Equivalent fare in today's prices, assuming base price for study fares is the year of the study.

For this model, the base year travel demands were derived from the Domestic Tourism Monitor and the International Visitor Survey. The forecast VHST annual patronage was 32.4 million passengers in 2021⁸, of which business travel accounted for 17 per cent⁹. The sources of overall VHST patronage are given in **Figure 3**, which shows diverted air trips accounted for 41 per cent of passengers, while diverted car trips and induced travel were 22 per cent and 20 per cent of the patronage respectively.

Figure 3 Source of VHST passengers (2021)



⁸ The study assumed that HSR services would commence operation in 2011, with detailed forecasts being presented in the report for 2021.

⁹ Arup & TMG, op. cit., Table 9.12, Figure 9.35.

2.5 Commentary

Both the VFT and Speedrail concepts provide low inter-capital HSR travel times. The VHST travel times are significantly longer (over four hours inter-capital) but the fares appear to be lower: for example, in today's prices, the Sydney-Canberra non-business fare is \$63, compared with \$68-\$102 and \$103-\$138 for VFT and Speedrail economy fares respectively.

A direct comparison between the forecasts of the three studies is not possible given the lengths of the three routes, the service patterns, the journey times and the forecast scenarios are all different. Nonetheless, an appreciation of the relationships between the three studies can be reached if it is supposed that the travel market in the corridor may have increased by an average of 2.5 per cent per annum over the period 1995-2021 (this is based on the growth of 2.5-3 per cent suggested by the VHST and VFT studies).

On this assumption, the three sets of forecasts are shown in **Table 4**, which suggests that the VFT and Speedrail forecasts were for greater HSR demands than the VHST study although, the longer VHST rail times will account for some of the difference.

Table 4 HSR forecasts for the three studies (million passengers per annum)

Route sector	Study			
	VFT		Speedrail	VHST
	1995	2021*	2021	2021
Brisbane-Melbourne	-	-	-	32.9
Sydney-Melbourne	9.5	18.1	-	12.1
Sydney-Canberra	-	-	5.2	3.7

*Projected assuming market growth of 2.5 per cent per annum.

As expected, the balance of the sources of HSR demand between Speedrail on the one hand, and the VFT and VHST studies on the other, is also different. Given that the distance between Sydney and Canberra is much shorter than Sydney to Melbourne or Brisbane, with car being the dominant mode of transport, there is proportionately more diversion from car to Speedrail and less from air. There is also a lower proportion of induced travel, which seems likely to be a reflection of the comparatively good current level of transport accessibility and range of mode options between Sydney and Canberra with a fast, convenient car journey, and rail and air services.

All three studies used an overall demand forecasting structure, consistent with the approach taken in this HSR study, which is designed to address the following questions in sequence:

- What is the size and geography of the travel market in the corridor and how is it split between the alternative transport modes (car, rail, coach and air)?
- How will these markets grow in the future?
- What is the potential for diversion from existing modes to HSR and what would be the level of induced travel? How sensitive is the level of HSR demand to HSR performance?

There are other similarities in the approach to forecasting HSR demands. The base market for the VHST study was derived from the precursor of the annual National Visitor Survey (NVS) used in this study, while the VFT and Speedrail studies undertook stated preference surveys to inform the logit mode choice models used to predict the diversion from other transport modes.

Although the demand forecasts for this study are not based on the previous work, nor seek to reproduce those forecasts, the previous studies are used as a point of comparison in **Appendix 1E**.

3.0 International HSR demand experience

3.1 Introduction

This section reviews international evidence on the following specific aspects of HSR forecasting:

- Travel demand elasticities.
- Impacts on existing rail services.
- Impacts on air services.
- Impacts on other modes and induced travel.

The international evidence is used to provide broad international benchmarks for the assessment of HSR forecasts for the east coast corridor.

3.2 Review of travel demand elasticities

The sensitivity of the demand forecasting procedures is measured in part by their response to changes in journey time and costs as measured by the elasticities of demand¹⁰. The values in **Table 5** are derived from published sources and relate to longer distance and/or inter-city travel demand. The measure of demand is usually trips and it is noted where trip kilometres are used. Where short and long run elasticities are quoted in the literature, the short run (SR) or annual (A) values are quoted, being judged to be more relevant to a study of modal diversion. Induced travel would normally be expected to be a medium term effect, although it is reported that after six months, Eurostar carried 30 per cent induced travel. Long run elasticities may be up to twice the short run values.

The reports listed in the table emphasise that the values are very sensitive to the mode shares for the context being studied.

Table 5 Examples of international and local evidence on travel demand elasticities

Elasticity of demand	Sources of direct elasticities and recommended average values
Domestic air travel: elasticity to air fare	Australian and NSW Governments ¹¹ : -0.2 to -1.3
Inter-urban rail travel: elasticity to rail fare	Wardman (2010) ¹² : -0.6 (SR) Hooper ¹³ : -0.7 to -1.0 Prideaux ¹⁴ : -0.6 to -1.2
Inter-urban rail travel: elasticity to rail journey time	Wardman (2011) ¹⁵ : -0.3 to -0.9 (SR, A) Prideaux: -0.9
Inter-urban rail travel: elasticity to rail service headway	Wardman (2011): -0.06 to -0.16 (SR, A)
Car travel: elasticity to car journey time	Wardman (2011): -0.07 to -0.19 (SR, A) Wallis ¹⁶ : -0.3 Graham ¹⁷ : -0.2 (vehicle kilometre elasticity)

¹⁰ For example, if rail fare is increased by (+) 10 per cent and the patronage on rail reduced by (-) nine per cent, then the direct demand elasticity is the ratio of these two changes or -0.9. Values close to zero indicate that the demand is not very sensitive to changes in that aspect of level of service, while values close to or exceeding 1.0 indicate a high level of demand sensitivity.

¹¹ Australian and NSW Governments, *Joint study on aviation capacity in the Sydney region*, 2012.

¹² Wardman, *Price Elasticities of Travel Demand in Great Britain, a Meta Analysis*, 2010.

¹³ Hooper, *The elasticity of Demand for Travel: a Review*, Institution of Transport Studies, Sydney, 1993.

¹⁴ Prideaux, *Future Demand for Rail Transport*, Transport and Energy Conference, Institution of Civil Engineers, London, 1980.

¹⁵ Wardman, *Review and Meta-Analysis of Time Elasticities of Travel Demand*, 2011.

¹⁶ Wallis and Schmidt, *Australasian travel demand elasticities - an update of the evidence*, Australasian Transport Research Forum, 2003.

¹⁷ Graham and Glaister, *Road traffic demand elasticity estimates: a review*, *Transport Reviews*, May 2004.

3.3 Impacts on rail services

Many HSR lines have been developed in corridors already served by rail such as those in France and Japan, which were principally designed to solve railway capacity constraints. With the introduction of HSR, there has been substantial growth in rail patronage in the affected corridors, and there are several studies referencing this growth¹⁸.

3.4 Impacts on air services

3.4.1 Air and Rail Competition and Complementarity

This study for the European Commission (EC)¹⁹ of the competition between HSR and air in Europe has contributed materially to the HSR demand forecasts. Case studies of eight European air/rail routes (**Table 6**) were used to understand the key drivers of market share. The eight routes were chosen to reflect a range of characteristics including different journey times, different countries and varying degrees of airline competition.

Table 6 The European Commission eight HSR case studies

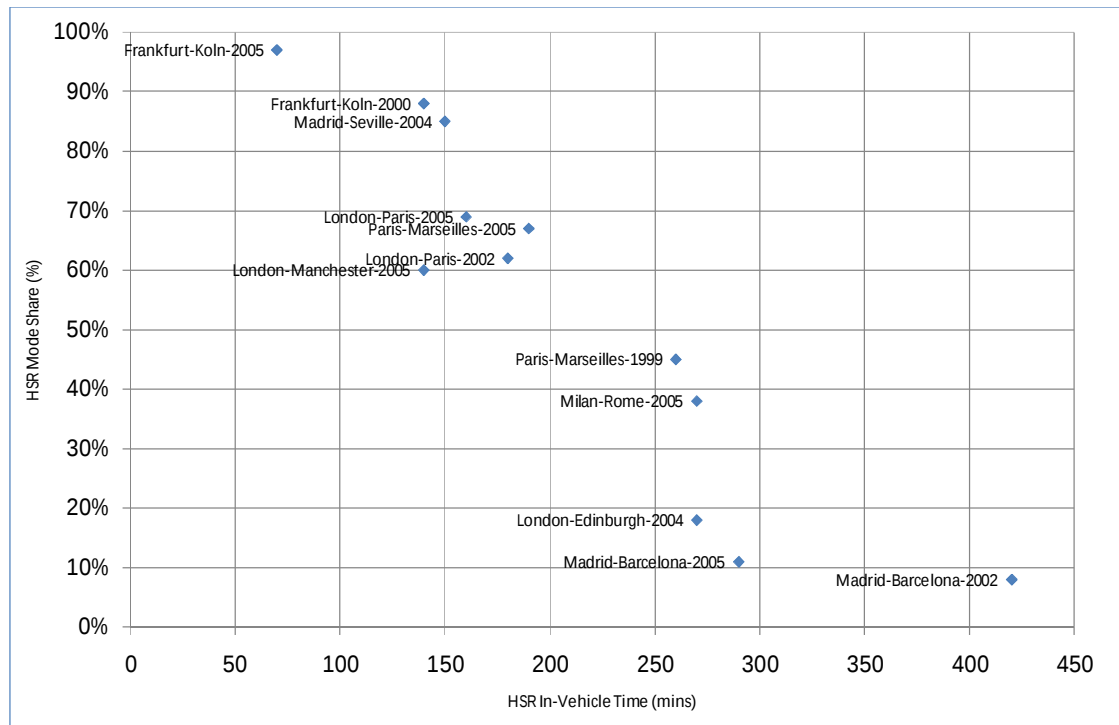
Route	Year
Frankfurt-Koln	2000, 2005
London-Edinburgh	2004
London-Manchester	2005
London-Paris	2002, 2005
Madrid-Barcelona	2002, 2005
Madrid-Seville	2004
Milan-Rome	2005
Paris-Marseilles	1999, 2005

The EC study found that the rail share of air and rail travel varied between the routes from 11 per cent (Madrid-Barcelona) to 97 per cent (Frankfurt-Koln). **Figure 4** illustrates the data. Where there is evidence of the share on a particular route varying through time, an additional point is recorded in the figure.

¹⁸ See for example: Gourvish, *The High Speed Rail Revolution: History and Prospects*, HS2 Ltd, 2010; Bilan LOTI, *Reseau ferre de France: TGV Atlantique*, 2001; LGV Nord, *Interconnexion Ile de France*, 2005; LGV Rhone-Alpes, 2006; LGV Mediterranee, 2007.

¹⁹ Steer Davies Gleave, *Air and Rail Competition and Complementarity*, European Commission, 2006.

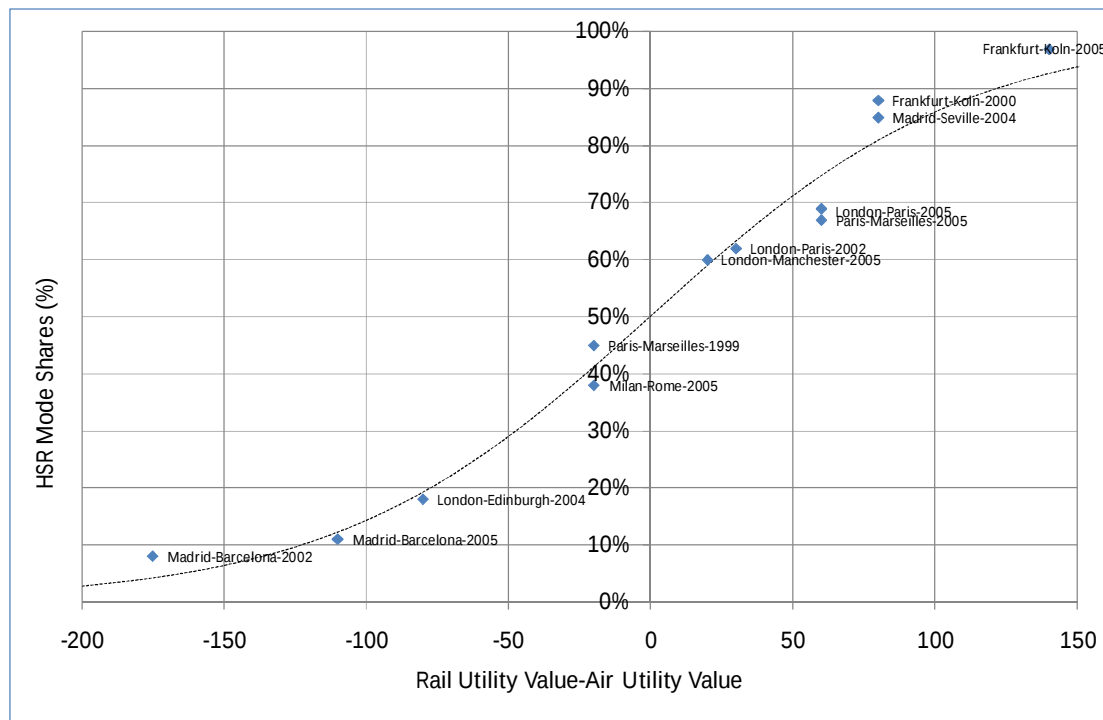
Figure 4 Evidence on the relationship of the HSR share of the air and rail market to rail journey time (Europe)



The market shares reported in the study include air passengers connecting to other air services (i.e. airport transfers), primarily because of the available data. It is pointed out that if these were excluded, then the rail shares would be higher than shown in the figure above. The report notes that, “*in most cases, rail travel is not competitive for [air] passengers connecting to [other] air services*”.

As part of the study, the factors influencing mode share (journey time, frequency access, etc – see **Section 4.2.1**) were combined into measures of the utility²⁰ of travel by HSR and air. The relationship between the HSR share and the difference in disutility between rail and air is illustrated in **Figure 5**. It is clear that the inclusion of the additional factors in the disutility calculation provides a stronger explanation of the variations in HSR shares in this data. The study established a mode choice model which reproduced the variation in HSR mode share with utility difference, represented by the dotted line in **Figure 5**.

Figure 5 Evidence on the relationship of the HSR share of the air and rail market to the difference in air and rail disutilities (Europe)



²⁰ The convention adopted in the EC study is that travel incurs a negative utility in terms of the time it takes and its cost.

3.4.2 The VHST study

For the VHST study, information on the split between HSR and air was obtained for 25 city pairs in France, Spain and Japan (**Table 7**). That information is reproduced in **Figure 6** which illustrates that for inter-city travel, there is an evidently close relationship between the rail share and its journey time. On this evidence, if the inter-city rail journey time increases above four hours, then air is likely to retain a majority share of this travel market.

Figure 6 Evidence of the HSR share relationship on the air and rail market to rail journey time (Europe and Asia)

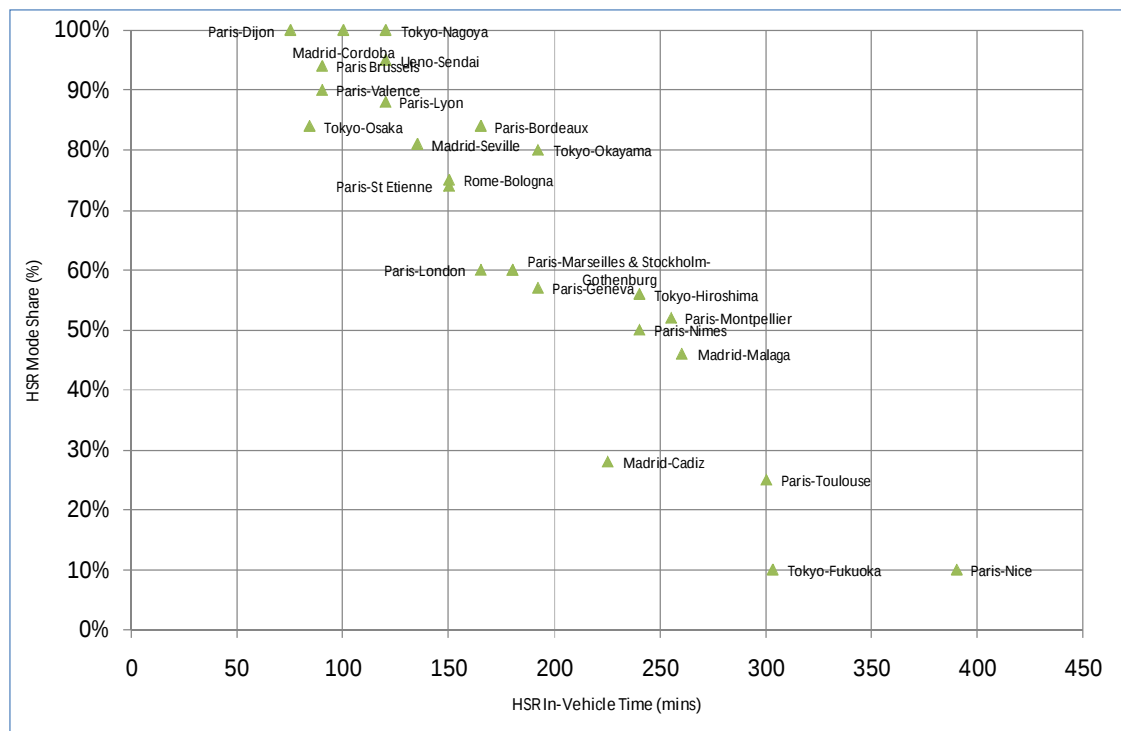


Table 7 Sample of HSR city pairs

City pair	Train system	Distance (kms)
Tokyo-Nagoya	Osaka-Shinkansen	342
Tokyo-Osaka	Osaka-Shinkansen	515
Ueno (Tokyo)-Sendai	Tohoku-Shinkansen	325
Tokyo-Fukuoka	Sanyo-Shinkansen	1,069
Tokyo-Okayama	Sanyo-Shinkansen	676
Tokyo-Hiroshima	Sanyo-Shinkansen	821
Paris-Valence	TGV	527
Paris-St Etienne	TGV	489
Paris-Dijon	TGV	285
Paris-Geneva	TGV	410*
Paris-Nimes	TGV	690
Paris-Marseilles	TGV	750
Paris-Montpellier	TGV	740
Paris-Toulouse	TGV	827
Paris-Bordeaux	TGV	567
Paris-Lyon	TGV	430
Paris-Nice	TGV	1,003
Rome-Bologna	AV	318
Paris-Brussels	Thalys	312
Paris-London	Eurostar	494
Stockholm-Gothenburg	X2000	455
Madrid-Cadiz	Talgo	628
Madrid-Cordoba	AVE	343
Madrid-Seville	AVE	471
Madrid-Malaga	AVE	414*

Source: table 9.24, VHST, 2001.

*Straight line distance estimate.

3.5 Impacts on other modes of transport and induced travel

Reliable data on the impacts of HSR on car and coach travel and the level of induced travel is far less comprehensive.

Nash²¹, in his report on HSR Overseas Experience for phase 1 of this study, reported the impacts of French, Spanish and Korean HSR services on other modes of transport and induced travel. Fundacion BBVA²² provides additional data for German HSR services. This information is displayed in **Figure 7**. The four rail corridors are: the French TGV service between Paris and Lyons (TGV Sud-Est), the Spanish AVE service between Madrid and Seville, the Korean KTX service between Seoul and Busan, and the German ICE service between Hamburg and Frankfurt.

²¹ Nash, *HSR Overseas experience Report, High Speed Rail Study Phase 1*, 2011.

²² Fundacion BBVA, *Economic Analysis of High Speed rail in Europe*, 2009.

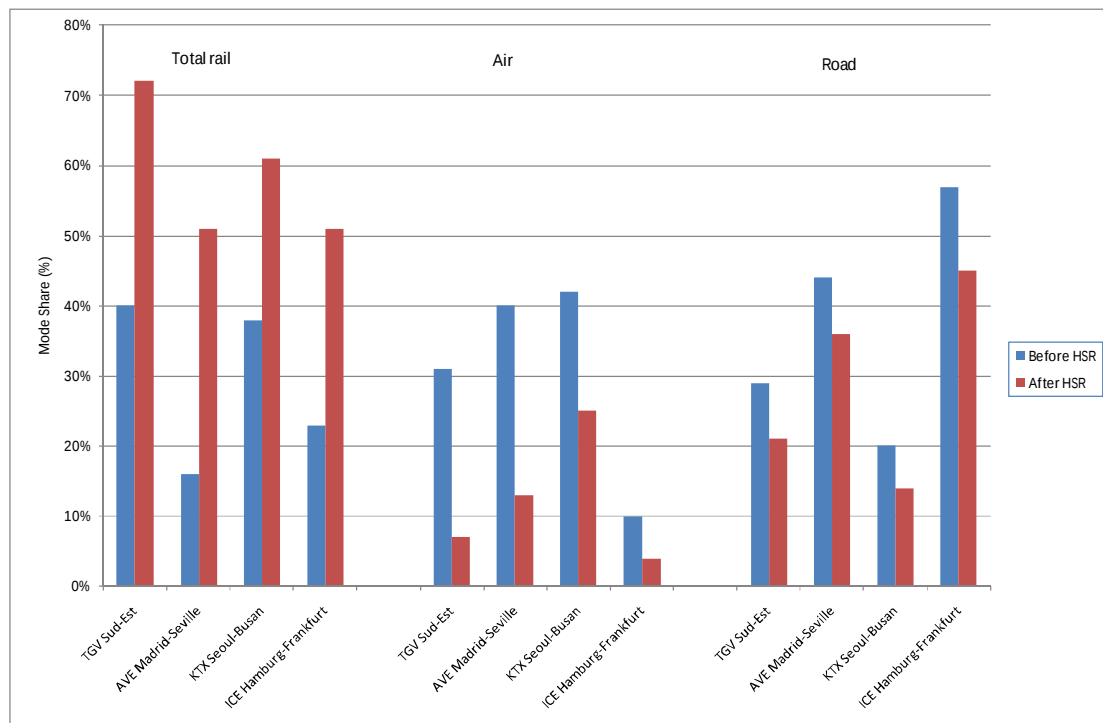
In all four rail corridors, there is a large increase in the rail mode share – from a 60 per cent increase for KTX (Korea) to more than a tripling of the mode share in the AVE (Spain) corridor.

Air travel is the most affected by HSR services, with all except the travel in the KTX (Korea) corridor being left with a minor share of their respective markets.

Finally, there are lower but still very significant impacts on the mode share of the road-based transport modes (car and coach).

Nash further comments that most HSR services have a substantial proportion of generated passengers, typically greater than 20 per cent of the total patronage and indeed, up to 30 per cent of the AVE (Spain) rail patronage was generated. Of the TGV Sud-Est traffic (France) which had not diverted from existing rail services, 50 per cent was generated, 33 per cent was diverted from air and 18 per cent from road. Of the KTX (Korea) patronage, 60 per cent was drawn from air with the rest being more or less equally drawn from conventional rail, road and generated traffic.

Figure 7 Market shares by mode before and after HSR

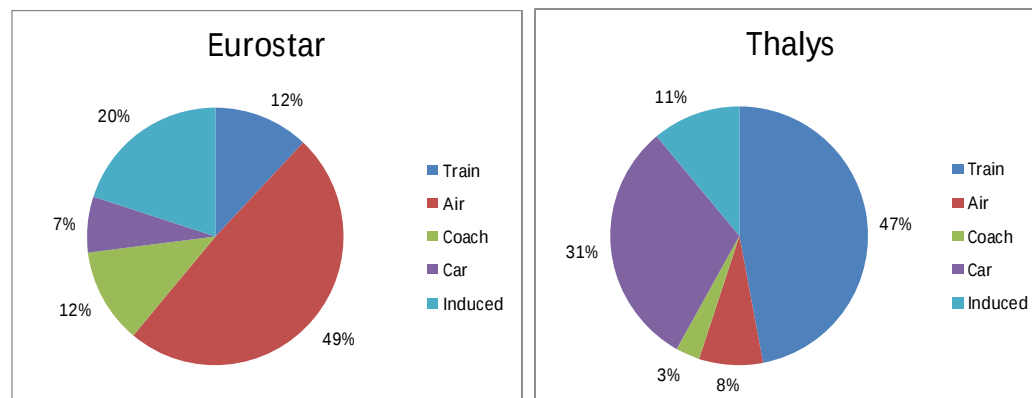


Segal²³ offers an assessment of the sources of the Thalys and Eurostar international HSR services (**Figure 8**). Almost half of Thalys demand derives from the existing rail corridors in which the service competes, whereas cross-channel rail travel was limited and Eurostar derives nearly half of its demand from air. Thalys also derives 31 per cent of its patronage from car travel, whereas only seven per cent of Eurostar passengers were sourced from car trips because the Channel Tunnel also provided improved international car connections via the Shuttle.

The context of the two services was quite different. Before the Channel Tunnel, there was no fixed link between England and France. The tunnel provided both the Eurostar rail connection and the Shuttle connection for road traffic. Conversely, Thalys operates in a transport corridor which already had good road and rail connections.

²³ Segal, *High Speed Rail – the Competitive Environment*, European Transport Conference, 2006.

Figure 8 Sources of Eurostar and Thalys rail demands



The Chinese experience (summarised in **Table 8**) demonstrates the level of induced travel by HSR is, based on the available evidence, estimated to be very high at 40-65 per cent depending on the context.²⁴

Table 8 Impacts of HSR lines in China

Route	HSR patronage (million pax/annum)	Diverted from other modes	Diverted from road or induced
Wuhan-Guangzhou	20	50% rail 5% air	45% (mainly induced)
Beijing-Tianjin	25	16% rail 4% bus	80% (at least 65% induced)
Changchun-Jilin	10	10% rail 20% bus	70% (40-50% induced)

Amos et al.²⁵ have in addition to reviewing the French and Japanese contexts, suggested that in Germany, 65 per cent of HSR patronage was drawn from existing rail services and of the remainder, 20 per cent was diverted from car and 15 per cent from air with very small numbers of generated trips. They suggest that when Eurostar was first introduced, it was established that 25-30 per cent of the total patronage was generated.

3.6 Commentary on the evidence

Considerable evidence has been assembled in the international literature on the impacts of HSR on air travel, and the EC study has investigated the issue in some depth. In **Figure 9**, the evidence on the HSR:air shares from the EC and VHST studies, and the report by Nash, has been combined to provide a comprehensive and evidently consistent picture of the relationship between the HSR share and train journey time.

However, the analysis in the EC study shows that factors other than HSR journey time must be allowed for in order to explain the full variations in the HSR:air shares. They measure the 'disutility' of both air and rail by combining in-vehicle journey times, with service frequency and check-in time, punctuality and reliability, terminal accessibility, price and service quality.

There appears to be less comprehensive information available on the other demand impacts of HSR, the diversion from car and induced travel, although the evidence confirms that both are significant.

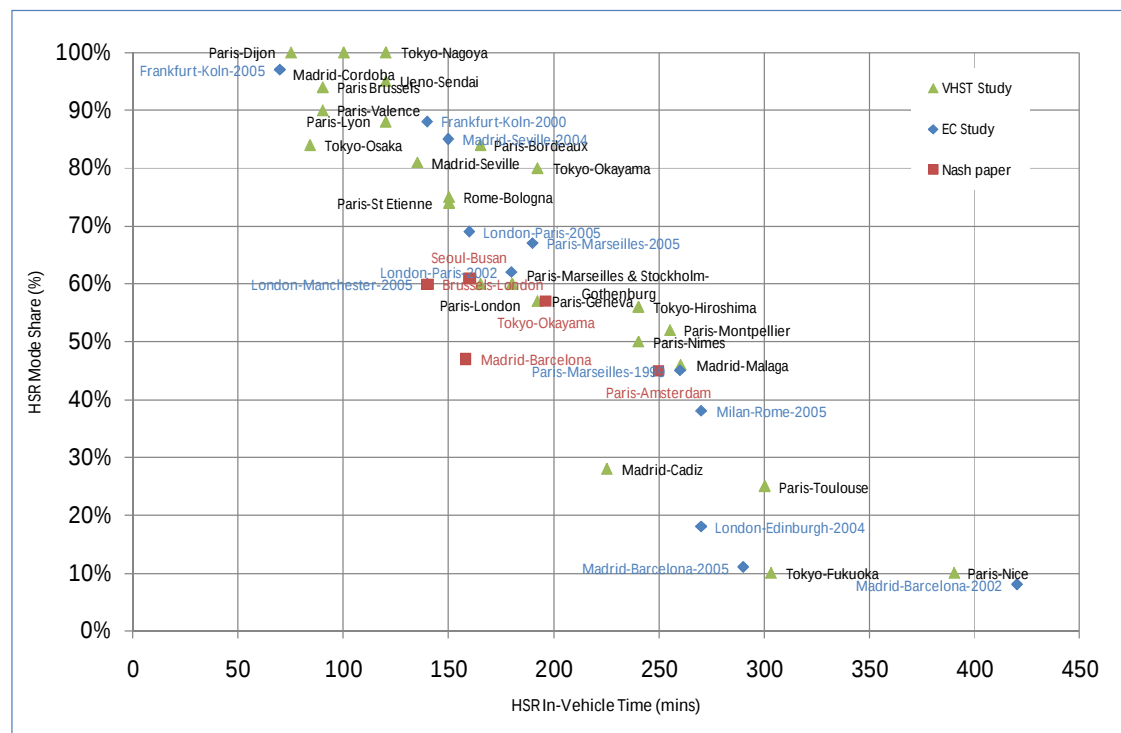
²⁴ Bullock et al, *High Speed Rail – The First three Years: Taking the Pulse of China's Emerging Program*, China Transport Topics No. 4, World Bank, 2012.

²⁵ Amos et al, *High Speed Rail: the Fast Track to Economic Development?*, World Bank, 2010.

Diversion from car is significant in all of the evidence reviewed. The most common range is around 20-30 per cent, including TGV Sud-Est, Thalys and the German high speed trains. Diversion rates lower than this are suggested for Eurostar (because of its atypical context) and for the Chinese railways and KTX, both of which have very low current car shares.

Most HSR services have a substantial proportion of generated passengers. However, the range is wide from relatively low levels of induced travel quoted for the German railways, Thalys and KTX, through the 20-30 per cent range for Eurostar and AVE, to the very high levels of TGV Sud-Est and the Chinese HSR system. Part of the explanation of these variations is likely to be the quality and extent of the transport system in the corridor prior to the introduction of HSR.

Figure 9 Evidence of the HSR share relationship on the air and rail market to rail journey time (combined EC and VHST studies and Nash evidence)



3.7 Accuracy of HSR forecasts

Finally, it is noted that concerns over the accuracy of rail project forecasting are also raised in the literature.

The UK National Audit Office²⁶ has recently released its report on High Speed 1, in which it comments that “[passenger] numbers, however, between 2007 and 2011 have been, on average, one third of the level that LCR forecast in 1995 for its bid ... [passenger] numbers were also around 30% below the Department’s 1998 forecasts, before it guaranteed the project debt”.

Bullock et al. also observes that “patronage on some of the [Chinese high speed rail] lines remains substantially below the opening-year forecasts developed in their respective feasibility studies”.

Conversely, Albalade et al.²⁷ report that the demand forecasts for the Tokyo-Osaka Shinkansen line underestimated patronage.

²⁶ National Audit Office, UK, *The completion and sale of High Speed 1*, 2012.

²⁷ Albalade et al, *High Speed rail: Lessons for Policy Makers from Experiences Abroad*, IREA University of Barcelona, 2010.

Of the five routes reported in the Bilan Loti reports which were reviewed, two of the routes were forecast reasonably accurately and for three the demand over-estimated the impact of the TGV route. Of the latter, TGV Nord was affected by the Eurostar forecasting errors.

With these concerns over the accuracy of rail project forecasting in mind, where there were uncertainties in the modelling, conservative decisions were taken, and the forecasts for the east coast HSR line have been benchmarked against the international evidence (see **Appendix 1E**).

4.0 Competitive analysis and success factors

4.1 Objectives

To inform the design of the HSR transport products, the key HSR success factors for market segments drawn from local and international literature are reviewed in this section to determine the factors influencing the choice of HSR and the surveys on this study.

4.2 International evidence on HSR

4.2.1 Air and Rail Competition and Complementarity

This paper for the EC²⁸ discusses the effectiveness of HSR in relation to its competitiveness with air. The paper includes a discussion of the 'drivers of market share' based on a review of eight European routes. The study conclusions on market share are reproduced below.

The case studies show that rail journey time is by far the most important factor determining rail/air market share. In principle, it is better to examine the difference between rail and air journey time rather than just the rail journey time, although in practice this may not make much difference to the results, because air journey times do not vary as much between routes as rail journey times do. The correlation is improved if we look at generalised journey time rather than purely at scheduled in-vehicle journey time. Generalised journey time takes into account whether each mode offers a high or low frequency service and also any check-in time. We found that generalised journey time explained most of the difference in rail market share across the routes that we studied.

However, we found that even allowing for generalised journey time variations there were still significant variations in market share across the routes that we studied. There were a number of reasons for this. Punctuality and reliability appeared to be very important factors in determining market share, and a number of the operators with whom we consulted emphasised that these were as important as journey time. The accessibility of terminals is a very important factor in determining market share on individual routes but as this is not within the control of the operators within the short term, it is not a factor that they emphasised. In contrast, the service quality available on board and in terminals did not seem to be a particularly important factor determining market share. However, this was in part because there was not much difference in the service quality offered by the different operators, except in first/business class which represents a small proportion of passengers.

Although there was some evidence that price was an important factor in determining market share, this was less clear than might have been expected. Rail achieved a high market share on some routes (such as London-Paris) despite relatively high prices. The main route on which price seemed to have had a significant effect on market share was the London-Edinburgh route, where the existence of a high frequency low cost airline service had caused significant switch from rail. In evaluating the affect [sic] of price variations, we also need to consider the existence of alternative lower cost modes of transport. For example, the high market share achieved by rail on the Rome-Milan route is the result of both relatively low rail fares and the lack of any lower priced alternative to rail transport (such as a bus service).

²⁸ Steer Davies Gleave, *Air and Rail Competition and Complementarity*, European Commission, 2006.

In summary, the paper argues that the main factor which drives HSR market share is the rail journey time. Check-in time is considered part of journey time, and the absence of the need for a long check-in for HSR is an advantage. It is also noted that rail must have a competitive service frequency.

Steer Davies Gleave observes that other factors accounted for the variations in mode shares for the routes which they studied. These factors were:

- The time and cost involved in accessing air and rail terminals: aside from journey time, accessibility to the competing modes of transport is one of the most important factors.
- Price and ticket conditions, in which the low cost airlines and yield management are significant issues.
- Reliability and punctuality, whose importance rail operators emphasised.
- Service quality on board and at terminals is thought to be of diminishing importance and not considered relevant by operators, but this may simply be because there are common standards used on competing modes.
- The availability of alternative (lower cost) modes, regarding which Steer Davies Gleave mentions coach and private car.
- Interchange is also an important consideration, with rail travel generally not competitive for passengers connecting to air services.

In regard to some of these factors, the presence of competition from low cost airlines is important.

4.2.2 High Speed Rail Overseas Experience Report (Nash 2011)²⁹

The findings of Nash concur with the Steer Davies Gleave report on journey time, reliability, accessibility of stations (particularly city centre stations), airport check-in times and waiting times generally, competitive fares, yield management and seat reservations systems all mentioned.

4.2.3 High Speed Rail – The Competitive Environment (Segal 2006)³⁰

Similarly, in this paper presented at the European Transport conference, it is argued that journey times are critical. The paper states that business travellers seek an uninterrupted journey (with the ability to work on the train), quality of service (catering, etc) and a 'turn up and go' experience with the associated service frequency. The paper also raises the issue of fares, accessibility and check-in.

4.3 Local evidence on HSR

4.3.1 Speedrail (SKM & MVA 1999)

Extensive market research was undertaken for the Speedrail project, including in-depth interviews and focus groups to investigate consumer preferences and perceptions of existing travel modes and HSR.

Table 9 is an extract from the Speedrail report, which details the advantages and disadvantages identified by survey respondents regarding their current modes of transport for journeys between Sydney and Canberra.

When questioned about the Speedrail service offering, the participants focused on cost, regularity and reliability, their views being summarised in **Table 10** (extracted from the Speedrail report).

²⁹ Ibid.

³⁰ Ibid.

Table 9 Speedrail - advantages and disadvantages of existing modes of transport between Sydney and Canberra

Car	Train
<u>Advantages</u> - Convenient - Easier with children - Flexibility - Need for car at destination - because of equipment , location of the ultimate destination, etc - Size of the travelling group/family - Luggage - For leisure trips and/or bringing the family up to join the respondent "you'd always drive"; where a family is involved the availability of a car "at the other end" is invaluable - It was felt that it was difficult to justify the expense of flying for a 3 hour leisure driving trip	<u>Advantages</u> - Cost - Fare - Duration and location of the visit - Not having to look for parking <u>Disadvantages</u> - Uncomfortable seats, the bumpy ride and the poor food - Safety at railway stations - Having to change trains was not desirable - Being tied to a schedule
Air	
<u>Advantages</u> For business trips: - Cost not a big issue, fares were either paid by the company or funded by frequent flyer points which were gained on other "longer" flights - Plane travel is considered to be more relaxing than driving when you are working and "you can work on the plane" - Membership of Qantas Club/Golden Wing is another important influence - ability to make phone calls, have meetings, have a shower "to freshen up" - Ability to purchase plane tickets in advance which reduces the fare (although this means there is less flexibility in your bookings later) <u>Disadvantages</u> - Check-in time - Total time including access - Expensive - Cramped and stressful	

Table 10 Speedrail - perceptions of HSR

HSR	
<u>Advantages</u> Overall HSR was perceived as a service that would be: - Convenient - Better than the existing train service - Reliable timetable - Speedy - Would be more relaxed and more refreshed upon arrival - Could do work on the train, can get paperwork in order for meetings, be able to use their electronic equipment, including their mobile telephone, as long as they were not disturbed by children - Reliability of timetable - Could sell travel by HSR to companies and they could reduce their fleet of vehicles	<u>Inhibiting features</u> - Cost was seen as a potential disadvantage; off peak rates were seen as necessary to promote usage by "ordinary" people; for leisure trips particularly - The need to "keep to a schedule" was another issue raised concerning HSR versus car travel - Travel in groups - Need for car at the other end - Frequent modal interchanges
<u>Issues raised:</u> - Security at stations and on trains - Access at stations: buses and taxis meeting trains, secure parking, car rentals, shuttle bus services - Ticketing arrangements - Timetabling schedules and frequencies – being able to catch a train when you needed it - Service at stations: waiting areas, baby changing rooms and facilities to look after unaccompanied children, money exchange (for tourists), luggage trolleys, speedy reclaim of luggage and no luggage limits - On train services, including services for business people (faxes, places to plug in computers, modems, ability to use mobile phones, collect e-mails), buffet car, a lounge area or observation carriage, video screen, music, bar - Comfortable seats - Luggage arrangements: no luggage restrictions, provision for luggage, being able to book in the luggage and not have to carry it, the amount of hand luggage you could take on (if significantly more than on a plane this would be a decided advantage), the amount of "book-on" luggage you could carry (e.g. for trade displays) and the speed with which this luggage can be retrieved at the end of the journey - The smoothness of the ride - Helpful staff - Cleanliness	

4.3.2 The current study - phase 2 surveys

The initial focus groups and the stated preference (SP) survey (**Appendix 1D**) for this study investigated why people would not choose to use HSR and what they would value most about HSR.

More than half the travellers interviewed in the main SP survey (travelling by air, car and conventional rail) did not consider that there were any current alternative modes possible for their journey. However, given a journey in the HSR catchment, most (81 per cent) of the respondents from the main SP survey would consider HSR.

Of those that would not consider HSR, the main reasons are given in **Table 11**. The SP survey results show that just under 80 per cent of respondents used their car for the journey. The predominant reasons for not considering HSR were inconvenience and the need for a car at the destination. Other specific reasons included: carrying luggage, goods or pets; slower than current mode; car is cheaper; sightseeing stops and family group travel.

The focus groups also suggested that the constraint of company travel policies prohibits consideration of HSR.

Table 11 HSR phase 2 study surveys (2012) – reasons for not considering HSR

Reason	Proportion of in-scope contacts*
Need car at the destination	43%
Not convenient	28%
Carrying luggage/goods/pets	10%
Perceived as slower than current mode	9%
Car is cheaper	5%
Stop for sightseeing along the way	5%
Family group	4%
Other reasons	37%

* The proportions sum to greater than 100% because multiple responses were allowed.

In the main SP survey, respondents were asked to name the aspects of HSR which they would most value and to rank them in order of importance. Interviewers then classified these according to the features of HSR reported in **Table 12**. The key results were as follows:

- Speed/journey time – 31 per cent of respondents put this first and for almost 60 per cent of respondents, it was one of the three valued features of HSR.
- Comfort – 15 per cent of respondents ranked this first, and 46 per cent included it in their three valued features. Comments included; no turbulence, more room and natural light than plane, car or current train; and liked being able to get up and move around.
- Other features specifically identified by more than 10 per cent of respondents were: the service goes direct to the city CBD, reliability, safety and avoids the airport.
- The ability to work, the availability of Wi-fi, the environmental benefits and integration with local public transport were also mentioned.

Table 12 Aspects of HSR most valued by respondents

Feature of HSR	Proportion of respondents ranking each feature 1st, 2nd or 3rd			Proportion of respondents ranking feature either 1st, 2nd or 3rd
	1st	2nd	3rd	
Speed	31%	26%	14%	58%
Comfort	15%	24%	23%	46%
Able to work	2%	4%	6%	8%
Direct to CBD	4%	5%	8%	11%
Wi-fi	1%	3%	10%	8%
Reliability	4%	6%	7%	13%
Safety	6%	5%	5%	13%
Avoids airport	4%	5%	6%	11%
Environment	3%	3%	4%	8%
Integrates with public transport	1%	3%	4%	5%
Other	28%	18%	14%	50%
Total respondents	2098	1719	1026	2098

Additionally, the focus groups suggested as reasons for considering HSR:

- The ability to retain control of luggage.
- Less wear and tear on the car.

4.4 Conclusions

The body of evidence examining factors that drive the take-up of HSR services indicates that the main determinant of HSR mode share is the journey time of HSR relative to the competing modes. Consumers perceive access times and check-in as part of the overall journey time in making their decision. This being the case, a successful HSR service requires competitive journey times complemented by:

- Convenient station access/egress arrangements.
- Convenient timetabling (frequencies and service patterns).
- An appropriate fare structure (that includes yield management).

Furthermore, there is a clear and consistent theme running through the literature that identifies the main attractions of HSR to be:

- Ability to use time productively (business or leisure activities).
- Access to city centres, including avoiding congestion.
- Comfort and the ability to relax.

Similarly, the disadvantages are consistently identified as:

- Connections to the final destination (including the need for a car at the destination).
- Wait time, interchanges etc.
- Unreliability.
- Carrying heavy items of luggage.

It is also apparent that there are specific factors influencing the decisions of business travellers such as company travel policies and the availability of business lounges.

Appendix 1B

Use of the National Visitor Survey data

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Prepared for

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March 2013

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March 2013

Quality information

Document	Appendix 1B
Ref	60238250-1.0-REP-0101-1B
Date	March 2013

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1.0 Introduction and objectives

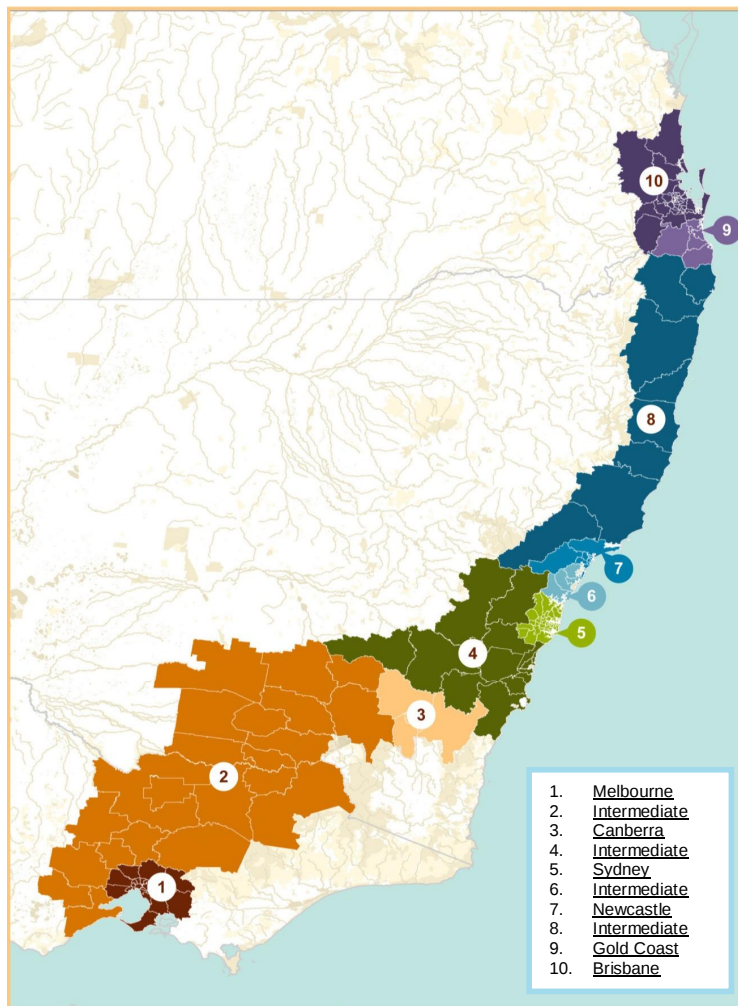
The demand forecasting procedures rely on an appreciation of the current patterns of travel demand along the east coast – it is these journeys, projected into the future, which High Speed Rail (HSR) would potentially serve. To this end, the size of the current travel market for the east coast study area was determined by origin and destination, trip purpose and transport mode from National Visitor Survey (NVS) data collected by Tourism Research Australia.

As the current travel market forming the basis of the HSR forecasts, the resulting market estimates were also verified against independent information, which included a specially-commissioned survey of interurban road traffic patterns.

2.0 The study area

With a preferred corridor established at the end of phase 1, the study area for the phase 2 demand forecasting focused on the preferred HSR corridor. This is illustrated in **Figure 1**, which also shows the sector breakdown which is used in the analyses of the base travel market.

Figure 1 The study area showing the analysis sectors



3.0 Establishing the base travel market in the study area

3.1 NVS data background

Since 2005, interviews have been conducted on an annual basis with approximately 120,000 Australian residents, aged 15 years and over. This sample was increased from 80,000 interviews annually between 1998 and 2004 in order to enhance estimates for smaller states/territories at the regional level. Respondents are interviewed in their homes using random digit dialling and a Computer Assisted Telephone Interviewing system¹. Respondents interviewed in the NVS are randomly sampled to be representative of the Australian population, based on place of residence, age and gender.

Interviews are conducted with people who have travelled for purposes including holiday, visiting friends and relatives, business, education and employment. The survey questions include the destination, purpose, mode of transport, travel party and demographics.

Expansion weights for the NVS are calculated on an individual trip basis. They take into account the age, gender and place of origin of the respondent, the size of the household in which they live, month of travel, the recall period applicable to the trip (for example, seven days for day trips, 28 days for overnight trips and three months for overseas trips) and the number of interviews with a return date in this recall period. The NVS is benchmarked to population estimates of those aged 15 years and over.

3.2 NVS data used for this study

The phase 2 base travel demands have been based on 11 years of NVS data collected between 2000 and 2010. This data comprises a total sample of over 146,000 day trips and overnight trips, which represents when expanded, 152 million trips in the base travel market in 2009.

The base market encompasses trips greater than 50 kilometres within the study area with an end in one of the major towns and cities: Melbourne, Sydney, Brisbane, Canberra, Newcastle, Wollongong and Gold Coast.

The following trips are considered unlikely to transfer to HSR and have been omitted from the base market:

- Short distance (less than 50 kilometres) and intra-urban/metropolitan area travel, amounting to 37.9 million trips annually.
- Trips within the regional 'intermediate' sectors, mainly by car between small towns and rural areas, amounting to 21.8 million trips annually.
- Longer trips between these 'intermediate' sectors, amounting to 5.4 million trips annually. Longer trips may transfer to HSR and, to this extent, HSR forecasts are conservative.
- Journeys to and from places that are external to the study area.

The resulting estimated size of the annual base market of trips² in the east coast corridor in 2009 is 152 million.

In combining the NVS data for all 11 years, more weight was placed on the more recent surveys and those with larger survey samples, and the combined data base was controlled to reproduce the overall characteristics of 2009. The NVS omits the travel of children under 15 years old and that of international visitors and factors have been devised from NVS data and other information provided by the Bureau of Infrastructure, Transport and Regional Economics (BITRE) to estimate this missing travel.

All statistics relating to the base market in this section, in the tables and figures, are derived from the processed NVS data. All tables and figures in the remainder of this section are derived from the NVS data as processed for this study and thus relate to the base travel market. Except for **Figure 2** to

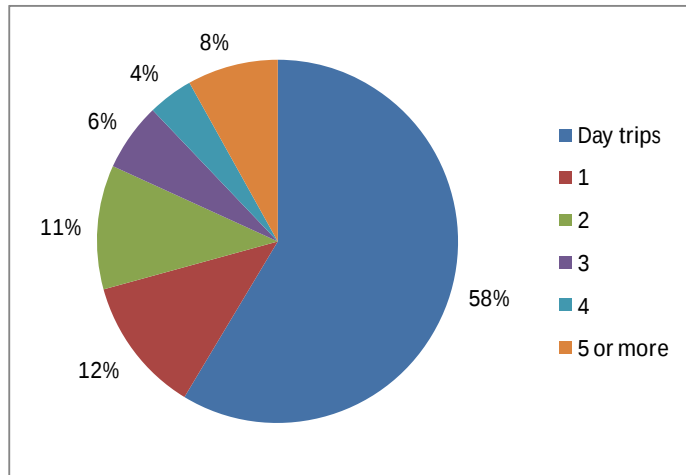
¹ The NVS was introduced in January 1998 replacing the Domestic Tourism Monitor. The descriptions which follow are taken from published information by Tourism Research Australia.

² A trip is a journey from one place to another by a single person. If three people travel together, these account for three trips. Most journeys involve an outbound and return journey, counting as two separate trips.

Figure 5, which tabulate the (unexpanded) interviews, all tables and figures are of expanded data (152 million trips).

Concerning the broad characteristics of the travel and travellers, 58 per cent were daytrips and 41 per cent involved an overnight stay (**Figure 2**), most overnight stays being for one or two nights.

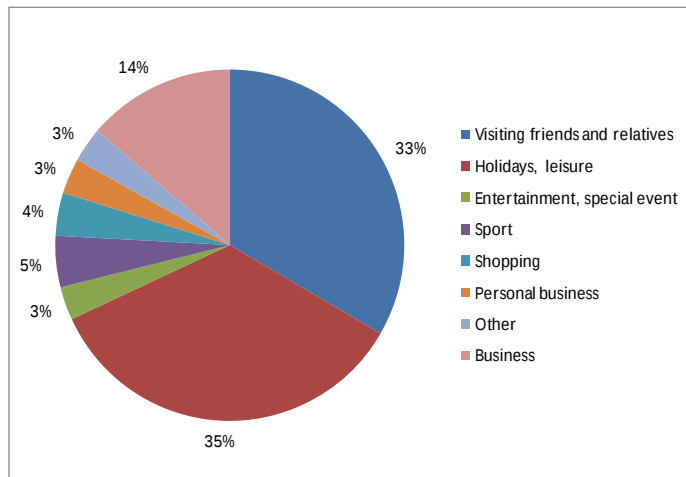
Figure 2 Distribution of east coast travel demand by nights away



Note: Number may not add to 100 per cent due to rounding

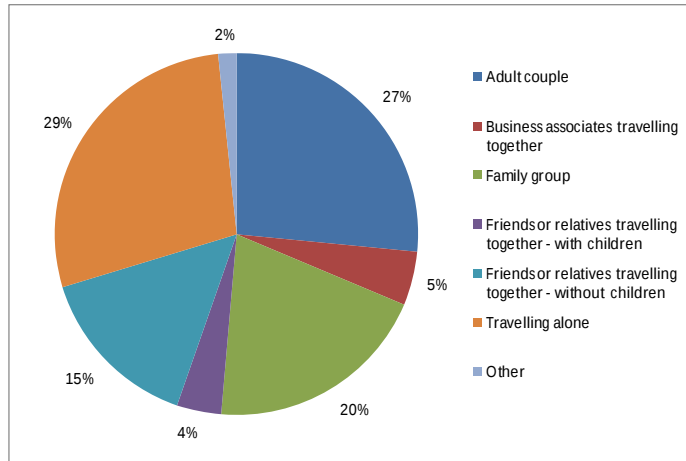
Approximately 14 per cent were trips on business (**Figure 3**), the remainder being for other purposes, almost 70 per cent being for holidays or visiting friends and relatives.

Figure 3 Distribution of east coast travel demand by the purpose of the trip



Information on the travel group is available for overnight stays (**Figure 4**). People travelling alone account for almost 30 per cent of all such trips, with a further 27 per cent being an adult couple (related), family groups account for 20 per cent of all journeys.

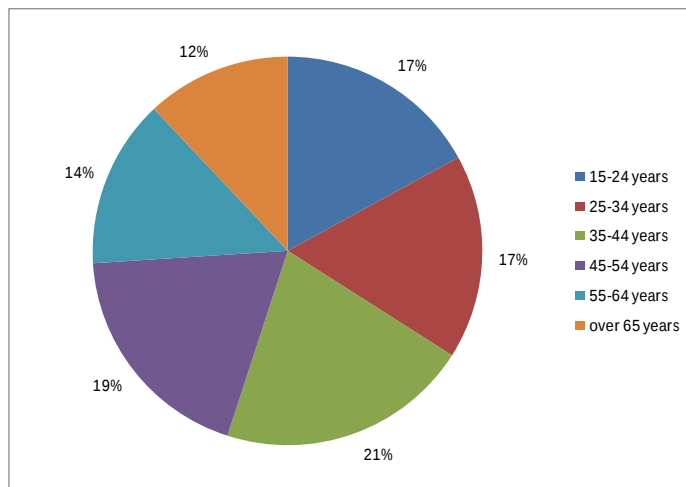
Figure 4 Distribution of east coast travel demand by the nature of the travel group (for journeys involving an overnight stay)



Note: Number may not add to 100 per cent due to rounding

There is an even distribution by age group (of those who responded to the survey) up to the 45–54 years age group; thereafter, the proportion of travellers reduces with increasing age (**Figure 5**). There is also an even split by gender (52 per cent being male).

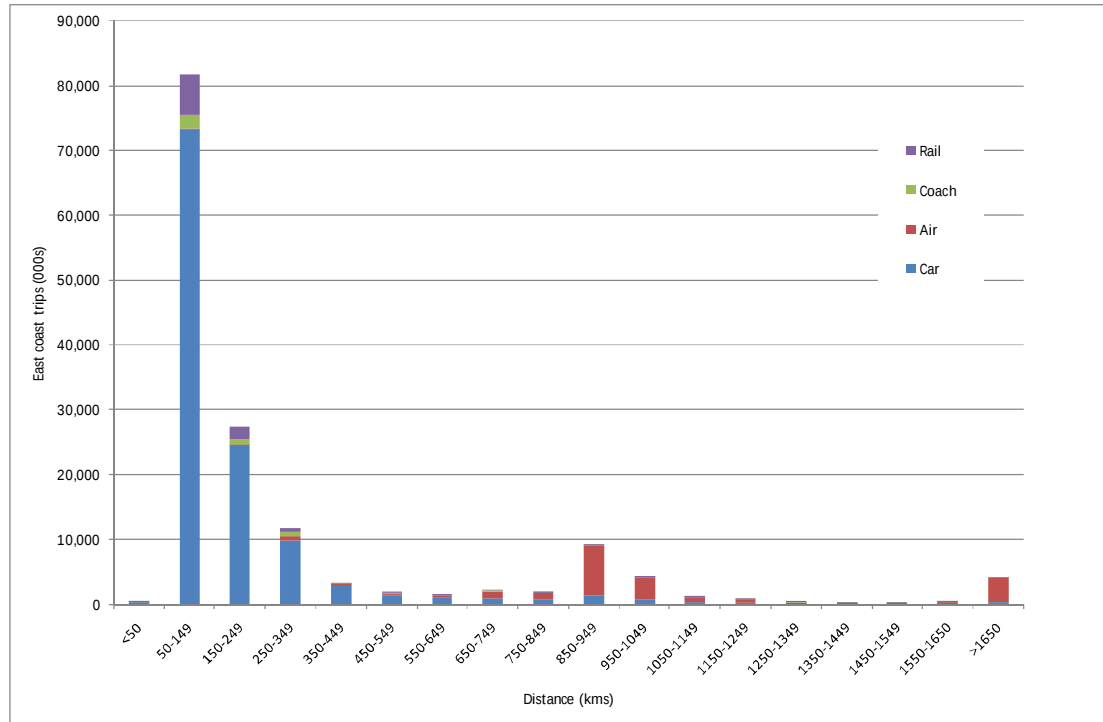
Figure 5 Distribution of east coast travel demand by age of survey respondent



Concerning the temporal distribution of travel demand, travel across the months of the year is broadly uniform, with the only significant peaks being around the Christmas/New Year and Easter holiday periods, while 54 per cent of trips occur on weekdays and 46 per cent at the weekend.

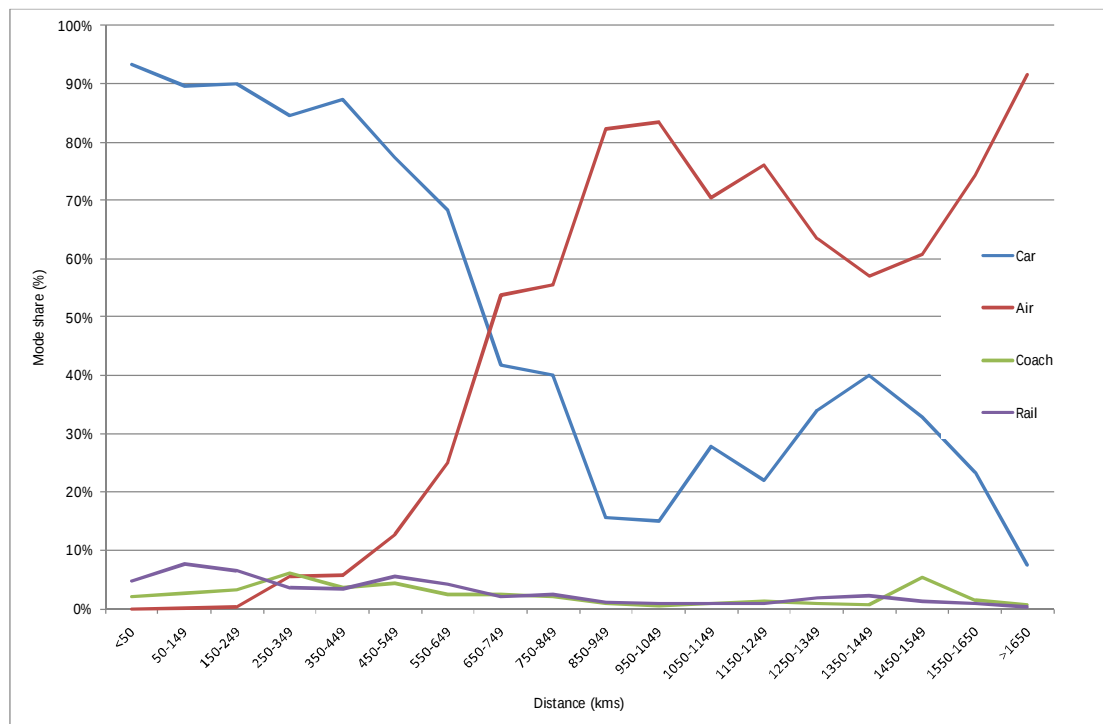
The overall patterns of travel demand in the east coast corridor by the length of the journey and transport mode are summarised in **Figure 6**. Short distance trips predominate (50-150 kilometres), and the peaks of demand for intercity travel (850-1,050 kilometres and above 1,650 kilometres) are apparent. For these long journeys air travel predominates whereas for shorter journeys, car travel predominates. How mode shares vary with distance is illustrated in **Figure 7**. Car travel accounts for most travel demand for journeys up to 450 kilometres. Then, as distances lengthen, air travel increasingly accounts for a greater proportion of travel demand, but it is also noticeable that car use continues to be significant even at the very long distances.

Figure 6 Total travel demand in the east coast corridor by distance band and mode



Source: NVS (2009).

Figure 7 Mode shares by distance band



4.0 The base market

In the demand forecasting 'intercity' trips are distinguished from 'long regional' and 'short regional' trips, defined in **Table 1**, as are two trip purposes (business and non-business, **Table 2**). Additional segmentations by party size and duration of stay have been investigated, but these have not been used because the limited benefits of the additional segments were judged to be outweighed by the extra complication.

Table 1 The geographical market classification

Sub-market	Description
Intercity	Journeys over 600 km between the main towns and cities.
Long regional	All other journeys greater than 250 km (includes Sydney-Canberra journeys).
Short regional	Journeys less than 250 km.

Table 2 Trip classifications

Trip purpose	Trips included in category
Business	Work, business, conferences/exhibitions/conventions/trade fairs, training and research (employed – not students).
Non-business	Visiting friends or relatives, holidays/leisure, entertainment/festivals, sport (participating and spectating), shopping, education (students), personal or health-related appointment.

Source: NVS (2009).

The distribution of corridor journeys by these distance and purpose categories is given in **Table 3**. Note that overall, 14 per cent of travel is on business, and being longer trips on average, business travel accounts for almost 40 per cent of intercity trips and less than 10 per cent of short regional travel.

Table 3 Distribution of travel by purpose and distance segments (000s, 2009)

Purpose	Geographic segment			
	Intercity	Long regional	Short regional	Total
Business	6,930	4,160	9,440	20,530
Non-business	11,280	19,960	100,010	131,250
Total	18,210	24,120	109,450	151,780

Note: Totals may differ because of rounding.

The overall distribution of the travel demand in the corridor by mode and purpose is given in **Table 4**.

Air travel is the dominant mode for intercity trips, particularly business, and remains an important mode for long regional business trips. In contrast, car travel accounts for over 90 per cent of short regional trips.

Table 4 Mode of transport of east coast travel by purpose and distance segment (2009)

Purpose	Mode of transport				Total trips (000s)
	Air	Car	Rail	Coach	
Intercity					
Business	96%	4%	0%	0%	6,930
Non-business	79%	19%	1%	1%	11,280
Long regional					
Business	42%	55%	2%	2%	4,160
Non-business	15%	76%	4%	5%	19,960
Short regional					
Business	0%	91%	7%	2%	9,440
Non-business	0%	90%	7%	3%	100,010
Total trips (000s)	20,500	118,000	9,100	4,200	151,780

Note: Totals may differ because of rounding.

The geographic pattern of the 152 million trips in the east coast corridor in 2009 is summarised in **Table 5** by the 10 analysis sectors, and illustrated in **Figure 8**. These are the total journeys in both directions between each pair of sectors. The short distance, intra and inter regional journeys described earlier which have not been considered because they are unlikely to significantly influence HSR patronage are identified by an 'x'. The term 'intermediate' refers to the communities along the corridor between these identified town and cities.

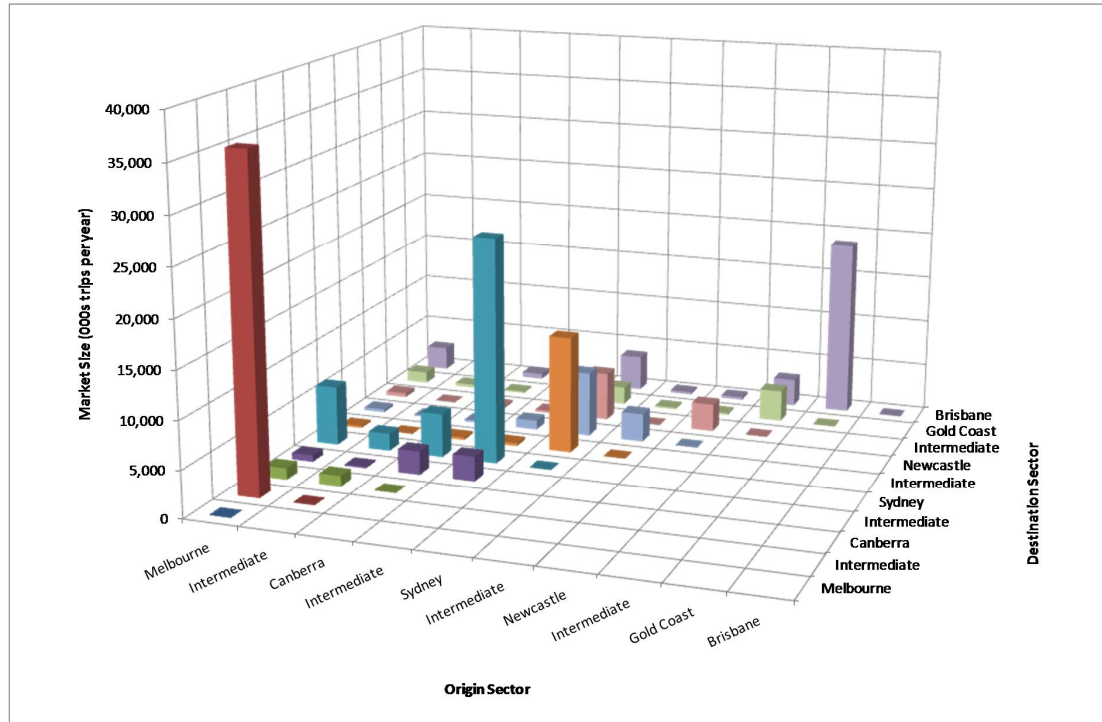
The largest demands are those relatively short movements between the major cities and their adjacent sectors. For example, the three tallest bars in the figure are for the 35 million trips between Melbourne and the intermediate area between Melbourne and Canberra, the 24 million trips between Sydney and the adjacent sector south of Sydney between Sydney and Canberra, and the 19 million trips between the Gold Coast and Brisbane. Other large demands are intercity, with over six million trips between Sydney and Melbourne and almost four million trips between Sydney and Brisbane.

Table 5 Phase 2 2009 base matrix (000s trips)

Sectors	Brisbane	Gold Coast	Intermediate	Newcastle	Intermediate	Sydney	Intermediate	Canberra	Intermediate	Melbourne	Total
Brisbane	X	18,780	2,920	280	240	3,780	580	560	500	2,480	
Gold Coast		X	3,340	200	180	1,880	400	160	340	1,200	
Intermediate			X	2,960	X	5,160	220	240	X	440	
Newcastle				X	3,020	6,900	980	220	140	320	
Intermediate					X	12,400	300	260	X	220	
Sydney						X	23,880	4,640	1,860	6,300	
Intermediate							2,640*	2,500	160	700	
Canberra								X	1,120	1,240	
Intermediate									X	35,180	
Melbourne										X	
Total											151,780

*Trips of over 50 kilometres between Wollongong and the remainder of the intermediate area in which it is included.

Figure 8 The geographic distribution of east coast travel demand (2009)



Car accounts for most travel in the corridor (**Table 6**) and typically over 80 per cent of the medium and shorter distance journeys (shaded in the table).

Table 6 Car share of east coast travel demand (2009)

Sectors	Melbourne	Intermediate	Canberra	Intermediate	Sydney	Intermediate	Newcastle	Intermediate	Gold Coast	Brisbane	Total
Melbourne		88%	29%	31%	11%	18%	25%	27%	7%	6%	78%
Intermediate			89%	88%	60%		86%		29%	28%	
Canberra				96%	78%	85%	82%	75%	25%	14%	
Intermediate				96%	87%	87%	90%	82%	40%	38%	
Sydney						85%	85%	77%	22%	12%	
Intermediate							95%		44%	33%	
Newcastle								95%	50%	36%	
Intermediate									96%	92%	
Gold Coast										94%	
Brisbane											
Total											78%

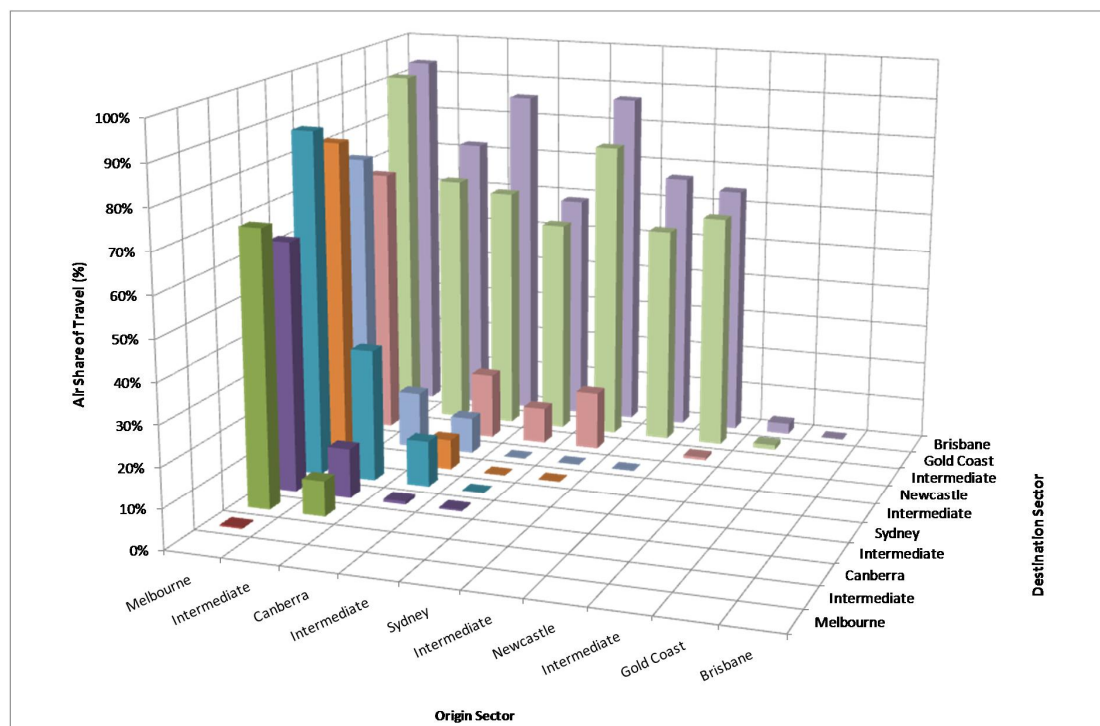
For the long distance journeys to and from the main cities, the air share of travel demand is very high (Table 7 illustrated in Figure 9), usually in excess of 70 per cent. The air share is between 60 per cent and 95 per cent for trips between Melbourne and Canberra, and between Melbourne and more distant sectors north of Canberra. Similarly, it is high between Brisbane and Sydney and between Brisbane and more distant sectors south of Sydney.

Of the highest air mode shares, around 90 per cent are between the three main cities (shaded in the table), which are long journeys with very high air service levels and airport accessibility. The air shares are also high for many of the other longer journeys.

Table 7 Air share of east coast travel demand (2009)

Sectors	Melbourne	Intermediate	Canberra	Intermediate	Sydney	Intermediate	Newcastle	Intermediate	Gold Coast	Brisbane	Total
Melbourne		0%	69%	63%	87%	82%	75%	68%	92%	94%	13%
Intermediate			9%	13%	33%		14%		65%	72%	
Canberra				1%	12%	8%	9%	17%	63%	86%	
Intermediate				0%	0%	0%	0%	9%	55%	59%	
Sydney						0%	0%	15%	77%	87%	
Intermediate							0%		56%	67%	
Newcastle								1%	60%	64%	
Intermediate									1%	3%	
Gold Coast										0%	
Brisbane											
Total											

Figure 9 Air share of east coast travel demand (2009)

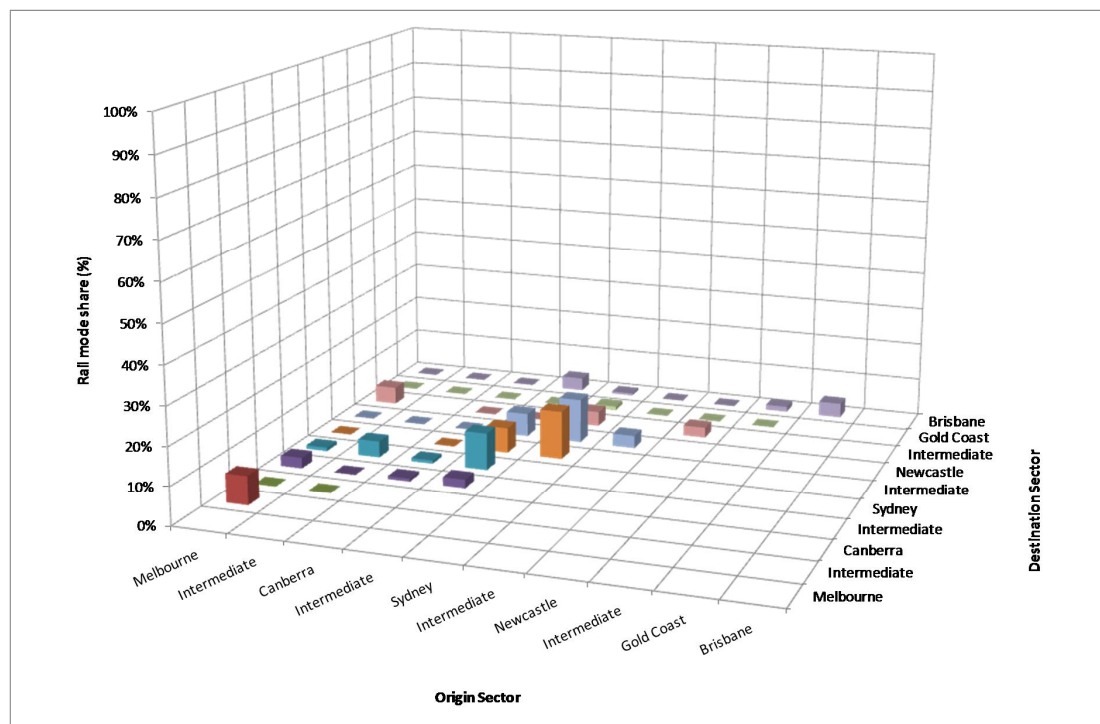


Conventional rail has a share of the base market in the short distance corridors around Sydney and Melbourne (**Table 8**, illustrated in **Figure 10**).

Table 8 Rail share of east coast travel demand (2009)

Sectors	Melbourne	Intermediate	Canberra	Intermediate	Sydney	Intermediate	Newcastle	Intermediate	Gold Coast	Brisbane
Melbourne		8%	0%	3%	1%	0%	0%	5%	0%	0%
Intermediate			0%	0%	4%		0%		0%	0%
Canberra				1%	1%	0%	0%	0%	0%	0%
Intermediate				2%	10%	7%	6%	0%	0%	3%
Sydney						13%	12%	4%	1%	1%
Intermediate							3%		0%	0%
Newcastle								3%	0%	0%
Intermediate									0%	1%
Gold Coast										4%
Brisbane										
										6%

Figure 10 Rail share of east coast travel demand (2009)

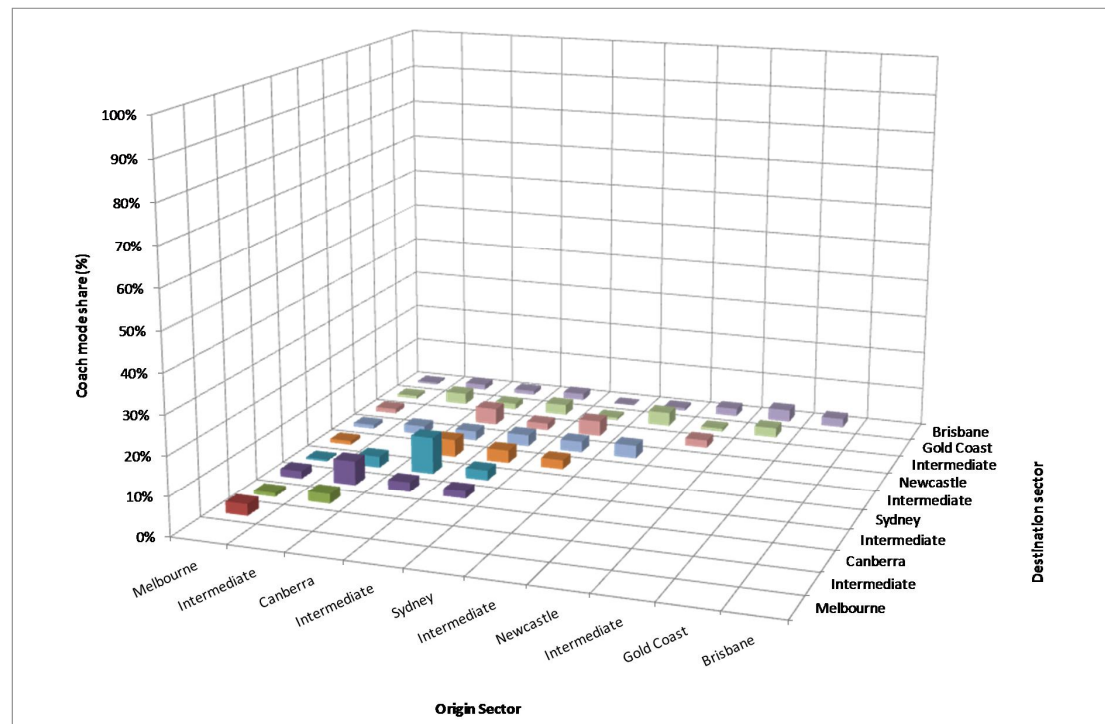


Coach travel accounts for a small part of the base market in the corridor, its share being highest between Sydney and Canberra (Table 9 and Figure 11).

Table 9 Coach share of east coast travel demand (2009)

Sectors	Melbourne	Intermediate	Canberra	Intermediate	Sydney	Intermediate	Newcastle	Intermediate	Gold Coast	Brisbane	Total
Melbourne		3%	1%	2%	0%	1%	1%	1%	1%	0%	3%
Intermediate			3%	6%	3%		2%		3%	1%	
Canberra				2%	10%	5%	2%	4%	2%	1%	
Intermediate				2%	3%	3%	3%	2%	3%	2%	
Sydney						2%	3%	4%	1%	0%	
Intermediate							3%		4%	1%	
Newcastle								2%	1%	2%	
Intermediate									2%	3%	
Gold Coast										2%	
Brisbane											
Total											

Figure 11 Coach share of east coast travel demand (2009)



5.0 Verification of the base market

5.1 Background

Travel surveys involving contacting people at their homes can be subject to biases and uncertainties and it is a consequently accepted practice to compare the results of such surveys with independent travel demand data relating directly to the relevant transport modes. Typically, this would be counts of public transport passengers and road traffic.

In phase 1 of the study, independent passenger count data for air and rail travel in the corridor was available to validate these aspects of the base market data. This verification is repeated below for the new base market estimate.

Although base car travel demands were also compared with traffic counts on the main strategic highways, this was not an effective validation because the medium and long distance traffic which is the market for HSR could not be distinguished from other components of the traffic streams.

Regional diversion to HSR was predicted to be an important factor in phase 1 and much of this patronage was forecast to be diverted from car travel. Evidence from the household travel surveys used in developing metropolitan transport models also emphasises the particular risks of bias in car travel demand estimates from household surveys³.

For these reasons, a large scale number plate matching survey was commissioned between Melbourne and Sydney to provide independent data which could be used to validate the base car travel demand estimates derived from the NVS.

5.2 Verification against independent rail and air travel data

Reliable independent information on current rail and air travel demands was obtained from CountryLink and BITRE, based on ticketing data. These sources are compared with the base demands in **Table 10** and **Table 11**.

For the relatively small numbers of rail trips, the base travel market estimates match the CountryLink values.

Table 10 2009 Annual rail volumes by route

Route	Phase 2 base market	CountryLink	Difference percentage
Sydney-Melbourne	68,000	75,000	-9
Brisbane-Sydney	26,000	27,000	-4
Sydney-Canberra	53,000	55,000	-4

The base market estimates for non-transfer air passengers are lower than the total air passenger counts, partly because transfer passengers are included in the counts but are not represented in the base market estimates⁴. The proportion of transfers on some of the key domestic routes has been obtained from an airline ticketing data base (MIDT), as shown in **Table 11**. Together, the evidence from these independent data sources suggests that the base market estimates of non-transfer air passengers on these routes are reasonable, the exception being the two Gold Coast routes where the base market may underestimate the air demands.

³ Ashley et al, *Recent information on the under-reporting of trips in household travel surveys*, Australasian Transport Research Forum, 2009.

⁴ Trips to/from places outside the study area are not included in the base market estimates which includes air journeys outside the study area (including international) involving a connecting leg within the study area. Air journeys within the study area which involve a transfer are generally included in the base market, but have been excluded from the base market totals in the table.

Table 11 2009 Base air volumes by route (millions)

Route	Phase 2 base market (direct, non-transfer trips)	Observed route passengers ⁵	Difference Percentage (%)	Estimated transfer percentage ⁶
Sydney-Melbourne	5.5	7.1	-23	15
Brisbane-Sydney	3.3	4.3	-24	22
Brisbane-Melbourne	2.3	2.7	-14	9
Gold Coast-Sydney	1.4	2.1	-31	17
Gold Coast-Melbourne	1.1	1.6	-31	0
Canberra-Melbourne	0.9	1.1	-21	12
Sydney-Canberra	0.6	1.0	-45	36

5.3 Verification against independent car travel data: the registration number survey

5.3.1 The registration number survey

Because traffic counts alone could not provide a convincing verification of the NVS-based patterns of car travel in the corridor, a large-scale vehicle registration number survey was commissioned as part of this study (described in greater detail in **Appendix 1C**). The chosen location for the survey was the southern half of the corridor, between Sydney and Melbourne. Should significant biases be found in the NVS-based estimates of car travel, the required car travel demand adjustment factors would be assumed also to apply to the northern half of the corridor between Brisbane and Sydney.

The nature of the information sought and the scale of the survey, which may be unprecedented, imposed constraints on its design:

- Some long distance car travel is likely to occur in part at night, implying the need for a 24 hour survey period.
- Much of this travel is at the weekends (**Appendix 3; Section 3.2**), implying that the surveys should encompass Saturday and/or Sunday.
- There was a need to survey a range of car journey lengths in case biases in the NVS data were a function of journey distance.
- The very long distance journeys by car, especially those between Melbourne and Sydney, could be expected to be quite rare.

In order to meet these requirements, surveys were commissioned which used specialised video equipment that could capture number plates both during the day and at night, and target sample size requirements were developed based on the long distance travel demands in the highway corridor between Melbourne and Sydney derived from the NVS.

The survey was carried out by Austraffic and occurred over five days, for the full 24 hours, capturing northbound traffic along the Hume Highway. The survey locations (as indicated in **Table 12** and **Figure 12**) were designed to estimate the six different light vehicle travel flows identified in **Table 13**, covering a range of travel distances.

The captured number plate data was later reviewed manually from the video footage and the number plate data was entered into a program which matched the number plates between the survey stations. Overall, 289,888 vehicles were observed and 95.4 per cent of plates were captured.

⁵ BITRE, *Domestic Airline Activity Statistics*, 2009.

⁶ Derived from the 2010 MIDT airline ticketing data base.

Table 12 Number plate survey locations

Site No.	Description
1	North of Seymour
2	South of Wodonga
3	North of Albury
4	South of Yass
5	South of Goulburn
6	South of Campbelltown

Figure 12 Survey locations

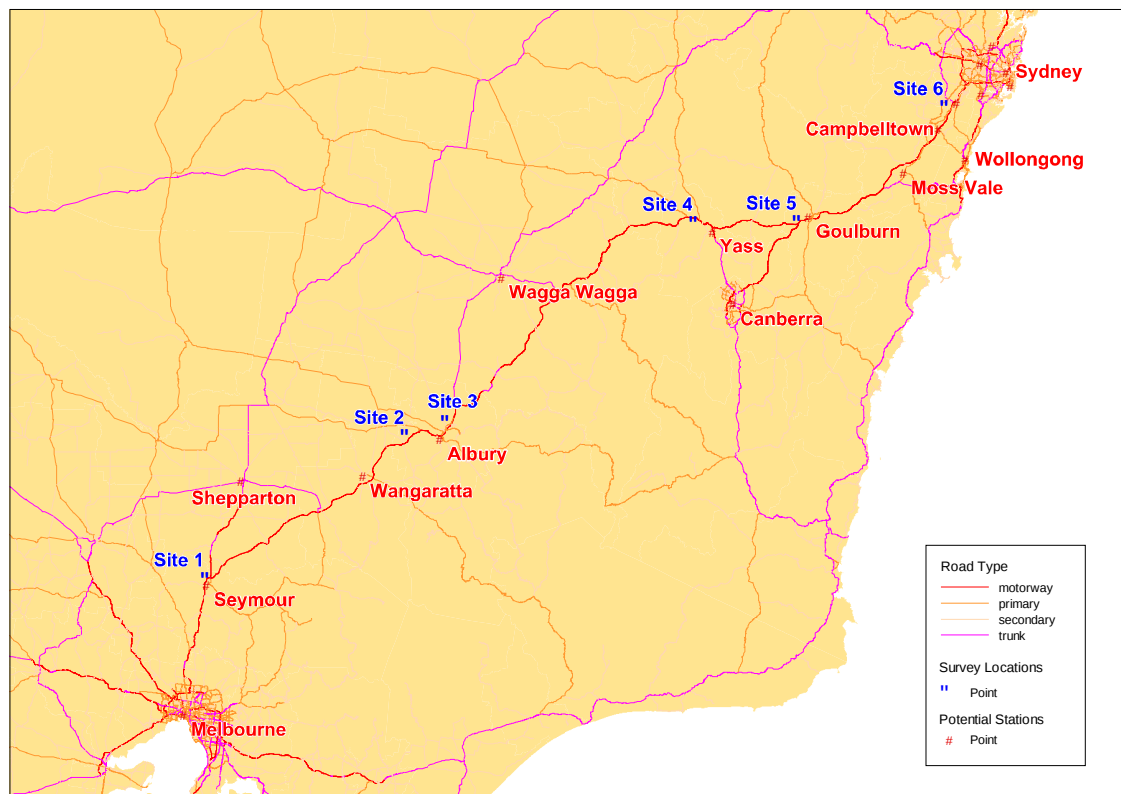


Table 13 Light vehicle flows surveyed

Targeted travel demand	Centre to centre journey distance
Melbourne-Albury	~300 km
Melbourne-Canberra	~700 km
Melbourne-Sydney	~900 km
Albury-Canberra	~350 km
Albury-Sydney	~600 km
Canberra-Sydney	~300 km

The data was matched to find identical plates at each pair of stations by algorithms which also allowed for very close matches, within a 24 hour maximum match time.

The matched registration numbers were processed to extract the six vehicle demand flows. As an example, on Monday 7 December 2011, 1,279 light vehicles were observed travelling between the Seymour site and the Wodonga site, 753 of which were also observed at the Albury site. Thus, it was concluded that 526 vehicles (the difference between these two observations) left the Hume Highway to go to the Albury-Wodonga area. That is, 526 vehicles travelled from the Seymour site catchment (i.e. the Melbourne area) to Albury-Wodonga. Similar calculations were made on the number plate data to establish each of the six demand flows in the table.

The demand flows thus derived from number plate survey data were expanded to represent a full seven day week and a full year based on the profile of traffic demands at two continuous traffic monitoring sites on the Hume Highway.

5.3.2 Verification of the base market against the number plate data

The NVS car travel data was processed to give the base market estimates for the six demand flows in **Table 14**. This involved making assumptions on the catchment areas of each of the survey stations and the average occupancy of the cars.

The comparison of the car travel in the corridor between Sydney and Melbourne estimated from the NVS data and the registration number survey is given in **Table 14**. The overall volume of traffic is closely matched, but there are variations for the different journeys. The largest variation is for the longest car journeys between Sydney and Melbourne where the survey will have missed trips via alternative routes such as the coast and some trips involving stopovers en route. Otherwise, the estimate of the order of magnitude of the base market car travel on each of these journeys is reassuringly consistent with the survey estimates.

The outstanding differences in flows at the sites are due to a combination of the data uncertainties associated with both surveys and also the inherent uncertainties in the comparison to two such different surveys. In regard to the latter point, it is neither possible to identify the precise catchment of each road survey site nor to be sure the zonal catchment areas that have been used for processing the NVS data precisely identify the catchments. Consequently, the scenario testing in **Appendix 1G** allows for uncertainties in the base market estimates including specifically those associated with current car travel demands.

Table 14 2009 Base car volumes by route (annual vehicles)

Journey	Phase 2 base market	Number plate survey
Melbourne–Albury	625,900	492,600
Melbourne–Canberra	203,400	163,200
Melbourne–Sydney	527,800	258,700
Albury–Canberra	60,800	80,700
Albury–Sydney	85,300	71,000
Canberra–Sydney	2,200,700	2,638,900
Total	3,703,900	3,705,200

5.4 Distributions of travel origins and destinations between CBDs and suburban areas in major metropolitan areas

The distributions of travel demand within the metropolitan areas in the base matrices are illustrated in **Figure 13** to **Figure 18** separately for residents of each city and visitors to each city. In all three cities, residents' trip origins and destinations are spread around the metropolitan areas, whereas there is a concentration of visitor trips in the city CBD.

Figure 13 Distribution of Sydney residents' trips in the base matrix

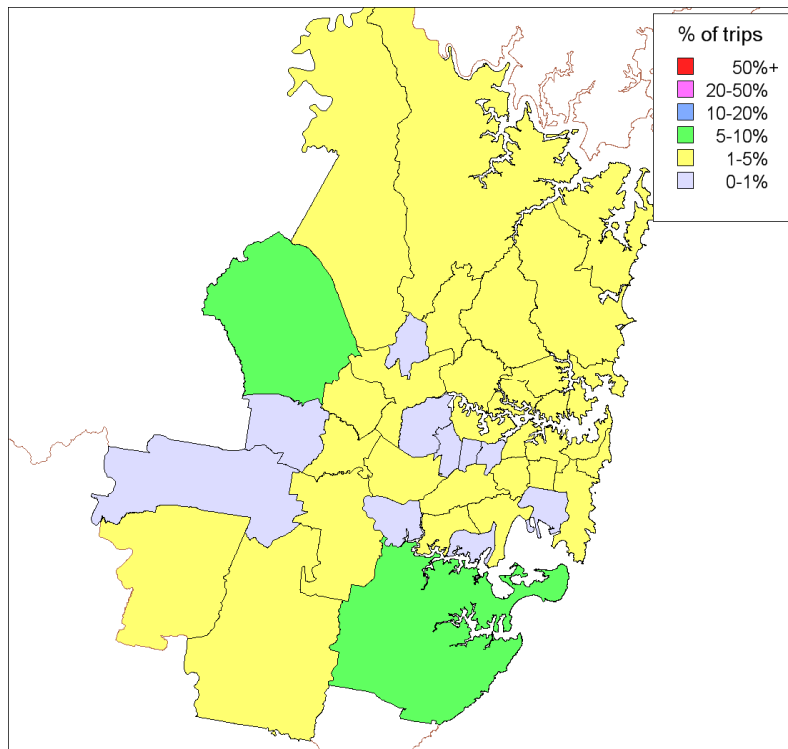


Figure 14 Distribution of Sydney visitors' trips in the base matrix

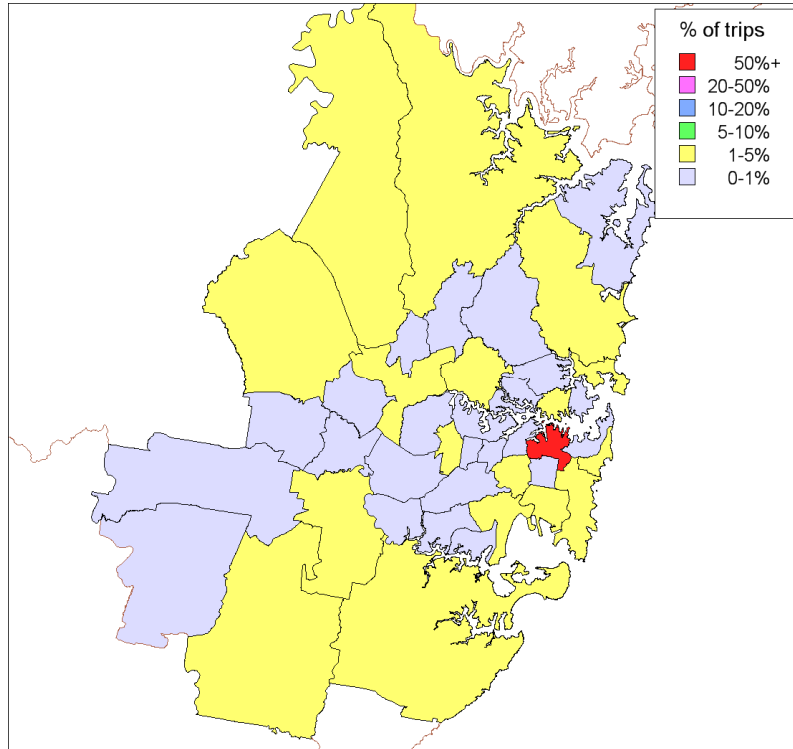


Figure 15 Distribution of Melbourne residents' trips in the base matrix

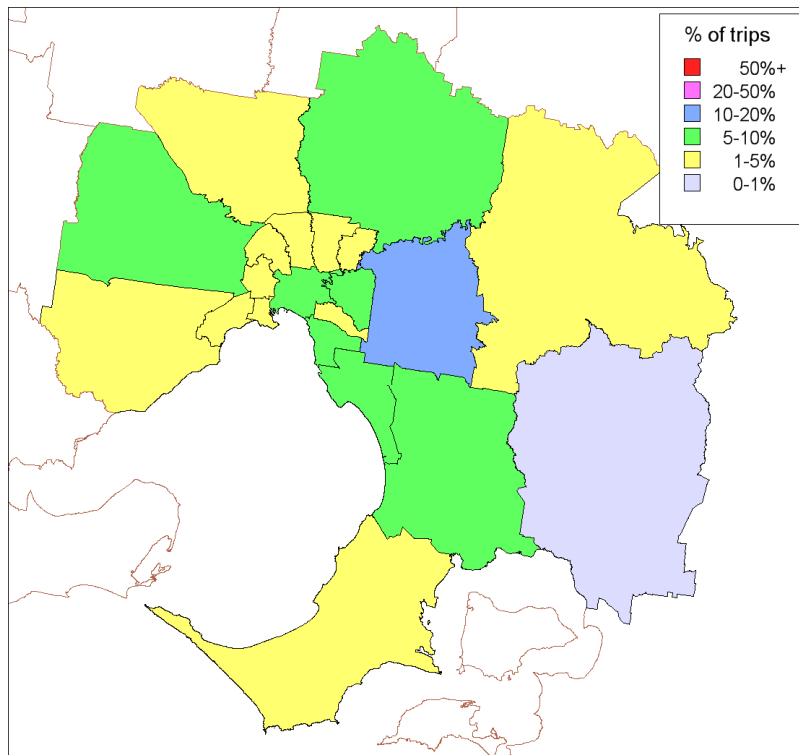


Figure 16 Distribution of Melbourne visitors' trips in the base matrix

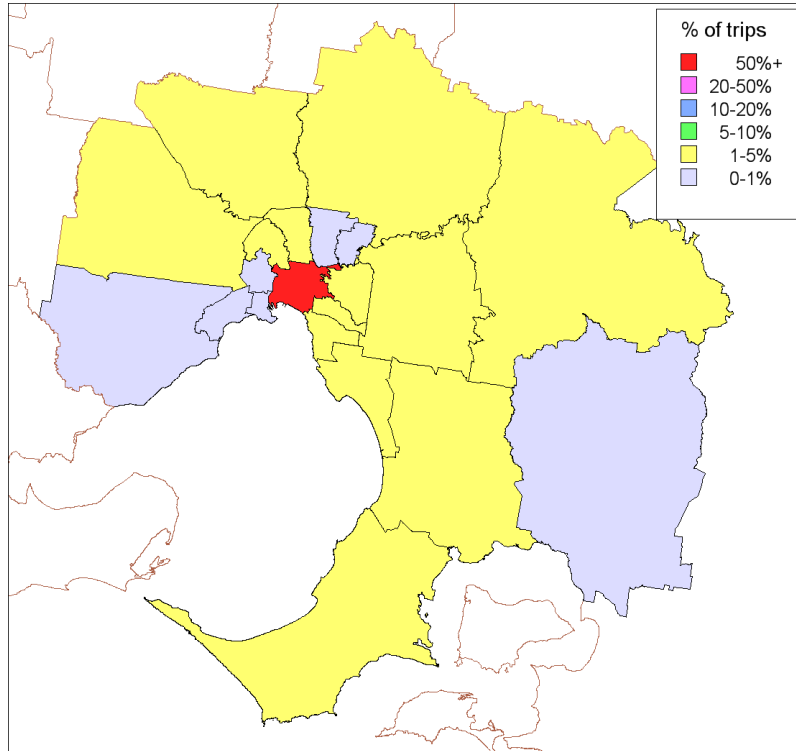


Figure 17 Distribution of Brisbane residents' trips in the base matrix

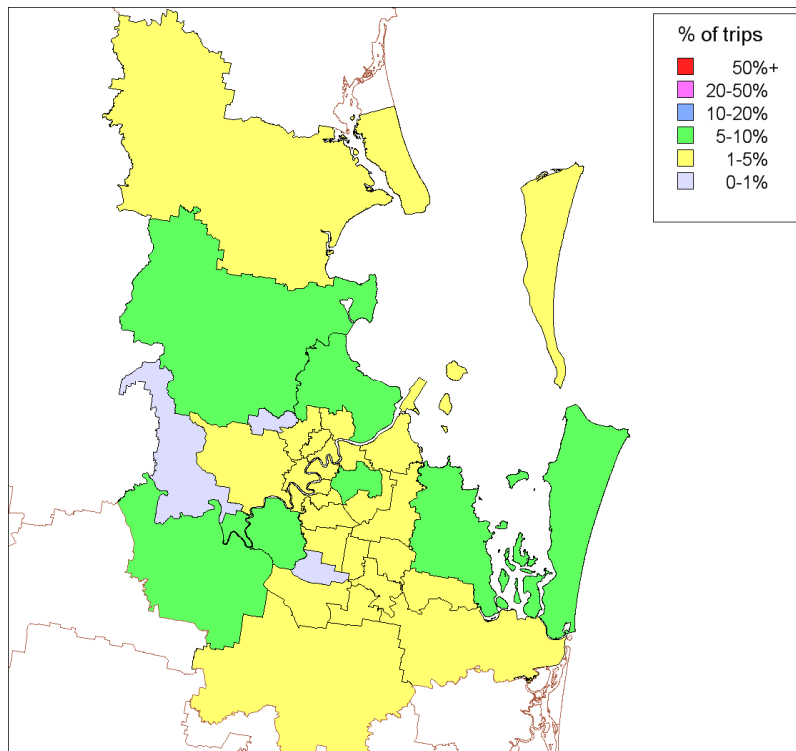
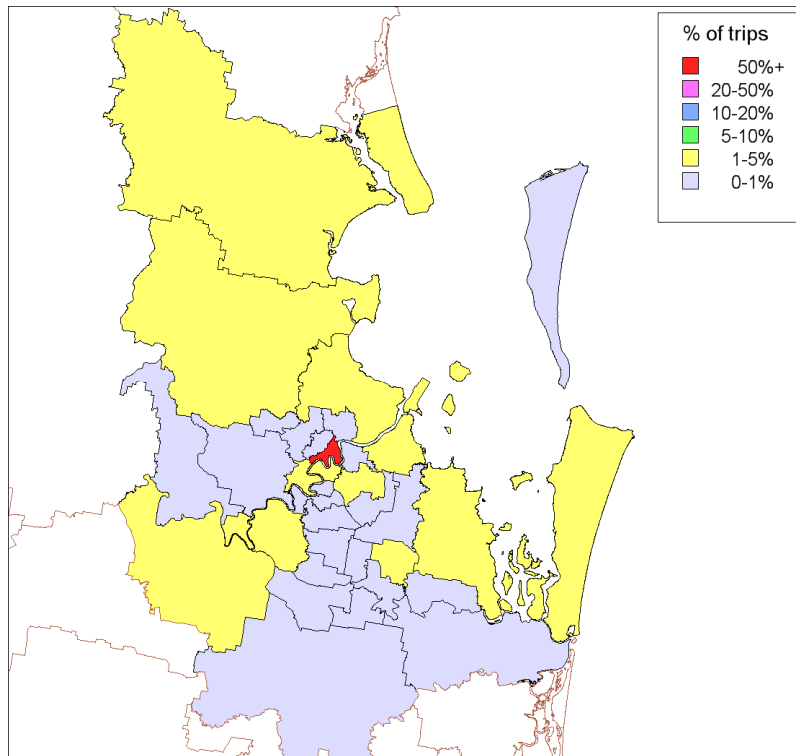


Figure 18 Distribution of Brisbane visitors' trips in the base matrix



The balance of metropolitan journeys between the CBD and outer areas is an important factor in determining the market for HSR. There is some available information on the distributions of the ground origins of trips to and from Brisbane and Sydney Airports which has been compared with the NVS data.

The distribution of the ground origins of all trips to and from Brisbane Airport is published in the *Brisbane Airport 2009 Master Plan*⁷. This does not distinguish residents from visitors and also encompasses international air passenger trips and other non-air passenger trips (such as the commuting of airport workers). This indicates that 47 per cent of trips are to/from the inner area of Brisbane. The equivalent figures for domestic air passengers in the east coast corridor from the phase 2 base matrices are 42 per cent. Thus, although these two data sources are not consistent in scope, the overall proportion of NVS base market trips generated in the inner and CBD areas of Brisbane is not incompatible with the airport data.

Similar information for Sydney airport is available from a 2006 survey of airport users, which Sydney Airport Corporation (SACL) has given approval to use. The earlier Speedrail surveys also provide additional data on both air and car travel in the Sydney-Canberra corridor (**Table 15**)⁸. Again, these data sources are not fully consistent in scope with the NVS base matrix, but the comparisons do not suggest that there is any bias in the proportion of trips starting or ending in central Sydney in the phase 2 base matrices.

⁷ Brisbane Airport Corporation, *Brisbane Airport 2009 Master Plan*, 2009.

⁸ SKM & MVA, *Speedrail Patronage and Revenue Forecasts, Supplementary to final report*, 1999.

Table 15 2009 Proportion of journeys beginning and ending in central Sydney: the phase 2 base matrices compared with Speedrail data and SACL air passenger surveys

Segment	Phase 2 2009 base matrices	Speedrail 1997/8 base matrices ⁹	SACL 2006 Domestic air passenger surveys ¹⁰
Car travel			
Business	42%	41%	-
Other	34%	36%	-
Air travel			
Business	63%	68%	49%
Other	53%	62%	53%

6.0 Verification conclusions

While there are individual differences, the verification exercises have demonstrated a strong overall consistency between the phase 2 base matrices and the independent data sources covering rail, air and car travel demands in the corridor.

⁹ The Speedrail data is for travel in the Sydney-Canberra corridor.

¹⁰ The SACL data is for all domestic air travel at Sydney Airport.

Appendix 1C

Number plate survey

Appendix 1C

Number plate survey

Prepared for

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March 2013

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March 2013

Quality information

Document	Appendix 1C
Ref	60238250-1.0-REP-0101-1C
Date	March 2013

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1.0 Introduction and objectives

Because traffic counts alone could not provide a convincing verification of the National Visitor Survey (NVS)-based patterns of current car travel in the corridor, a large-scale vehicle registration number survey was commissioned as part of this study. The chosen location for the survey was the southern half of the corridor, between Sydney and Melbourne.

The nature of the information sought and the scale of the survey, which may be unprecedented, imposed constraints on its design:

- Some long distance car travel is likely to occur in part at night, which implied the need for a 24 hour survey period.
- Much of this travel occurs at the weekends, which implied that the surveys should encompass Saturdays and/or Sundays.
- There was a need to survey a range of car journey lengths in case biases in the NVS data were a function of journey distance.
- The very long distance journeys by car, especially those between Melbourne and Sydney, were expected to be quite rare.

2.0 Survey background

The number plate survey was designed to estimate the number of car journeys between the survey locations – broadly, Melbourne, Albury-Wodonga, Canberra and Sydney. Austraffic was commissioned to conduct the survey of vehicles on the Hume Freeway/Highway. While the scope of the study was light vehicles, this was extended for the Federal Department of Infrastructure and Transport to include Heavy Vehicles. The survey was conducted in the north-easterly direction.

3.0 Methodology

Austraffic has a proven methodology for conducting Origin/Destination (OD) video surveys. Video surveys use specialised video equipment that captures vision of number plates during the day and night. For this study, the survey comprised the following survey sites in **Table 1**.

Table 1 Number plate survey locations

Site no.	Description (all north-east-bound on Hume Freeway)
1	North of Seymour, just west of Seymour-Avenel Rd
2	South of Wodonga, east of Indigo Creek Rd
3	North of Albury, north of Ettamogah Rd
4	South of Yass, north of on-ramp to Yass Valley Way
5	South of Goulburn, south of Drews Rd
6	South of Campbelltown, between Menangle Rd and Narellan Rd

The Hume Highway video survey was installed on 5 and 6 December 2011. An onsite job safety analysis was conducted in line with Austraffic's business management system. The sites were positioned with regard to safety considerations and the need to find appropriate roadside poles to secure the equipment to that were not located beyond the next nearest intersection. All video sites were checked prior to actual commencement of the survey period to ensure the video was in focus and recording correctly. The video equipment was synchronised to ensure accuracy of data. All survey equipment was checked regularly for about 16 hours each day. Batteries and recording drives/cards were replaced daily. On completion of the survey on 12 December 2011, the video equipment was collected.

The survey was designed to capture number plates over five days from Wednesday 7 December - Sunday 11 December 2011 inclusive. Extra video was captured at stations 2-6 on the morning of Monday 12 December 2011 to allow plates captured before midnight on Sunday to be matched along the Hume Freeway/Highway.

The captured data was later reviewed manually from the video footage, allowing staff to pause each vehicle as it passed, ensuring highly accurate number plate readings and vehicle classification. Number plate data was entered into the Austraffic Origin-Destination (OD) software program, which matches the number plates between the survey stations.

While the video technology allowed the capture of the majority of number plates, a small percentage of plates were not accurately visible due to:

- Dirty, obscured or missing plates, or cars travelling very close together.
- Direct sunlight – at some times during daylight hours some cameras were subject to sunlight shining directly onto the front of the lens, causing glare which severely restricted the ability to read the number plates during these periods. Given the constraints on positioning the cameras due to considerations of safety, optimum results and road conditions, brief intervals of sun glare were unavoidable in some locations.
- Motorcycles – due to the orientation of the cameras facing oncoming traffic, motorcycles, which are not required to display front number plates, were not recorded.

A major vandalism incident occurred at most stations on the night of Saturday 10 December. All video equipment at stations 1-5 was badly damaged and thrown into nearby grasslands, and hard drives and other equipment was stolen. The damage was reported to each local police station. The vandalism resulted in a loss of data at these five stations for all of Saturday night and at stations 2 and 3 on Friday night (as the hard drives had not been replaced on Saturday). Austraffic made every effort to reinstate all the survey stations with spare equipment. This occurred progressively on Sunday morning and for the remainder of the survey data collection continued. The actions performed by Austraffic during the analysis to take into account these data outages are described in the next section.

4.0 Analysis

From the video footage, number plates, vehicle type and time were recorded for each vehicle at each site. The vehicle classes reported were:

- Cars and light commercial vehicles.
- Trucks and buses.

While Austraffic attempted to record all vehicle number plates at each survey site, technical issues occasionally prevented viewing of all number plates. The total passing traffic volumes were recorded and the percentage of missed plates reported. The number of missed plates for each site is shown in **Table 2**. For the hours when the vandalism occurred, Austraffic estimated missing traffic volumes and number plates in line with trends for that site. Overall, 289,888 vehicles were observed and 95.4 per cent of plates were captured.

Table 2 Captured plates report

Site	Total count	Plates captured	Capture rate
1	27,083	26,459	97.7%
2	29,732	29,073	97.8%
3	24,037	23,293	96.9%
4	33,588	30,737	91.5%
5	58,794	57,019	97.0%
6	116,654	109,948	94.3%
Total	289,888	276,529	95.4%

All number plate data was entered into Austraffic's OD computer software analysis suite. The data was matched to find identical plates from one site to the next. The data matching was also refined to allow for very close matches where the characters may have been the same (e.g. 'O', 'Q' and '0') or have only been partially recorded due to impaired visibility of the number plate. A 'wildcard' character was used in data entry and processing where the entire plate could not be recorded accurately. Misclassified vehicles with the same plate were corrected.

After reviewing the matched data, the trip tables were produced using an agreed match time for through traffic trips. A 24 hour maximum match time was used to define continuous trips between all of the stations. Trips which took longer than 24 hours were not considered.

On the Saturday night of the surveys, vandalism caused video outages at sites 1-5 and all vision during the night time hours was lost. Video was also lost on Friday night at sites 2 and 3 from the same incident. To account for these video outages, Austraffic adjusted the traffic volumes and match rates during those times based on the traffic volumes/match rates before and after that time of day and from other days for the same sites.

Where missed plates occurred either through vandalism or poor visibility, the trip tables were adjusted in line with trends for that site over the day so that the trip tables reflect the total passing traffic volumes.

The issues involved with factoring for missed number plates are complex. Austraffic analyses the data cell by cell and hour by hour. The missed plates factor takes into account the percentage for each site, within each cell, within each hour of the trip tables. Austraffic uses a factor based on probability to increase the through traffic to compensate for missed plates. The factor is the inverse of the captured plate's percentage for the inbound site, multiplied by the captured plate's percentage for the outbound site.

Austraffic allowed for survey 'shutdown errors' where the survey ended before inbound trips had time to complete their journey. While the survey ceased at midnight on the Sunday at site 1 near Seymour, the video recording was extended for a number of hours at each site further to the north. The last site near Campbelltown continued recording until 1pm on the Monday. Therefore, adequate time was allowed for vehicles to be captured at subsequent sites further along the freeway.

5.0 Detailed results

Detailed results are available from the survey for light vehicles only, heavy vehicles only or all vehicles, as illustrated by the following examples. **Table 3** shows the total number of matched number plates at each pair of survey sites over the five days of surveys and the total traffic volumes (light vehicles) at each survey site. As an example, site 1E is at Seymour, where 20,364 light vehicles were observed passing the site during the survey period. Of these, according to the registration number matching, 8,399 vehicles were also observed at site 2N (Wodonga) and 1,868 at site 6N (Campbelltown).

Table 3 Overall results matrix (light vehicles): the matched registration numbers at each pair of sites

OD Matrix	Destination	2N	3N	4E	5N	6N
Origin	Recorded	22,271	17,640	24,211	46,019	89,742
1E	20,364	8,399	4,896	3,616	2,492	1,868
2N	22,271		5,962	4,287	3,081	2,394
3N	17,640			5,501	3,756	2,896
4E	24,211				9,418	6,289
5N	46,019					25,269

The matching data is available for each hour of each day of the survey. For example, in **Figure 1**, which relates to the Seymour and Wodonga sites (sites 1E and 2N), the hourly light vehicle traffic volumes at each site over the survey period are given, together with the number of matched numberplates of vehicles travelling between these two sites.

Figure 2 and **Figure 3** show the matches for successively longer journeys, from Seymour to Yass and Campbelltown respectively. The matches reduce as a proportion of the traffic flow as the distance increases, corresponding with the lower frequency of the longer journeys. The much higher traffic volumes at Campbelltown en route to Sydney are also apparent.

Figure 1 Hourly traffic volumes at sites 1E (Seymour) and 2N (Wodonga), and the counts of matched number plates

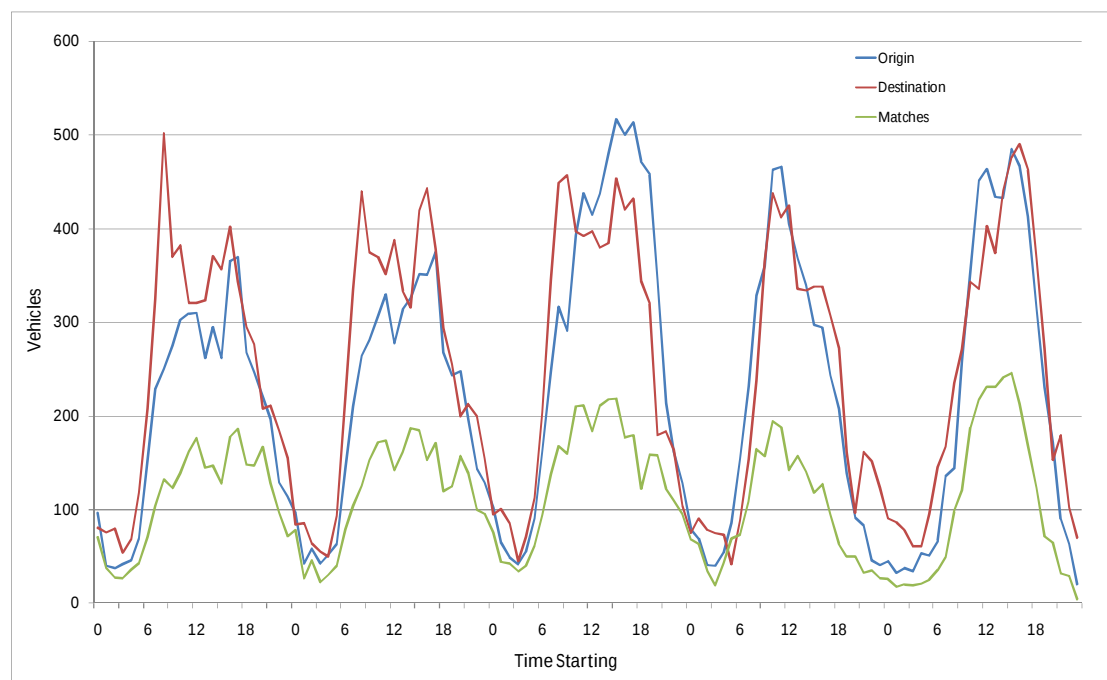


Figure 2 Hourly traffic volumes at sites 1E (Seymour) and 4E (Yass), and the counts of matched number plates

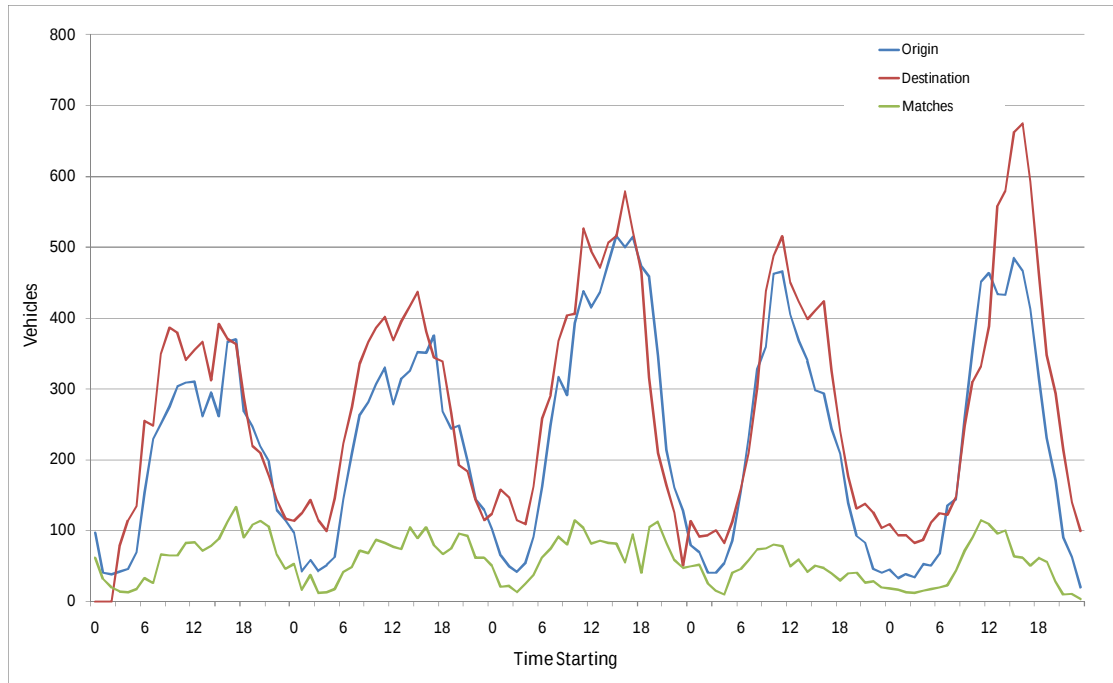
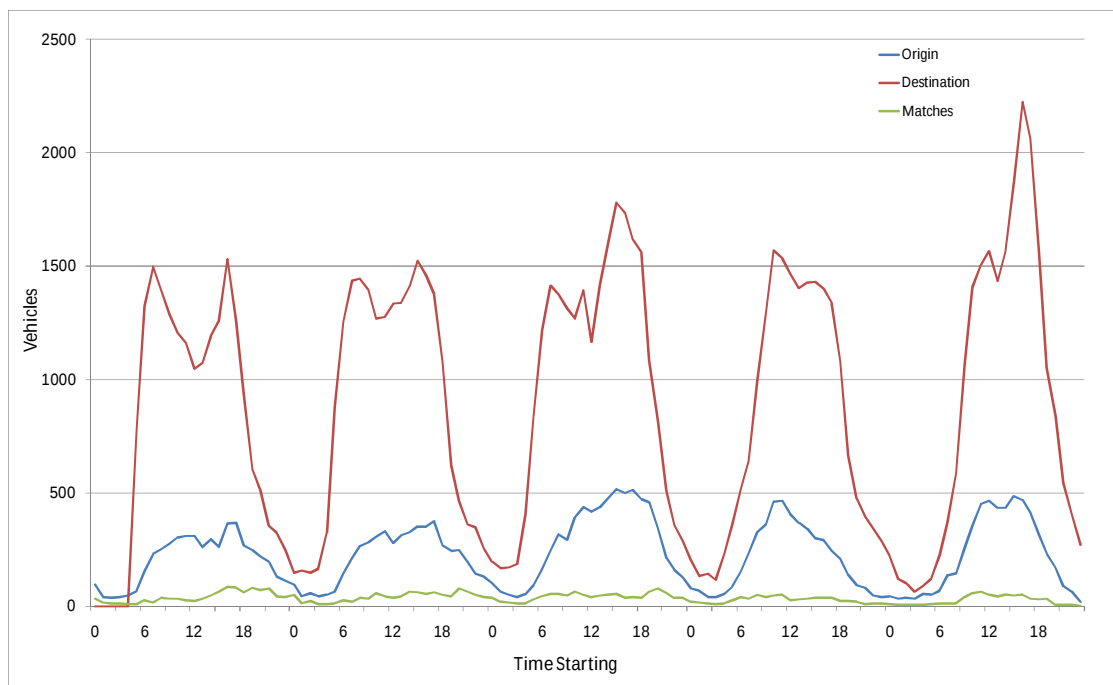


Figure 3 Hourly traffic volumes at sites 1E (Seymour) and 6N (Campbelltown), and the counts of matched number plates



By recording the time at which each registration number is observed, information on the time taken by each vehicle to travel between each pair of sites is obtained. **Figure 4** to **Figure 6** illustrate the distributions of journey times in 15 minute bands for journeys from Seymour to Wodonga, Yass and Campbelltown respectively.

For the shortest journey, between Seymour and Wodonga, most vehicles take between 1 hour 30 minutes and 2 hours 15 minutes. As the journey time increases, a greater spread of journey times is also apparent.

Figure 4 The distribution of travel times between sites 1E (Seymour) and 2N (Wodonga)

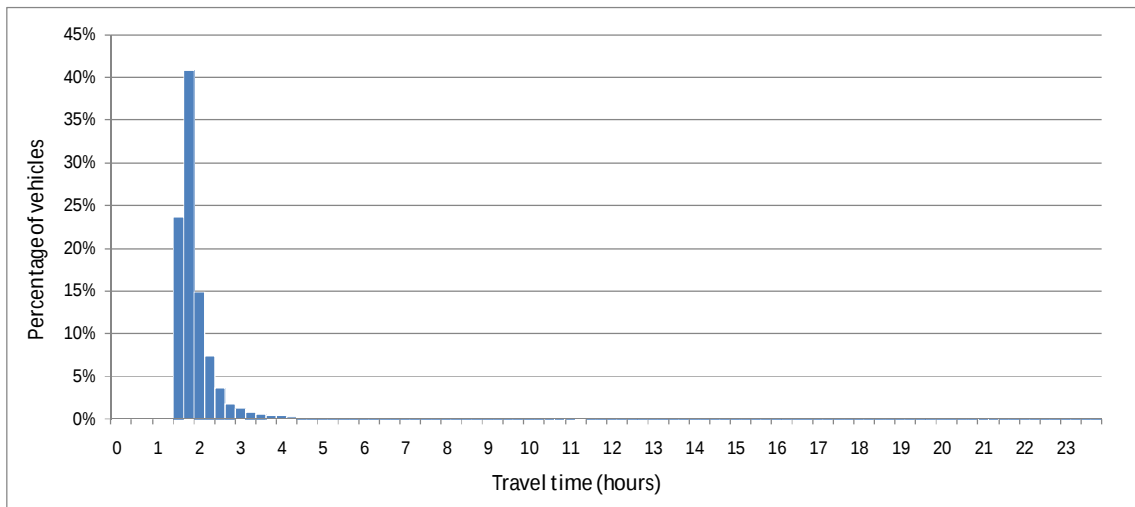


Figure 5 The distribution of travel times between sites 1E (Seymour) and 4E (Yass)

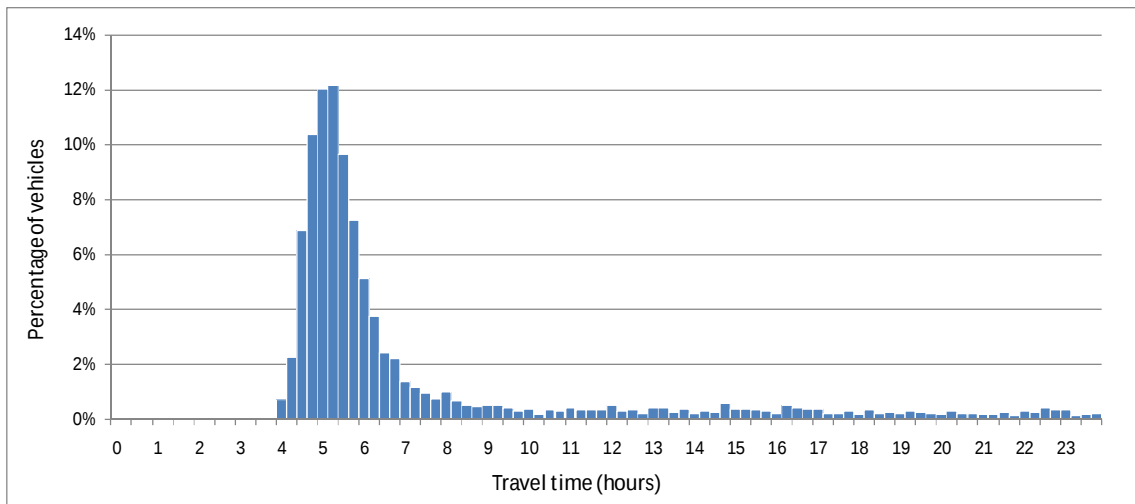
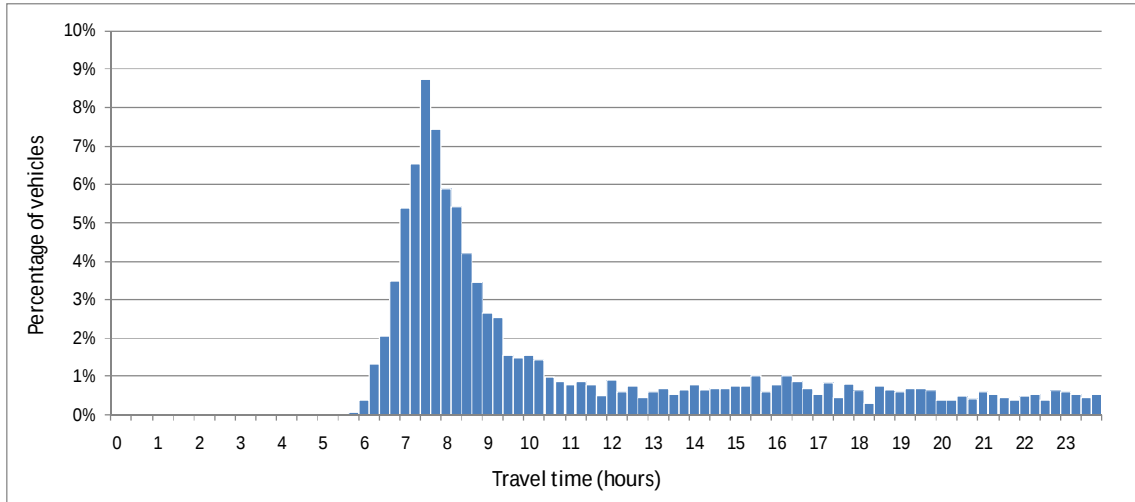


Figure 6 The distribution of travel times between sites 1E (Seymour) and 6N (Campbelltown)



From the same travel time data, information is available on the variations in the average and median journey times between each pair of sites by hour of the day and day of the survey. **Figure 7** to **Figure 9** provides this information for the same three journeys (Seymour to Wodonga, Yass and Campbelltown respectively). It is apparent from these figures that not only does the variation in travel time increase as journey distance increases but, for the longer trips, it also varies markedly by time of day.

Figure 7 Average and median travel times through the survey period for journeys from site 1E (Seymour) to site 2N (Wodonga)

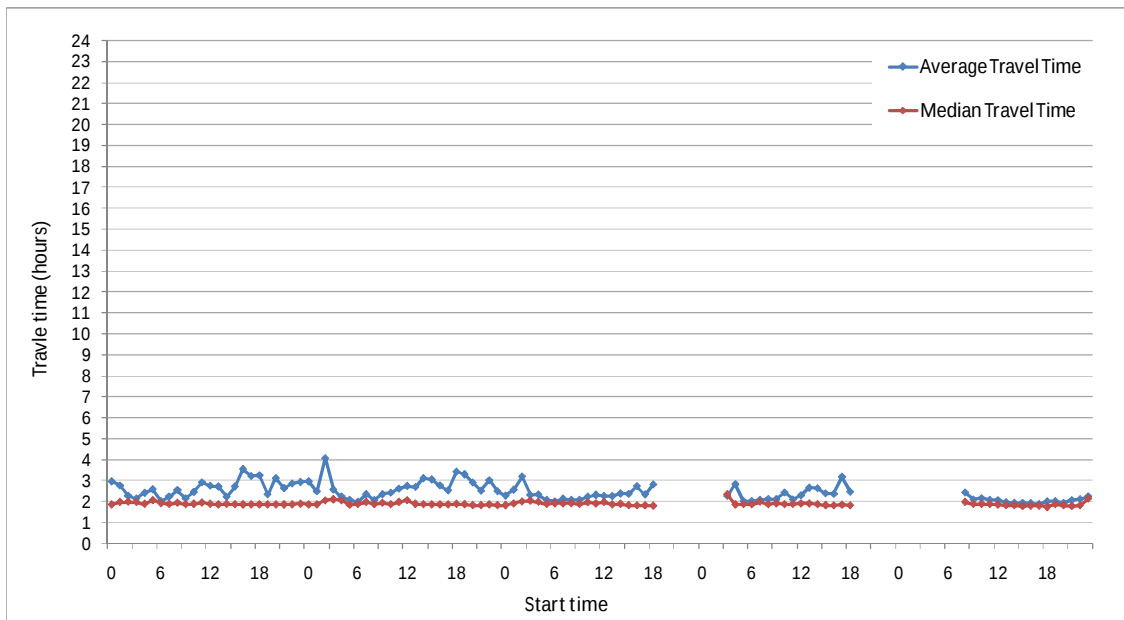


Figure 8 Average and median travel times through the survey period for journeys from site 1E (Seymour) to site 4E (Yass)

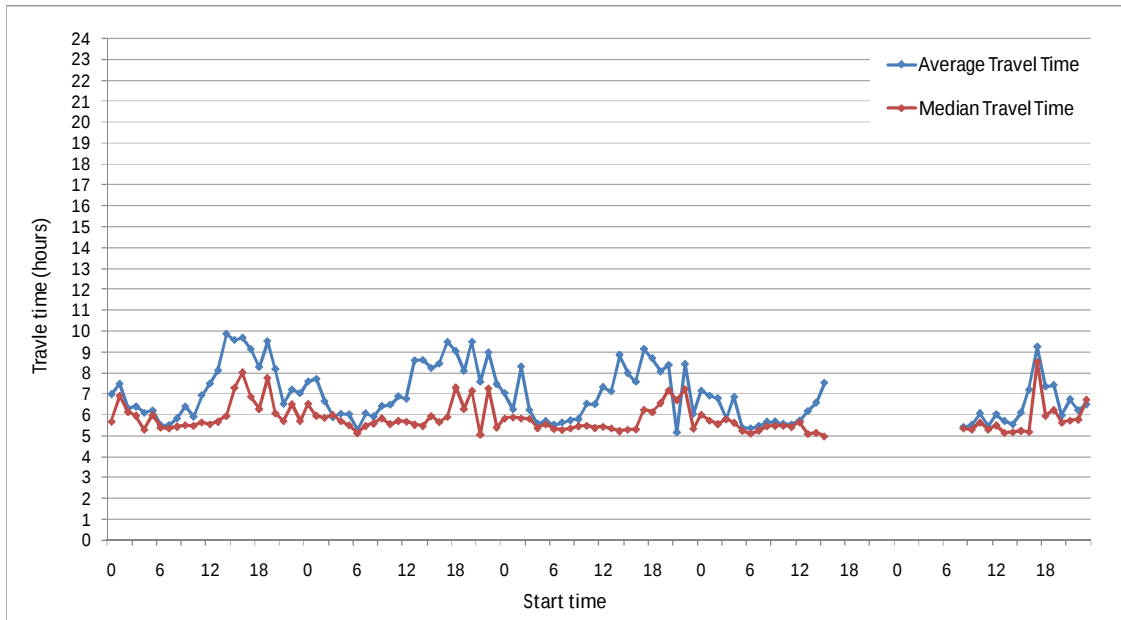
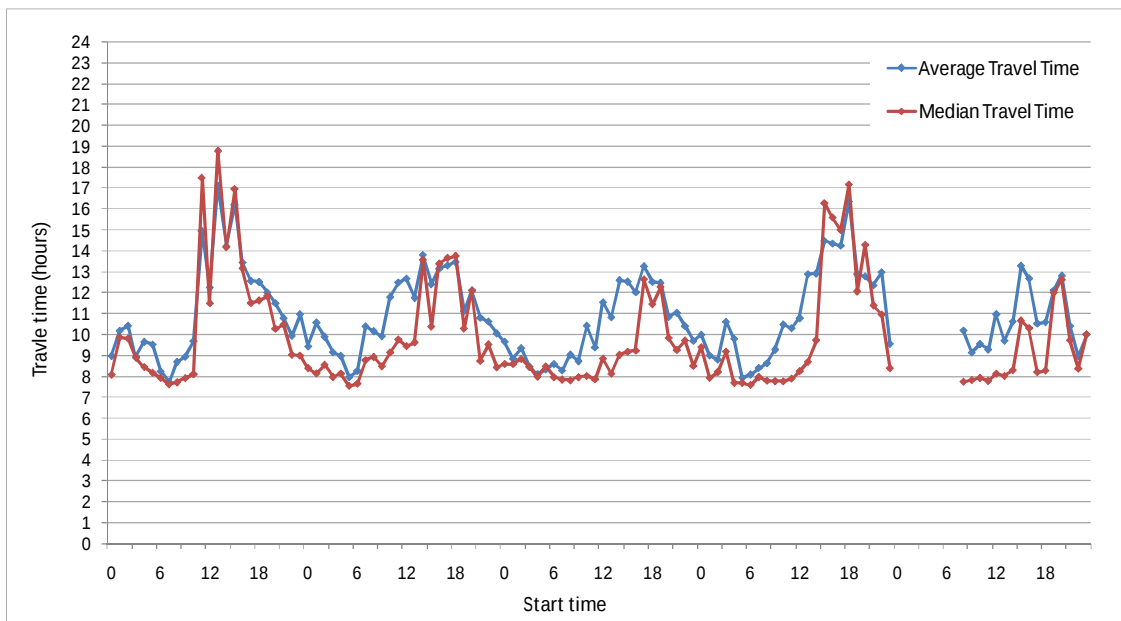


Figure 9 Average and median travel times through the survey period for journeys from site 1E (Seymour) to site 6N (Campbelltown)



Appendix 1D

Stated preference survey

Appendix 1D

Stated preference survey

Prepared for

Department of Infrastructure and Transport

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March 2013

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March 2013

Quality information

Document	Appendix 1D
Ref	60238250-1.0-REP-0101-1D
Date	March 2013

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1.0 Introduction and objectives

The phase 1 demand model parameter values were based on a distillation of local and international experience. In recognition of the importance of demonstrating that these parameter values are representative of local travel choice behaviour and the demand forecasts appropriately sensitive to the attributes of the high speed rail (HSR) service, a stated preference (SP) survey of the choice of travel mode was carried out in the east coast corridor.

The objectives of the survey were to investigate the key demand model parameters:

- The scaling parameters, which determine the overall sensitivity of the shares for each transport mode to changes in transport accessibility.
- The time values of medium and long distance travellers, which determine how sensitive mode shares are to transport prices.
- The choice of station and mode of station access.
- The extent of preference (or otherwise) for HSR over-and-above the measurable improvements in level-of-service (journeys times, service frequencies, fares, access and egress), referred to as the HSR alternative specific constant (ASC).

Because many of these issues relate to the HSR service and its attractiveness in comparison with current modes of transport, information on current transport choices (referred to as revealed preference) would be of limited usefulness. It is in such circumstances that SP survey techniques are appropriate.

Where evidence of travel choice behaviour cannot be obtained in real life, for example where a new transport mode such as HSR is being considered, SP survey techniques provide a means of exploring how people making relevant journeys would react to the introduction of such a mode.

This survey followed international practice, in that people making relevant journeys within the east coast study area were identified and presented with hypothetical scenarios in which an HSR service would provide for their journey, and asked to choose between their existing transport mode and HSR. Each survey respondent was presented with nine different scenarios in each of which the competitive position of HSR relative to their current mode was varied.

Statistical analysis of the data on travel choices obtained from SP surveys then provides considerable information on how people weigh up the different aspects of each transport mode in choosing between the alternatives.

The survey was informed by focus group discussions and a pilot survey. The survey began with a recruitment interview involving initial telephone contact to identify people who had made relevant journeys and were willing to participate in the survey. Specific journey information was obtained which was incorporated into a subsequent SP interview.

2.0 Development of designs and format

2.1 Chosen movements and modes

On the grounds of survey efficiency, it was decided to restrict the number of home ('production') areas that would be surveyed to six cities/towns as shown in **Table 1**. This includes two major cities (Melbourne and Sydney), two large population centres (Canberra and Newcastle) and two regional towns (Albury-Wodonga and Wagga Wagga). With the emphasis on longer distance travel, behaviour is expected to be transferable between locations.

For each of these areas, the likely demand to other areas was investigated using the National Visitor Survey (NVS)-based travel demand market information (see **Appendix 1B** for more detail), having regard to the modes used, separately for business and leisure purposes. Origin/destination (OD) movements to destinations which were considered unlikely to be part of the potential HSR market were ignored, being either too short or too long (e.g. Brisbane-Melbourne), or having too little demand.

In addition, it was decided that, for any OD cell, modes with a share less than 20 per cent would be excluded, though an exception was made for Newcastle-Sydney in order that current rail users could be included in the sample. This again was on the grounds of survey efficiency.

On this basis, the set of chosen movements and modes was as illustrated in **Table 1**, which also indicates those chosen for the pilot.

Table 1 Sample movements

Home location	Destinations	Modes for business	Modes for non-business	Included in pilot
Melbourne	Albury	Car	Car	Yes
	Shepparton¹	Car	Car	Yes
	Canberra	Air	Car and air	Yes
	Sydney	Air	Car and air	Yes
Albury-Wodonga	Melbourne	Car	Car	Yes
	Canberra	Car	Car	Yes
	Sydney	Car and air	Car and air	Yes
Wagga Wagga	Canberra	Car	Car	No
	Sydney	Car	Car	No
Canberra	Melbourne	Air	Car and air	No
	Albury	Car	Car	No
	Wagga Wagga	Car	Car	No
	Sydney	Car and air	Car	No
	Newcastle	Air	Car	No
Sydney	Melbourne	Air	Car and air	No
	Albury	Car and air	Car	No
	Wagga Wagga	Car and air	Car	No
	Canberra	Car and air	Car	No
	Newcastle	Car	Car	No
	Port Macquarie	Car and air	Car	No
	Gold Coast	Air	Car and air	No
	Brisbane	Air	Car and air	No
Newcastle	Canberra	Car and air	Car	No
	Sydney	Car and rail	Car and rail	No
	Brisbane	Air	Car and air	No

Interview quotas were then defined according to four dimensions: home area, purpose, journey length, and mode. The base travel demand market was used to provide guidance as to whether the quotas were realistic and to ensure that the survey budget was not unnecessarily spent chasing observations for movements with very small demand. The quotas were designed to support an efficient process of reaching the target of 2000 respondents.

¹ Shepparton was removed after the pilot as respondents did not vary their choice of mode in the SP.

Minimum quotas were only set on collections of cells (e.g. total business travellers from each origin), and in order to ensure that some sample was collected for smaller movements, a maximum quota was set for specific cells that were expected to be easily sampled (such as Melbourne-Sydney business travel by air).

In summary, the quotas were:

- Melbourne = 500.
- Albury-Wodonga = 150.
- Wagga Wagga = 150.
- Canberra = 250.
- Sydney = 650.
- Newcastle = 300.
- Overall business sample ≥ 500 .
- Overall air sample ≥ 900 .
- Overall rail sample ≥ 50 .
- Regional destination (Albury-Wodonga, Wagga Wagga, Port Macquarie and Gold Coast) ≥ 200 .

2.2 Presentation and design of the stated preference experiments

It was decided to link two separate SP questions – on station choice and mode choice – using a simplified version of the experiment previously undertaken successfully for Speedrail². The form of the experiment is set out in **Figure 1** to **Figure 3**. The sequence of the interview is as follows.

Prior to the SP questions, each respondent is asked to choose their preferred mode of access to each of the station options (CBD, airport and Craigieburn in the example).

The respondent is then offered different travel contexts ('scenarios') to consider, in which the characteristics of their access to the stations, their journeys by HSR and their existing mode of transport are changed.

For each such context, the station choice SP offers station options detailing travel to the station for each option, based on the respondent's reported modal preferences (these are in the form of 'cards', **Figure 1**).

The respondent expresses a preferred station (in this case, the CBD station) and, in the mode choice SP which immediately follows, is offered more details on the HSR journey to compare with a journey by their current mode of transport (either air, car or rail depending on the context of their journey). The SP questions for car and air are illustrated in **Figure 2** and **Figure 3** respectively.

This process is repeated for each of the travel scenarios.

² SKM, *Speedrail*, Technical Note TN15: Stated Preference Experiment Fieldwork, 1999.

Figure 1 Example of station choice SP card

If the following options were available, which would you choose for your journey between Melbourne and Sydney?



Location of Melbourne HSR Station:		CBD	Airport	Craigieburn
Travel to HSR Station	Method of travel	Taxi	Car (as driver)	Car (as driver)
	Travel time	20 mins	50 mins	60 mins
	Travel cost	\$30	\$0	\$0
Travel on HSR	Fare (one-way)	\$120 (economy)	\$115 (economy)	\$110 (economy)
	Time on the train	3 hours	2 hours 50 mins	2 hours 40 mins
	Frequency	1 train every 15mins	1 train every 30mins	1 train every hour

Which access station would you prefer

CBD

Airport

Craigieburn

Figure 2 Example of mode choice SP card (HSR vs. car)



Travel to HSR Station	Method of travel	Taxi
	Travel time	20 mins
	Travel cost	\$30
Travel on HSR	Fare (one-way)	\$120 (economy)
	Time at station	15 mins
	Time on the train	3 hours
	Frequency	1 train every 15mins
Travel from HSR Station	Travel time	10 mins
	Travel cost	\$5
Overall one-way journey	Expected total travel time	3 hours 45 mins
	Expected total travel cost	\$155 (one-way)
	Frequency	1 train every 15mins

I would use HSR



Time in car (excluding stops for sightseeing or	6 hours 30 mins
Cost (Petrol, tolls and parking)	\$100 (one-way)

I would use car

Figure 3 Example of mode choice SP card (HSR vs. air)



Travel to HSR Station	Method of travel	Taxi
	Travel time	20 mins
	Travel cost	\$30

Travel on HSR	Fare (one-way)	\$120 (economy)
	Time at station	15 mins
	Time on the train	3 hours
	Frequency	1 train every 15mins

Travel from HSR Station	Travel time	10 mins
	Travel cost	\$5

Overall one-way journey	Expected total travel time	3 hours 45 mins
	Expected total travel cost	\$155 (one-way)
	Frequency	1 train every 15mins

I would use HSR



Travel to Airport	Method of travel	Taxi
	Travel time	50 mins
	Travel cost	\$45

AIR JOURNEY	Time at airport	1 hour
	One-way fare (class)	\$140 (economy)
	Time on plane	1 hour 10 mins
	Frequency	1 plane every 15 mins

Travel from Airport	Travel time	30 mins
	Travel cost	\$25

Overall one-way journey	Expected total travel time	3 hours 30 mins
	Expected total travel cost	\$210 (one-way)
	Frequency	1 plane every 15 mins

I would use air

Note that two forms of presentation were possible, according to whether the respondent elected to receive a printed version by post or a web-based version. In both cases, however, the SP was customised to previously obtained travel data, and in both cases the main interviews were conducted by telephone. Therefore the distinction between the two forms of presentation was merely a matter of convenience for the respondent as to how they wanted to view the SP.

The basis of the SP approach is to present a sequence of choices (the scenarios) in which the variables relating to each alternative are varied in a systematic way. The plan which underlies this variation is referred to as the 'design'. In developing the design, it is also necessary to decide how many scenarios should be offered to each respondent.

Separate designs were required for a) station choice, b) HSR vs. air mode choice, c) HSR vs. car mode choice and d) HSR vs. rail mode choice. In each case, the layout involved a set of blocks of nine scenarios, using an orthogonal design, with most variables at three levels³. It was found possible to use the same design for the different purposes and OD pairs, though some variations in the choice of values for levels were necessary.

A simulation testing process was set up separately for the four designs, with sufficient flexibility to be able to apply to different purposes and OD pairs. The simulation involved making assumptions about the generalised cost parameters (based primarily on the phase 1 model) together with some reasonable level of variation around these, and allowing for further random effects.

The simulation process had three primary aims: to investigate the likely level of 'trading' (a given respondent is considered to trade if he/she does not always choose the same alternative whatever the scenarios presented); to ensure that, given the simulated responses, the input coefficients could be

³ That is, in the design, three alternative values of the variable are offered to each respondent, and the variations for each attribute are independent of the variations for the other attributes (an orthogonal experimental design).

adequately recovered by estimation; and to enable variations to the levels and the underlying design to be quickly tested.

The combinations of modes, purposes and OD pairs required for the pilot were given priority in the testing process. A target level (maximum) of 25 per cent non-trading respondents was set to ensure that an adequate sample of useable pilot data would be obtained, though it was not always possible to achieve this, particularly for short distance car travel where the access and egress costs associated with HSR made it very difficult to make HSR competitive.

Overall, however, it was considered that satisfactory designs for piloting could be achieved. An important feature of the design is that HSR times and costs were pivoted off existing mode times and costs (subject to some realism constraints). This meant that in some cases, to induce trading, lower values of HSR times and, in particular, fares might be offered than would be the case in practice. However, these values were still considered to be credible.

2.3 Questionnaire development and implementation

The main part of the questionnaire development is largely intended to ensure the collection of the data required to provide a basis for 'customising' the SP. As noted, the interview was conducted in two parts. The initial recruitment interview starts with a screening section (including scope and willingness to participate), followed by a section which elicits the key data about the respondent's existing travel. Following this, the main SP questionnaire can be prepared, with the SP itself either delivered by post or made available by the web. In both cases, the questions are interviewer-administered over the telephone, using computer-assisted telephone interviewing technology.

In addition to the SP data, the main survey collects information about alternative modes that might have been used, offering the possibility of a revealed preference (RP)⁴ estimation for the current journey. Finally, some general socio-economic questions are also asked, with a view to providing possible segmentation variables and confirming the representativeness of the sample.

The various routing possibilities within the questionnaire were set out in a flow chart and thoroughly tested for consistency. A key feature of the approach was the need to link the initial recruitment questionnaire with the main SP questionnaire. This required careful testing.

A preliminary version of the questionnaire was tested through in-depth interviews with 16 respondents. As well as reactions to the general structure of the questionnaire and the SP questions, information was obtained as to possible reasons for not trading, the importance of a careful description of the access/egress arrangements, the need for a prepared set of answers to potential questions about HSR, and the willingness to use the web-based form of the SP. This information was taken into account for the final version of the pilot.

2.4 Piloting and sampling

The survey company I-view purchased a set of telephone numbers from Sample Pages (also referred to as Electronic White Pages). These numbers were a random set of residential telephone numbers from the postcodes specified for the pilot in Melbourne and Albury. A target sample of 100 respondents was proposed for the pilot, which focused on recruiting respondents travelling to the destinations (as well as via the modes and for the purposes) shown in **Table 1**.

The overall pilot sample was 98 completed responses (after removing two which turned out to be incomplete). To give an indication of the effort required to collect this sample, contact was made with 1,505 persons (which required 5,909 phone calls due to unanswered phones calls, call backs and answering machines). Of the 1,505, 54 per cent refused⁵ to answer the survey and six per cent could not be understood. Of the remaining 602 who were in principle willing participants, 63 per cent did not fit the criteria and a further 13 per cent were not used as the quota had already been met. Hence,

⁴ In which estimation is based on actual choices of the respondent.

⁵ The recruitment survey starts with "Good morning/afternoon/evening my name is, I am from the market research firm I-view. I am calling in relation to the Australian Government's high speed rail study between Melbourne, Sydney, Canberra and Brisbane". It is possible that some of the refusals were because respondents were not interested in HSR.

interviews were initiated with 147 people; however, 49 of these dropped out between the recruitment and follow-up survey.

Of the 98 completed surveys, 77 were conducted using a web link and 21 by posting hardcopy cards.

The recruitment interview typically took 10 minutes and the follow-up interview, which included the SP cards, took 15 to 20 minutes.

Interviewers were requested to note down any feedback from the respondents, any trends they detected in the way people responded, and to enquire as to how easy respondents found the task and whether they felt that the choices offered to them were realistic. The feedback provided has been grouped into the following general themes:

Level of engagement

- Despite being an onerous task with a lot of information to digest, most respondents stated that they were able to understand the task and that the scenarios offered were realistic. Although the interview took some time to complete, most people remained engaged due to the interest they showed in being asked about HSR.
- In particular, Albury-Wodonga respondents were found to be much more willing to undertake the survey on first contact than those in Melbourne.

Support for HSR

- A lot of comments were made about how respondents would like to see HSR built in Australia.
- A number of people that did not choose HSR in any of the scenarios commented on closing that they would consider HSR for other journeys, but that it just did not suit this particular journey.

Potential improvements to SP

- Respondents tended not to look at the time and cost implications of accessing different HSR stations, and SP response data strongly demonstrated that most had a clear preference as to which station was most convenient to their house. In fact, a lot of respondents found the station access choice a hindrance and wanted to proceed straight to the mode choice scenarios.
- The numbers presented in the SP occasionally looked unrealistic.
- The hard copy cards were difficult and needed to be improved. Many respondents were intimidated by having 18 different sheets of paper.
- A lot of people did not want an incentive when it came to the end of the survey. They preferred not to give out personal details rather than receive a \$10 gift card. But the incentive was felt to be worthwhile mentioning up front in order to attract interest.
- Not many business trips were collected. Although a number of respondents were professionals, typically the last journey they had made (or the most memorable) was a leisure journey. It was felt that they could have been prompted to talk about a business journey instead.

The general characteristics of the pilot sample were considered to be a good representation of the wider population (of course, the population making long distance journeys will not necessarily be representative of the general population). A range of discrete choice models was estimated for different market segments using BIOGEME⁶. The results indicated that the desired coefficients could be recovered and, taking into account the small sample and the standard error of the estimated parameters, the key values were within expected bounds. Some parameters such as frequency and check-in time proved to be insignificant and changes were made to the survey to improve this.

⁶ M Bierlaire, *BIOGEME: A free package for the estimation of discrete choice models*, Proceedings of the 3rd Swiss Transportation Research Conference, Ascona, Switzerland, 2003.

Based on the interviewer feedback, independent reviews and the analysis of the data outputs, the following improvements and modifications were made:

- The definition of 'in scope' respondents was tightened such that:
 - People using frequent flyer points (or other free flights) were excluded.
 - Non-home-based journeys must start within the home city.
 - Air transit passengers were excluded.
 - For air or rail journeys which were part of a multi-destination tour, the questionnaire was restricted to asking about the first leg of the tour only.
- The categories for qualitative questions were refined based on the responses given in the pilot.
- Refined wording was designed to ensure parking costs were captured in access/egress journeys.
- The look of the of SP cards was improved to make them easier to understand.
- Additional interviewer training was held to enable them to respond to a wider range of potential questions from respondents. This also included a matrix of approximate HSR travel times for the interviewer.
- Frequency was made more prominent on the SP cards and is now shown alongside the total travel time and cost.
- Upper and lower ranges were placed on values presented in the SP (and inputs values) to ensure more realistic trading (for example, an upper limit of two hours was set on flight times).
- The \$10 gift card offered as an incentive to respondents was retained but the respondent was given the option at the end of the survey to opt out of this if they did not wish to give out their address details.

3.0 Main survey

3.1 Dates and numbers

Interviewers for the main survey were briefed on 5 March 2012 and commenced recruitment on 6 March 2012. A sample of 2,633 respondents had been recruited by 25 March 2012 and the required 2,000 follow-up surveys were completed by 4 April 2012, with some allowance for drop out between the two surveys.

The main survey focused on recruiting respondents from Melbourne, Sydney, Canberra, Newcastle, Wagga Wagga and Albury, travelling to the destinations (as well as via the modes and for the purposes) shown in **Table 1**.

To collect the sample, a total of 49,548 phone calls were made in order to speak with 31,120 people. Of those, 44 per cent refused to answer the survey, and eight per cent could not be understood. Of the remaining 13,447 who were in principle willing participants, 72 per cent did not fit the criteria and a further five per cent were not used as the quota had already been met. Hence, interviews were initiated with 3,024 people, but 1,024 of these (34 per cent) dropped out between the recruitment and follow-up survey.

With the exception of the number of calls required to make contact (which was especially high in the pilot at almost four calls per contact in comparison to 1.6 in the main survey), these figures demonstrate considerable consistency between the pilot and main survey. About 43 per cent of those contacted were willing to take part, but of those only 23 per cent were in scope. A third dropped out subsequently. The final sample was therefore only 6.4 per cent of those with whom contact was made.

The sample was derived from a random sample (Electronic White Pages) of telephone numbers.

The recruitment interview typically took 12 minutes and the follow-up interview, which included the SP cards, took 18 minutes. The respondent was encouraged to select the email version, as the pilot had shown this to be the easiest for the respondents to understand, and it was also easier for I-view to administer. As a result, the mail-out version was only required in 245 of the 2,000 cases.

As the number of changes made between the pilot and main survey was small, the two datasets were pooled for a final sample of 2,098 individual responses. Most quotas were met, with the exception of air and business travel, which were lower than expected. In both cases the possible shortfall was identified mid-way through the survey and interviewers were requested to ask for business and/or air trips first rather than asking for their most recent journey. Although this resulted in a slight increase in the proportion of business travel (20 per cent to 21.4 per cent, with a target of 25 per cent), there was no increase in the air travel sample.

3.2 Data cleaning process

The data was put through a thorough process to check for erroneous entries. The result of this process was the removal of 37 respondents from the SP sample and a further eight from the RP sample potentially available for RP analysis (see **Section 2.3**). The reasons for their omission were typically on the grounds of either erroneous or highly unrealistic responses, which had resulted in further unrealistic numbers being presented on the SP choice cards.

3.3 Sample demographics

The general characteristics of both the main sample and the pilot can be compared to general Australian Bureau of Statistics demographics along the east coast and are shown in **Figure 4** to **Figure 7**. Generally, these characteristics indicate that the sample provides a good representation of the wider population (of course, as noted, the population making long distance journeys will not necessarily be representative of the general population). Note that the sample tends to under-represent those in the lower age groups.

Figure 4 Comparison of pilot and main sample to population – current status

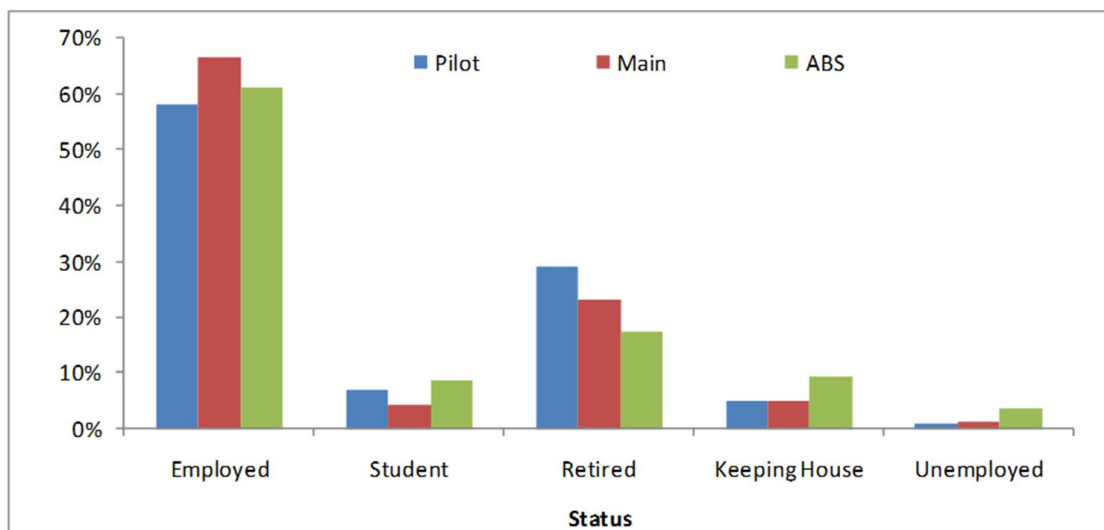


Figure 5 Comparison of pilot and main sample to population – household income (\$000's)

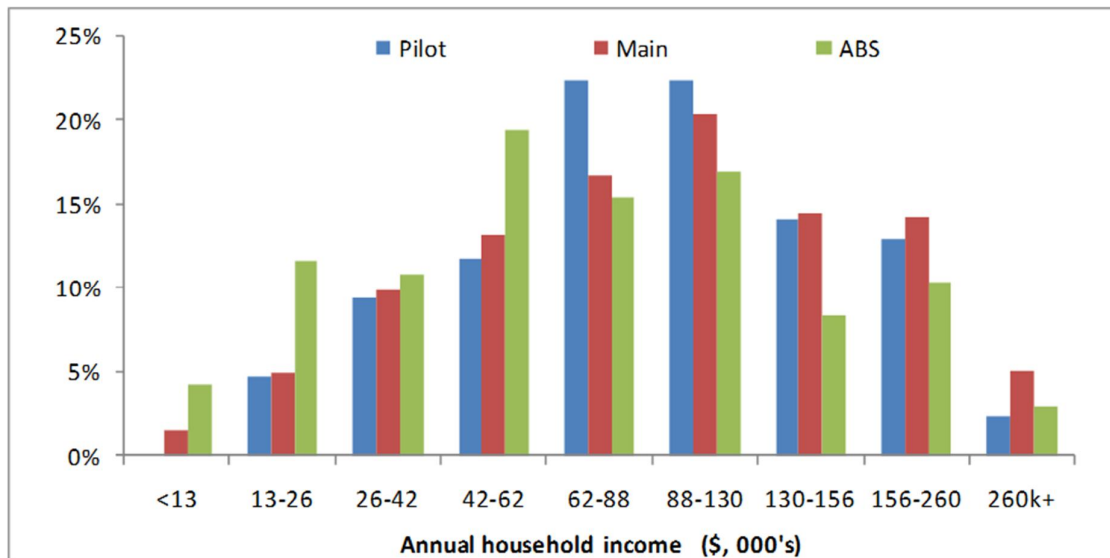


Figure 6 Comparison of pilot and main sample to population – age

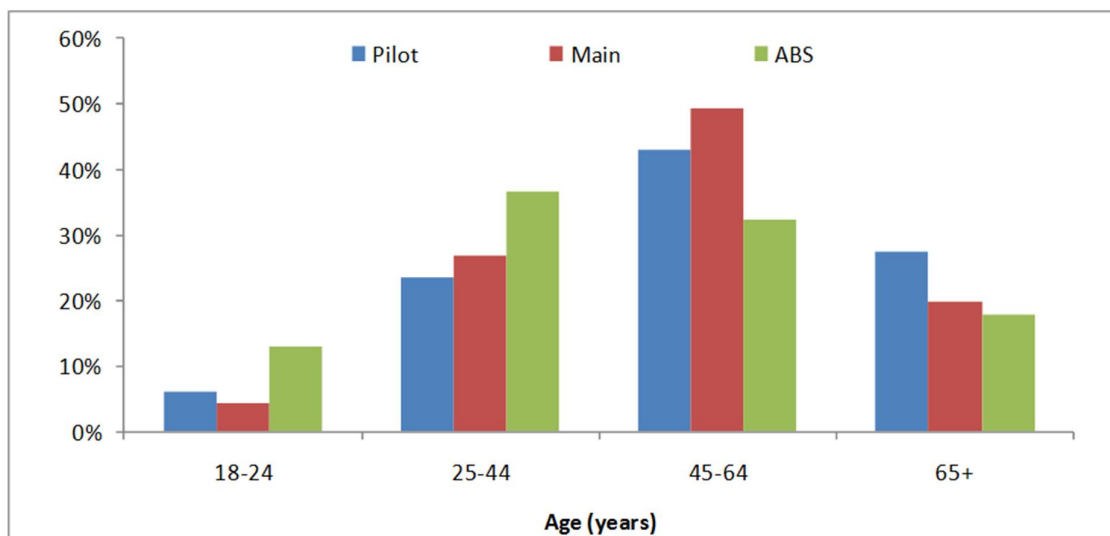
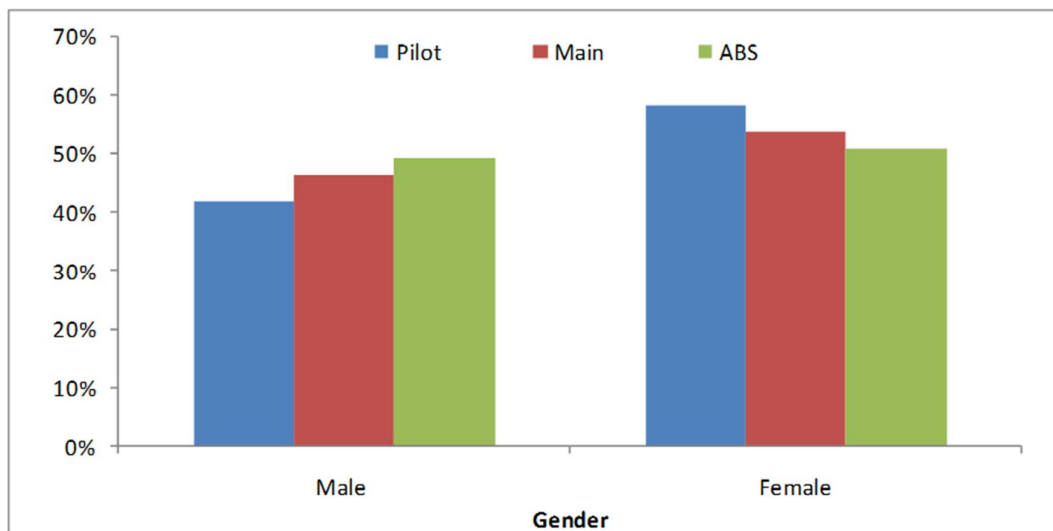


Figure 7 Comparison of pilot and main sample to population – gender



3.4 Overall sample characteristics

This section provides further information on the final sample.

Table 2 Sample by origin

Origin	Count
Melbourne	556
Albury-Wodonga	191
Wagga Wagga	150
Canberra	251
Sydney	650
Newcastle	300
Total	2098

Table 3 Sample by destination

Destination	Count
Albury-Wodonga	128
Canberra	386
Sydney	904
Melbourne	375
Wagga Wagga	19
Newcastle	77
Port Macquarie	42
Gold Coast	65
Brisbane	95
Shepparton	7
Total	2098

Table 4 Sample by current mode

Mode	Count
Air	732
Car	1254
Rail	112
Total	2098

Table 5 Sample by trip purpose

Purpose	Count
Leisure/holiday	703
Business	449
Commute	10
Visiting friends and relatives (VFR)	755
Education	15
Other	166
Total	2098

Table 6 Sample by who paid for the journey

Who paid	Count
I did	1684
Someone else in group	85
Employer	329
Total	2098

Table 7 Sample by group size, split by purpose and current mode

Group size	Business			Non-business			Overall
	Air	Car	Rail	Air	Car	Rail	
1	234	74	12	142	150	35	647
2	45	38	4	174	550	36	847
3	16	6	0	42	140	9	213
4	10	3	0	44	187	8	252
5	1	1	0	13	69	2	86
6	1	1	0	2	15	2	21
>6	2	1	0	6	19	4	32
Total	309	124	16	423	1130	96	2098
Average	1.43	1.60	1.25	2.53	2.73	2.46	2.41

Table 8 Sample by trip duration (nights away), split by purpose and current mode

Nights away	Business			Non-business			Overall
	Air	Car	Rail	Air	Car	Rail	
1	58	36	6	17	126	37	280
2	72	32	4	30	176	22	336
3	71	19	5	69	236	12	412
4	55	17	0	95	168	8	343
5	27	9	0	61	91	1	189
6	12	3	0	42	79	2	138
7	6	0	0	17	33	0	56
8-10	5	3	1	36	96	6	147
11-14	2	2	0	19	46	5	74
15-30	0	2	0	13	38	2	55
>30	1	1	0	3	3	0	8
Total	309	124	16	423	1130	96	2098
Average	2.39	2.46	1.38	5.04	4.21	2.63	3.91

Table 9 Sample by frequency of trip

Frequency of trip	Count
More than once per week	13
Weekly	44
Monthly	243
Every 3 months	600
Every 6 months	413
Every year	327
Less than yearly	219
First time	239
Total	2098

3.5 Characteristics of the revealed preference mode choices

The following section provides further information on the current choices available to respondents (**Table 10**), why people that choose car do so (**Table 11**), the class people flew (**Table 12**) and ticket type for those using rail (**Table 13**).

Table 10 Sample by current mode and other available modes

Current mode	Would also consider	Count	Percentage of current mode
Air (732)	Car	115	16
	Rail	64	9
	Car and rail	37	5
	None	516	70
Car (1254)	Air	244	19
	Rail	206	16
	Air and rail	117	9
	None	687	55
Rail (112)	Car	35	31
	Air	2	2
	Car and air	0	0
	None	75	67
Total		2098	

It is noteworthy that for all current modes, more than half the travellers did not consider any alternative modes possible (**Table 10**).

Table 11 Car sample reason for using car

Reason for car*	Count	Percentage of proportion of times mentioned
Convenience	710	57
Car at destination	243	19
Sightseeing	53	4
Luggage	104	8
Children	75	6
Other	192	15
Total respondents	1254	

* Multiple responses were possible so percentages add to more than 100.

Table 12 Air sample by ticket class

Class	Count
Economy	715
Business	17
Total	732

Table 13 Rail sample by type of ticket concession (Rail)

Rail concession	Count
Student	11
Pensioner	45
Other	11
No concession	45
Total	112

3.6 HSR station access

This section details the choice of mode that respondents reported they would use to access an HSR station if it were located at the place stated in the SP survey. All respondents were asked to provide access details to a CBD station, but for non-central stations they were able to opt out if they stated they would not consider travelling to the given location⁷. A summary of the stations offered is provided in **Table 29**. For the central stations in Melbourne, Canberra, Sydney and Newcastle, as well as Parramatta station in Sydney, it was made clear that no dedicated parking facilities were available. For other locations, a parking charge per day was suggested, and the level of public transport access was described.

Table 14 Melbourne HSR station preference

Would you consider non-central stations?*	Count	Percentage
No	249	50
Yes – Airport	137	27
Yes – Craigieburn	46	9
Yes – both	67	13
Total	499	100

* This question was only added after the pilot, where respondents were asked to provide details on all three stations. Consequently, the totals here are lower than in **Table 15**.

Table 15 Melbourne HSR station access mode

Access mode	HSR station location		
	CBD	Airport	Craigieburn
Public transport services	390	44	24
Other	17	0	2
Taxi	62	49	12
Pick up/drop off	85	61	25
Car (parked)	0	96	77
Rental car	1	0	0
Total	555	250	140

⁷ The station access question was preceded by: "Please imagine that a High Speed Rail service has been built in <ORIGIN> and there are a number of stations that you could choose to use. Select which station you would prefer to use based on the options shown on the following card."

Table 16 Sydney HSR station preference

Would you consider non-central stations?	Count	Percentage
No	245	38
Yes – Parramatta	72	11
Yes – Homebush	246	38
Yes – Both	87	13
Total	650	100

Table 17 Sydney HSR station access mode

Access mode	CBD	Parramatta	Homebush
Public transport services	479	114	102
Other	17	7	1
Taxi	92	9	22
Pick up/drop off	61	29	37
Car (parked)	0	0	160
Rental car	1	0	1
Total	650	130	323*

* Ten people said they would use Homebush but then could not nominate an access mode.

Table 18 Canberra HSR station preference

Would you consider a non-central station?	Count	Percentage
No	54	22
Yes – Canberra Airport	197	78
Total	251	100

Table 19 Canberra HSR station access mode

Access mode	Civic	Airport
Public transport services	61	29
Other	12	0
Taxi	67	35
Pick up/drop off	110	71
Car (parked)	0	60
Rental car	1	0
Total	251	195*

* Two people said they would use an airport station but then could not nominate an access mode.

Table 20 Albury-Wodonga HSR station preference

Would you consider a non-central station?*	Count	Percentage
No	32	21
Yes – 15 km north	118	79
Total	150	100

* This question was only added after the pilot, where respondents were asked to provide details on both stations. Consequently, the totals here are lower than in **Table 21**.

Table 21 Albury-Wodonga HSR station access mode

Access mode	Central	15 km north
Public transport services	2	9
Other	20	9
Taxi	44	21
Pick up/drop off	62	43
Car (parked)	63	72
Rental car	0	0
Total	191	154

Table 22 Wagga Wagga HSR station preference

Would you consider a non-central station?	Count	Percentage
No	36	24
Yes – 20 km south	114	76
Total	150	100

Table 23 Wagga Wagga HSR station access mode

Access mode	Central	20 km south
Public transport services	3	9
Other	11	3
Taxi	37	18
Pick up/drop off	51	38
Car (parked)	48	43
Rental car	0	0
Total	150	111

Table 24 Newcastle HSR station preference

Would you consider a non-central station?	Count	Percentage
No	38	13
Yes – 15 km west	262	87
Total	300	100

Table 25 Newcastle HSR station access mode

Access mode	Central	15 km west
Public transport services	71	68
Other	52	2
Taxi	41	18
Pick up/drop off	135	66
Car (parked)	0	103
Rental car	1	0
Total	300	257*

* Five people said they would use an outer station but then could not nominate an access mode.

3.7 HSR choices

The following tables detail the choices respondents made with respect to HSR, such as the preferred class for business travellers (**Table 26**), the aspects of HSR that respondents most valued (**Table 27**), and how they would get from the HSR station at their destination city to their final destination (**Table 28**).

Table 26 Choice of HSR class, business travellers only

HSR class	Count	Percentage
Standard	361	80
Premium	88	20
Total	449	100

Table 27 Aspects of HSR most valued

Feature of HSR	Ranking		
	1st	2nd	3rd
Speed	643	440	142
Comfort	322	406	235
Able to work	46	62	57
Direct to CBD	79	82	80
Wi-fi	15	54	98
Reliability	92	100	74
Safety	129	85	55
Avoids airport	77	80	65
Environment	68	55	38
Integrates with the wider public transport network	31	43	40
Other	596	312	142
Total	2098	1719	1026

The SP survey stated that the HSR station at the destination would be located in a central location. Respondents were asked how they would get from there to their final destination (**Table 28**).

Table 28 HSR egress mode (from a central station)

Destination	Egress mode						Total
	Walk	Rental car	Pick up/drop off	Taxi	Bus/local train	Other	
Albury-Wodonga	18	9	44	42	13	2	128
Canberra	34	19	118	141	74	0	386
Sydney	113	25	58	200	495	13	904
Melbourne	50	14	31	88	189	3	375
Wagga Wagga	2	1	9	7	0	0	19
Newcastle	10	4	22	15	26	0	77
Port Macquarie	7	5	13	11	5	1	42
Gold Coast	4	16	10	20	14	1	65
Brisbane	11	12	21	15	33	3	95
Shepparton	2	0	4	0	1	0	7
Total	251	105	330	539	850	23	2098

The proportion of walk egress is usually 10 per cent or higher. For Sydney and Melbourne, local public transport egress is at least 50 per cent but for other destinations it is 20 per cent on average.

As found in the pilot survey, there continued to be strong support for HSR among respondents, as evidenced in the comments they made, particularly for those who chose HSR in every mode choice scenario.

4.0 Main survey – analysis of SP data

Initially, the two SP experiments (station choice, mode choice) were analysed separately. Only ‘traders’⁸ were included, and the analysis was done separately for different markets. All models have been estimated using BIOGEME.

One of the features of SP analysis is that each respondent provides responses to a number of choice scenarios, so that the data has the quality of a panel, in that there may be significant variation in the choice behaviour between respondents leading to variations in their responses to the different travel contexts. In analysing the data, allowance should be made for possible ‘within respondent’ correlations in the random terms. Unfortunately, these can lead to long run times for estimation. Because of this, the general approach has been to check whether the key parameters are sensitive to a panel specification. If they are not, the analysis is conducted without allowing for the panel effect.

In **section 4.1** the analysis of the station choice SP is briefly discussed. **section 4.2** briefly discusses the mode choice analysis separately for the three current modes. Based on what has been learnt from this, **section 4.3** then describes how the combined analysis was carried out.

⁸ Respondents who, faced with the nine choice tasks, chose differently on at least one occasion. Data for non-traders does not affect the statistical analysis.

4.1 Analysis of station choice SP

The following station choices (**Table 29**) were available in principle to each respondent.

Table 29 HSR access station names

Origin	Station 1	Station 2	Station 3
Melbourne	CBD	Airport	Craigieburn
Albury-Wodonga	Existing rail station	15 km north of CBD	
Canberra	Civic	Airport	
Wagga Wagga	Existing rail station	20 km south of CBD	
Sydney	CBD	Parramatta	Homebush
Newcastle	Central	15 km west of CBD	

Following feedback from the pilot survey, a survey question was included that asked whether the respondent would consider using an HSR station that was not in the centre of their home city. Almost one-third of respondents (31 per cent) said they would only consider a central station and therefore did not participate in the station choice SP.

Of those that stated they would consider a non-central station, only 32 per cent actually traded within the station choice SP, a lower than hoped for proportion but consistent with the experience of the pilot survey.

Respondents from regional areas tended to be the most likely to firstly, consider using a non-central station (see **section 3.6**) and secondly, to trade between station options (see **Table 30**). By contrast, those from a capital city strongly preferred a CBD station. Peripheral stations that did not have both good public transport and parking available (such as Parramatta in Sydney) were particularly unattractive. Non-business travellers were most likely to trade (**Table 32**) as were people currently travelling by rail (**Table 31**).

Table 30 Station choice trading by origin

Origin	Sample	Willing to consider non-central station	Not asked question (pilot)	Eligible for station choice SP	Traders	Percentage of Traders
Melbourne	556	250	57	307	76	25
Albury-Wodonga	191	118	41	159	60	38
Wagga Wagga	150	114	0	114	44	39
Canberra	251	197	0	197	67	34
Sydney	650	405	0	405	103	25
Newcastle	300	262	0	262	111	63

Table 31 Station choice trading by current mode

Origin	Sample	Willing to consider non-central station	Not asked question (pilot)	Eligible for station choice SP	Traders	Percentage of traders
Air	732	419	39	458	131	29
Car	1254	831	59	890	285	32
Rail	112	96	0	96	45	47

Table 32 Station choice trading by trip purpose

Origin	Sample	Willing to consider non-central station	Not asked question (pilot)	Eligible for station choice SP	Traders	Percentage of traders
Business	449	280	19	299	87	29
Non-business	1649	1066	79	1145	374	33

The variables presented in the station choice SP are shown in **Table 33**.

Table 33 HSR SP variables available (station choice)

Attribute	Short form	Source	Notes
Access time	ATIME	SP	-
Access cost	ACOST	SP	-
In vehicle time	TIME	SP	Non-central stations have the same time or less
Frequency	WAIT	Fixed	Same for each station, only varies between scenarios (therefore does not affect station choice)
Fare	FARE	SP	Non-central stations have the same fare or less

Note: SP indicates that the variable is actually varied within the options presented to a particular respondent.

From the station choice SP, the following utility function can be tested:

$$U = \gamma_c (\text{VoT} \cdot [\text{Time} + \rho_a \cdot \text{Atime}] + \phi_a \cdot \text{Acost} + \text{Fare}) + \varepsilon$$

where VoT is the value of time, γ_c is a scaling parameter (here expressed in money units), ρ_a is the VoT multiplier for access time, and ϕ_a is a parameter allowing for a potentially different response to money spent on access as opposed to fare (though a value close to 1.0 would be expected). It may also be appropriate to include alternative specific constants (ASCs) for particular station locations (e.g. city centre or airport). ε represents the random term.

As the station choice SP data is more limited than the mode choice data, a smaller number of segmentations are possible. The analysis began by looking separately at Melbourne, Sydney and regional origins (Canberra, Newcastle, Albury-Wodonga and Wagga Wagga). Initially, a preferred model was found using all of the available data, which was then broken into business and non-business purposes.

Three models were tested with all purposes combined:

- Basic (x1).
- Panel ASC (x4).
- Panel ASC allowing for ASC correlation (x5) (not for regional station choice).

The Panel ASC model allows for an additional individual-specific random term to be attached to each station ASC, with variance to be estimated, as a way of allowing for 'repeated observations'. In model x4 these terms are assumed to be independent, but in model x5, for Sydney and Melbourne where there are multiple options, they are allowed to be correlated, and the extent of correlation is treated as an additional parameter to be estimated. Essentially the ASC parameters are estimated as multi-variate normally distributed: for model x4 the variance matrix has only diagonal entries, but for model x5 off-diagonal elements relating separately to the Sydney and Melbourne ASCs are added. In the tables, the terms *sasc* represent the square root of the ASC variances, while the 'ASC correlations' are calculated as the ratio of the off-diagonal element to the product of the standard deviations on the diagonal.

Given that the models for Sydney and regional origins both looked sensible, as did Melbourne after some adjustment, a combined model was estimated as shown in **Table 34**, in which separate ASCs are estimated for the various non-central stations, but other parameters are the same regardless of origin. Since for both Sydney and Melbourne the x5 model was preferred to x4, x4 was not estimated for the combined model and x5 was chosen to represent the 'panel effect'. Different scaling has also been allowed for, relative to Sydney: for the regional origins the scale is not significantly different from 1, but for Melbourne it is significantly lower, indicating a greater randomness. This means that the variations between individuals in the sample in the way stations are selected are greater for Melbourne than elsewhere.

In reporting the estimation results, square brackets contain the parameter symbols which were used in the utility equation, but for ease of understanding a somewhat expanded description of the parameter is also given in the first column. Commentary on the results follows the table.

Table 34 Combined station choice, model comparison

Parameters	x1		X5	
	Para	T-test	Para	T-test
VoT (\$/hr) (all purposes combined)	18.12	6.79	16.02	8.25
$\rho(\text{ACOST}) [\varphi_a]$	0.55	10.16	0.45	8.19
$\rho(\text{ATIME}) [\rho_a]$	1.38	7.06	1.15	7.51
MELB AIRPORT ASC (\$)	8.25	3.73	6.38	2.15
CRAIGIEBURN ASC (\$)	9.55	3.35	8.29	1.92
OUTER REGIONAL ASC (\$)	3.44	6.59	3.75	5.98
PARRAMATTA ASC (\$)	2.94	1.98	3.50	1.62
HOME BUSH ASC (\$)	3.84	4.12	3.88	3.25
B_COST $[\gamma_c]$	-0.0961	-11.32	-0.1420	-10.93
sasc, melb airport (\$)			18.30	6.34
sasc, craigieburn (\$)			19.60	4.33
sasc, outer regional (\$)			8.76	12.68
sasc, parramatta (\$)			7.88	3.23
sasc, homebush (\$)			9.08	7.54
ASC Correlation (SYD)			0.79	8.43
ASC Correlation (MELB)			0.48	5.77
MELB SCALING	0.50	7.14	0.61	6.41
REGIONAL SCALING	0.99	9.94	1.17	9.50
Number of observations	4104		4104	
Number of individuals	4104		456	
Significant parameters	10		8	
Log likelihood	-2672.95		-2375.11	
LL per obs	-0.651		-0.579	

The ASCs should be interpreted as the additional implied penalty in dollars.

In summary, looking at the analysis across all origins, the following trends are evident:

- Although the ASC panel model is a considerable improvement on the basic model, the generalised cost coefficients (i.e. VoT, φ_a and ρ_a) are not greatly affected.
- In the cases where there are two ASCs (Melbourne and Sydney) there is significant positive correlation between the two; for Melbourne, the correlation 0.48 is not as strong as for Sydney (0.79).
- $\rho(\text{ACOST}) [\varphi_a]$ is consistently < 1 (regional and city), suggesting that access costs may not be fully taken into account.
- $\rho(\text{ATIME}) [\rho_a]$ is < 1 for regional but > 1 for city; note that the mode of access will typically be different between central stations (with limited or no parking facilities) and non-central stations, and this has not been allowed for in the analysis.

- The mean ASCs are small (all < \$10), though the significant positive values imply a disadvantage relative to the central station. However, as noted, there is considerable individual-specific ASC variation, suggesting that the population is divided between those favouring a central station and those favouring a non-central station.
- Values of time generally look reasonable (though without constraining the access time ρ , Melbourne VoTs were low); when segmenting by purpose, business had higher values than leisure.

4.2 Analysis of mode choice SP data (all modes)

The mode choice presented to each respondent was a binary choice between their current mode and HSR.

The total proportion of trading between HSR and the current mode was 65 per cent of the sample, with three quarters of the non-traders choosing HSR in every scenario. The following tables provide a breakdown of who the non-traders⁹ are.

Respondents currently travelling by air were more likely to trade than those travelling by car, while rail passengers (Newcastle-Sydney) overwhelmingly switched to HSR (**Table 35**). Car travellers were the most likely to choose only their current mode, predominantly due to the convenience of having a car at the destination end of their journey. The study did not collect car ownership data, but according to **Table 10**, 152 of the air travellers and 35 of the rail travellers did consider the car mode.

Table 35 Non-traders by mode

Mode	Total sample	Non-traders		Among non-traders, HSR only	
		Count	Percentage	Count	Percentage
Air	732	224	31	203	91
Car	1254	438	35	278	63
Rail	112	69	62	66	96
Total	2098	731	35	547	75

People in regional areas (Albury-Wodonga and Canberra) typically traded more than those based in Melbourne or Sydney (**Table 36**). Note that the Newcastle sample contains a large portion of rail journeys (112 out of 300) which were less inclined to trade. The high proportion of non-traders in Wagga Wagga is due to an issue discovered early in the survey, which resulted in the HSR service presented being too attractive. This was subsequently modified, resulting in much more trading.

Table 36 Non-traders by origin

Origin	Total sample	Non-traders		Among non-traders, HSR only	
		Count	Percentage	Count	Percentage
Melbourne	556	196	35	148	76
Albury-Wodonga	191	42	22	21	50
Wagga Wagga	150	66	44	60	91
Canberra	251	54	22	35	65
Sydney	650	227	35	151	67
Newcastle	300	146	49	132	90

⁹ In addition to non-traders, 23 observations noted as having extreme or incorrect values have been removed for the mode choice estimation (18 currently travelled by car, and five by air).

Respondents travelling to large centres such as Melbourne, Brisbane and the Gold Coast were more likely to trade than those travelling to regional areas (**Table 37**).

Table 37 Non-traders by destination

Destination	Total sample	Non-traders		Among non-traders, HSR only	
		Count	Percentage	Count	Percentage
Albury-Wodonga	128	48	38	21	44
Canberra	386	130	34	86	66
Sydney	904	327	36	275	84
Melbourne	375	114	30	93	82
Wagga Wagga	19	10	53	8	80
Newcastle	77	41	53	23	56
Port Macquarie	42	17	40	7	41
Gold Coast	65	17	26	13	76
Brisbane	95	24	25	20	83
Shepparton	7	3	43	1	33

As found in the pilot survey, it was difficult to make people travelling over short distances trade (**Table 38**), though the non-traders were mainly only choosing HSR rather than their current mode (mainly car). In addition, the short regional sample includes respondents from both Wagga Wagga-Canberra and Newcastle-Sydney rail trips, which both had high incidences of choosing HSR only. Respondents making long regional trips (typically over 250 kilometres and not between capital cities) were the most likely to trade. Of those that did not trade, there was a much higher incidence of people remaining with their current mode for long regional trips, compared with the other two markets.

Table 38 Non-traders by distance

Distance	Total sample	Non-traders		Among non-traders, HSR only	
		Count	Percentage	Count	Percentage
Intercity	854	285	33	247	87
Short regional	411	225	55	190	84
Long regional	833	221	27	110	50

Business travellers (about 21 per cent of the sample) were slightly more likely not to trade (**Table 39**).

Table 39 Non-traders by purpose

Purpose	Sample	Non-traders		Among non-traders, HSR only	
		Count	Percentage	Count	Percentage
Business	449	181	40	133	73
Non-business	1649	550	33	414	75

Looking at the data by mode, distance and purpose at the same time (**Table 40**) shows that the air-long regional sample is the most likely to trade, while, among the non-traders, air inter-capital and rail short regional were likely to choose HSR in every scenario. For car, short regional journey trading occurred less than half of the time. There is only a small difference between purposes, with business slightly more likely not to trade.

Table 40 Non-traders by mode, distance and purpose

Mode	Distance	Purpose	Sample	Non-traders		Among non-traders, HSR only	
				Count	Percentage	Count	Percentage
Air	Inter-capital	Business	260	104	40	95	91
Air	Inter-capital	Non-business	360	104	29	96	92
Air	Long regional	Business	49	7	14	6	86
Air	Long regional	Non-business	63	9	14	6	67
Car	Inter-capital	Business	5	2	40	0	0
Car	Inter-capital	Non-business	229	75	33	56	75
Car	Long regional	Business	71	30	42	6	20
Car	Long regional	Non-business	650	175	27	92	53
Car	Short regional	Business	48	27	56	16	59
Car	Short regional	Non-business	251	129	51	108	84
Rail	Short regional	Business	16	11	69	10	91
Rail	Short regional	Non-business	96	58	60	56	97

The variables presented in the mode choice SP are shown in **Table 41**.

Table 41 SP variables available (mode choice)

Attribute	Short form	HSR	Air	Standard rail	Car
Access time	ATIME	SP	RP	RP	N/A
Access cost	ACOST	SP	RP	RP	N/A
Check-in time	CHECK	Constant	SP	None	N/A
In vehicle time	TIME	SP	SP	SP	SP
Frequency	WAIT	SP	SP	SP	N/A
Fare	FARE/COST	SP	SP	SP	SP
Class	CLASS	Fixed	RP	RP	N/A
Egress time	ETIME	RP	RP	RP	N/A
Egress cost	ECOST	RP	RP	RP	N/A

Note: SP indicates that the variable is actually varied within the options presented, while RP indicates that the variables are fixed for all the options presented, but can still vary between individuals (RP data). This reflects the fact that the options presented in the SP were in the context of a particular sampled journey: with the exception of HSR station choice, it was not considered realistic to modify the access and egress arrangements.

For the mode choice, initially the analysis was undertaken separately by current mode (binary choice). The following utility functions were tested:

$$U_{\text{HSR,Air,Rail}} = \gamma_c (\text{VoT} \cdot [\text{Time} + \rho_c \cdot \text{Check-in} + \rho_w \cdot \text{Wait} + \rho_a \cdot \text{Acc_time} + \rho_e \cdot \text{Egr_time}] + \varphi_a \cdot \text{Acc_cost} + \varphi_e \cdot \text{Egr_cost} + \text{Fare}) + \varepsilon$$

$$U_{\text{Car}} = \gamma_c (\text{VoT} \cdot \text{Time} + \text{Cost}) + \varepsilon$$

where, as with station choice, VoT is the value of time, γ_c is a scaling parameter (here expressed in money units), ρ_a is the VoT multiplier for access time, and φ_a is a parameter allowing for a potentially different response to money spent on access as opposed to fare (though a value close to 1.0 would be expected), with ε representing the random term. In addition, corresponding parameters ρ_e , ρ_c and ρ_w are the VoT multipliers for egress time, check-in time and waiting time, while φ_e allows for a potentially different response to money spent on egress. The HSR utility function also includes an ASC to allow for the additional utility that may be associated with this mode.

Note that for HSR and air, 'check-in' refers to the time spent checking-in (the additional time before departure that you have to arrive) as opposed to 'wait', which represents the expected waiting¹⁰ time between services. The non-car utility functions may also include an ASC.

Following these initial estimates, the data were pooled in various ways with the aim of estimating the most consistent overall models. The aim was, for each market, to provide appropriate values of:

VoT – value of time (\$/hr)

ρ_c – ratio of check-in time to in vehicle time utility

ρ_a – ratio of access time to in vehicle time utility

ρ_e – ratio of egress time to in vehicle time utility

ρ_w – ratio of expected wait time for next service to in vehicle time utility

φ_a – ratio of access cost to fare utility

φ_e – ratio of egress cost to fare utility

ASC_{HSR} (minutes)

When data for more than one current mode was pooled, the ASCs were defined relative to the car mode. In addition, there was some possibility of providing evidence about the hierarchical coefficients (i.e. the ratio of the scaling parameters between nests) and the scaling parameters themselves.

Keeping in mind how the HSR demand model was set up, the data was segmented by current mode, purpose and distance. Current mode is car, air or standard rail. Purpose is business and non-business (leisure, visiting friends and relatives, education etc). Distance is described in detail below.

¹⁰ Waiting time is a non-linear function of service frequency ($\text{wait} = 0.72 \times \text{headway}^{0.75}$). This is the function used in the demand model, and is in general use in the Australian context for situations where headways vary from short to quite long. It closely reflects the recommended curves in the UK Passenger Demand Forecasting Handbook for rail.

Table 42 shows the highway distances (city centre to city centre) between all of the OD pairs included in the survey. The highlighting shows how the OD pairs have been classified into three distance/city type categories consistent with the HSR demand model.

Table 42 Distance matrix (kilometres between origin and destination for surveyed movements)

Destination	Origin					
	Melbourne	Albury-Wodonga	Wagga Wagga	Canberra	Sydney	Newcastle
Melbourne		327		666	878	
Shepparton	189					
Albury-Wodonga	327			350	554	
Wagga Wagga				245	458	
Canberra	666	350	245		290	438
Sydney	878	554	458	290		158
Newcastle				438	158	
Port Macquarie					384	
Gold Coast					840	
Brisbane					938	789

	Short regional (< 250 km)
	Long regional
	Inter-capital(> 600 km)

Data was analysed by mode (all purposes and distances combined) and then by individual segments. As noted, when analysing by mode (on a binary basis), the ASC is attached to the HSR option.

Three types of models were tested, with some variations around these by fixing non-significant rho (ρ) 'ratio' parameters to 1.0:

- Basic (x1).
- Panel ASC (x4).
- Distributed VOT (x6).

The x4 model allows for an additional individual-specific random term to be attached to the ASC, with variance to be estimated ('repeated observations'). For the mode choice analysis, another form of panel model (x6) was considered in which the Value of Time follows a lognormal distribution. This requires two parameters to be estimated from which the mean and the coefficient of variation (CV, ratio of the standard deviation to the mean) of the distribution can be calculated. The variance parameter actually reported is referred to as $svot^{11}$.

For each mode, the preferred model was chosen and then run separately for the distance/purpose segments. However, the rail sample consisted primarily of non-business travellers (38 out of 43 once non-traders were removed) and therefore only represents the short regional, non-business, rail travel market. These models are presented in the tables below. As with the station choice models, in reporting the estimation results, square brackets contain the parameter symbols which were used in the utility equation, but for ease of understanding a somewhat expanded description of the parameter is also given in the first column. Commentary on the results follows the tables.

¹¹ CV may be calculated by means of the formula $CV = \sqrt{(\exp(\sigma^2) - 1)}$, where $\sigma = svot$.

Table 43 Air, preferred model (x4) segmented by distance and purpose

Parameters	Intercapital – business		Long regional – business		Inter-capital – non-business		Long regional – non-business*	
	Parameter	T-test	Parameter	T-test	Parameter	T-test	Parameter	T-test
VoT (\$/hr)	78.00	12.19	60.00	5.15	18.90	7.94	32.16	2.70
$\rho(\text{ACOST})$ [φ_a]	0.5	3.21	0.5	1.22	0.2	2.65	0.2	0.50
$\rho(\text{ATIME})$ [ρ_a]	0.4	1.89	0.7	1.22	0.9	2.88	-0.1	-0.05
$\rho(\text{ECOST})$ [φ_e]	0.5	1.76	0.7	1.36	0.3	2.57	0.5	0.85
$\rho(\text{ETIME})$ [ρ_e]	1.0	fixed	1.0	fixed	1.0	fixed	0.9	0.97
$\rho(\text{WAIT})$ [ρ_w]	0.3	1.14	0.5	1.32	1.3	2.52	0.5	0.93
$\rho(\text{CHECK})$ [ρ_c]	0.6	3.01	0.9	2.35	0.7	2.87	0.4	0.86
HSR ASC (\$)	2.15	5.04	1.99	2.21	1.89	5.92	-57.30	-3.71
B_COST [γ_c]	-0.03	-13.66	-0.04	-7.28	-0.05	-19.06	-0.04	-8.70
sasc (\$)	1.61	9.50	2.26	5.14	1.65	12.04	50.50	5.46
svot								
Number of obs.	1386		369		2286		486	
Number of ind.	154		41		254		54	
Signif. params.	6		5		9		4	
Log likelihood	-595.2		-148.1		-977.4		-208.5	
LL per obs	-0.429		-0.401		-0.428		-0.429	

* Did not converge, so results are only indicative of parameter values.

Note: Air is not relevant for short regional movements.

Table 44 Rail, all purposes and distances, preferred mode choice model

Parameters	x6_fixed	
	Parameter	T-test
VoT (\$/hr) - mean	19.49	4.58
$\rho(\text{ACOST})$ [ϕ_a]	1.0	fixed
$\rho(\text{ATIME})$ [ρ_a]	1.1	2.60
$\rho(\text{ECOST})$ [ϕ_e]	1.0	fixed
$\rho(\text{ETIME})$ [ρ_e]	1.0	fixed
$\rho(\text{WAIT})$ [ρ_w]	1.0	fixed
$\rho(\text{CHECK})$ [ρ_c]		
HSR ASC (\$)	2.29	0.73
B_COST [γ_c]	-0.138	-4.58
sasc (\$)		
svot	0.672	4.73
Number of observations	387	
Number of individuals	43	
Significant parameters	4	
Log likelihood	-197.21	
LL per obs	-0.510	

In none of the estimated models for rail was the HSR ASC significantly different from zero (**Table 44** above). As noted above, this model is considered to apply to the short regional, non-business, rail travel market.

Table 45 Car, preferred model (x6) for non-business segmented by distance

Parameters	Short regional – non-business		Long regional – non-business		Inter-capital – non-business*	
	Parameter	T-test	Parameter	T-test	Parameter	T-test
VoT (\$/hr)	16.97	7.42	22.53	17.30	14.23	8.87
$\rho(\text{ACOST})$ [φ_a]	1.0	fixed	1.0	fixed	1.0	fixed
$\rho(\text{ATIME})$ [ρ_a]	0.9	3.44	0.8	5.74	-1.3	-2.02
$\rho(\text{ECOST})$ [φ_e]	1.0	fixed	1.0	fixed	1.0	fixed
$\rho(\text{ETIME})$ [ρ_e]	0.4	1.78	-0.7	-2.90	0.6	1.15
$\rho(\text{WAIT})$ [ρ_w]	0.0	fixed	0.0	fixed	0.0	fixed
$\rho(\text{CHECK})$ [ρ_c]	1.0	fixed	1.0	fixed	1.0	fixed
HSR ASC (\$)	8.09	2.14	-1.80	-0.84	-0.90	-0.11
B_COST [γ_c]	-0.09	-11.07	-0.05	-24.02	-0.03	-12.48
sasc (\$)						
svot	0.50	4.82	1.03	15.90	0.74	9.13
Number of obs.	1098		4221		1296	
Number of ind.	122		469		144	
Signif. params.	5		5		4	
Log likelihood	-573		-2072		-634	
LL per obs [#]	-0.522		-0.491		-0.490	

* Did not converge, so results are only indicative of parameter values

[#] LL is abbreviation for Log Likelihood

Table 46 Car, preferred model (x6) for business segmented by distance

Parameters	Short regional – business*		Long regional – business*	
	Parameter	T-test	Parameter	T-test
VoT (\$/hr)	45.76	2.57	264.91	1.35
$\rho(\text{ACOST})$ [ρ_a]	1.0	fixed	1.0	fixed
$\rho(\text{ATIME})$ [ρ_a]	-0.1	-0.08	1.4	1.94
$\rho(\text{ECOST})$ [ρ_e]	1.0	fixed	1.0	fixed
$\rho(\text{ETIME})$ [ρ_e]	1.0	2.20	1.7	7.86
$\rho(\text{WAIT})$ [ρ_w]	0.0	fixed	0.0	fixed
$\rho(\text{CHECK})$ [ρ_c]	1.0	fixed	1.0	fixed
HSR ASC (\$)	-0.41	-0.02	1.18	0.02
B_COST [γ_c]	-0.03	-4.46	0.00	-3.17
sasc (\$)				
svot	0.70	3.13	1.39	1.88
Number of obs.	189		369	
Number of ind.	21		41	
Signif. params.	3		2	
Log likelihood	-107		-228	
LL per obs [#]	-0.569		-0.618	

*Did not converge, so results are only indicative of parameter values.

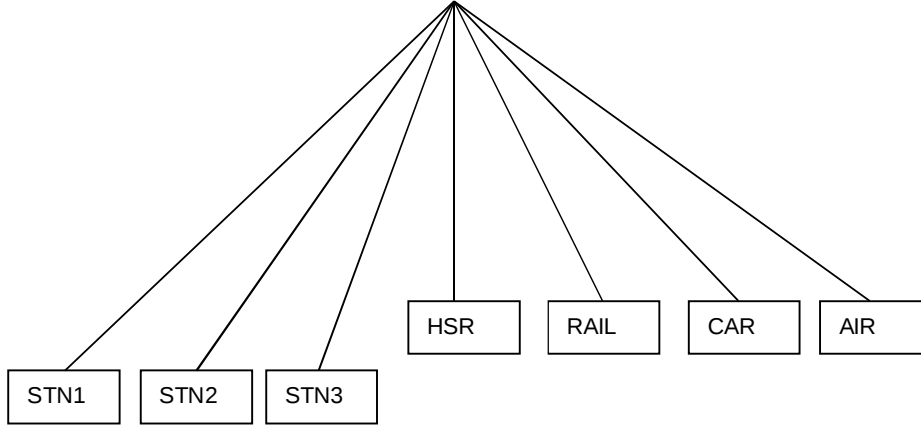
[#] LL is abbreviation for Log Likelihood

It can be seen that while the key values of time are generally sensible, less plausible values (and in some cases, wrongly signed) for the other generalised cost weights (access, egress, etc.) were obtained in a number of cases, leading to some constraints being imposed. This is a general issue that is addressed in **Section 5.3**. It should be borne in mind that, as set out in **Table 41**, some of these variables only had limited variation.

4.3 Combined estimation

Having obtained generally plausible results from the individual choice tasks, the next stage was to pool all the data, and this led to questions as to how the mode choice and station choice tasks should be structured. In the demand model, the station choice model was conditional on the choice of HSR, and this suggested a nested structure. However, it was decided to adopt a non-nested structure as shown in **Figure 8**. This reflects that, while the two SPs are linked, the respondent is never directly presented with the choice between multiple HSR stations and their current mode. Instead, there are two distinct steps: (a) choose an HSR station (b) compare this HSR choice to the current mode. A scale factor has therefore been estimated for the station choice experiment (with the expectation that this will be > 1), which results in seven options, the three station choices, and four higher mode choices. This avoids the loss of information from the station choice data when HSR is not selected in the mode choice when estimating a fully nested model.

Figure 8 Non-nested structure for combined mode and station choice estimation



A number of variants were examined. The general assumption in transport forecasting models is that scaling parameters will be held constant in time units, with allowances for increases in VoT reflecting rising income. For convenience, most of the detailed (segmented) analysis has kept the scaling parameters in money units, but the combined analysis models were estimated in both time and money units. The models based on time units were marginally preferred, and since this corresponds with the forecasting requirements, these have been retained.

The general specification for this model has the form:

$$\lambda_{SP1} \cdot \gamma_{T, purp, sec} \cdot (T + C / VoT_{purp, sec})$$

The T and C terms denote **all** the relevant cost and time elements, including ASCs.

This specification allows both scaling parameter γ_T and value of time V to vary with purpose and distance sector. The parameter λ_{SP1} allows for a different scale to apply to the station choice data.

As written, the notation implies that a separate scaling parameter and value of time were estimated for each combination of purpose and sector. In fact, a slightly more parsimonious approach to estimation was adopted, treating the two effects as independent and multiplicative. In both cases, the estimated basic parameters (γ_T and value of time V) relate to the non-business purpose and the inter-capital distance. The 'Δ' parameters modify these parameters for the business purpose, and the 'p' parameters modify them for the other distances.

Thus, for the scaling parameter $\gamma_{T, purp, sec}$ was estimated as:

$$(\gamma_T + \Delta \gamma_T \cdot \delta_{Bus}) \left(1 + \sum_{sec=L, S} p_{T, sec} \cdot \delta_{sec} \right)$$

and the Value of time $VoT_{purp, sec}$ was estimated as:

$$(V + \Delta V \cdot \delta_{Bus}) \left(1 + \sum_{sec=L, S} p_{sec} \cdot \delta_{sec} \right)$$

where 'Bus' indicates Business purpose and 'sec' relates to distance, and the δ (0,1) variables indicate whether the category applies.

As a result, the overall specification can be expanded to:

$$\lambda_{SP1} \cdot (\gamma_T + \Delta\gamma_T \cdot \delta_{Bus}) \cdot \left(1 + \sum_{sec=L,S} p_{T,sec} \cdot \delta_{sec} \right) \cdot \left(T + \frac{C}{\left[(V + \Delta V \cdot \delta_{Bus}) \cdot \left(1 + \sum_{sec=L,S} p_{sec} \cdot \delta_{sec} \right) \right]} \right)$$

The overall model (y10a) seems generally to replicate the previous separate analysis, and the 'expt 1' parameter is much greater than 1, showing that the station choice SP is more deterministic than the mode choice SP. The ASC analysis is very similar to what was obtained both on the station choice and on the mode choice and the counter-intuitive results for the rho (ρ) values have largely disappeared, though the access and egress multipliers may still be considered on the low side.

The results (**Table 47**) show that, although the long regional value of time remains significantly higher than inter-capital, the scaling parameters are now in line with expectations and this is the final combined model tested.

In this table, parameters prefixed with 'd' are intended to be added to the basic parameter according to particular segments (thus, for example, the parameter dVOTbus is added to the basic parameter VOT when the respondent is a business traveller). Correspondingly, parameters prefixed with 'ρ' should have 1 added to them as a weight before combining with the generic time or cost variables. ASCs apply to all modes except car¹². Note that, in this model, the ASCs for air and HSR have not been segmented by distance, only by purpose. An additional column of commentary is provided on these results.

¹² These parameters are estimated as the additional weighting relative to IVT. For example, if walking time is 2.5*IVT, p would be 1.5 etc. This allows significant difference from IVT (p = 0) to be easily assessed.

Table 47 Combined estimation segmented by distance with scaling parameter in time units

Parameter	y10a		Comments
	Parameter	T-test	
Number of obs.	16200		
Log-likelihood	-9186		
ASC_AIR (\$)	36	10.02	Large deterrent relative to car
ASC_HSR (\$)	1.36	0.83	No significant difference relative to car
ASC_MEL2 (\$)	5.99	4.08	Implied additional cost Airport relative to Melbourne Central
ASC_MEL3 (\$)	6.85	3.57	Implied additional cost Craigieburn relative to Melbourne Central
ASC_RAIL (\$)	5.97	2.7	Small deterrent relative to car
ASC_REG2 (\$)	2.42	6.5	Implied additional cost relative to Central station
ASC_SYD2 (\$)	1.93	1.38	Insignificant (Parramatta) relative to Sydney Central
ASC_SYD3 (\$)	3.18	3.45	Implied additional cost Homebush relative to Sydney Central
B_TIME (1/min) [γ_T]	-0.0066	-22.5	Scaling factor for non-business
Expt1 [λ_{SP1}]	2.8	16.75	Scaling factor for station choice SP (lower in hierarchy)
VOT (\$/hr)	14.46	24.45	Base Value of Time for non-business, inter-capital
dASC_AIRbus (\$)	32.2	2.91	Additional large deterrent relative to car for business
dASC_HSRbus (\$)	-8.03	-1.19	Insignificant
dB_TIMEbus (1/min) [$\Delta\gamma_T$]	-0.0056	-6.34	Additional scaling factor for business – implies almost double time sensitivity
$\rho(B_TIME _r)$ [$p_{T,LR}$]	0.236	3.26	Slightly increased (23 per cent) time sensitivity for long regional
$\rho(B_TIME _s)$ [$p_{T,SR}$]	0.763	4.9	Substantially increased (76 per cent) time sensitivity for short regional
dVOTbus [ΔV] (\$/hr)	43.80	9.83	Additional value of time for business (implies a factor of 4) ¹³
pVOTlr [p_{LR}]	0.464	5.88	Increased value of time (46 per cent) for long regional relative to inter-capital
pVOTsr [p_{SR}]	-0.275	-4.16	Reduced value of time (28 per cent) for short regional relative to inter-capital
$\rho(ACOST)$ [ϕ_a]	0.59	14.12	Implies less notice taken of access cost, relative to fare
$\rho(ETIME)$ [ρ_a]	1.16	15.14	Implies slightly more notice taken of access time, relative to IVT [#]
$\rho(ECOST)$ [ϕ_e]	0.328	4.62	Implies less notice taken of egress cost, relative to fare
$\rho(ETIME)$ [ρ_e]	0.659	6.09	Implies less notice taken of egress time, relative to IVT
$\rho(WAIT)$ [ρ_w]	0.402	1.81	Implies less notice taken of waiting time, relative to IVT
$\rho(CHECK)$ [ρ_c]	0.843	5.88	Implies slightly less notice taken of check-in time, relative to IVT [#]

[#] IVT is abbreviation for In-Vehicle Time

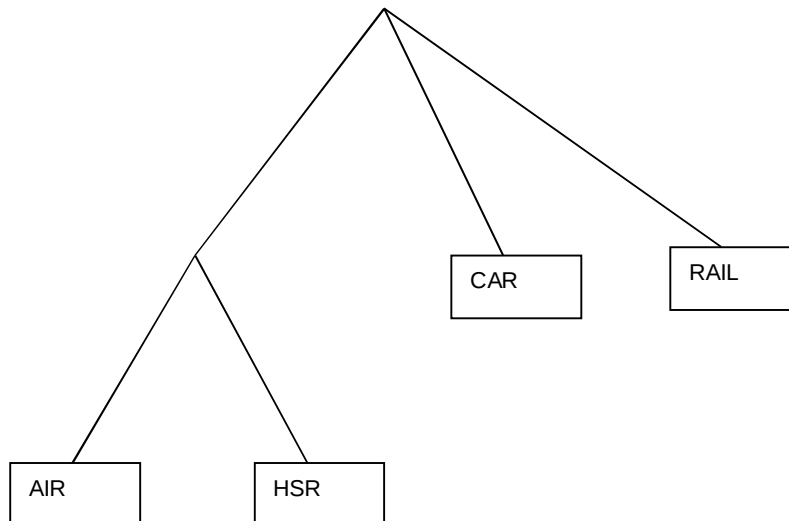
¹³ The base per hour value (non-business) is \$14.46, to which \$43.80 must be added for Business, giving a Business value of \$58.26, which is 4.03 times the non-business value.

The SP can also be used to confirm that the mode choice hierarchy used in the demand model (see **Figure 9**) is the best hierarchy to adopt. For the purpose of this investigation the station choice data was omitted. The following four combinations have been tested in the lower nest:

- a) Air and HSR.
- b) Car and HSR.
- c) Rail and HSR.
- d) Air, rail and HSR.

However, it should be noted that, since all availability sets are binary, the scope for testing the hierarchy is very limited. Essentially, the scaling parameters for car, rail and air are being compared. The results provide some comfort that the scaling is higher (more deterministic) for air, and this is in line with the assumed RP model. They suggest that a nesting parameter of 1.3-1.4 is appropriate with the lower nest parameter being more sensitive for the inter-capital journeys. The short regional model does not need to be nested (as air is not available).

Figure 9 Nested structure for combined mode choice estimation (as in demand model)



5.0 Recommendation on coefficients and implementation for demand model

As can be seen from the above commentary, the overall analysis of the SP is complex, because of a) the two experiments, b) the potential differing response by current mode, and c) different segments, particularly in relation to journey length. As set out in earlier sections, the approach has been first to carry out separate analyses, and then to try and estimate overall models.

A particular issue is the relationship between the scaling factors and the values of time, and how they vary with journey length. This issue (sometimes referred to as 'cost damping') is currently a topic of discussion in modelling. It is obvious from the analysis that has been carried out that there is considerable correlation between the scaling factor and the VoT, and also that different results can be obtained according to whether the scaling factor is cast in time or money units. Of course, this only becomes an issue when one starts trying to segment the effects.

The primary focus is on values of time and on the ASC for HSR, since it is considered that this is where the SP has the largest contribution to make. The conclusions are based on a mixture of statistical indicators and *a priori* expectations. On grounds of practicality, no attempt has been made to build a single model allowing for all possible effects. However, when there is some uncertainty about the stability of the results, this is indicated.

The general list of issues where the SP can make some contribution to the overall demand model is as follows:

- a) Scaling parameters.
- b) Choice hierarchy.
- c) Generalised cost specification, including access/egress.
- d) Value of Time.
- e) HSR ASCs.
- f) Station choice issues (ASCs).
- g) The variation in all of these by i) purpose and ii) distance.

The approach taken is that the overall demand model specification will be retained, and the SP results used to enhance it where appropriate.

5.1 Scaling parameters

Based on the coefficients estimated for the combined estimation model (see **Table 47**) the following values were obtained:

Scaling factors (time units)

Non-business inter-capital:	-0.00662
Non-business Long Regional:	$-0.00662 * 1.236 = -0.0082$
Non-business Short Regional:	$-0.00662 * 1.763 = -0.0117$
Business inter-capital:	$-0.00662 - 0.00561 = -0.01223$
Business Long Regional:	$-0.01223 * 1.236 = -0.0151$
Business Short Regional:	$-0.01223 * 1.763 = -0.0216$

Although values of time and ASCs are also available from this model, it is considered more appropriate for them to be separately estimated for each distance/purpose combination, using the scaling parameters obtained in the combined SP analysis. This is discussed below.

In relation to the scaling factors, it is noteworthy that when expressed in time units, the Business values are larger, suggesting a greater sensitivity to time, or a lower variance (in time units) indicating fewer random (non-modelled) effects on choice.

With regard to the distance effect, the SP data supports an increase in the sensitivity with declining distance. The ratio of LR to inter-capital is 1.236 from the SP data and the ratio of SR to inter-capital is 1.763. This general relationship with distance is consistent with the international evidence (**see box overleaf**).

It is generally considered that the scaling factors obtained from an SP analysis should not be directly used for a demand model, but should be re-scaled using data relating to actual choices (RP). There are two sources of data available for this – the somewhat limited RP data collected in the SP survey, and the more extensive data from the NVS. Both data sources have been used, but greater confidence is placed in the NVS analysis. The RP analysis should also be used to determine the appropriate ASCs for existing modes.

The approach taken was firstly to reach conclusions about the appropriate generalised cost specification from the SP analysis and then, using the relative scaling parameters given above, to estimate an overall scale to make the demand responsiveness to generalised cost compatible with the RP data. The results of this re-scaling are given in **Section 5.5**.

International evidence of the variation of scaling parameters with distance

The expected values of the scaling parameters of the logit model were reviewed in the HSR context. With generalised times expressed in units of minutes, scaling parameters are directly comparable (and, where appropriate, transferable) between studies/models.

The scaling parameter values in the table below confirm the expected trend of reducing parameter values as distances increase: from 0.04 to 0.08 for metropolitan journeys to around 0.02 for long-distance inter-city journeys. Despite this variation, there is a large degree of consistency in the broad magnitude of the scaling parameters.

International evidence on the values of the scaling parameters used in inter-city/interurban travel demand studies

Source	Mode choices	Values of scaling parameters (trip purpose)
Inter-city/long-distance		
EC (SDG, 2006)	Air/HSR	0.010
US/Texas (Brand et al)	Air/car	0.009, 0.022 (business); 0.005, 0.029 (non-business)
PBKA (MVA, 1986)	Air/rail/car	0.007, 0.008, 0.011 (business)
HST-OOST (international), the Netherlands		0.02 (business); 0.01, 0.02 (other)
Regional medium distance		
Speedrail Study: Sydney-Canberra trips	Air/HSR/other	0.02 (business), 0.013 (other)
Regional short distance		
Speedrail Study: intermediate trips	HSR/other	0.037 (business), 0.017 (other)
Regional Fast Rail Study, Victoria	Car/rail	0.014 (other)
LDTM, The Netherlands (MVA, 1985)		0.05, 0.04 (Business); 0.017, 0.03 (optional)
Metropolitan models		
Melbourne Integrated Travel Model (MITM)	Car/PT	0.05, 0.08 (other)
Auckland Regional Transport Model (ART3)		0.04 (other)

Notes: Costs in units of minutes. Where more than one scaling parameter value is given, the scaling parameter (the factor applied to generalised time) varies by mode, and the range of values used is indicated in the table (in no particular order).

References

EC report by SDG: Air and Rail Competition and Complementarity, 2006.

Daniel Brand et al., Forecasting High-Speed Rail Ridership, Transportation Research Record 1341, 1992.

Paris-Brussels-Cologne/Amsterdam Study, Forecasts of Air Travel, The MVA Consultancy 1986.

The Long Distance Travel Model for the Netherlands, Coefficients and other Parameters used in the Model, The MVA Consultancy, 1985.

5.2 Modal hierarchy

Regarding the modal hierarchy, the SP data can only provide weak information, but the analysis in **Section 4.3** suggested that the choice between HSR and air had a higher scaling parameter (by a factor of about 1.4).

The SP analysis also suggests a global scaling factor of 2.8 for the station choice process relative to the mode choice. This strongly supports the fact that station choice is more sensitive to time than mode choice.

5.3 Generalised cost weights

Turning now to the generalised cost components, the combined SP analysis [y10a] (see **Table 48**) delivers the following weights (the existing assumptions from the demand model are presented for comparison):

Table 48 Generalised cost coefficients (same for all modes, purposes and distances)

Coefficient	Demand model	SP	t-ratio of difference from 1.0
Access time [ρ_a]	2.0	1.16	2.09
Access cost [ϕ_a]	1.0	0.59	9.81
Check-in time [ρ_c]	1.0	0.843	1.10
Wait time* [ρ_w]	2.0	0.402	2.69
In-vehicle time	1.0	1	
Fare	1.0	1	
Egress time [ρ_e]	2.0	0.659	3.15
Egress cost [ϕ_e]	1.0	0.328	9.47

* Applied to non-linear transformation of headway.

With the exception of check-in time, the SP values are all significantly on the low side, and therefore merit some discussion. Note first that the egress variables were not varied within the SP for an individual respondent, so that the measured effect is due to RP variation between respondents.

The analysis suggests that both access and egress costs are weighted significantly lower than main mode cost. At least in the context of long-distance travel, this does not seem unreasonable in principle. However, it is considered illogical that an increase in access/egress cost would be perceived more favourably than the same increase in main mode cost, and on this basis it was not proposed to change the current assumptions.

The argument is more difficult in relation to the other (time) components. Of the four elements (access, check-in, wait and egress), check-in is not significantly different from one, but the other three are, even if the t-statistics are not especially strong. In addition, the model assumes a value of two for access and wait. As far as wait time is concerned, the non-linear transformation of headway (in line with Australian Transport Council (ATC) Guidelines¹⁴) is essentially consistent with the recommended UK approach to rail forecasting in *Passenger Demand Forecasting Handbook*¹⁵ after allowing for the factor of two. Given the weight of evidence behind this, the SP result for wait time was not accepted.

This leaves access and egress times. The SP results give values on either side of one, access being 1.16 and egress 0.66. There is, however, more confidence that access time has been appropriately considered by respondents through the station choice SP, where it was one of only five variables to be considered. Egress time was only included at the end of a long list of variables to be considered as part of the mode choice SP and did not vary between scenarios. For these reasons, less attention is

¹⁴ Australian Transport Council, *National Guidelines for Transport System Management in Australia*, 2006.

¹⁵ Association of Train Operating Companies, *Passenger Demand Forecasting Handbook*, 2011, Section B4.6.2.

paid to the egress time coefficient and as it is not believed that there is any significant evidence that access and egress should be differentially weighted, it is assumed that their values should be the same. Further, experience with the demand model made it clear that having too low weightings on access and egress time resulted in the HSR stations having very large and seemingly unreasonable catchments – principally because of fast car access in regional areas. Since the value of 2.0 in the model is more in line with international experience (though it is noted that it is higher than the value of 1.4 in the ATC guidelines), it was proposed to stay with the existing value.

It may be noted that, given the dominance of the main mode costs and times, it is quite difficult to obtain convincing results from SP for the ancillary aspects of access and egress. In addition, the station choice exercise possibly over-emphasised the importance of access time (leading to rather extreme results in the case of Melbourne).

On balance, therefore, it is not considered that these SP results are sufficiently reliable to lead us to change the generalised cost assumptions. Sensitivity tests have been carried out to check that the key results from the SP (e.g. VoT, scaling factors) are not significantly affected by constraining the weightings on generalised cost to the existing demand model values. The consistency of the VoTs can be seen in the following tables (**Table 49** to **Table 51**) discussed below.

5.4 Values of time and ASCs

Although for convenience of analysis a combined model has been estimated, the model will be implemented separately for each purpose and distance combination. It is therefore considered appropriate to derive the best model to fit each separate data set, but maintain certain key aspects consistent with the combined analysis (the scaling parameters were fixed as in model y10a (**Table 47**), as well as the ratio of business to non-business value of time).

Hence, as the last significant piece of SP analysis, for each distance sample (inter-capital, long regional, and short regional) the models were re-estimated. In the first place, this used the generalised cost weights as estimated in y10a. It was then repeated, constraining the weights as recommended in the previous paragraphs. Finally, this last run was repeated, but with the ASCs in time rather than money units, and additionally, separately by purpose (although in cost terms the ASCs were not significantly different for business/non-business, they were in time terms).

Hence, to summarise, in **Table 49** to **Table 51** four different models¹⁶ are presented, separately for the three distance sectors:

- | | |
|----------------------------------|---|
| a) y10a_dist3 | y10a specification but fixing all coefficients as estimated for y10a other than ASCs and overall Value of Time. |
| b) Y10a_dist3_GC | the same specification as a) but fixing all generalised cost coefficients as in the demand model. |
| c) y10a_dist3_GC_time2 | the same specification as b) but estimating all ASCs in time rather than money terms. |
| d) y10a_dist3_GC_time2bus | the same specification as c) but additionally allowing ASCs to vary by purpose. |

In all cases, it can be seen that the impact of the constrained generalised cost weights and reformulating the ASCs in time units on the values of time and the overall model fit is relatively modest. As would be expected, a larger effect is seen on the ASCs and, on this basis, the values from the last set of models (d) were used.

¹⁶ NB for reasons of auditability, names for the model variants have been maintained both here and in Tables 49-51.

Table 49 Intercity ASC model runs

Parameter	a) y10a_dist3		b) y10a_dist3_GC		c) y10a_dist3_GC_time2		d) y10a_dist3_GC_time2bus	
	Para-meter	T-test	Para-meter	T-test	Para-meter	T-test	Para-meter	T-test
Number of obs.	4977		4977		4977		4977	
Log-likelihood	-2552		-2608		-2620		-2606	
ASC_AIR (\$)	31.7	8.9	-15.6	-4.53				
ASC_AIR (mins)					-82.8	-6.19		
ASC_AIRbus (mins)							74.4	1.19
ASC_AIRnb (mins)							-66.1	-4.55
ASC_HSR (\$)	-6.19	-2.12	-33.9	-11.71				
ASC_HSR (mins)					-122	-9.4		
ASC_HSRbus (mins)							48.4	0.78
ASC_HSRnb (mins)							-134	-10.04
B_TIME (1/mins) [γ_T]	-0.0066	fixed	-0.0066	fixed	-0.0066	fixed	-0.0066	fixed
VOT (\$/hr)	13.74	30.45	15.12	30.01	15.72	29.71	15.18	29.78
dB_TIMEbus (1/min) [$\Delta\gamma_T$]	-0.0056	fixed	-0.0056	fixed	-0.0056	fixed	-0.0056	fixed
pVOTbus [ratio-1]	3.029	fixed	3.029	fixed	3.029	fixed	3.029	fixed
$\rho(\text{ACOST})$ [ϕ_a]	0.59	fixed	1	fixed	1	fixed	1	fixed
$\rho(\text{ATIME})$ [ρ_a]	1.16	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{ECOST})$ [ϕ_e]	0.328	fixed	1	fixed	1	fixed	1	fixed
$\rho(\text{ETIME})$ [ρ_e]	0.659	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{WAIT})$ [ρ_w]	0.402	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{CHECK})$ [ρ_c]	0.843	fixed	1	fixed	1	fixed	1	fixed
Derived parameters								
VOT_nbus (\$/hr)	13.7		15.1		15.7		15.2	
VOT_bus (\$/hr)	55.4		60.9		63.3		51.2	

In **Table 49**, the non-business VoT is about \$15/hr and the business VoT is about \$60/hr. For business, the ASCs for air and HSR are highly correlated and the overall significance of both is low, but the difference between them is significant (t-stat is about 4.9), suggesting that HSR carries an advantage of about 26 minutes. For non-business, there is again an advantage in favour of HSR of about 70 minutes (the t-stat is about 8.8).

Table 50 Long regional ASC model runs

Parameter	a) y10a_dist3		b) y10a_dist3_GC		c) y10a_dist3_GC_time2		d) y10a_dist3_GC_time2bus	
	Para-meter	T-test	Para-meter	T-test	Para-meter	T-test	Para-meter	T-test
Number of obs.	5445		5445		5445		5445	
Log-likelihood	-3058		-3189		-3189		-3152	
ASC_AIR (\$)	43.8	9.54	-23.2	-4.57				
ASC_AIR (mins)					-23.2	-4.57		
ASC_AIRbus (mins)							-109	-9.31
ASC_AIRnb (mins)							-37.7	-2.58
ASC_HSR (\$)	-3.2	-1.75	-36.2	-22.42				
ASC_HSR (mins)					-36.2	-22.42		
ASC_HSRbus (mins)							-92.8	-10.4
ASC_HSRnb (mins)							-99.4	-16.89
B_TIME (1/mins) [γ_T]	-0.0082	fixed	-0.0082	fixed	-0.0082	fixed	-0.0082	fixed
VOT (\$/hr)	20.46	28.95	22.56	27.54	22.56	27.54	21.12	27.92
dB_TIMEbus (1/min) [$\Delta\gamma_T$]	-0.0069	fixed	-0.0069	fixed	-0.0069	fixed	-0.0069	fixed
pVOTbus [ratio-1]	3.029	fixed	3.029	fixed	3.029	fixed	3.029	fixed
$\rho(\text{ACOST})$ [ϕ_a]	0.59	fixed	1	fixed	1	fixed	1	fixed
$\rho(\text{ATIME})$ [ρ_a]	1.16	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{ECOST})$ [ϕ_e]	0.328	fixed	1	fixed	1	fixed	1	fixed
$\rho(\text{ETIME})$ [ρ_e]	0.659	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{WAIT})$ [ρ_w]	0.402	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{CHECK})$ [ρ_c]	0.843	fixed	1	fixed	1	fixed	1	fixed
Derived parameters								
VOT_nbus (\$/hr)	20.5		22.6		22.6		21.1	
VOT_bus (\$/hr)	82.4		90.9		90.9		85.0	

In **Table 50**, the non-business VoT is about \$21/hr and the business VoT is about \$85/hr. Note that these are higher values than for inter-capital, an unexpected finding but one which emerges consistently from the analysis. For business, the ASCs are again highly correlated, but the difference is not significant. The difference is much greater in the case of non-business, however, suggesting an advantage of about 60 minutes in favour of HSR (therefore similar to the inter-capital effect) and significant (t-stat = 4.4).

Table 51 Short regional ASC model runs

Parameter	a) y10a_dist3		b) y10a_dist3_GC		c) y10a_dist3_GC_time2		d) y10a_dist3_GC_time2bus	
	Para-meter	T-test	Para-meter	T-test	Para-meter	T-test	Para-meter	T-test
Number of obs.	1674		1674		1674		1674	
Log-likelihood	-926		-967		-940		-938	
ASC_HSR (\$)	3.04	3.14	-18.8	-11.78				
ASC_HSR (mins)					-90.2	-15.69		
ASC_HSRbus (mins)							-97.3	-9.51
ASC_HSRnb (mins)							-88.6	-13.99
ASC_RAIL (\$: mins)	8.11	4.31	-7.1	-2.66				
ASC_RAIL (\$: mins)					-30.9	-2.94		
ASC_RAILbus (mins)							-68.5	-3.55
ASC_RAILnb (mins)							-17.2	-1.38
B_TIME (1/mins) [γ_T]	-0.0117	fixed	-0.0117	fixed	-0.0117	fixed	-0.0117	fixed
VOT (\$/hr)	9.72	12.73	12.66	12.94	9.90	15.01	9.60	14.36
dB_TIMEbus (1/min) [$\Delta\gamma_T$]	-0.0099	fixed	-0.0099	fixed	-0.0099	fixed	-0.0099	fixed
pVOTbus [ratio-1]	3.029	fixed	3.029	fixed	3.029	fixed	3.029	fixed
$\rho(\text{ACOST})$ [ϕ_a]	0.59	fixed	1	fixed	1	fixed	1	fixed
$\rho(\text{ATIME})$ [ρ_a]	1.16	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{ECOST})$ [ϕ_e]	0.328	fixed	1	fixed	1	fixed	1	fixed
$\rho(\text{ETIME})$ [ρ_e]	0.659	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{WAIT})$ [ρ_w]	0.402	fixed	2	fixed	2	fixed	2	fixed
$\rho(\text{CHECK})$ [ρ_c]	0.843	fixed	1	fixed	1	fixed	1	fixed
Derived parameters								
VOT_nbus (\$/hr)	9.7		12.7		9.9		9.6	
VOT_bus (\$/hr)	39.2		51.0		39.9		38.7	

In **Table 51**, the non-business VoT is about \$10/hr and the business VoT is about \$40/hr. For business, the difference in the ASCs (this time between HSR and rail) is not significant. Once again, however, a difference of about 70 minutes in favour of HSR is found in the case of non-business (t-stat = 6.0).

Overall, the values of time shown in **Table 52** are recommended. The larger values of time for longer distance travel is supported by international experience (**see box overleaf**).

The evidence for higher values of time in long distance contexts

The value of time is one of the important parameters in demand forecasting. There are recommended values in Australia. For example, the Austroads recommended values are \$42.17/hr and \$13.18/hr for business and non-business car trips respectively (in \$2010).

The available local and international evidence is persuasive for an increase in the value of time with trip distance; see for example, the references below. Specific UK and Australian high speed rail experience is reviewed below (values have been updated by GDP/capita growth). All studies have used higher values of time than is usual in urban/local studies, reflecting the specific nature of the study context.

UK HS2 Study (London-Birmingham)

In broad terms, the values of time suggested for high-speed and classic rail in this project were around double that of Webtag standard values (similar to Austroads), and are also broadly compatible with the values in the London Airport surface access models.

Comparison of VoTs (UK pence/min, 2002 prices and values)

Segment	PSM classic rail	PSM HSR	NRTS	WebTAG	LASAM (2003)
Business	51.20	61.60	51.40	36.85	63.8/67.9
Commuting	12.6	18.1	23.76	8.4	-
Leisure NCA	13.7	18.6	13.76	7.43	25.3
Commuting NCA	12.6	18.1	17.65	8.4	-

PSM: Planet Strategic Model (based on stated preference data).

NRTS: models estimated from the National Rail Travel Survey.

LASAM: London Airports Surface Access Model, 2003 (medium income values of time).

NCA: Non car available.

Very Fast Train Study (Sydney-Melbourne, 1991)

The following are the understood values of time obtained in stated preference surveys in 1987, updated to 2010:

- Car: \$95.60/hr and \$44.40/hr for business and non-business respectively.
- Air: \$105.00/hr and \$40.80/hr for business and non-business respectively.
- Coach: \$33.90/hr for all purposes.
- Rail: \$13.50/hr for all purposes.

Speedrail (Sydney-Canberra)

These are the model values (derived through stated preference) updated to \$2010:

- Sydney-Canberra market, business: \$78.50/hr.
- Sydney-Canberra market, non-business: \$16.20/hr.
- Intermediate markets, business: \$31.00/hr.
- Intermediate markets, non-business: \$17.50/hr.

References

Abrantes and Wardman, *Meta Analysis of UK Values of Time: an Update*, Transportation Research, 2001.

Wardman, *Public Transport Values of Time*, Working Paper 564, December 2001.

Institute for Transport Studies, University of Leeds and John Bates Services, *Values of Travel Time Savings In the UK*, Technical Report to Department for Transport, January 2003.

Table 52 Values of time (\$2012/hr)

Purpose	Distance		
	Short regional	Long regional	Inter-capital
Business	40	85	60
Non-business	10	21	15

Regarding the ASCs, there is some evidence of a preference in favour of HSR per se, relative to the modes air (inter-capital and long regional) and rail (short regional).

For business, the effect is weak. However, for non-business a difference of 60-70 minutes is found in each distance segment. It may be noted that in all cases a constant check-in time of 15 minutes, weighted by a factor of one, was included in the HSR options, but this has so far not been assumed in the model forecasts. If this is removed from consideration, then the SP suggests that the HSR ASCs for business travel are close to zero while those for non-business are broadly 45-55 minutes.

Finally, some observations on station choice are made. Over and above access considerations, the city centre locations are favoured, with (on average) peripheral locations having a \$6-\$8 penalty in Melbourne, and \$2-\$3 in Sydney and the regions. An attempt to estimate an access-mode-specific penalty suggested that relative to the most preferred (walking), P&R (park and ride) had a penalty of about \$2.50, public transport of \$3, and both pick up/drop off and taxi of about \$4.25. While these appear logical, their significance is relatively low.

5.5 Calibration to revealed preference data

As explained at the outset, the SP data has been used to support and extend the phase 1 demand model. It was not the intention to develop a new free-standing model based entirely on the SP data. Ideally, a panel-based analysis would be used throughout, but this leads to long and complicated estimations. The panel analysis was therefore confined to smaller segments of the overall data, and it has been shown that the key modelling results (and VoT in particular) are not strongly dependent on the inclusion of a panel effect (**Section 4**).

There are various issues where the SP data analysis can have an influence to a greater or lesser extent. It has not moved away from the general structure of a segmentation based on a) business vs non-business and b) a division by distance into short regional, long regional, and inter-capital.

In the case of the choice hierarchy, the model assumption is supported (albeit, in statistical terms, weakly) that HSR is most similar to the air mode, and that these two modes should therefore continue to be represented in a lower nest. In addition, the analysis strongly supports the fact that station choice is more sensitive to time than mode choice.

A key modification emerging from the SP analysis relates to the scaling parameters. The values in the phase 1 demand model (in time units) vary inversely with distance, and are the same for business and non-business. The SP data strongly suggests that the business scales should be higher. In addition, the variation with distance is somewhat different from that assumed in the phase 1 model.

On this basis, the recommendation was that the relative values from the SP should be maintained, but that a further overall scale should be estimated using the RP data. The relative values for scaling factors at the highest level are (minutes):

Table 53 Sensitivity parameters from SP study

Segment (s)	Business	Leisure
Inter-capital	-0.0122	-0.0066
Long regional	-0.0151	-0.0082
Short regional	-0.0216	-0.0117

These values have been used, together with the generalised cost weightings and VoT set out in the previous sections, to construct an 'SP Utility' value. This SP Utility applies separately for business and non-business and for journeys by four modes (air, car, coach and rail) within the east coast study area, as sampled in the NVS.

Four modes, two trip purposes, three geographic segmentations and nine geographic sectors were considered:

Modes: $m \in \{\text{air, car, coach, rail}\}$

Purposes: $p \in \{\text{business, leisure}\}$

Geographic Segments: $s(i, j) \in \{\text{short-regional, long-regional, intercity}\}$

Geographic Sectors: $a(i) \in \{1, 2, 3, 4, 5, 6, 7, 8, 9\}$

All model parameters were segmented by trip purpose (i.e. separate business and non-business models were estimated). Thus, for brevity, in the model specification that follows no reference is made to trip purpose.

The model was estimated as a multinomial mode choice model of the form:

$$T_{i,j,m} = T_{i,j,\bullet} \frac{e^{U_{i,j,m}}}{\sum_m e^{U_{i,j,m}}}$$

where:

$T_{i,j,m}$ is the number of trips produced in zone i , attracted to zone j , travelling by mode m .
 $T_{i,j,\bullet} = \sum_m T_{i,j,m}$

$U_{i,j,m}$ is the utility of trips produced in zone i , attracted to zone j , travelling by mode m .

Utility functions were defined as:

$$U_{i,j,m} = \bar{\beta} \beta_{s(i,j)} C_{i,j,m} + ASC_{s(i,j),m} + K_{a(i),a(j)}$$

where:

$\bar{\beta}$ is a scaling parameter (to be estimated).

$\beta_{s(i,j)}$ is the sensitivity parameter for mode m trips, estimated from the SP study (see **Table 53**).

$C_{i,j,m}$ is the generalised cost for mode m trips produced in zone i , attracted to zone j .

$ASC_{s(i,j),m}$ is a constant for mode m trips travelling in segment s (to be estimated).

$K_{a(i),a(j),m}$ is a constant¹⁷ for mode m trips travelling from sector $a(i)$ to sector $a(j)$.

The estimation utilised:

- 1) Trip matrices $T_{i,j,m}$ derived from the NVS data.
- 2) Generalised cost components $C_{i,j,m}$ extracted from the demand model.

¹⁷ A small number of mode/location ASCs have been used to ensure a close match with NVS data.

The average expansion factor used to derive the trip matrices was in the order of 10^3 . Consequently, the matrices were multiplied by 10^{-3} prior to estimation to prevent inflation of the calibration statistics. The estimation results were as follows.

Table 54 Estimation results

$\overline{\beta}$	Mode	Segment	Business		Non-business	
			Value	T-ratio	Value	T-ratio
			0.3168	29.6	0.3287	60.3
$ASC_{s(i,j),m}$	Air	Inter-capital	1.8345	25.8	1.0416	41.5
		Long regional	0.1304	3.1	-0.3771	-13.1
		Short regional	-0.3139	-1.2	0.0739	0.4
	Car	Inter-capital	0.0000	n/a	0.0000	n/a
		Long regional	0.0000	n/a	0.0000	n/a
		Short regional	0.0000	n/a	0.0000	n/a
	Coach	Inter-capital	-2.0082	-5.8	-1.4958	-12.2
		Long regional	-2.2935	-17.3	-1.5091	-38.1
		Short regional	-2.4535	-21.9	-1.7333	-48.3
	Rail	Inter-capital	-2.5198	-5.8	-1.2425	-9.5
		Long regional	-2.4359	-16.9	-2.0954	-43.6
		Short regional	-2.6054	-32.0	-2.4491	-97.2
$K_{a(i),a(j),m}$	Air	1-4,4-1,6-1,2-3*	1.8252	10.8		
		1-4,4-1,6-1,6-9,7-9*			1.1716	15.5
	Rail	4-5,6-5,7-5*	1.5220	1.6466	51.0	48.5
		2-1*	1.4169	1.3610	40.4	38.8
Log-likelihood			-6,197.5		-43,306.4	

*A-B denotes constants applied to trips originating in sector A, destined to sector B.

Hence, using the observed mode choice in the NVS, an overall scaling parameter has been estimated, together with ASCs for the modes (relative to car). It can be seen that for business, the scaling factor was 0.32 and for non-business it was 0.33: these values therefore multiply the SP scaling factors given in **Table 53**, resulting in lower sensitivity. The results of the estimation were highly significant, in terms of values different both from zero and one.

Diagnostic plots were made to illustrate the fit of the estimated models to the calibration data, and show the relationship between mode share and utility difference assumed by the model and defined by the function:

$$P_m = \frac{e^{\Delta U_m}}{e^{\Delta U_m} + 1}$$

where P_m is the mode share for mode m , and ΔU_m is the utility difference, defined as:

$$\Delta U_m = U_m - U_{\bar{m}}$$

where

$$U_{\bar{m}} = \ln \left(\sum_{s \neq m} e^{U_{i,j,s}} \right)$$

is the composite cost of modes other than m .

The diagnostic plots that follow illustrate the extremely good fit of the estimated models to the calibration data. The dashed line in each figure defines the relationship between mode share and the utility difference between that mode of transport and (the composite of) the others. Data points (i.e. circles) denote the aggregated observed data, the size of each data point being proportional to the number of trips it represents.

Figure 10 Observed air mode shares for business travel plotted against the model estimate

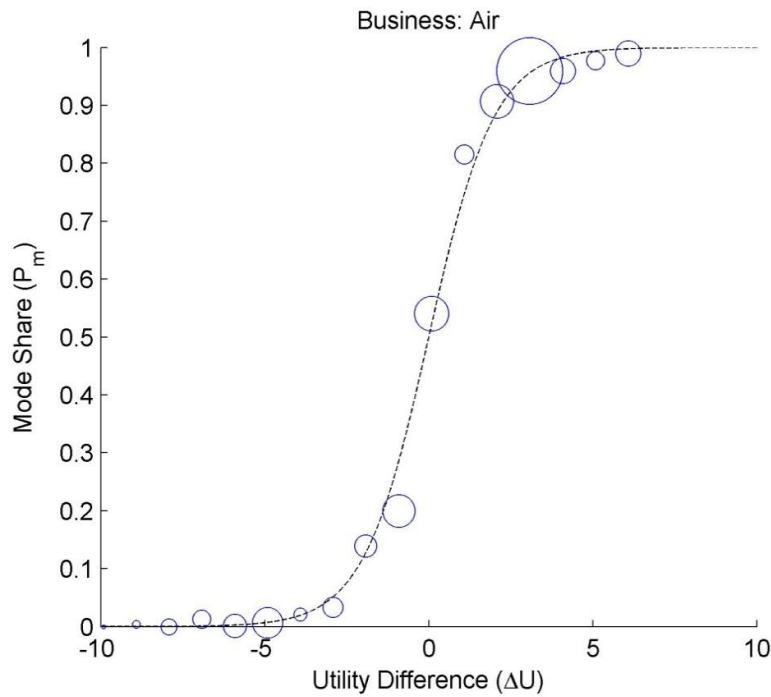


Figure 11 Observed car mode shares for business travel plotted against the model estimate

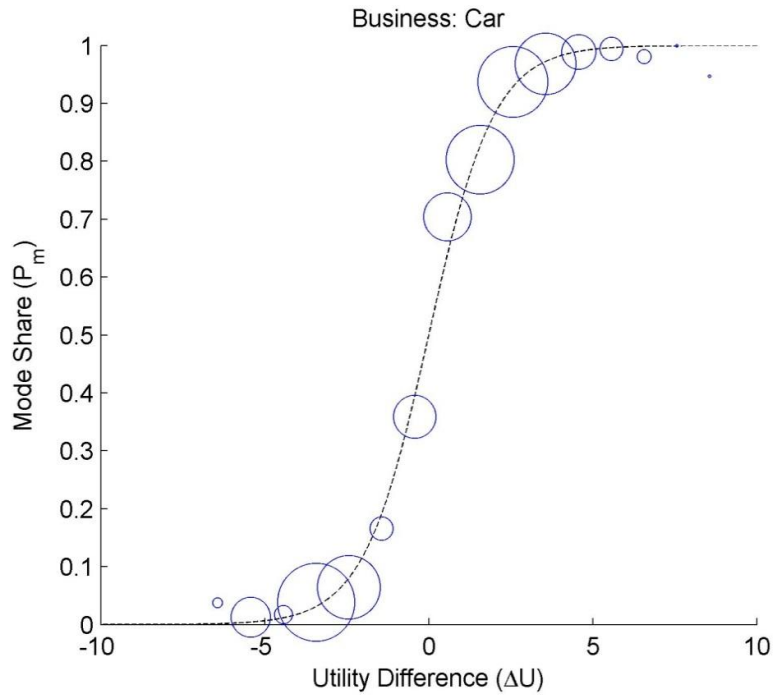


Figure 12 Observed coach mode shares for business travel plotted against the model estimate

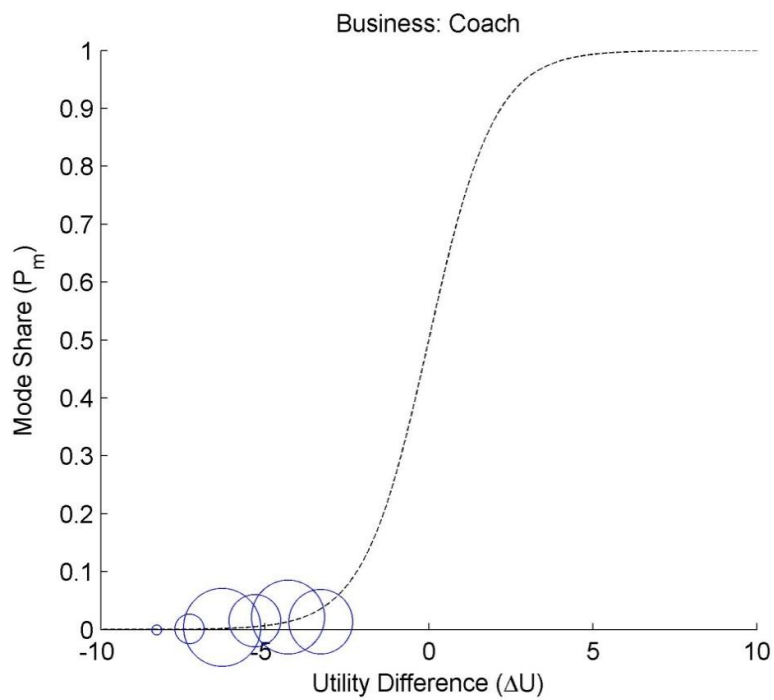


Figure 13 Observed rail mode shares for business travel plotted against the model estimate

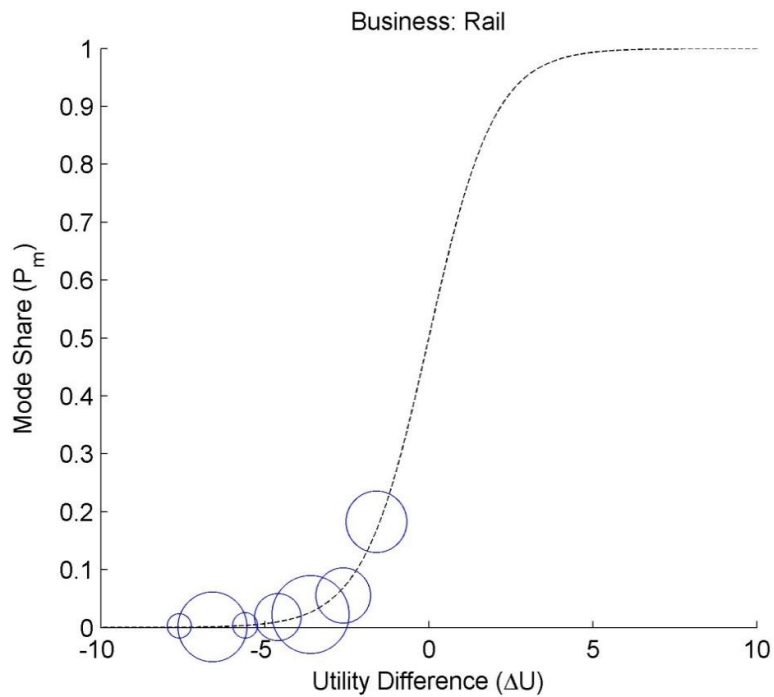


Figure 14 Observed air mode shares for non-business travel plotted against the model estimate

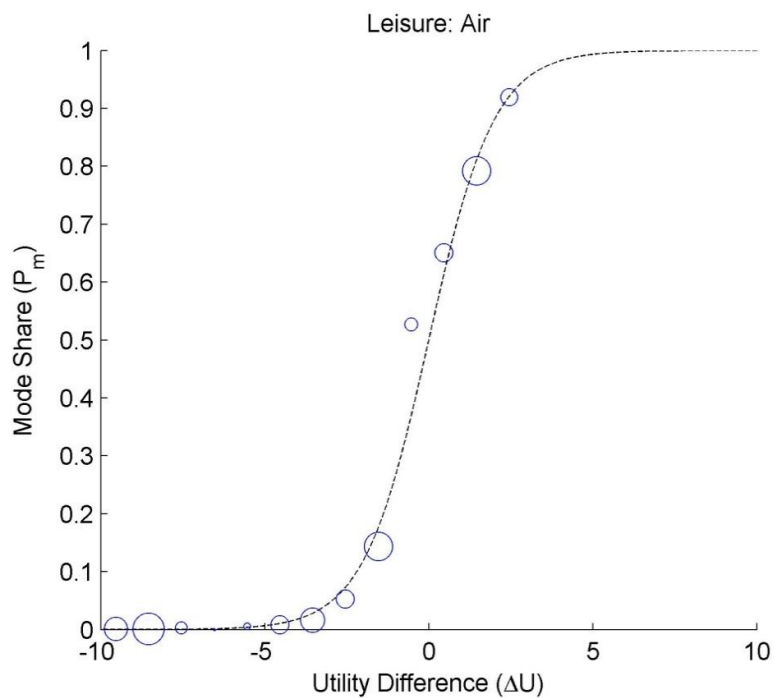


Figure 15 Observed car mode shares for non-business travel plotted against the model estimate

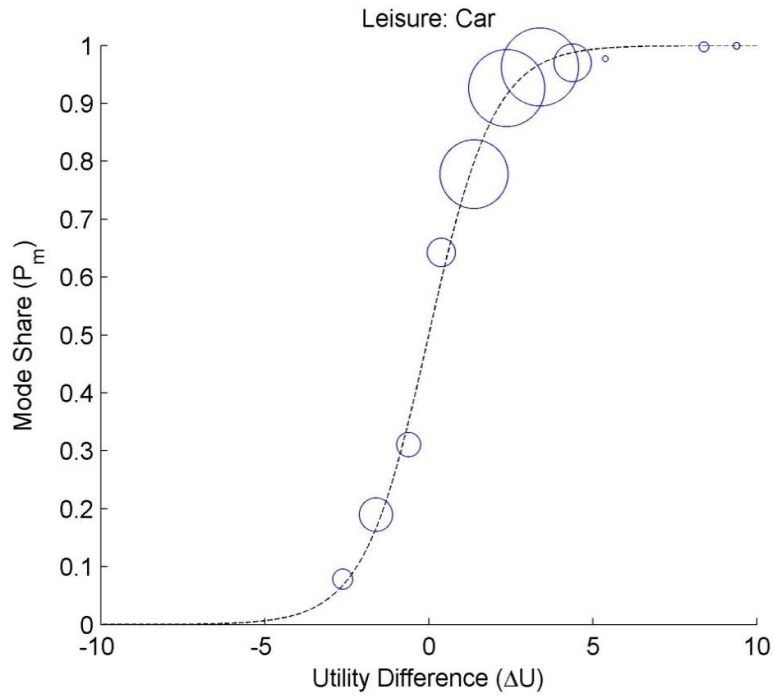


Figure 16 Observed coach mode shares for non-business travel plotted against the model estimate

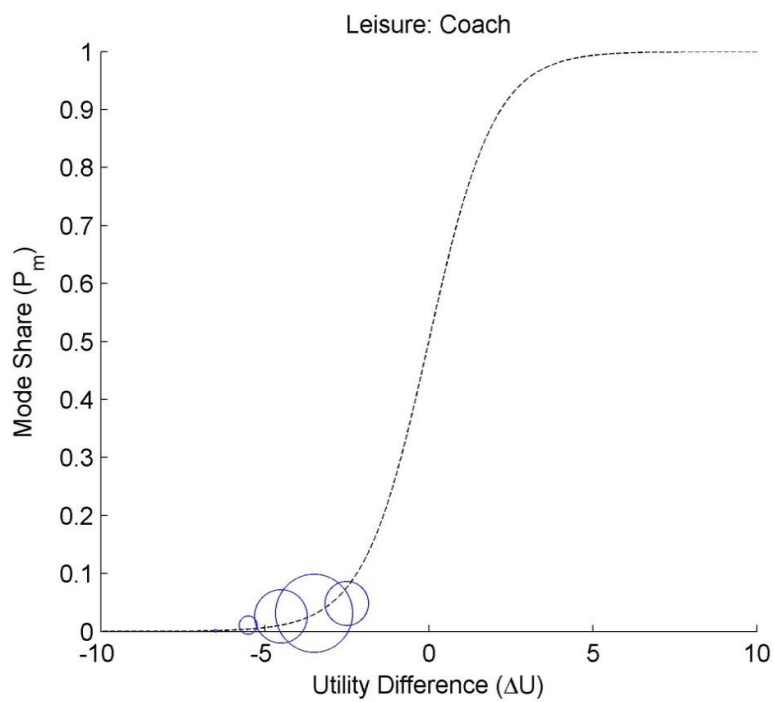
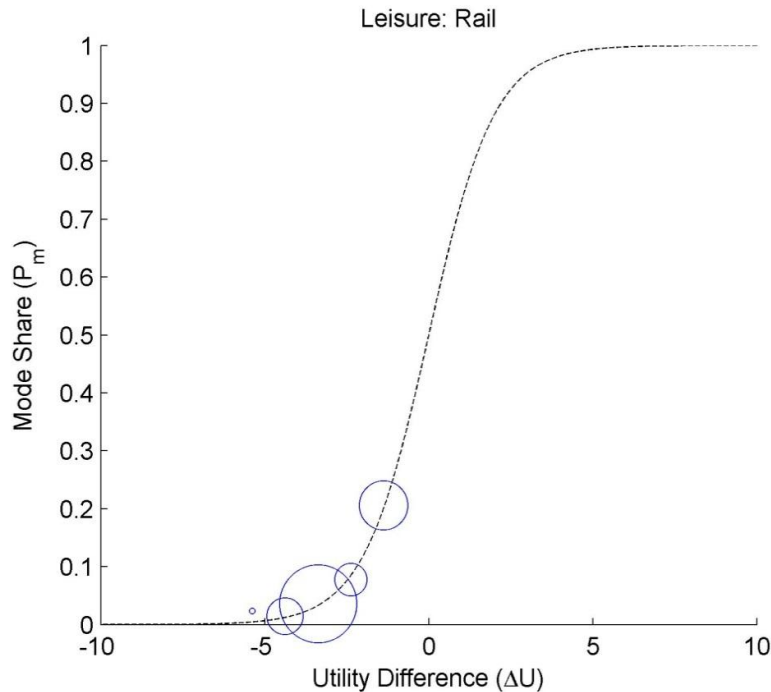


Figure 17 Observed rail mode shares for non-business travel plotted against the model estimate



In addition, an attempt was made to carry out a similar estimation using the RP data from the SP survey. Based on **Table 10**, of those who claimed to have some choice (820), car was available to 754, air to 579 and rail to 461. The choice proportions were, respectively, 75 per cent, 37 per cent and eight per cent (as a percentage of availability). An overall scaling parameter of 0.25 was estimated. Although this is considered much less reliable than the NVS estimation, it does confirm that the multiplier is considerably less than one.

6.0 Conclusions

The resulting demand model has been implemented and it has been concluded that it gives stable and convincing mode share estimates.

Overall, the SP has been successful. Although the results for the generalised cost weights were not considered sufficiently convincing to make the case for departing from the received wisdom incorporated in the model, it has been confirmed that, apart from the ASCs, the general modelling results are not affected by constraining them. Plausible VoTs have been derived and, although the higher values for long regional relative to inter-capital were unexpected, they are well supported in the SP analysis.

After examining ASCs for HSR, it has been concluded that the existing assumptions, of no difference between air and HSR for inter-capital and long regional, and of no difference between rail and HSR for short regional, are confirmed for business. For non-business there is a definite indication that HSR might be more positively viewed, with an advantage in favour of HSR of 45-55 minutes.

The structure of the existing demand model has been confirmed.

Overall, the SP has delivered a more robust demand model, as well as providing a substantial database which could be further analysed for more detailed segmentation.

In addition to the technical results produced from the SP, the survey itself provided a number of useful indications of the likely response to an HSR line. Interest among respondents was generally favourable, and indeed this assisted in cooperation with the survey. In both the pilot and the main

survey there was strong support for HSR, and many respondents chose HSR in all scenarios presented, while some of those who never chose it still said that they would consider it for other journeys. Rail passengers were most likely to switch to HSR, followed by air. As expected, there was less response from existing car travellers, many of whom will have reasons other than time and cost for choosing the car mode.

The general impression was that HSR was seen as a good choice for journeys to the large centres such as Melbourne, Brisbane and the Gold Coast, while those living in the regional areas were, if anything, more enthusiastic. For those living in the major cities there was a strong impression that central stations were preferred to peripheral locations, especially those that did not have both good public transport and parking available (such as Parramatta in Sydney). This was less of an issue for those living in the regional areas.

Appendix 1E

Demand forecasting procedures

Appendix 1E

Demand forecasting procedures

Prepared for

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March 2013

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March 2013

Quality information

Document	Appendix 1E
Ref	60238250-1.0-REP-0101-1E
Date	March 2013

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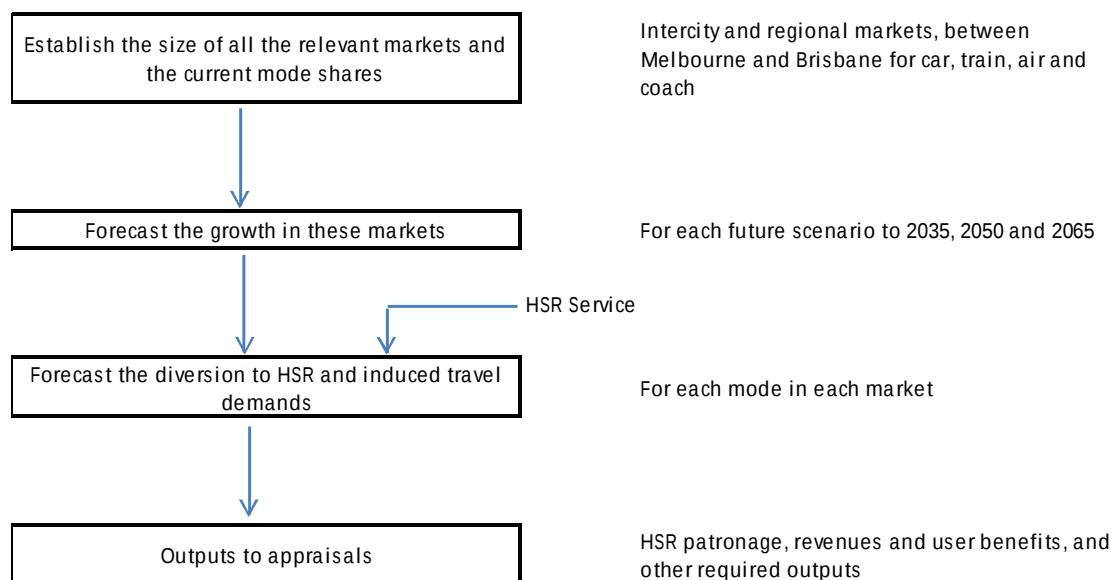
1.0 Introduction and objectives

The multi-modal transport model for the east coast corridor is designed to estimate demand, revenues and user benefits for High Speed Rail (HSR) system alternatives and to assess the impacts of changes in the key attributes of HSR transport products and competing transport modes.

For phase 1, a strategic forecasting approach (**Figure 1**) was designed to answer the key demand questions concerning the nature of the current markets in the Brisbane-Sydney-Melbourne east coast corridor, how they will grow in future, the potential for diversion to HSR and the extent to which HSR may stimulate demand.

The logic of this approach was also adopted in the previous Australian HSR studies, such as the Very Fast Train Study¹ and Speedrail².

Figure 1 Structure of demand forecasting for the east coast corridor



Estimates of the current market size and mode shares were derived from the National Visitors Survey (NVS)³ over an 11 year period between 2000 and 2010.

Travel demand growth was then projected as a function of the future population growth projections in the corridor and income growth, based on techniques used by the Bureau of Infrastructure, Transport and Regional Economics (BITRE). In order to estimate the diversion to the proposed new HSR services and the induced travel brought about by the consequent improvements in accessibility, models of mode choice and induced travel were developed based on a combination of international and local experience and evidence.

This process has been further developed for phase 2, and the principal changes which have been incorporated in this demand forecasting procedure are summarised in **Table 1**.

¹VFT: Access Economics, *Cost benefit study of the Very Fast Train Project*, 1990.

Arup and TMG, *East Coast Very High Speed Train Scoping Study, Phase 1 Preliminary Study Final Report*, 2001.

²SKM & MVA, *Speedrail Patronage and Revenue Forecasts*, supplement to final report, 1999.

³Tourism Research Australia, *National Visitors Survey*.

Table 1 Model enhancements

Module	Enhancements to the specification
Study area, zone system and level of transport service	A more detailed zone system in the phase 2 study area and improvements to the transport level-of-service data.
Base market	Incorporation of the improved base market estimates described in Appendix 1B .
Market projections	Incorporation of the findings of a review of the elasticity of light vehicle travel growth to income by BITRE (Appendix 1H).
The mode choice model	Incorporation of the findings of a major stated preference (SP) survey in the corridor (Appendix 1D). Development of the demand model on the updated base market data. An extended demand model structure, incorporating a more detailed station and airport access methodology and new procedures for representing a mix of HSR services.
Model outputs	Factors for patronage ramp-up after opening. An extended output template.

2.0 Model zone system and transport level-of-service

Within the phase 2 study area, the zone system (**Figure 2**) comprises 167 internal zones, and there are 11 external zones, which represents a doubling of the number of zones from phase 1. In metropolitan areas, zone sizes have been selected to enable differentiation between the potential HSR station locations. Outside the state capital areas, further refinements have been made affecting Wollongong, Wagga Wagga, Gold Coast and Newcastle.

Transport level-of-service data (**Table 2**) was assembled for the base year (2009) in phase 1 from timetables, maps and other sources.

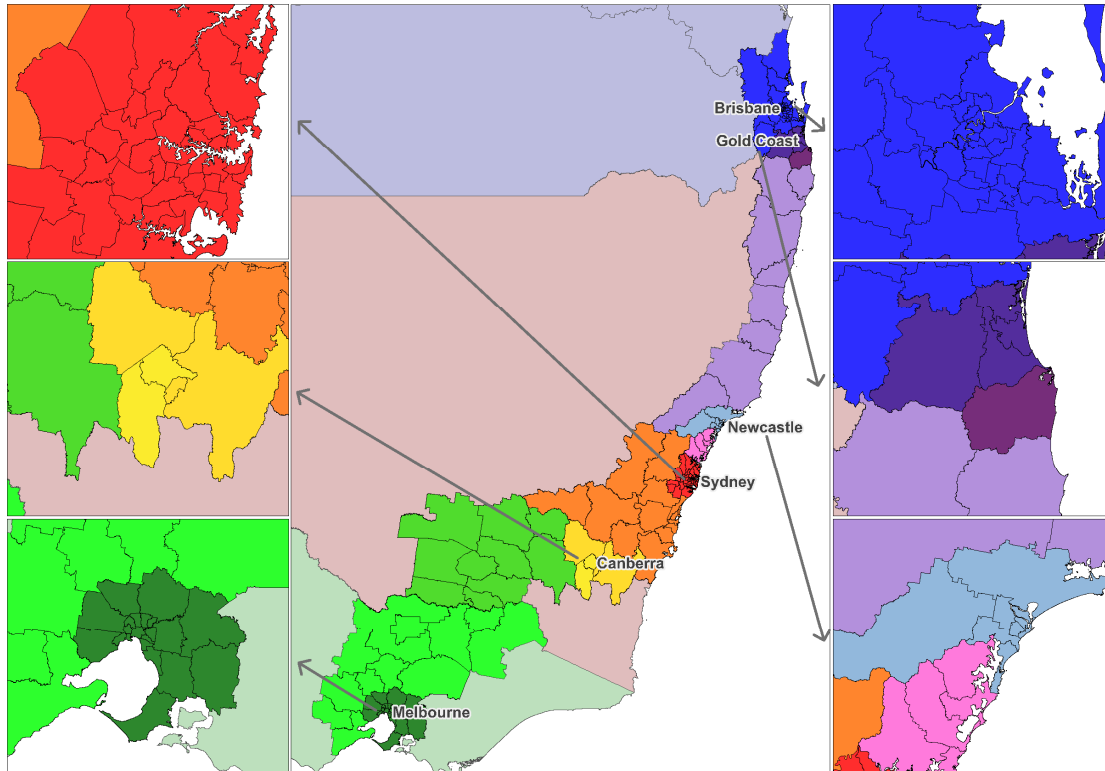
This data has been audited and generally enhanced for the new zone system. Specific tasks undertaken include:

- Establishing transport level-of-service data for the refined zone system.
- Incorporation of metropolitan transport level-of-service data from the state transport models.
- Incorporation of road journey time information derived from the corridor registration number survey.
- Expansion of the coverage of the air services to regional areas.
- Incorporation of additional information on air fares.

Table 2 Level of service data specification

Mode	Level of service characteristics in the model
Air	In-vehicle time, service frequency, access/egress, check-in time, fare.
HSR	In-vehicle time, service frequency, fare, interchange, access/egress.
Bus, coach and conventional rail	In-vehicle time, service frequency, fare, access/egress.
Car	In-vehicle time, vehicle operating cost.

Figure 2 Zone system



The smaller figures on the left and right show in greater detail the zones in areas of greater residential density.

3.0 Base market

The updated base market described in **Appendix 1B** has been incorporated in the model.

4.0 Market projections

4.1 Background

The increase in future travel demand is expected to be driven by two main factors: population growth and economic growth. Improvements in transport accessibility are a third influence on the travel demands for each mode. For phase 1, the future demand forecasting methodology was based on techniques used by BITRE⁴, supplemented by analysis of corridor aviation demands and the evidence of previous demand studies⁵.

The formulation is an elasticity model sensitive to the trip origin and destination populations and income (as measured by Gross Domestic Product (GDP)/capita). The further influence of transport accessibility and prices (the generalised cost of travel by each mode) on the balance of overall travel demand between the transport modes is derived from the induced travel demand model (**Section 1.5**).

Concerning the income elasticities used in this model, the following sections describe the evidence for each transport mode.

⁴ BITRE, *National road network intercity traffic projections to 2030*, WP71, 2009.

⁵ Speedrail, op. cit.

4.2 Air travel trends in the corridor

Through an analysis of past trends in aviation demand between 1994 and 2010 in the east coast corridor⁶, the elasticity of aviation demand to income has been verified. This was a period of considerable change in the Australian (and global) aviation industry, with such notable events as:

- 2000 – Virgin Blue launched.
- 2001 – Collapse of Ansett.
- 2001 – World Trade Centre terrorist attack (9/11).
- 2002 – Bali bombings.
- 2003 – SARS outbreak.
- 2003 – Qantas established low cost subsidiary Jetstar.
- 2006 – Australian Airlines ceased operation.
- 2007 – Tiger Airways commenced in Australia.

A model of aviation demand was fitted to the trends in air travel. The model uses an income elasticity of +1.0 and an air fare elasticity of -0.3, consistent with the expected demand elasticities. The fit of this model to the past trends in air travel is summarised in **Figure 3** to **Figure 5**.

For the major routes in the study area, the model predicts the trend in aggregate demand well (**Figure 3**). Smaller routes (i.e. less than one million air passengers per year) have been pooled into three categories (**Figure 4** and **Figure 5**):

- Established minor routes (e.g. Canberra-Sydney and Canberra-Brisbane).
- New minor routes (e.g. Sunshine Coast routes).
- Regional routes (e.g. Albury-Wodonga, Wagga Wagga, Dubbo, Coffs Harbour, Port Macquarie and Ballina).

Regional route data prior to 2005 is not included in this analysis due to significant changes in service patterns caused by the collapse of airlines in the period of 2001 to 2003. While there were variations in the trends between the individual routes, it is clear that the model is effective at predicting the aggregate trends across the three categories of smaller routes listed above.

It is concluded that aviation models incorporating GDP/capita elasticity values of +1.0 fit the trends in air travel for the east coast routes affected by the proposed HSR service. This elasticity is broadly consistent with the *Sydney Aviation Capacity Study* (which quotes a range for domestic travel of +0.4 to +1.2)⁷.

⁶ BITRE Aviation Statistics Data: Domestic Airline Activity, Domestic Totals and Top Routes, regular publication.

⁷ *ibid.*

Figure 3 Comparison of a model back-forecast with air travel trends, 1994-2010: total of major routes

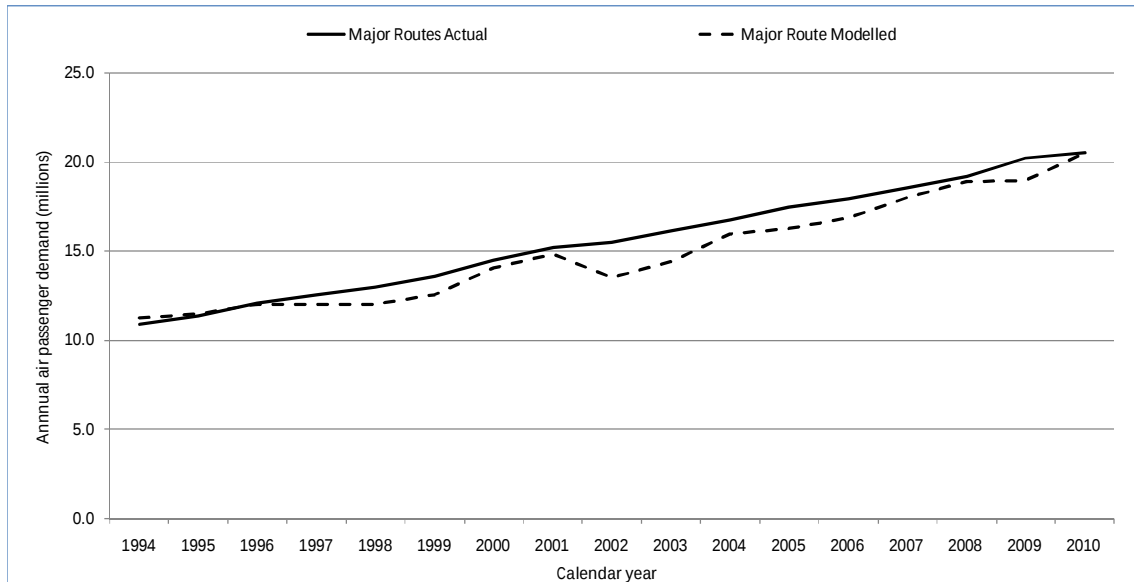


Figure 4 Comparison of a model back-forecast with air travel trends, 1994-2010: minor routes

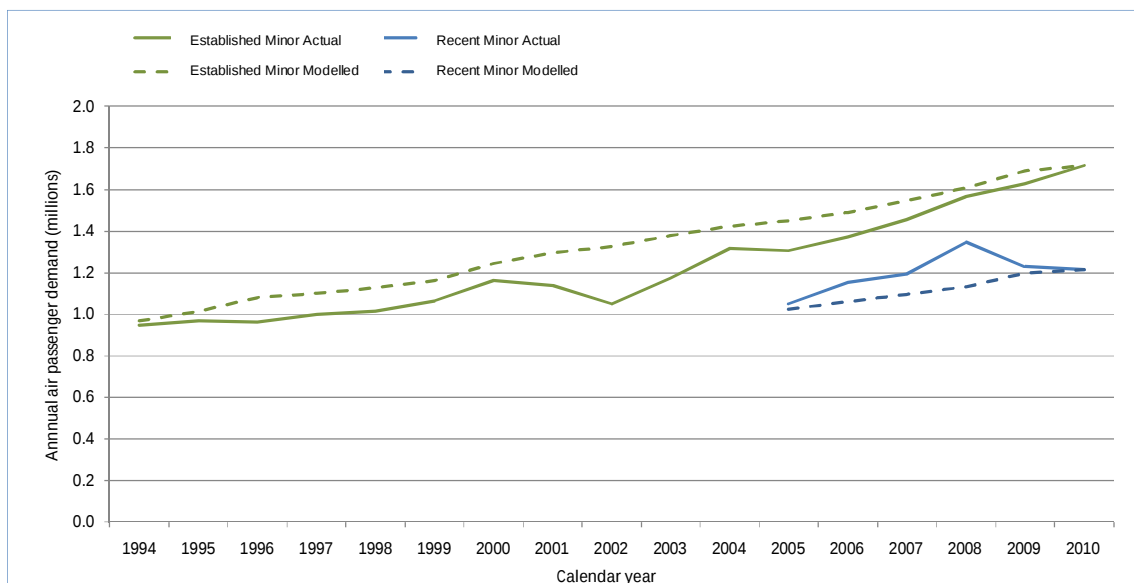
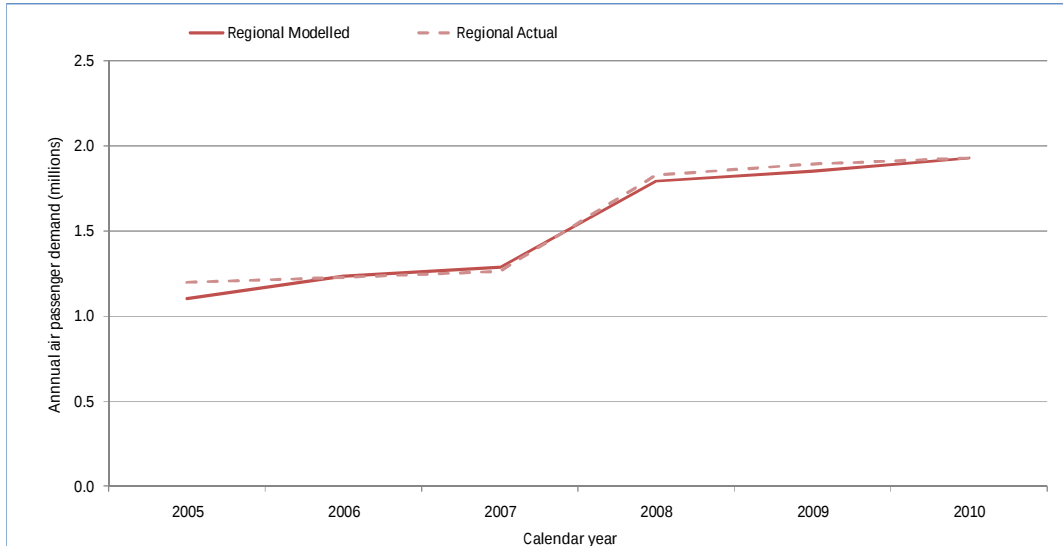


Figure 5 Comparison of a model back-forecast with air travel trends, 2005-2010: regional routes



4.3 Rail travel trends in the corridor

The evidence on rail travel demand from ticketing data for long distance rail travel (**Figure 6** and **Figure 7**) shows no overall growth over the past decade in the XPT Sydney-Melbourne train service and no growth in the period 2006-2009 in other parts of the east coast corridor. However, the XPT trend suggests that it may have been affected by the introduction of low cost airline services and that it would be inappropriate to conclude that the income elasticity is insignificant, especially as there appears to have been a general return to patronage growth in recent years.

With this background, it has been preferred to use the relatively low income elasticity (+0.57) established in the Speedrail study. This income elasticity has also been used for coach travel.

Figure 6 Ten-year trend in Sydney-Melbourne XPT patronage

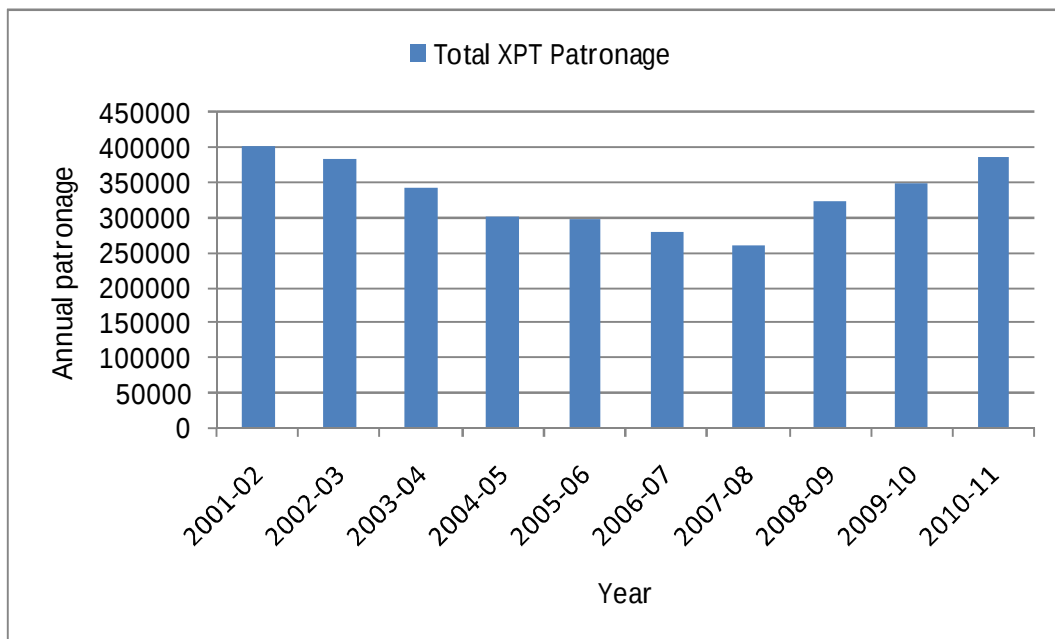
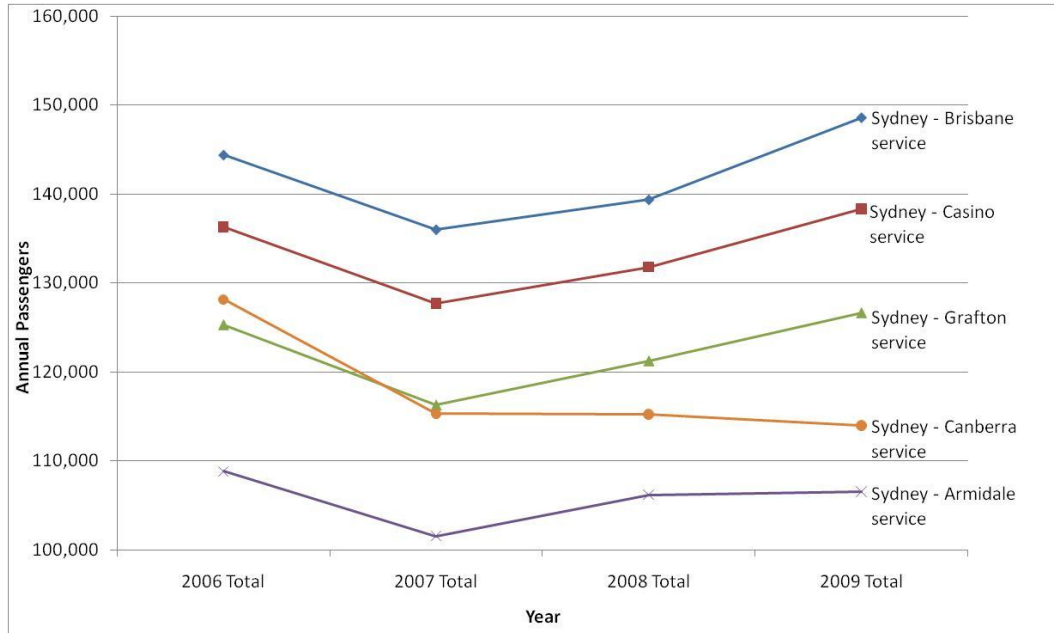


Figure 7 Three-year trends in other regional rail services



4.4 Analysis of traffic trends in the corridor

Diverted car travel is an important component of the HSR demand forecasts, but there is uncertainty regarding the future rates of car travel growth.

An initial analysis of car travel trends in the NVS data over the period 2000-2011 did not suggest that there had been major growth in car travel in the corridor and a recent independent report by Tourism Research Australia⁸ suggested that car travel for holidays was reducing in Australia as people choose more overseas holidays. International advisors confirmed that the projection of car travel demand is also a concern in the forecasts for High Speed 2 in the United Kingdom.

Clarification of the issue was sought through an analysis of the trends in light vehicle traffic flow on the major inter-capital highways in the corridor. BITRE analysed the trends in light vehicle traffic volumes at 56 sites (**Figure 8** and **Figure 9**) on the Hume Highway and Pacific Highway over the two decades to 2011 (refer to **Appendix 1H** for a detailed description of this work).

⁸ Tourism Research Australia, *What is driving Australians' travel choices?*, 2011.

Figure 8 Victorian traffic count site locations

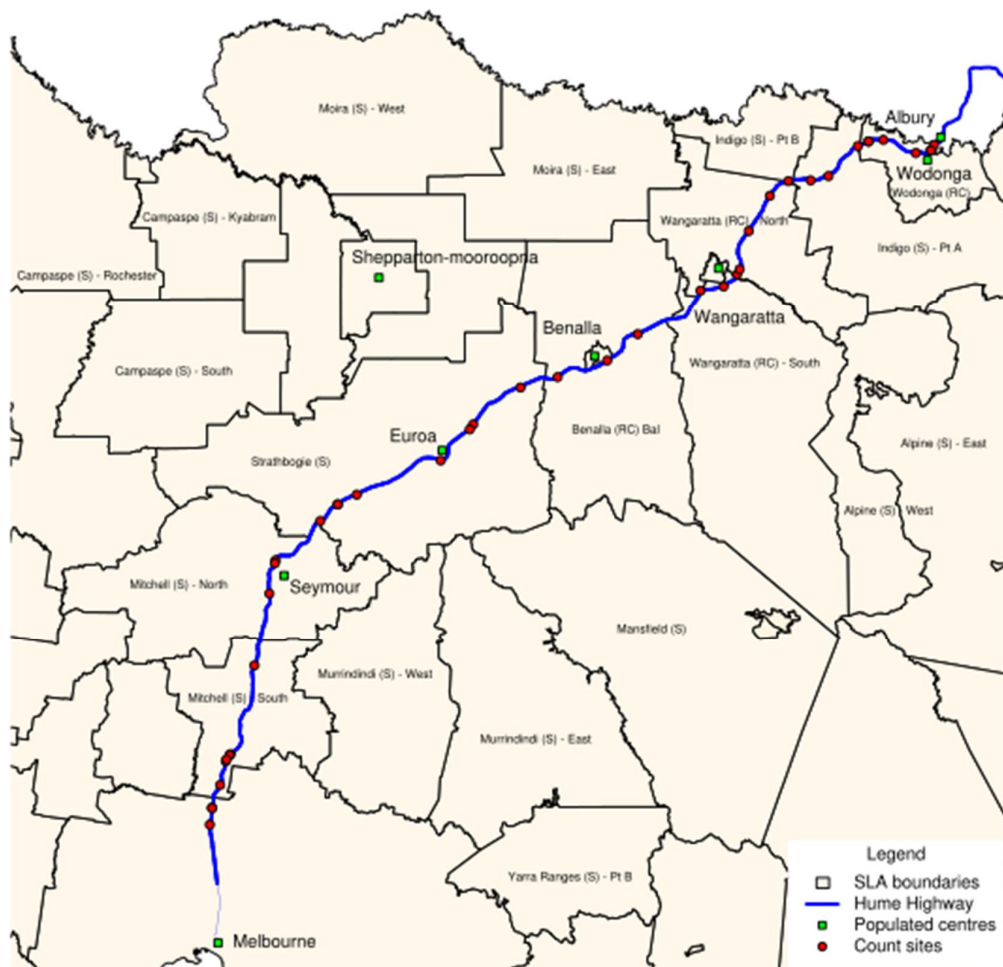


Figure 9 NSW traffic count site locations



BITRE estimated the relationship between the growth in rural light vehicle traffic on these highways and the growth in per capita GDP and population and changes in fuel prices, allowing for the impacts of network changes in the corridor.

Traffic count data demonstrates that rural car traffic has grown, on average, by approximately 2.8 per cent per year over the past two decades across rural sections of the Hume Highway in Victoria. Traffic data from NSW sections of the Hume Highway and Pacific Highway shows that rural light vehicle traffic has grown on average by approximately 2.7 per cent per year between 1991 and 2011 on the Hume Highway and by over three per cent per year on the Pacific Highway.

Over the same period, published Australian Bureau of Statistics (ABS) population statistics record average annual population growth rates of 1.0 per cent, 1.1 per cent, 1.2 per cent and 2.1 per cent in NSW, Victoria, the ACT and Queensland respectively, very much less than the traffic growth rates in the corridor. Over the same period, income (GDP/capita) increased by 1.8 per cent per year on average and real car fuel prices by 1.6 per cent per year on average.

The analysis sought to relate the growth in traffic at these sites to population, income and fuel price trends, with two specifications of income based on GDP and Gross National Expenditure, and two specifications of population based on local population and a broader catchment population. Different statistical methods were also tested based on traffic levels ('in-levels') and growth rates ('first differences'), with a linear model and one allowing for random effects. Additionally, the data sets used varied as data needed to be imputed to establish a consistent growth rate data set.

The statistical models were all inelastic to fuel prices, with the most common range being -0.1 to -0.2.

Using the raw traffic count data, the simple 'in-levels' models imply a statistically significant and positive income elasticity for rural light vehicle traffic across all three sections. The Victorian Hume Highway data implies an average income elasticity for light vehicle rural traffic volumes of +0.5 to +0.8, depending on the estimation method used. Statistically, the elasticity is significantly less than one. The NSW Hume Highway and Pacific Highway data implies an average income elasticity of around +1.2 for these sections.

Assigning missing traffic count data and estimating the relationship using the annual change in light vehicle traffic volumes appears to imply broadly similar long-run elasticities. The results show that light vehicle traffic growth has a statistically significant and positive correlation with income, with income elasticity at around +0.5 to +0.8 across Victorian sections of the Hume Highway, and at +1.1 on NSW sections of the Hume Highway and possibly higher on the Pacific Highway.

The difference in the measured income elasticity across the Victorian and NSW count sites could be influenced by differences in the relative distribution of count site locations across each section, unaccounted-for network changes and differences in the relative composition of trip types across the two road sections⁹.

Having considered all of the modelling results and recognising the weakness of some of the statistical models relating to shortcomings in the data, the analysis confirms that car travel demand grows significantly with income. It is concluded that, for the purposes of this study, an income elasticity of +0.8 should be assumed, while a more conservative assumption for shorter journeys would be appropriate.

4.5 Conclusions on income elasticities

The values on which the demand forecasting is based are given in **Table 3**. The air, coach and rail elasticities derive from phase 1, as described above. The car elasticities derive from the BITRE analysis. Both the car and air elasticities have been adjusted downwards slightly to ensure that there is no duplication of the income effect with the mode choice/induced travel model. For short regional journeys, the nominal elasticities have been halved as described above.

The elasticities are assumed to mature through time, the maturity rate for air being consistent with the aviation capacity study data¹⁰. For car, coach and rail, a faster maturation rate has been used, as a conservative assumption.

Table 3 Travel demand elasticities to income growth

Year	Air	Car		Rail/coach	
		Inter-capital/long regional	Short regional	Inter-capital/long regional	Short regional
2009	1.0	0.8	0.4	0.57	0.28
2035	0.88	0.62	0.31	0.44	0.22
2050	0.82	0.54	0.27	0.38	0.19
2065	0.76	0.46	0.22	0.33	0.16

Finally, it is expected that the distribution of employment within metropolitan areas could have an effect on HSR demand separate from that of population, particularly for business travel. However, as the states' employment distribution projections for the three metropolitan areas do not change significantly in the future, this factor can be ignored in the projections (because of its stability through time).

⁹ The Victorian data includes count sites spread across the entire length of the Hume Highway, whereas most of the count sites on the Hume Highway and Pacific Highway in NSW are located within 200 kilometres of Sydney.

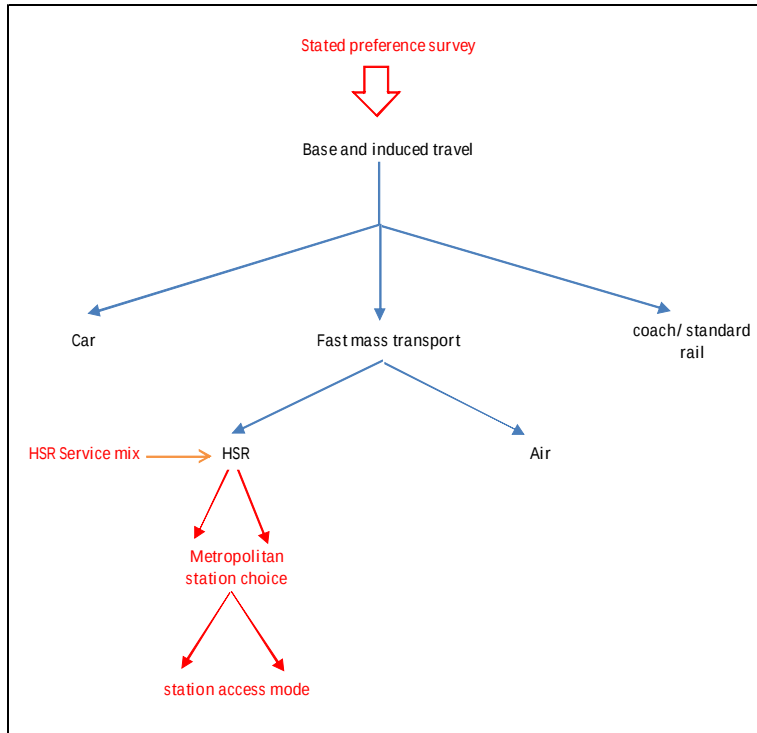
¹⁰ Australian and NSW governments, *Joint study on aviation capacity in the Sydney region*, 2012.

5.0 Demand forecasting procedures

5.1 Overview

The structure of the demand forecasting procedures is illustrated in **Figure 10**, with the additional components incorporated in phase 2 highlighted in red.

Figure 10 Extended model structure



The impacts of HSR in the east coast corridor would be twofold: a transfer of demand from existing modes to HSR and an overall increase in travel demand caused by the improved accessibility (referred to as induced demand). Although improved accessibility is also likely to affect the nature and rate of development in the corridor, this has not been taken into account in the forecasts.

The demand forecasting procedures forecast the amount of transfer from other modes to HSR using a model of transport mode choice, called a 'hierarchical logit' model. The model has been extended to include a forecast of the additional travel induced by HSR.

The model distinguishes between business and non-business travel, reflecting their different patterns, modal preferences and cost sensitivities. The structure of the model has been derived from existing models and transport research, both Australian and international.

The mode share model forecasts the amount of diversion from the existing modes to the HSR service in relation to the comparative levels of service and the relative travel costs (fares or vehicle operating costs). Changes in journey times, service frequencies, ease of access to rail stations and airports and the fares or operating costs all influence the amount of mode shift to HSR. The results of the SP survey, described in **Appendix 1D**, have been incorporated in this component of the model.

The pattern of train services along the line is a consideration. There would be a mixture of stopping, limited stop and non-stop services. The demand forecasting procedures have been developed to enable passenger demands to be appropriately allocated across the different services as well as ensure that the attractiveness to passengers of a mix of services is appropriately reflected in the HSR demand forecasts.

In the cities, there are decisions to be made on central station locations and peripheral 'park and ride' stations. Station design concepts need to provide appropriate numbers of parking spaces. For these reasons, the forecasting procedures included specific detail on the choice of mode by HSR passengers for accessing stations and their choice of station. For egress at the destination, the model chooses the most accessible stations, allowing for the egress modes available.

5.2 Incorporating the stated preference survey conclusions

Various standard parameter values have been updated in the model based on the results of the SP survey (**Table 4** and **Table 5**). The most important changes are to the values of time, which are those estimated from the SP survey. Additional minor changes have been made to average group sizes and average parking durations (based on the average length of visit).

The waiting time parameter accords with established practice. Vehicle operating costs represent the perceived component of costs. For non-business travel this is fuel plus parking costs. The estimates were based on the ABS Survey of Motor Vehicle Usage (for average fuel consumption) and average fuel prices sourced from the Australian Institute of Petroleum. The values assume that businesses perceive the full resource cost of operating a vehicle.

Daily parking costs are assumed in 2009. The high cost is applied to metropolitan airport long-term parking, medium costs to Canberra Airport and low costs to peripheral HSR station parking. Parking charges are not applied at regional HSR stations.

Table 4 Values of time and other parameters: phase 2

Parameters	Market	Unit	Business	Non-business
2009 value of time (\$2012)	Inter-capital	\$/hr	57	14
	Long regional	\$/hr	81	20
	Short regional	\$/hr	38	9.5
Waiting time factor	All	-	2.0	

Table 5 Values of time and other parameters: phase 2

Parameters	Market	Unit	Business	Non-business
2009 parking charges (\$2012 per day)	High	\$	48	21
	Medium	\$	21	16
	Low	\$	24	10.50
Group size	All	People	1.4	2.4
Parking duration	All	Days	2.0	3.6
Vehicle operating costs (\$2012)	All	Cents/km	31.2	15.5
Air check-in time	All	Mins	45	
HSR interchange penalty	All	Mins	20	

The key parameters for the hierarchical logit model structure have been determined directly from the findings of the SP survey, or adjusted in relation to those estimates. In this structure, the scaling parameters for the choice between the existing modes of transport were taken from the SP model and then re-scaled to the NVS data as described in **Appendix 1D**. These are the 'second level' parameters in **Table 6**, covering the choice between car, fast mass transport and coach/standard rail.

The induced demand parameters at the first level were set to phase 1 values or based on a nesting factor¹¹ of 1.4, whichever was the smaller, being designed to accord with international experience on the levels of induced HSR demand.

A nesting factor of 2.5 for business and 4 for non-business was used for the third level in the model (HSR: air choice) to retain broad consistency with the modelling for the European Commission¹².

The alternative specific constants (ASCs) for the existing modes of transport were estimated as part of the re-scaling process (**Table 7**), thus ensuring that the model reproduces the existing mode shares in the corridor. For inter-capital trips, the ASCs for HSR were based on the modelling for the European Commission and set at five minutes in favour of HSR for business and non-business, thus retaining compatibility with the independent evidence on HSR inter-capital mode shares. For long regional and short regional trips, the HSR ASCs were set relative to air and rail respectively based on the SP: that is, zero for business and 50 minutes in favour of HSR for non-business.

Table 6 Phase 2 model scaling parameters (for generalised costs measured in minutes)

Market	Business			Non-business		
	Top level	Second level	Third level	Top level	Second level	Third level
	Induced demand	Car: fast mass transport: coach/rail	HSR: air	Induced demand	Car: fast mass transport: coach/rail	HSR: air
Inter-capital	-0.0020	-0.0039	-0.0097	-0.0016	-0.0022	-0.0087
Long regional	-0.0025	-0.0048	-0.0120	-0.0019	-0.0027	-0.0108
Short regional	-0.0030	-0.0068	-0.0171	-0.0027	-0.0038	-0.0154

Table 7 The updated model ASCs (mins, measured relative to the car mode)

Market	Business				Non-business			
	Air	Coach	Rail	HSR	Air	Coach	Rail	HSR
Inter-capital	-473	518	650	-478	-479	687	571	-484
Long regional	-27	479	509	-32	140	560	777	90
Short regional	46	359	381	381	-19	451	637	587

Note: Negative values increase the attractiveness of a mode. Some location-specific rail and ASCs were also calibrated.

5.3 Metropolitan station choice and access mode

Two further levels have been added to the model to forecast metropolitan station access mode choice and station choice (**Figure 11**).

For a central city station, access from home or workplace is by public transport and taxi, with car drop-off/pick-up making minor contributions, but no parking is assumed. For stations located outside the central area (including those at airports), access is by taxi, car (the latter including parked with a charge, where space is provided, and drop-off/pick-up) and public transport.

For HSR journeys from homes or workplaces in each metropolitan zone, the station choice model estimates the allocation between the metropolitan stations based on their relative accessibilities (which are derived from the access mode choice model).

The parameters of the access mode and station choice models (**Table 8**) were set to reflect the access mode and station preferences of respondents to the SP survey and what is known about airport access mode shares.

¹¹ The ratio of the scaling parameters at adjacent levels in the hierarchy.

¹² Steer Davies Gleave (for the European Commission), *Air and Rail Competition and Complementarity*, 2006.

Figure 11 Station choice model structure including access modes

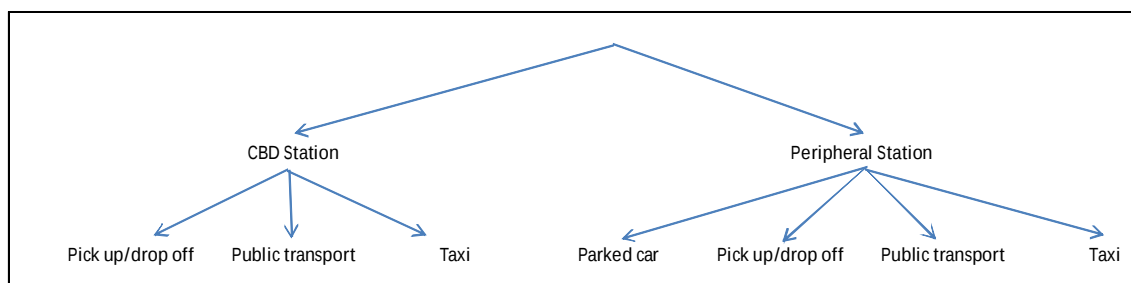


Table 8 Station and access mode choice parameters

Parameter	Taxi	Parked car*	Pick up/ drop off	Public transport		
				Metropolitan CBD HSR station	Other metropolitan HSR station	Airport stations
Pick up/drop off time weight	-	-	2	-		
Access journey time weight	2.0					
ASC (mins)	-	40	20	-70	-30	-10
Scaling of station/ Mode choice	-0.025/-0.05					

*Parked car is assumed to be unavailable to visitors.

5.4 HSR service mix

This new sub-model allocates HSR passengers between the services available for their journey based on the comparative journey times and service frequencies. It also calculates a measure of the overall attractiveness of the mix of available services, on which the forecasts of diversion to HSR are based.

The approach to allocating passengers between a mix of HSR services draws on the Rooftop model concept developed in the United Kingdom¹³, which has also been applied in Australia on detailed train service studies (such as Victorian Regional Fast Rail).

The Rooftop model forecasts passenger preferences between differently-timed train services using a time profile of passenger demand through the day. As such, detail is not available for the high speed forecasts, and is not relevant when forecasting 20-50 years ahead. A simplified procedure has been developed which simulates the behaviour of the Rooftop model.

The following process is applied for each pair of stations on the HSR network.

If more than one service provides for HSR journeys between a pair of stations, the quickest HSR service is taken as the reference service and defined as 'service 1'. This service has frequency f_1 .

If any other service takes the same time as the reference service, then the journeys between the pair of stations are simply shared between the two services in proportion to their respective frequencies. If the other service is slower then, using the same allocation process, it is allocated a smaller share of the journeys by reducing its service frequency. The amount of the frequency reduction is proportional to the extra journey time over the reference service.

¹³ Passenger Demand Forecasting Handbook, Version 5, Association of Train Operating Companies, 2009.

The frequencies of the slower services are reduced by a factor (fitted to reproduce the Rooftop model) to reflect the lower attractiveness of their longer journey times:

$$f_s' = f_s * (1 - 4.8 * t_s / (60 / f_1)) \text{ for } s > 1$$

where:

f_s' is the modified value of f_s for service s

t_s is the excess journey time over service 1

and if the frequency factor is less than 0 it is reset to 0.

The HSR demand between each pair of stations is allocated to each service in proportion to these modified frequencies.

The forecasts of the demand model are based on the characteristics of the fastest service (service 1) but with its service frequency increased to allow for the additional slower services, based on their modified frequencies:

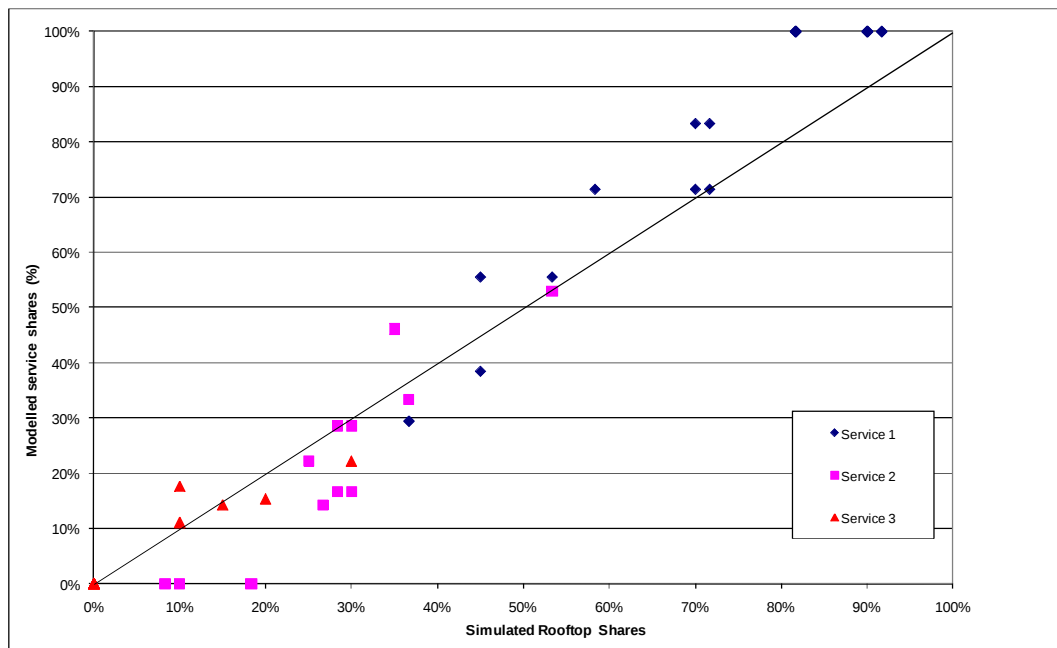
$$f_1' = f_1 + \sum_{s>1} f_s * (1 - 4.8 * t_s / (60 / f_1))$$

Comparisons of the results of this formula against a Rooftop model simulation for three competing services in **Figure 12** demonstrate the reasonable match.

Tests of the effects of this process on the HSR service gave the following illustrative forecasts:

- Two different services link Melbourne and Canberra. Both have the same journey time, but one has twice the service frequency; the more frequent service is allocated 67 per cent of the passenger demand.
- In another test of the same service pattern, but with identical frequencies, the passenger demand is split equally between the two services.
- There are two services between Newcastle and Brisbane, of which one is 10 minutes faster and has twice the frequency; this is allocated all of the passenger demand.

Figure 12 Comparison of the share of passengers between three HSR services for the service mix model and the Rooftop model



6.0 Model outputs

6.1 Output templates

The demand forecasting procedures are designed to generate inputs to the commercial performance and economic appraisals for each planning year including passenger demand, fares revenue and transport user benefits.

The model output templates provide both summary and detailed analyses of the model forecasts for all appraisals.

The main templates provide the overall summaries by trip purpose and 10x10 sector breakdowns of:

- Total corridor demand with and without HSR.
- HSR trips, passenger kilometres and revenues.
- Reductions in air, rail and coach revenues.
- Road vehicle kilometres.
- The overall user benefits by purpose in minutes and dollars.
- The resource cost adjustment for unperceived vehicle operating costs.
- An estimate of the overall metropolitan road decongestion benefits arising from HSR.
- Number of HSR passengers who access HSR by park and ride and the parking revenues.

The station access template provides statistics on the modes of access to every HSR station.

The services outputs template gives the station-to-station matrix of travel demand by purpose for every HSR service, identifying interchanging passengers.

The service mix template gives passenger loadings along the line for each service and the boardings/alightings at every HSR station.

The financial matrices template provides a number of the main outputs on a grouped station-to-station basis for input to the financial modelling used in the appraisal of commercial performance.

The economics template provides detailed economic data for every cell in the travel demand matrix by purpose, enabling the economic appraisal.

6.2 Key formulae

The benefit is measured as the difference between the base 'overall' travel cost and the with-HSR 'overall' travel cost, where 'overall' allows for all the available modes of transport.

The measure of the overall cost is the logsum¹⁴. Its general form is:

$$(1/\lambda) * \ln (\sum_m \exp(\lambda * \text{generalised cost}_m))$$

where:

λ is the model parameter

m refers to the set of transport modes

the generalised cost includes in-vehicle time, waiting time, access time, check-in time, fares and out-of-pocket costs; costs are converted to equivalent minutes of in-vehicle time using the model values of time; also included is the alternative specific constant for each mode (from the model)

the logsum is in units of travel time minutes.

¹⁴ Rand, *Using the Logsum as an Evaluation Measure*, Working paper, AVV Transport Research Centre, 2005.

The benefit (ignoring induced travel) is then:

$$\text{Benefit (in minutes)} = \text{Total base trips} * (\log\text{sum}_{\text{base case}} - \log\text{sum}_{\text{with-HSR case}})$$

This can be converted to dollars using the appropriate value of time. This formula is extended to include the benefits of induced travel using either the rule of a half or a more accurate method using the following analytical formula¹⁵:

$$\text{Benefit} = (\text{Total base trips} / \beta) * \{\exp[\beta * (\log\text{sum}_{\text{with-HSR case}} - \log\text{sum}_{\text{base case}})] - 1\}$$

where β is the induced travel parameter.

A resource cost correction is calculated for the unperceived car costs. This is:

$$\text{RCA} * (\text{car distance} / \text{group size}) * \{(\text{total base trips} + \text{induced trips}) * \% \text{car}_{\text{with-HSR case}} - \text{total base trips} * \% \text{car}_{\text{base case}}\}$$

where RCA is the resource cost/vehicle kilometre adjustment, different for business and non-business.

Metropolitan road decongestion costs are:

$$\text{CGC} * (\text{car vehicle distance}_{\text{met areas}} / \text{group size}) * \{(\text{total base trips} + \text{induced trips}) * \% \text{car}_{\text{with-HSR case}} - \text{total base trips} * \% \text{car}_{\text{base case}}\}$$

where CGC is congestion cost/kilometre expressed in \$ (from the state metropolitan models).

6.3 Ramp-up of demand

Following the introduction of new transport infrastructure and services, there is a delay in the level of demand achieving forecast levels as travellers adapt to the availability of a new transport facility. Where the new facility is markedly different to existing transport infrastructure and services, the delay is likely to be longer. The time the travel demands take to build up to the expected levels is referred to as the ramp-up period.

A five year ramp-up profile for the HSR service is presented in **Table 9** on the basis of broad assumptions about the lag times for demand build-up as a function of the trip purpose (**Table 10**). This suggests that 40 per cent of the forecast demand would be expected in the first year after opening.

A review of available information on the ramp-up of transport demand is presented in **Table 11**. Ramp up on toll roads is typically expected to be achieved within two years and this is reported to be true of some HSR services (e.g. many of the French TGV services). But for other HSR services it has taken longer: the Thalys service between Paris, Brussels, Cologne and Amsterdam and the Tokaido service in Japan are both reported to have achieved ramp-up of demand in five years.

Many European and Japanese HSR services were developed in corridors that already had high levels of rail demand, which likely shortened the ramp-up period significantly. This is not the case along the east coast of Australia. The proposed HSR profile is very similar to that assumed for the Californian High Speed Train. While this is somewhat longer than originally assumed for Speedrail, the demand pattern on the east coast HSR includes longer and less frequent journeys.

Table 9 HSR ramp-up assumption

Year after opening				
Opening year (1)	2	3	4	5
40%	55%	75%	90%	100%

¹⁵ Williams and Moore, 'On the appraisal of highway investments under fixed and variable demand', *Journal of transport economics and policy*, 1990.

Table 10 Ramp-up/lag assumptions by source of HSR travel (the number of years ramp-up for each segment)

Purpose	Source of HSR travel		
	Diverted from air	Diverted from other modes	Induced
Business	2	3	4
Other	3	4	5

Note: a lag of three years implies that full demand is achieved at the beginning of year four.

Table 11 Ramp-up evidence and assumptions

Sources (reports)	Year after opening				
	Opening year (1)	2	3	4	5
Speedrail					
Core	78%	95%	100%	100%	100%
Induced	20%	40%	60%	80%	100%
TGV benchmark	85%	95%	100%	100%	100%
East Coast Very High Speed Train					
Central	70%	90%	100%	100%	100%
Long run commuting affect	Between 5 and 15 years from opening, relating to relocations of homes and jobs				
Californian High Speed Rail ¹⁶					
Madrid-Seville	2 years				
TGV Atlantique	3-4 years				
Thalys	6 years				
California	40%	55%	70%	85%	100%
HSR Overseas Experience Report (Nash ¹⁷)					
Tokaido, Japan	5 years				
Seville-Madrid	5 years				
Korea	2 years, but 50% of demand transferred from existing rail services				
United Kingdom inter-capital services	Instantaneous except for commuting where home/job changes take up to 5 years				

¹⁶ Cambridge Systematics, *California High-Speed Rail 2012 Business Plan, Ridership and revenue forecasting*, 2011.

¹⁷ Nash, *HSR Overseas Experience Report*, High Speed Rail Study Phase 1, 2011.

7.0 Performance of the demand forecasting procedures

7.1 Introduction and objectives

The forecasts of the final model are analysed in this section and compared with the previous Australian studies and international experiences.

7.2 Implications of the revised projections

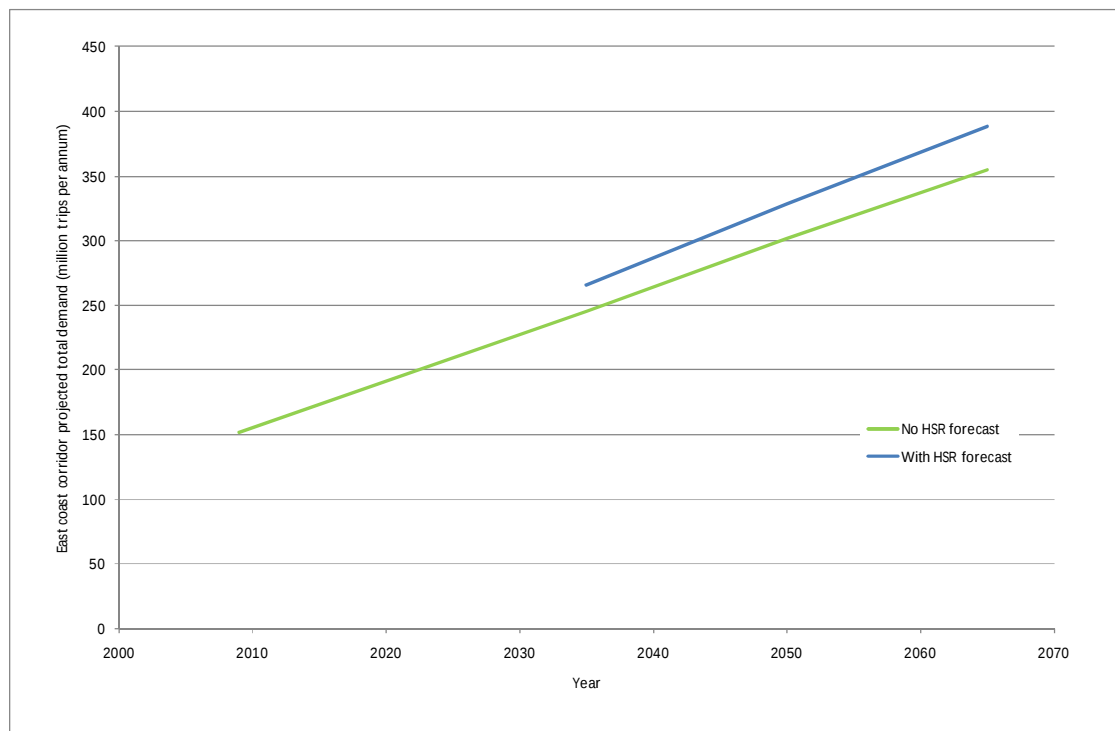
The base travel market projections are illustrated in **Figure 13**. Compared with the previous Australian studies, all three of which expected average market growth rates of 2.5-3 per cent per annum, without HSR, these are modest projected rates of travel demand growth:

- 1.8 per cent per annum to 2035.
- 1.4 per cent per annum to 2050.
- 1 per cent per annum to 2065.

These travel demand growth rates are higher than the equivalent growth rates of population in the study area (1.1 per cent per annum to 2035, then 0.9 per cent per annum to 2050 and then 0.7 per cent per annum to 2065) due to the additional influence of income growth.

Figure 13 also demonstrates the additional corridor demand generated by the presence of HSR.

Figure 13 Growth in travel demand in the east coast corridor



7.3 The performance of the access/egress and station choice models

The expected HSR station access and egress mode shares were taken from the responses to the SP survey, and are documented in **Table 12**. The corresponding model estimates of HSR station access and egress mode shares for 2009 are given in **Table 13**, for direct comparison purposes.

For the main city stations, the SP survey results suggested that over 70 per cent of respondents would use public transport to access the station, while taxi and pick up/drop off would make a minor access contribution. The model is reasonably consistent with this; only Melbourne has a mode share of less than 70 per cent for public transport. For egress, 61 per cent of SP respondents would use public transport, with most of the remainder choosing taxi. The model shows the same general result.

For the regional stations, the SP survey results suggested a broad spread across the taxi, pick up/drop off and park and ride modes and a small public transport share of access. The model does not include public transport access to regional stations but reflects the spread across the other modes with a greater emphasis on park and ride. For SP respondents, the main egress modes are taxi and pick up/drop off, with some public transport use. Except for the public transport share, the model satisfactorily reflects the SP respondents' preferences. It should be noted that the SP respondents were commenting on a centrally-located station whereas, in the model test, most of the regional stations are not centrally located.

Table 12 Expected HSR station access mode shares

Mode of access*	Cities	Regional
Taxi	13%	22%
Car parked or hired	-	31%
Pick up/drop off	12%	34%
Bus/local train	74%	14%
Mode of egress*	Cities	Regional
Taxi	26%	37%
Rental car	4%	8%
Pick up/drop off	9%	34%
Bus/local train	61%	21%

*Excludes other modes and walking.

Source: Stated Preference Survey.

Table 13 Model estimates of HSR station access mode shares (2009)

Stations	Entries + exits at home end (of residents)				Entries + exits at destination end (of visitors)			
	Taxi	PNR	KNR	PT	Taxi	PNR	KNR	PT
Melbourne	32%	0%	17%	52%	40%	0%	16%	44%
Melbourne North	29%	61%	9%	0%	67%	0%	33%	0%
Shepparton	15%	74%	11%	0%	23%	0%	77%	0%
Albury-Wodonga	6%	87%	7%	0%	20%	0%	80%	0%
Wagga Wagga	14%	77%	9%	0%	46%	0%	54%	0%
Canberra	57%	15%	27%	0%	72%	0%	28%	0%
Southern Highlands	11%	88%	1%	0%	35%	0%	65%	0%
Sydney South	30%	62%	8%	0%	62%	0%	38%	0%
Sydney	22%	0%	5%	73%	30%	0%	8%	62%
Sydney North	45%	37%	10%	9%	68%	0%	24%	8%
Central Coast	19%	70%	11%	0%	57%	0%	43%	0%
Newcastle	12%	77%	11%	0%	36%	0%	63%	0%
Taree	26%	51%	23%	0%	43%	0%	57%	0%
Port Macquarie	27%	59%	14%	0%	58%	0%	42%	0%
Coffs Harbour	22%	60%	18%	0%	43%	0%	57%	0%
Grafton	15%	69%	15%	0%	34%	0%	66%	0%
Casino	6%	89%	5%	0%	16%	0%	84%	0%
Gold Coast	35%	51%	15%	0%	59%	0%	41%	0%
Brisbane South	26%	55%	20%	0%	39%	0%	60%	0%
Brisbane	15%	0%	6%	79%	11%	0%	10%	79%
Overall	26%	36%	11%	27%	39%	0%	25%	36%

PNR: parked car; KNR: pick up/drop off; PT: public transport

There is published information on airport access, provided in **Table 14**, to compare with the estimates of the model in **Table 15**. Allowing for uncertainties regarding the reliability and coverage of these airport statistics the comparisons are reasonable, but the wide variations between the airports in the balance between taxi and car are not reproduced by the model.

Table 14 Published airport access mode shares (%)

Airport statistics	Overall			
	Taxi	Parked or rented car	Car pick-up/drop-off	Public transport
Sydney (2006)	37%	32%*	19%	12%
Brisbane (2009)**	8%	83%		8%
Melbourne (2008)	17%	61%		14%

* This includes 12 per cent classified as minibus, which are assumed to be largely connections to offsite parking.

** An estimate which probably includes airport workers; Sydney and Melbourne data refers to air passengers only.
Sourced from published airport data.

Table 15 Model estimates of airport combined access/egress mode shares (% , 2009)

Phase 2 Airport access	Overall			
	Taxi	Parked or rented car	Car pick-up/drop-off	Public transport
Sydney Airport	49%	17%	19%	15%
Brisbane Airport	54%	13%	21%	12%
Melbourne Airport	33%	29%	26%	12%

The model of metropolitan station choice is designed to forecast how city residents would choose between the central station and other stations. Referring to **Table 16**, the model suggests that the peripheral stations would be chosen by up to 35 per cent of city residents, with the remaining 65-75 per cent preferring the central station.

In the SP survey, Melbourne residents were given a choice of Craigieburn and 22 per cent of respondents said that they would consider the regional station as an option. Sydney residents were given the option of Homebush (but not the peripheral stations) and 51 per cent said that they would consider this station as an option. In practice, within the SP experiment the proportion actually choosing the peripheral stations was much lower.

It was concluded that the model estimates which give these alternative stations minority shares of the access demands are reasonable in relation to the SP responses. While it is possible that the model may over-predict the use of such stations, it was judged inappropriate to build in the model a preference against non-central stations without stronger evidence.

Table 16 Phase 2 estimates: access/egress at city stations (000's, 2009)

Station	Access/egress trips	
	by residents	by visitors
Melbourne	3358	6711
Melbourne North	1812	325
Sydney South	1506	227
Sydney	6167	9034
Sydney North	1789	308
Brisbane South	1168	181
Brisbane	2013	2530

7.4 Elasticities of demand

The model sensitivities were compared with the elasticities implied by the review of international experience in **Table 17** and are in reasonable correspondence with the independent evidence. In forecasting, the growth in income exceeds the growth in fares, and this reduces the fares elasticities of demand in the future years.

Table 17 A comparison of the implied model direct demand elasticities (2009)

Test	Direct elasticities	
	Phase 2 model	Expected range from independent evidence
With HSR:		
HSR fare	-0.8	-0.6 to -1.0
HSR in vehicle journey time	-0.4	-0.3 to -0.9
Car journey time	-0.3	-0.1 to -0.3
HSR headway	-0.1	~ -0.1
Without HSR:		
Air fares ¹⁸	-0.2	-0.2 to -1.0

7.5 Consistency with international experience

7.5.1 Scope

In the following paragraphs the demand forecasts for 2035 are compared with the international evidence assembled in **Appendix 1A**. The HSR forecasts are for the final alignment and stations but, for consistency with the independent evidence, do not include the impacts of increased air congestion at Sydney Airport.

7.5.2 The split between air and HSR

Drawing on the review of international experience of the impacts of high speed rail on air travel, **Figure 14** and **Figure 15** are reproduced from **Appendix 1A** with east coast HSR intercity forecasts for 2035 added to the figures¹⁹. **Figure 14** derives from the European Community review while **Figure 15** reproduces the analysis of all of the evidence in **Appendix 1A**, but excludes the individual data labels for clarity.

The consistency of the east coast HSR intercity forecasts with international experience is evident in these comparisons. In **Figure 14** and **Figure 15**, relative to HSR journey time, the forecasts for the longest route, between Melbourne and Brisbane, are at the higher end of the range of the international evidence (but still very low). The Sydney-Canberra share is lower than the expected range for journeys of less than two hours, but this is largely explained by the relatively high proportion of transfer passengers which are assumed in the forecasts not to divert to HSR.

¹⁸ The air fares elasticity with HSR is much higher: -1.0.

¹⁹ The international statistics relate to all air intercity passengers, including transfers, and to be consistent the east coast forecasts of HSR shares have been adjusted to allow for the air transfer passengers who are not included in the forecasts (and are assumed not to transfer to HSR).

Figure 14 HSR:air shares forecast by the final model for 2035 versus the evidence of the European Commission review

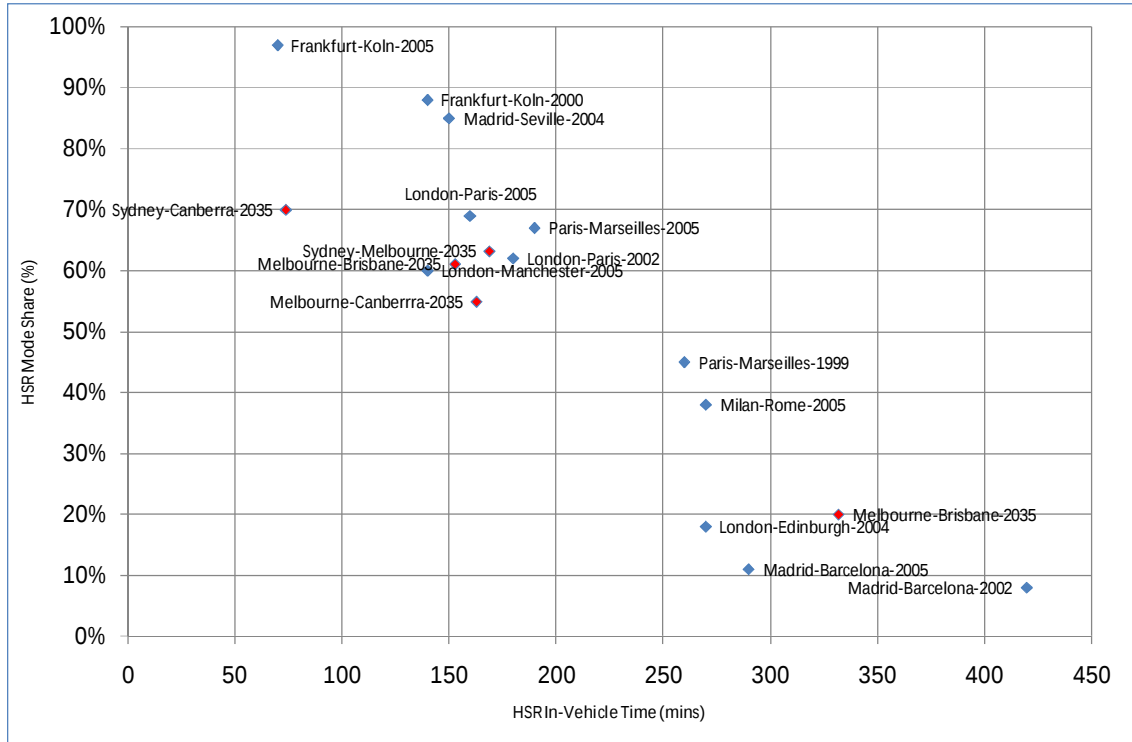
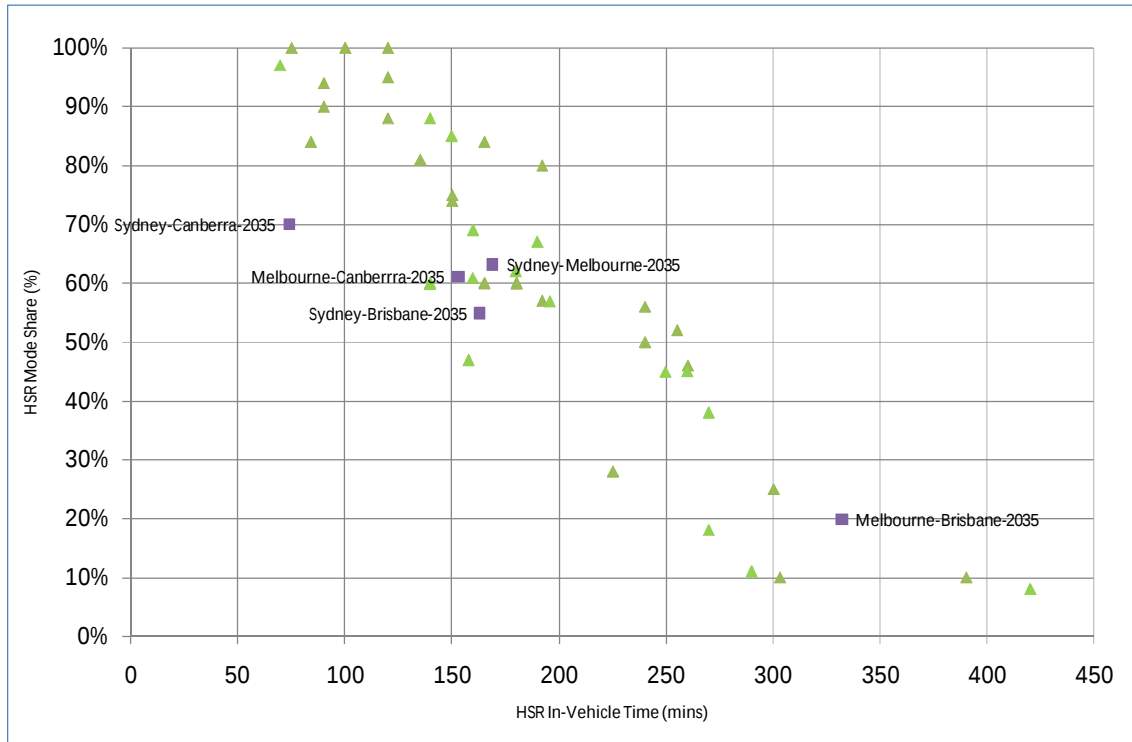


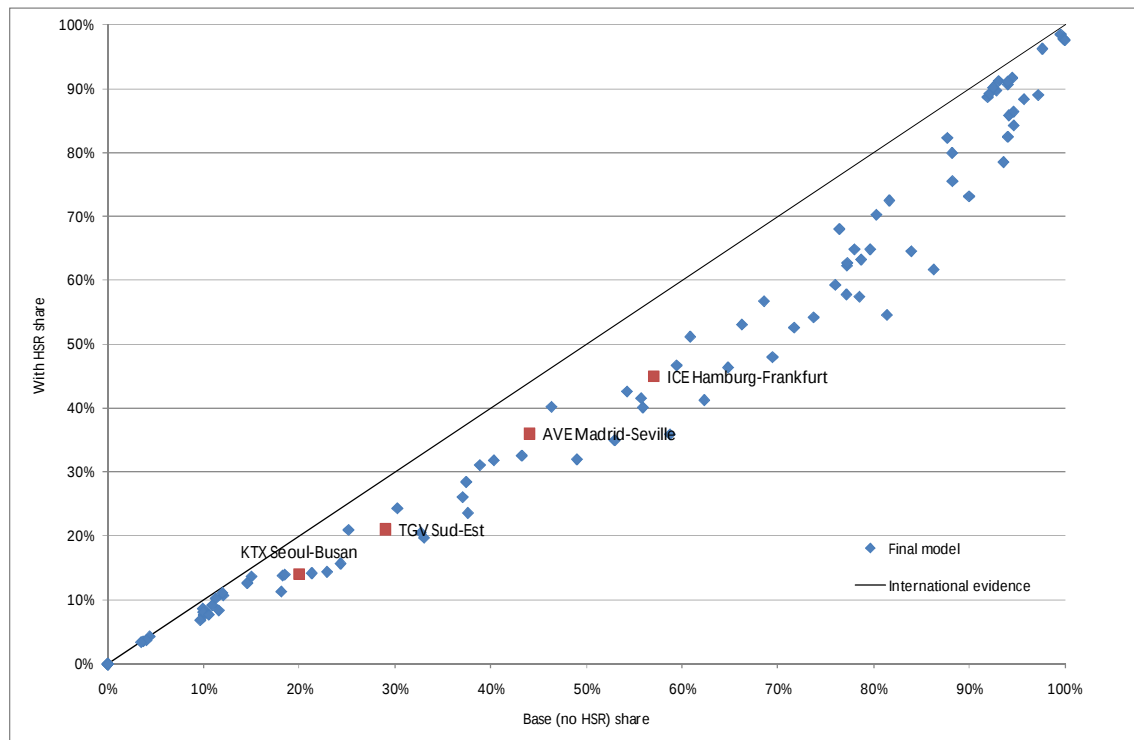
Figure 15 HSR:air shares forecast by the final model for 2035 versus the full international evidence



7.5.3 The diversion from car and induced travel

The forecasts of car transfer in the east coast corridor are reproduced in **Figure 16** and the limited international evidence is also included and identified. It is again clear that there is considerable consistency, providing strong support for the forecast of diversion from car provided by the model.

Figure 16 Forecasts of the diversion from car (2035) versus the international evidence



The sources of HSR demand in the model forecasts are presented in **Figure 17** and **Figure 18**.

Overall, 19 per cent of HSR trips are induced, with long regional trips showing the highest induced travel (23 per cent) and short regional trips the lowest (eight per cent). The international experience suggest that the most common range is 20-30 per cent, and these forecasts are thus on the conservative side of this range.

On average, 51 per cent of HSR trips are diverted from air, with this impact being greatest on business and inter-city travel (65 per cent and 77 per cent diversion from air respectively). Diversion from air is of course negligible for short regional trips.

HSR trips diverted from car represent 26 per cent. According to the international review, the most common range of diversion is 20-30 per cent. This impact is greatest for non-business and short regional trips (with 34 per cent and 75 per cent diversion from car respectively).

There is some diversion from rail for short regional trips (10 per cent) and very little from coach.

Figure 17 Source of HSR travel demand in 2035

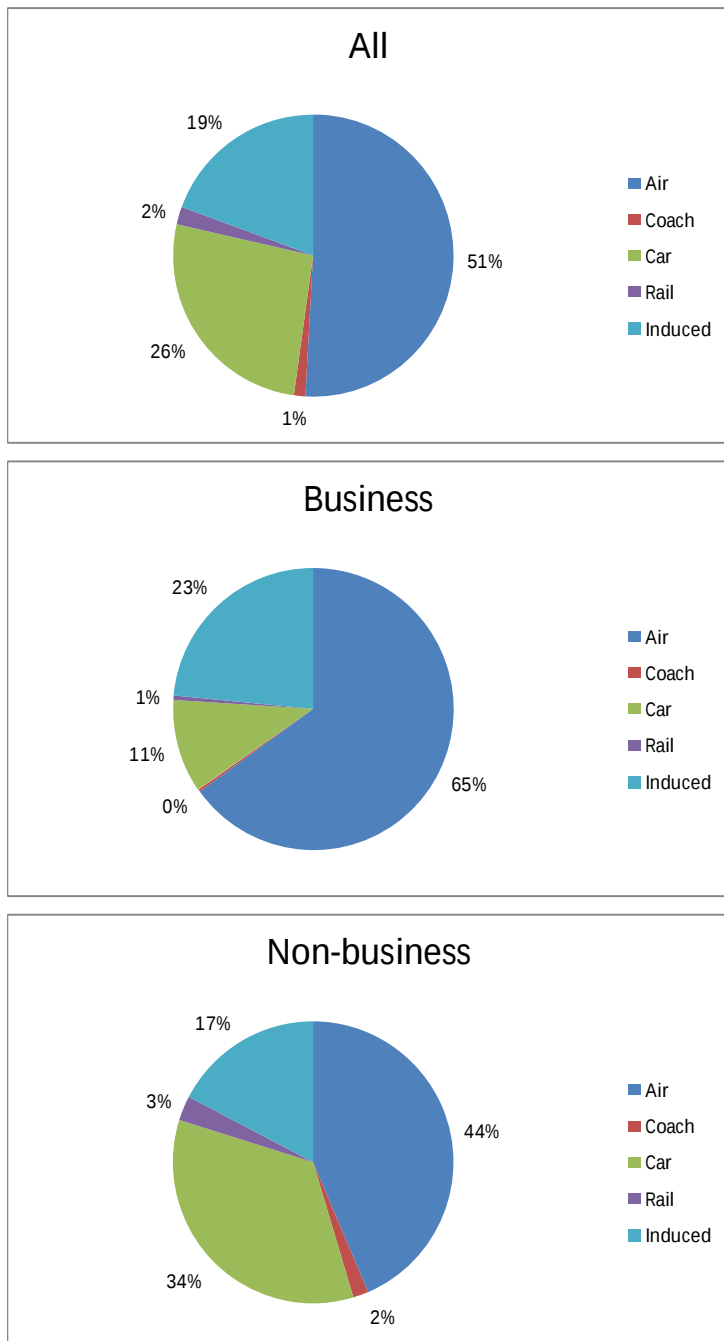
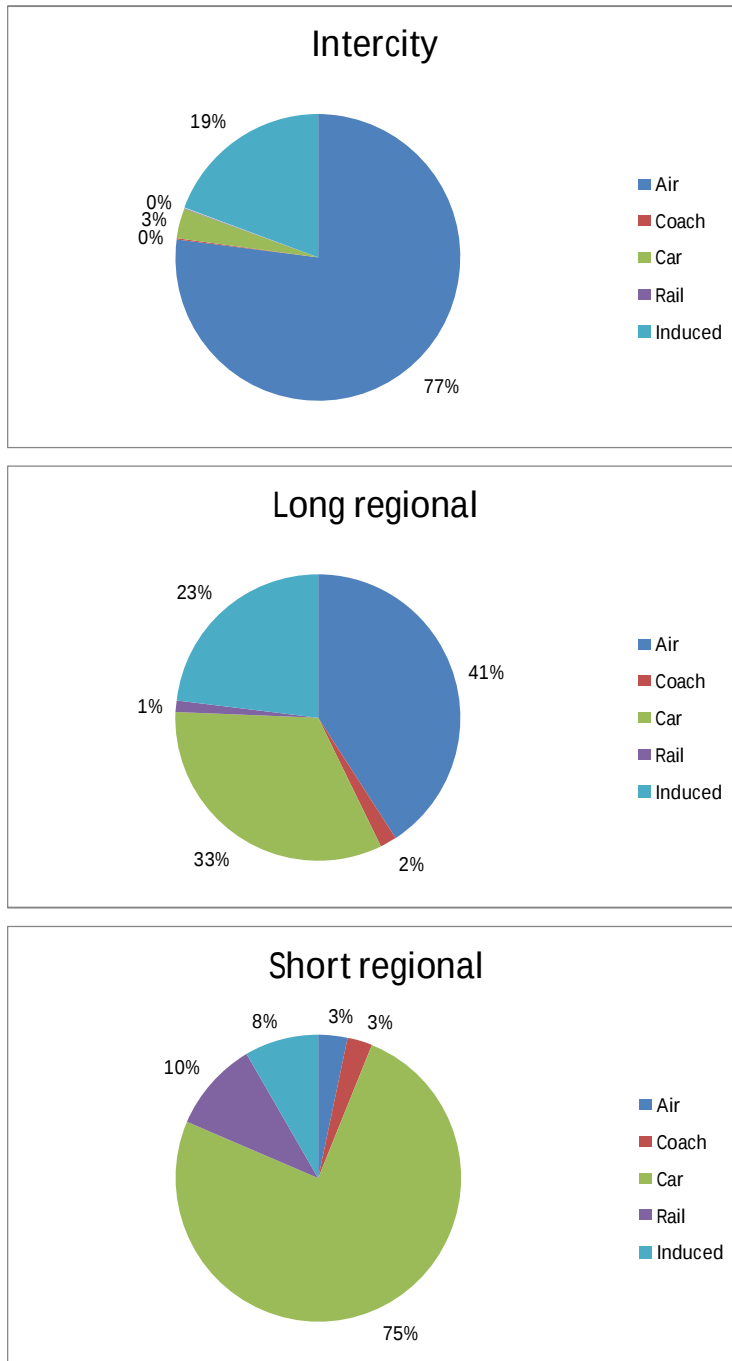


Figure 18 Source of HSR travel demand in 2035



7.5.4 Shares by trip length

Figure 19 and **Figure 20** show for business travel the estimated mode shares in 2035 without HSR by distance band and the forecast impacts of HSR. **Figure 21** and **Figure 22** provide the same information for non-business travel.

Over distances between 300 and 1,000 kilometres, HSR is forecast to gain a significant share of the business travel market. At shorter distances, car predominates. At long distances, air is forecast to be competitive with HSR and above 1,500 kilometres to account for most trips.

The relationships for non-business travel are similar. The main difference is that the HSR share at each distance band is lower than that for business because car is forecast to continue to retain a significant share of the market for all but the longest distances.

Figure 19 Phase 2 model: travel by distance (by road) band, without HSR, business, 2035

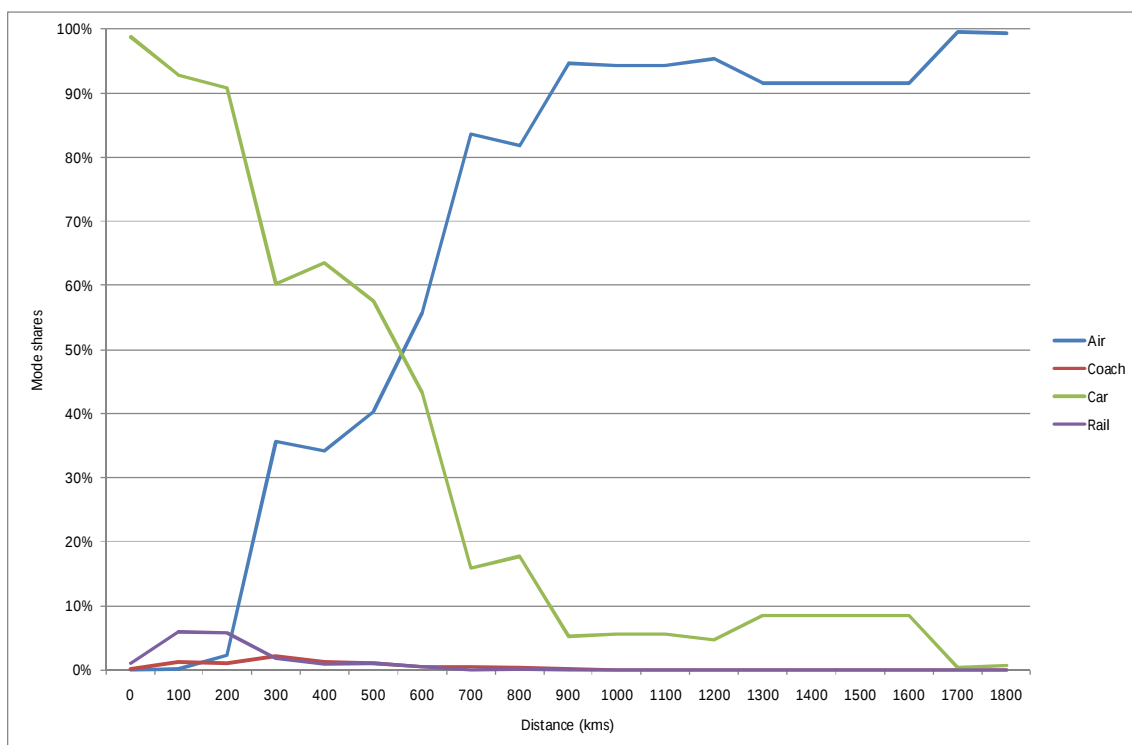


Figure 20 Phase 2 model: travel by distance band, with HSR, business, 2035

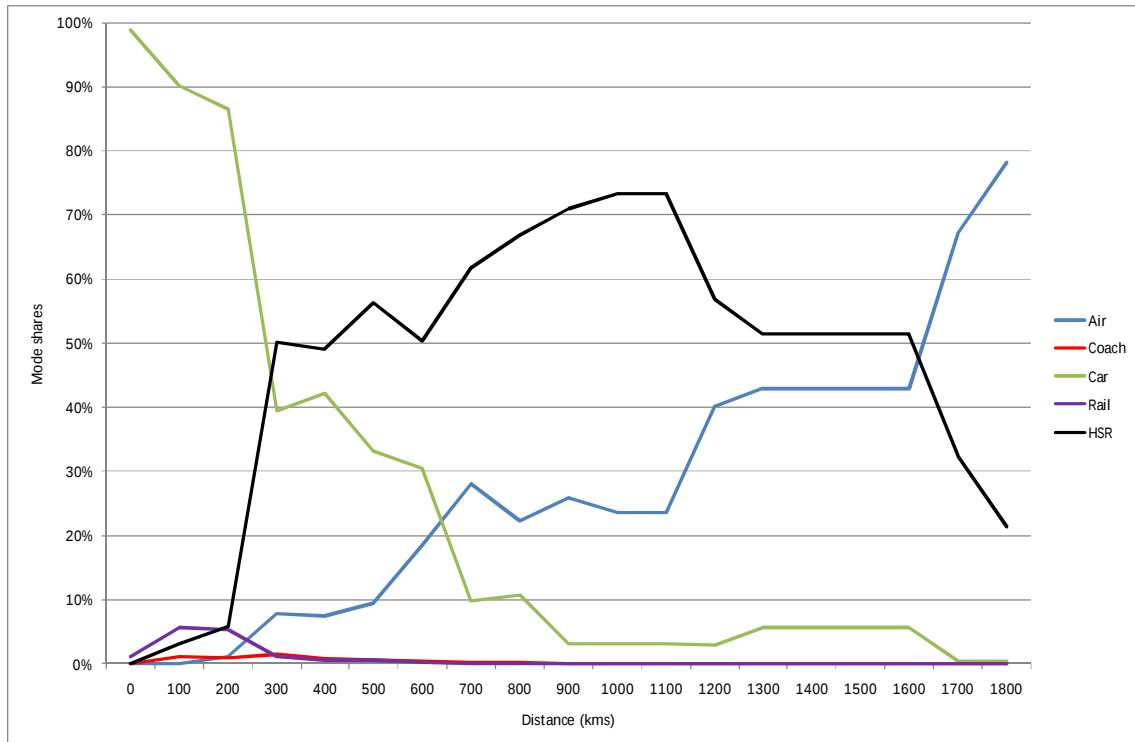


Figure 21 Phase 2 models: travel by distance band, non-business, no HSR, 2035

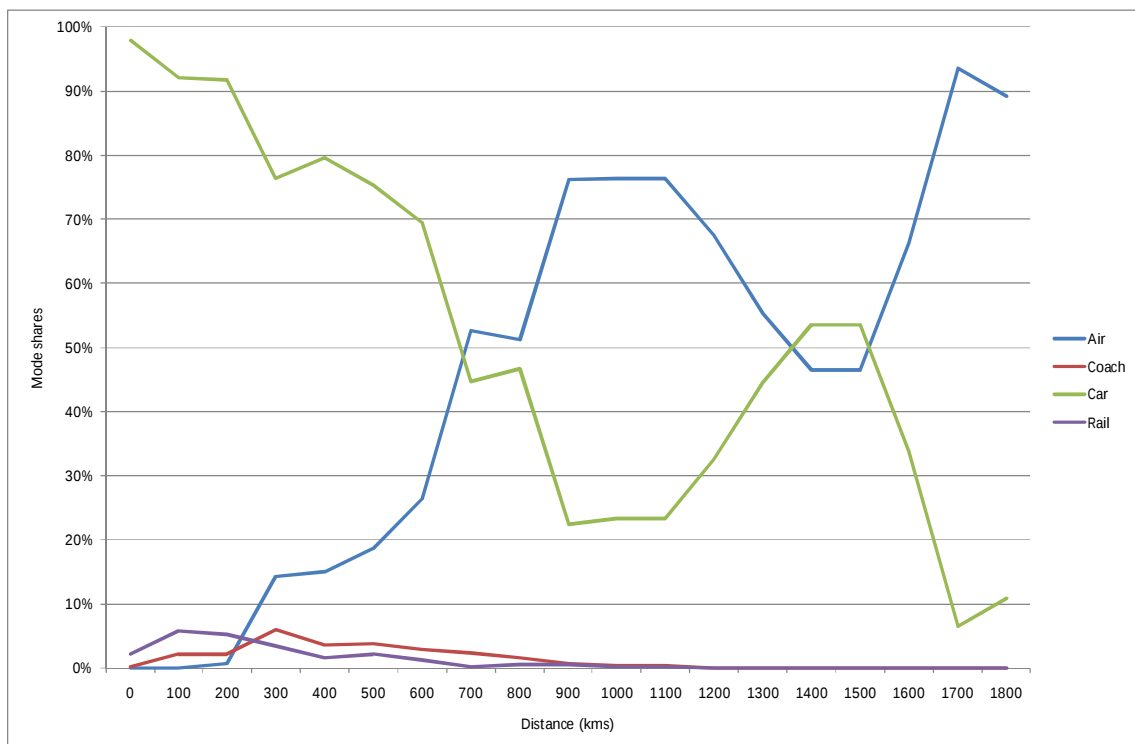
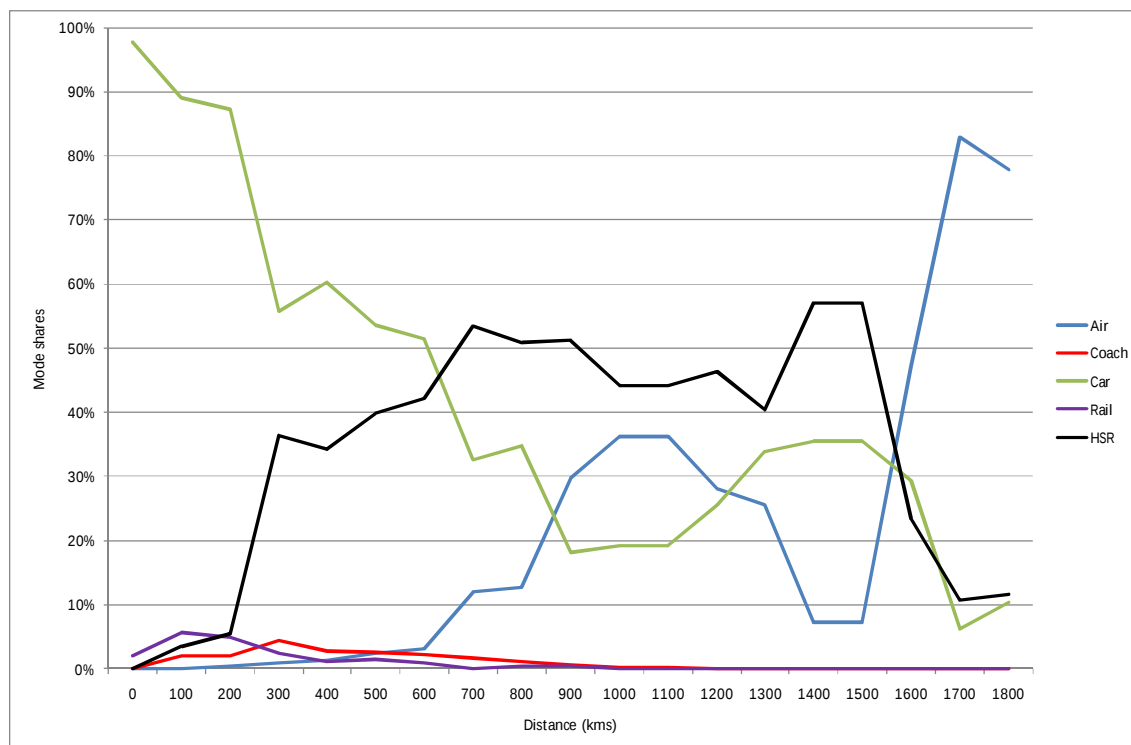


Figure 22 Phase 2 model: travel by distance band, non-business, with HSR, 2035



7.6 Comparisons with previous local studies

The analysis in **Appendix 1A** of the forecasts of the three previous Australian HSR studies is reproduced in **Table 18**, to which are added the east coast HSR forecasts (for 2021, by interpolation).

There is a large degree of consistency with the previous studies: the overall corridor forecast is very similar to that from the Very High Speed Train Study (VHST); the forecast for Sydney-Melbourne is very close to that for the Very Fast Train Study, but higher than VHST; the forecast for Sydney-Canberra is between the VHST and Speedrail forecasts²⁰.

Table 18 The HSR forecasts for the four studies at 2021 (millions of passengers per year)

Route sector	Study			
	VFT*	Speedrail	VHST	East coast HSR forecast**
Brisbane-Melbourne	-	-	32.9	36.6
Sydney-Melbourne	18.1	-	12.1	18.7
Sydney-Canberra	-	5.2	3.7	4.2

*Projected assuming market growth of 2.5 per cent per year.

**Interpolated value.

²⁰ VFT, op. cit.
Speedrail, op. cit.
VHST, op. cit.

Appendix 1F

The base case and economic parameters affecting travel demand

Appendix 1F

The base case and economic parameters affecting travel demand

Prepared for

Department of Infrastructure and Transport

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March 2013

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March 2013

Quality information

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Ref	60238250-1.0-REP-0101-1F
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1.0 Introduction

In forecasting the future demand for high speed rail (HSR), population and employment projections, estimates of future level-of-service for each mode of transport and projections of economic factors such as income and the cost of travel by each mode of transport are used. In the case of aviation, assumptions are required on further investment in Sydney aviation capacity and the future air services. Taken together, these descriptions of the future scenario are referred to as the base case (without HSR).

The implications of variations to the assumptions made for the future base case have also been analysed (**Appendix 1G**).

2.0 Population forecasts

The future populations for the east coast model zones have been derived from a combination of state and Australian Bureau of Statistics (ABS) projections. The list of data sources is given in **Table 1**; all states provided a central forecast to various future horizons, while Queensland also provided low and high population scenarios.

As model zones are defined mainly as aggregations of 2010 Statistical Local Areas (SLAs), the zone populations were obtained by a straightforward aggregation of state forecasts in most cases. The exception to this approach was Queensland, which supplied Local Government Area (LGA) population forecasts, which were disaggregated to SLAs using ABS 2010 population statistics.

Beyond the state forecast horizon, the growth rate from the corresponding ABS long-term 'capital city' or 'balance of state' population projection was used to extrapolate SLA populations to 2056.

Trends in capital city and the balance of state growth rates to 2056 were extrapolated to 2065 and then controlled to the ABS national forecast growth in this period (ABS does not provide a geographical breakdown beyond 2056).

For states which did not provide low and high forecasts (NSW, Victoria, ACT), the medium series was factored based on the differential between the Low, Medium and High series in the ABS long term forecasts (distinguishing the state capital from the rest of the state).

Minor modifications to the projection were made to account for the information provided by ACT, which provided suburb populations to 2021 and the total ACT population to 2059.

The resulting projections for each state (only that part within the east coast study area) are summarised in **Table 2** and **Table 3**.

Table 1 Medium forecast series by state

Area	Data source	Provider	Geometry	Coverage
National	3235.0 - Population by Age and Sex, Regions of Australia, 2010 Population Estimates by Age and Sex, Summary Statistics by Geographical Classification (ASGC 2010), 2005 and 2010	ABS	SLA 2010	2005,2010
	3222.0 - Population Projections, Australia, 2006 to 2101 Projected population, components of change and summary statistics - Australia, state/territory, capital city/balance of state, 2006–2101	ABS	National, Capital/ Balance of state	2006-2101, 2006-2056
ACT	ACT Population Projections for Suburbs and Districts: 2001 to 2021, Policy Division, ACT Chief Minister's Department <i>Table 1: Summary</i>	ACTG*	'Suburb', 'District'	2001-2021
	ACT Population Projections: 2009 to 2059, Policy Division, ACT Chief Minister's Department <i>Table 1: Summary</i>	ACTG*	ACT Boundary	2009-2059
NSW	NSW Statistical Local Area Population Projections (April 2010) <i>NSW SLA Population Projections, 2006-2036</i>	NSW BTS**	SLA 2006	2006-2036 (5 year inc)
	Final TDC October 2009 Release Population Forecasts Estimated Resident Population (ERP) by TZ2006 (Total persons)	NSW BTS**	Transport Zone 2006	2006-2036 (5 year inc)
QLD	Projected population by local government area, Queensland, 2006 to 2031, Office of Economic and Statistical Research, Queensland Treasury <i>Low, Medium, High series</i>	QLD OESR***	LGA 2011	2006-2031
VIC	Victoria in Future 2011 – pre-release data 4 July 2011 Estimated Resident Population, 2010 and projected Census years	Victorian DoT****	SLA 2010	2010, 2011-2051 (10 year inc)

*ACT Government.

** NSW Bureau of Transport Statistics.

***QLD Office of Economic and Statistical Research.

****Victorian Department of Transport.

Table 2 Population forecast series by state (millions)

State	2010	2035	2050	2065
Low scenario				
East coast study area NSW	6.5	8.0	8.6	8.9
VIC	5.0	6.6	7.4	7.8
QLD	3.0	4.1	5.0	5.7
ACT	0.36	0.41	0.41	0.40
External to study area	7.5	9.4	10.3	10.9
Australia total	22.3	28.6	31.6	33.7
Medium scenario				
East coast study area NSW	6.5	8.3	9.2	9.9
VIC	5.0	6.9	7.9	8.7
QLD	3.0	4.6	5.5	6.4
ACT	0.36	0.47	0.53	0.57
External to study area	7.5	10.3	11.7	12.9
Australia total	22.3	30.6	34.7	38.4
High scenario				
East coast study area NSW	6.5	8.7	10.2	11.6
VIC	5.0	7.3	8.8	10.2
QLD	3.0	5.1	6.1	7.0
ACT	0.36	0.54	0.67	0.80
External to study area	7.5	11.2	13.5	15.7
Australia total	22.3	32.9	39.2	45.4

Table 3 Medium population forecast for 33 communities (millions)

Communities	Medium			
	2010	2035	2050	2065
Melbourne: Inner 15 km	1.3	1.7	1.9	2.2
Melbourne: Southeast	1.9	2.4	2.7	3.0
Melbourne: Northwest	0.90	1.6	1.8	2.0
Geelong - Ballarat	0.41	0.59	0.68	0.70
Bendigo - Mansfield	0.22	0.36	0.42	0.43
Shepparton - Bright	0.21	0.25	0.27	0.27
Albury - Wodonga	0.10	0.13	0.13	0.14
Riverina	0.07	0.07	0.07	0.08
Wagga Wagga	0.11	0.12	0.12	0.12
Canberra	0.43	0.58	0.64	0.69
Goulburn	0.03	0.03	0.03	0.03
Young - Lithgow	0.05	0.05	0.05	0.05
Moss Vale - Milton	0.14	0.19	0.20	0.20
Wollongong	0.29	0.34	0.35	0.36
Picton, Penrith, Castlereagh	0.37	0.48	0.54	0.60
Campbelltown - Maroubra	1.3	1.8	2.0	2.2
Parramatta	0.67	0.83	0.94	1.0
Sydney: Inner 10 km	0.84	1.0	1.2	1.3
Hornsby - Hawkesbury River	1.0	1.4	1.5	1.7
Gosford - Cooranbong	0.37	0.49	0.55	0.60
Newcastle	0.48	0.60	0.63	0.64
Singleton	0.03	0.04	0.04	0.04
Taree	0.09	0.11	0.11	0.11
Port Macquarie - Kempsey	0.12	0.16	0.17	0.17
Coffs Harbour	0.09	0.11	0.12	0.12
Grafton	0.05	0.06	0.06	0.06
Ballina - Casino	0.15	0.18	0.19	0.19
Gold Coast - Tweed Heads	0.60	0.94	1.1	1.2
Beaudesert	0.03	0.06	0.07	0.08
Brisbane: Outer North (Maroochydore)	0.38	0.63	0.75	0.85
Brisbane: South (Jimboomba)	0.60	1.2	1.4	1.6
Brisbane: North (Caboolture)	0.39	0.57	0.69	0.81
Brisbane: Inner 20 km	1.1	1.3	1.6	1.9
External	7.5	10.3	11.7	12.9
Total	22.3m	30.6m	34.8m	38.4m

3.0 Employment forecasts

In the commuting forecasts to the centres of Sydney and Brisbane, state forecasts of the growth in central city area employment have been used. Beyond the state projection periods to 2065, it has been assumed that the central city employment growth will be the same as the overall population growth of the metropolitan area.

4.0 Road and public transport level-of-service scenarios

For the three major cities, level-of-service data for journeys by road and public transport have been taken from the state transport models for the latest forecast year available (Melbourne: 2031, Brisbane: 2031, Sydney: 2036). The state transport model future scenarios include future infrastructure and service improvements. In the absence of very long term projections from the city models, this level-of-service is assumed to apply in all future scenarios.

Outside the metropolitan areas, transport level-of-service by road, rail and coach is assumed unchanged from 2009, presuming that future infrastructure investment will maintain inter-urban transport levels of service.

5.0 HSR services and fares

The appropriate HSR service patterns have been developed as described in **Appendix 2A** to serve the demand forecasts. A fare structure for HSR was developed as a function of distance and purpose (**Figure 1** and **Figure 2**, shown for 2035), and this has been used for all of the HSR forecasts. This was set to be broadly similar to Brisbane-Sydney and Sydney-Melbourne inter-capital air fares, but the distance function implied that for significantly shorter and longer distances the HSR fares were, respectively, lower and higher than air fares. It is notable that the average air fares for non-business travel show only a small variation with distance.

Figure 1 HSR business fares (2035)

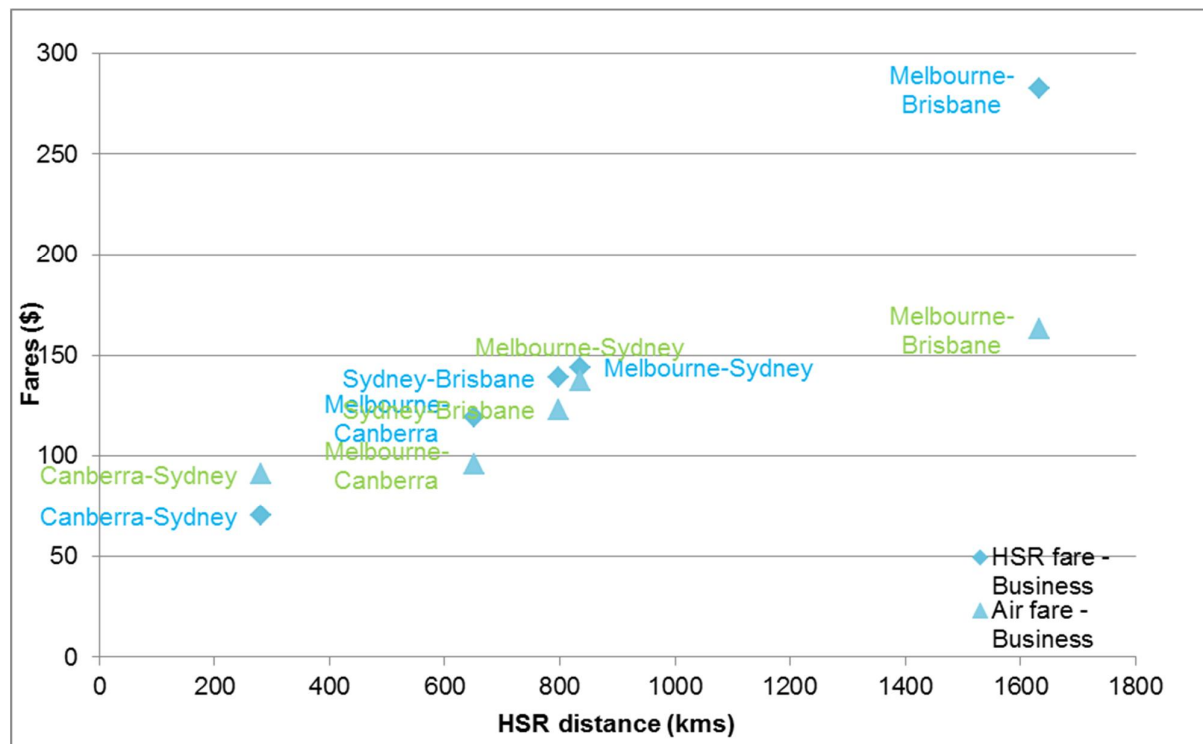
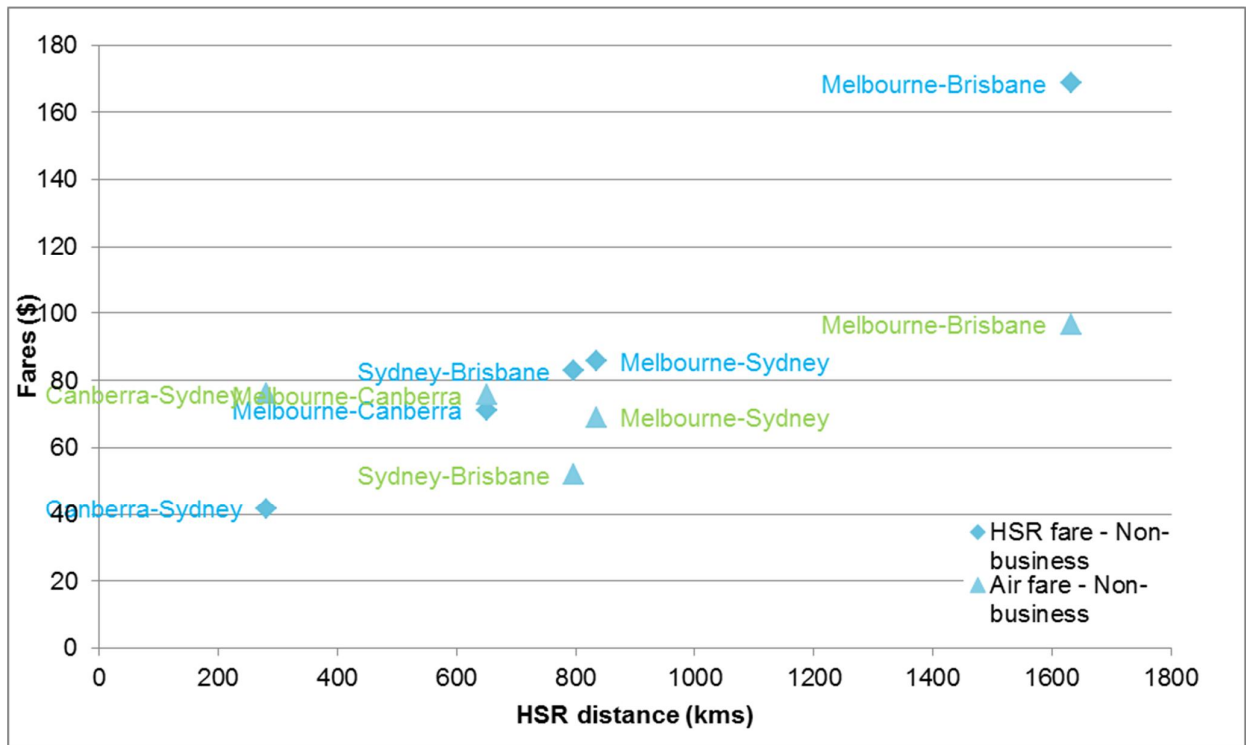


Figure 2 HSR non-business fares (2035)



6.0 Aviation scenarios

The base case assumes no second Sydney Airport, although aviation capacity is assumed to increase with greater flight frequencies and increasingly larger aeroplanes. Based on the Australian/NSW Governments' *Joint Study on aviation capacity in the Sydney region* (the Joint Study)¹ and BITRE aviation forecasts, domestic air service frequencies at Sydney Airport were assumed to increase by 36 per cent between 2009 and 2035, and remain constant thereafter when the airport has reached capacity. For services which do not use Sydney Airport and would therefore not be capacity-constrained (such as Brisbane-Melbourne), the increases in frequency assumed were larger: 60 per cent, 80 per cent and 100 per cent in 2035, 2050 and 2065 respectively. Air fares were assumed to continue to decline until 2015 (at 0.5 per cent per year) and then remain constant in real terms through the forecast period, consistent with the Joint Study².

International experience³ supports the following conclusions regarding the response of airlines to competing HSR services:

- Air services are likely to be curtailed or withdrawn where HSR services offer a competitive transport alternative.
- Full service carriers (FSCs) would continue to support their network strategies on major intercity routes, albeit with smaller aircraft, but they may reduce service frequencies on low yield routes.

¹ Australian and NSW Governments, *Joint Study on aviation capacity in the Sydney region*, Canberra, 2012.

² *ibid.*

³ For example, the Eurostar services across the English Channel, the Paris-Marseille TGV service and the HSR services in China.

- Low cost carriers (LCCs) are likely to respond by transferring services to more profitable routes.
- A reduction in the air market size following the introduction of HSR may serve to increase competition between FSCs and LCCs for some major intercity routes, and ultimately put some downward pressure on air fares.

The sensitivity tests reported in **Appendix 1G** include tests of the impacts on the HSR forecasts of variations in both air and HSR fares, including one scenario in which air fares are reduced by 50 per cent for two years.

The patronage at Sydney Airport was 37 million passengers per annum in 2010. According to the aviation capacity study, by around 2035, the airport is expected to be at capacity. Passenger demand would exceed the available seat capacity and, increasingly, air passenger demand at Sydney Airport would be suppressed. Based on the aviation capacity study, the economic costs of congestion at Sydney (Kingsford Smith) Airport have been modelled as longer delays (on average an 11 minute increase in unexpected delays) due to reduced reliability and a seven per cent increase in aviation prices to account for the reduced ability of passengers to travel at their preferred times and the use of higher prices to spread peak demand.

For the scenario tests (**Appendix 1G**), a sensitivity test has been defined in which additional aviation capacity is assumed in the Sydney region. This assumes that even if an additional airport were built, Kingsford Smith would remain the preferred destination because of its proximity to the centre of Sydney and its well-developed supporting infrastructure. This could not be easily replicated by a new airport in any location. As a result, Sydney (Kingsford Smith) Airport would remain at or near to capacity in terms of slot utilisation.

7.0 Economic scenarios

The characteristics of the economic scenarios are specified in detail in **Appendix 5A** and **Appendix 5B**, and are simply summarised in **Table 4**. Essentially, over a period of steadily increasing average income, there are expected to be no large real changes in transport costs, except for standard rail fares which increase over 50 per cent in real terms in the future scenarios.

Table 4 The base economic scenario

Economic input	Description
Gross state product/capita	Forecast to grow on average 1.1% to 1.5% per year in real terms to 2065 in the corridor, varying by state.
Air fares	Decline by 0.5% per year in real terms from 2012 to 2015, then constant. This is consistent with the aviation capacity study.
Standard inter-urban/country rail fares	From 2011, a real increase of 55% by 2035, then a gradual increase to 2065 (a 65% increase over 2011).
Coach fares	From 2011, a 3% real increase by 2065.
Vehicle operating costs	From 2011, a 13% real increase by 2065.
Airport/station parking charges	Constant in real terms in \$2012.
Taxi fares	Constant in real terms in \$2012.
Local metropolitan bus and rail fares	Constant in real terms in \$2012.

Appendix 1G

Demand forecasts

Appendix 1G

Demand forecasts

Prepared for

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March 2013

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March 2013

Quality information

Document	Appendix 1G
Ref	60238250-1.0-REP-0101-1F
Date	March 2013

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1.0 Introduction

The conclusion of the report on phase 1 of this study was a set of shortlisted corridors, together forming the study area for phase 2. In phase 2, these shortlisted corridors have been reviewed to determine a detailed preferred alignment for the High Speed Rail (HSR) corridor and to identify the most suitable station locations.

These decisions have been informed by the differences in HSR demand and user benefits between alternative alignments and station locations, derived from the demand forecasting procedures. This appendix presents forecasts for the preferred alignment. All forecasts presented here assume the preferred HSR system is completed between Brisbane and Melbourne and are not factored for ramp-up of demand used in appraisal.

2.0 HSR forecasts for the preferred alignment

2.1 The HSR service

The broad characteristics of the final alignment and service patterns are summarised in **Table 1**. Journey times between Sydney and the other metropolitan areas are well under three hours. There are 20 stations on the line, including peripheral metropolitan stations and stations in other towns and cities.

Table 1 The preferred alignment

Express services	Express journey times
Sydney-Melbourne	2 hours 44 minutes
Brisbane-Sydney	2 hours 37 minutes
Sydney-Canberra	1 hour 4 minutes
Canberra-Melbourne	2 hours 10 minutes
Stations	
Melbourne, Melbourne North, Shepparton, Albury-Wodonga, Wagga Wagga, Canberra, Southern Highlands, Sydney South, Sydney, Sydney North, Central Coast, Newcastle, Taree, Port Macquarie, Coffs Harbour, Grafton, Casino, Gold Coast, Brisbane South, Brisbane.	
Service patterns	
Inter-capital express and regional, with varying stopping patterns.	

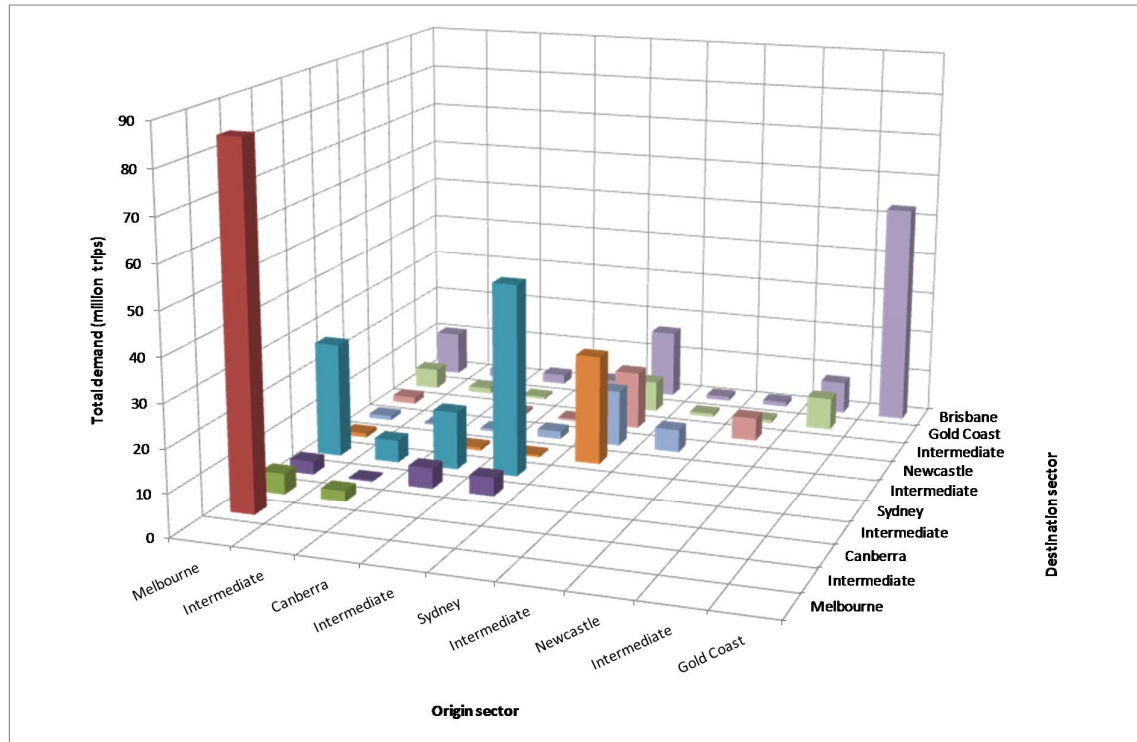
2.2 Overall HSR forecasts

Total demand in the corridors by all modes with HSR is forecast to increase from 152 million trips in 2009 to 388.7 million in 2065 (**Table 2**). The distribution of this demand by origin and destination sector for 2065 is illustrated in **Figure 1**. Local travel to the major metropolitan areas accounts for the largest sector to sector flows, followed by travel between the major metropolitan areas.

Table 2 The preferred alignment: overall statistics

Statistic	2065
Total demand (with HSR, million trips)	388.7
HSR passengers (million)	83.6
HSR passenger kilometres (billion)	53.1

Figure 1 Origins and destinations of total demand with HSR, 2065



HSR demand (**Table 2**) is forecast to be approaching 84 million passengers in 2065. The origins and destinations of passengers forecast to use the HSR are illustrated in **Figure 2**. The two main intercity sectors, Sydney-Melbourne and Brisbane-Sydney, are forecast to account for the largest individual demands on the HSR line.

Overall, HSR takes a 22 per cent share of the travel market in 2065, which is summarised by sector in **Table 3**. The HSR mode share of the shorter journeys is forecast to be low, typically five-15 per cent, and to reach its maximum for the inter-city journeys (Sydney-Melbourne and Brisbane-Sydney) at 60-70 per cent. For other, long journeys HSR is forecast to win on average around 25-45 per cent of the market.

Figure 2 Origins and destinations of HSR passengers¹, 2065

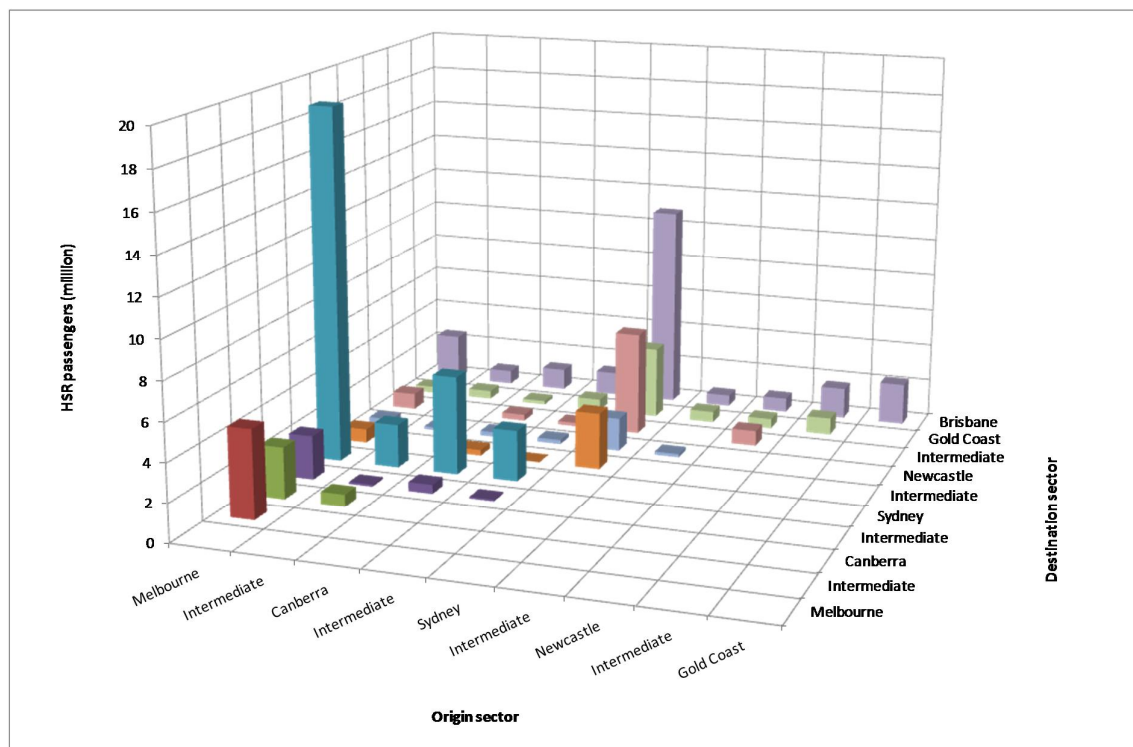


Table 3 HSR market share for 2065, % trips

Sectors	Melbourne	Intermediate	Canberra	Intermediate	Sydney	Intermediate	Newcastle	Intermediate	Gold Coast	Brisbane	Total
Melbourne	X	6%	56%	76%	70%	73%	32%	53%	7%	24%	
Intermediate		X	25%	28%	43%	X	39%	X	33%	37%	
Canberra			X	10%	38%	39%	41%	46%	34%	50%	
Intermediate				2%	6%	4%	12%	38%	44%	56%	
Sydney					X	12%	13%	40%	52%	67%	
Intermediate						X	3%	X	72%	59%	
Newcastle							X	15%	65%	68%	
Intermediate								X	12%	22%	
Gold Coast									X	4%	
Brisbane										X	
Average											22%

¹ This includes trips to and from Wollongong accessing HSR at Sydney South or Southern Highlands stations.

The number of HSR passengers boarding, alighting and interchanging at each HSR station is given in **Figure 3**.

Sydney Central station at the heart of the network caters for the most passengers, followed by the other three city stations, Melbourne, Brisbane and Canberra. The peripheral stations to the three major cities (Melbourne North, Sydney South, Sydney North and Brisbane South) also attract patronage (mainly city residents rather than visitors).

Of the regional stations, Gold Coast attracts most passengers, while other regional stations serving smaller populations are forecast to cater for fewer passengers. Nonetheless, almost 50 per cent of HSR passengers either board or alight at the regional stations².

There is significant interchange between the north and south sections of the high speed line at Central station in Sydney (**Table 4**)³. The reduction in Sydney station boardings and alightings if interchangers are excluded is illustrated in **Figure 3**.

Figure 3 Annual boardings/alightings/interchanges by HSR station, 2065

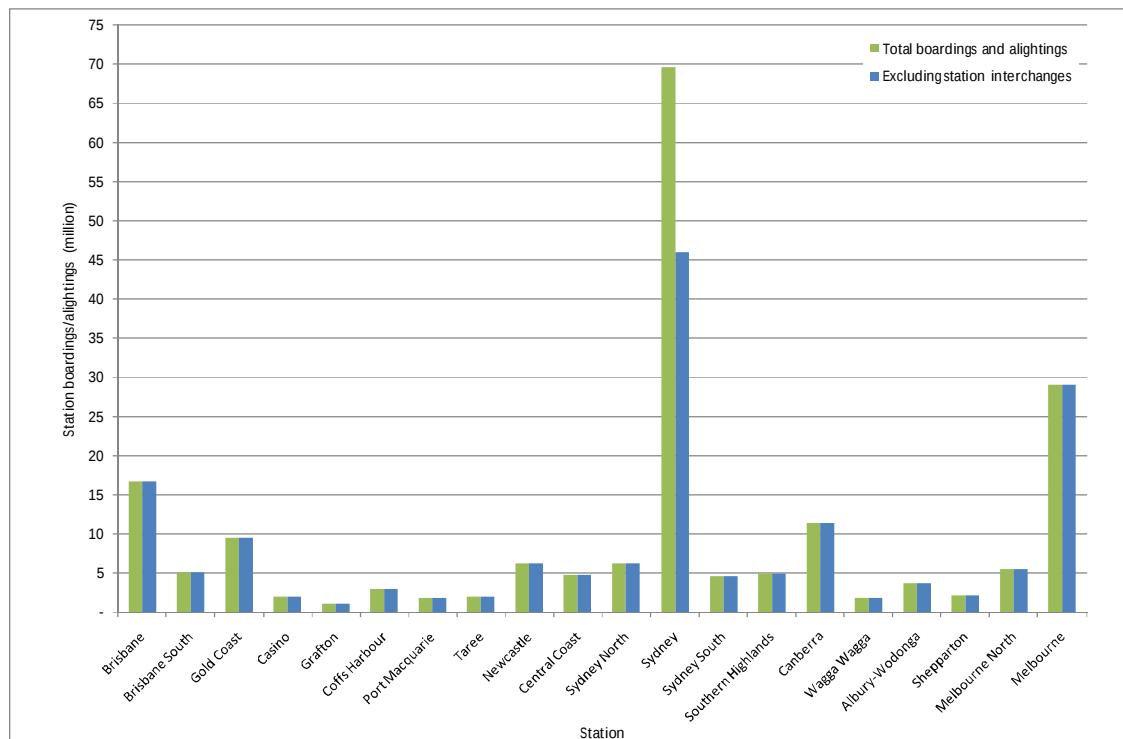


Table 4 Annual number of passengers interchanging at Sydney Central station (million per year) in 2065

Station	Sydney Central
Boarding/alighting passengers	45.9
Interchanging passengers*	11.9

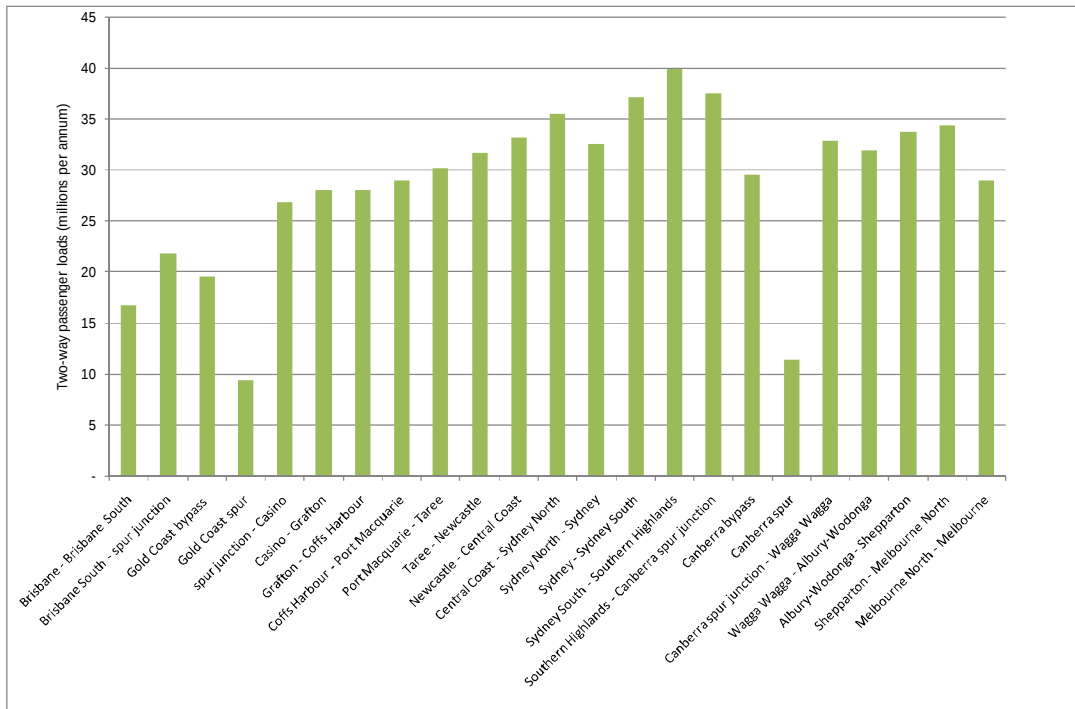
*An interchanging passenger generates two boarding/alighting trips at the interchange.

² All stations except the four major city stations and the four city peripheral stations.

³ Interchanging passengers generate two HSR trips, one for each of the services they use. Each passenger boards and alights the service during a journey so the combined boarding, alighting and interchange numbers are twice the number of passengers.

Figure 4 gives the overall HSR loadings for 2065. The loadings are higher on the line south of Sydney to Melbourne with 30-40 million passengers per annum along the line.

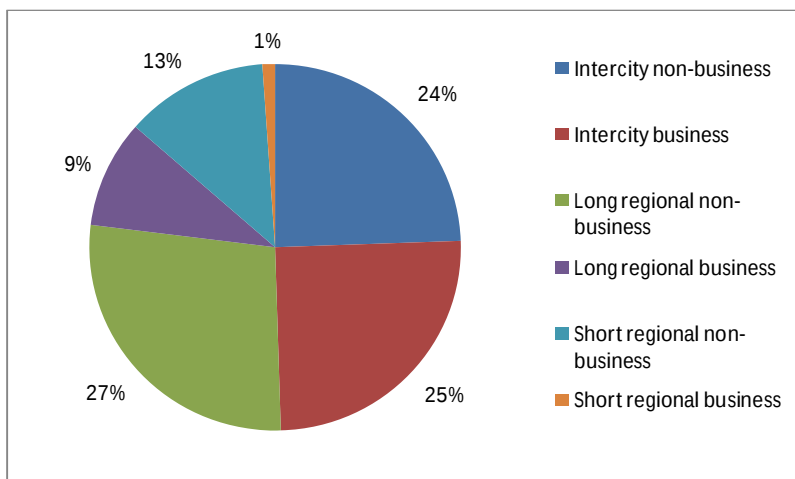
Figure 4 Annual HSR line loadings in 2065



2.3 The influence of segment and purpose on the HSR forecasts

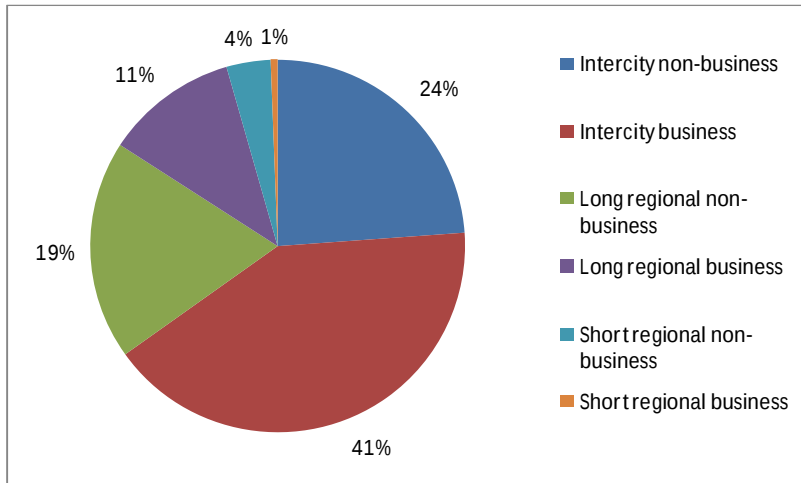
The sources of HSR patronage are summarised for 2065 in **Figure 5** below. Intercity trips account for almost 50 per cent of HSR patronage, broadly split equally between business and non-business. The long regional segment accounts for 36 per cent and the short regional 14 per cent of HSR trips, the business proportion of these demands becoming smaller as the distance reduces.

Figure 5 Source of HSR travel demand in 2065 by journey type



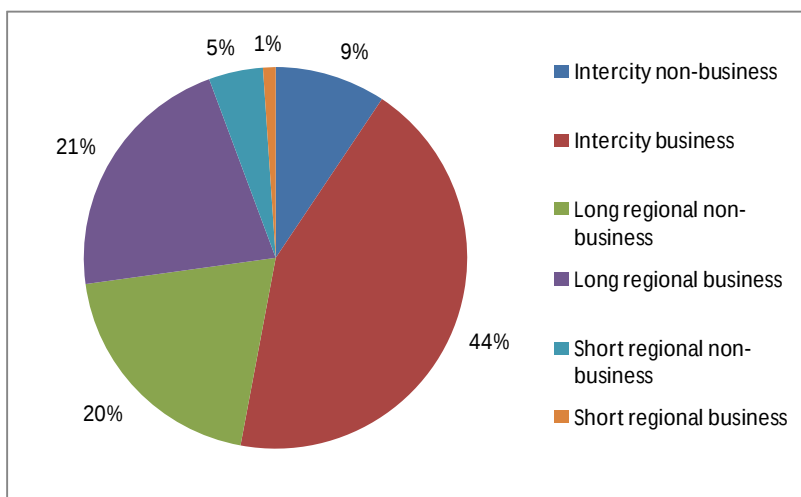
The equivalent distribution of HSR revenues is illustrated in **Figure 6**. Sixty-five per cent of revenues are generated by intercity trips, to which the highest fares apply, whereas just four per cent are gained from short regional trips. Revenues are low for short regional travel due to the small proportion of HSR trips, their shorter distance and the low yields. Business passengers account for just over one third of HSR passengers but more than half of HSR revenues, due to the higher yields.

Figure 6 Source of HSR revenues in 2065



Similarly, referring to **Figure 7**, 65 per cent of the user benefits of HSR are attributable to intercity and long regional business travel (for which the time savings are more highly valued). The user benefits for short regional travel are small, given that the private car is the preferred mode for such trips, and the majority of non-business user benefits are for long regional trips, for which HSR can offer a substantial improvement over existing transport options.

Figure 7 Source of HSR user benefits in 2065



2.4 The influence of the characteristics of HSR on the forecasts

Sensitivity tests have been used to illuminate the contributions to these forecasts of individual aspects of the HSR service and competitive context.

The sensitivity tests involved successively removing or amending aspects of the competitive context to give an insight into their relative contributions to the forecasts. The sequence was as specified in **Table 5** and the steps accumulate. The sequence was chosen to be sensible and logical but it should be borne in mind that, because these effects are inter-related, a different sequence could influence the outcomes.

The tests broadly indicate the proportionate contribution to the HSR forecasts of: congestion at Sydney Airport, the advantage of no HSR check-in time, the penetration of HSR into the city centres, the preference indicated in the stated preference surveys of HSR over air (the alternative specific constants (ASCs) in **Appendix 1D**), and the high speed of HSR compared to conventional rail services and highways.

Table 5 The cumulative sensitivity tests

Cumulative steps	Scenario attribute	Change
1	Sydney Airport congestion	The unpredictable waiting time and time-switching penalties for Sydney-based air travel (these are equivalent to 33 minutes in-vehicle time and 7% fare penalties on air travel to/from Sydney Airport) were set to zero.
2	Air check-in etc	Encompasses the additional time spent at the airport, related to check-in requirements and the time taken to traverse the airport. This was set to zero
3	CBD penetration	CBD access is one of the main benefits of HSR. In order to illustrate its importance, the HSR service was terminated at the peripheral stations in Melbourne and Brisbane (Craigieburn and Browns Plains respectively) and Homebush station replaced Central station in Sydney.
4	HSR preference	For non-business long and short regional trips, the stated preference survey indicated a significant preference for HSR over air (long regional) and rail (short regional) after allowing for level-of-service differentials, equivalent to 50 minutes journey time. This was removed.
5	HSR speed	A test was done with a much slower 100km/h rail service, equivalent to a 200% increase in journey time, broadly equivalent to motorway speeds.

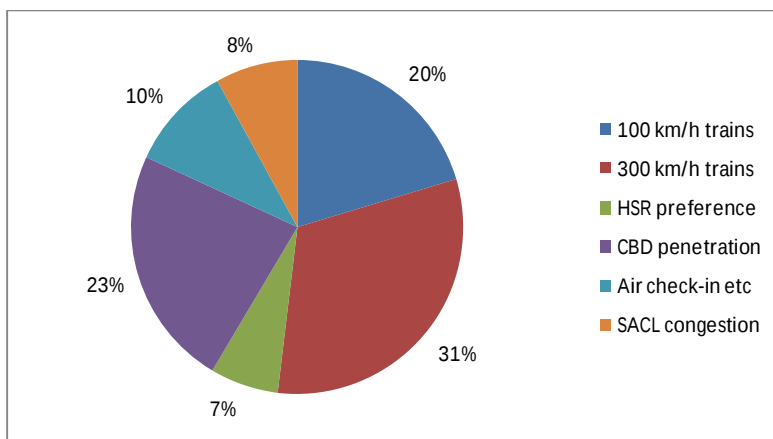
The results of these sensitivity tests for HSR travel demand are illustrated in **Figure 8**. Referring to the figure:

- The congestion at Sydney Airport in the reference case scenario accounts for about eight per cent of HSR patronage.
- The additional time spent at the airport, related to check-in requirements and the time taken to traverse the airport, is not required for HSR and this accounts for around 10 per cent of HSR patronage.
- One of the principal benefits of HSR over air travel, acknowledged internationally, is that it provides direct services between city centres and this is estimated to account for around 23 per cent of patronage compared to stopping the service at a peripheral station.
- The forecasts assume that some travellers would have a preference for HSR over and above the level-of-service benefits (the HSR 'ASC'). This benefit, estimated from the stated preference survey, accounts for approximately seven per cent of HSR patronage.
- The second principal benefit of HSR is of course its high speed and short journey times. This high speed of 300 kilometres per hour (as compared with a more conventional rail speed of

100 kilometres per hour) is estimated to account for approximately 31 per cent of HSR patronage.

- The 100 kilometres per hour HSR line is still considerably faster for shorter distance rail journeys than conventional rail lines because of its limited stops. It provides a very large improvement in service frequencies, connectivity and rail times for medium and longer journeys, which accounts for the residual patronage on the 100 kilometres per hour train service.

Figure 8 Source of HSR travel demand by HSR competitive characteristic



Note: Total does not add up to 100% due to rounding

The equivalent results for HSR revenues and user benefits in **Figure 9** and **Figure 10** are similar to those for HSR travel demand, with the greatest proportion of both HSR revenues (61 per cent) and user benefits (53 per cent) arising from the HSR speed and its CBD penetration.

Figure 9 Source of HSR revenues related to the competitive context

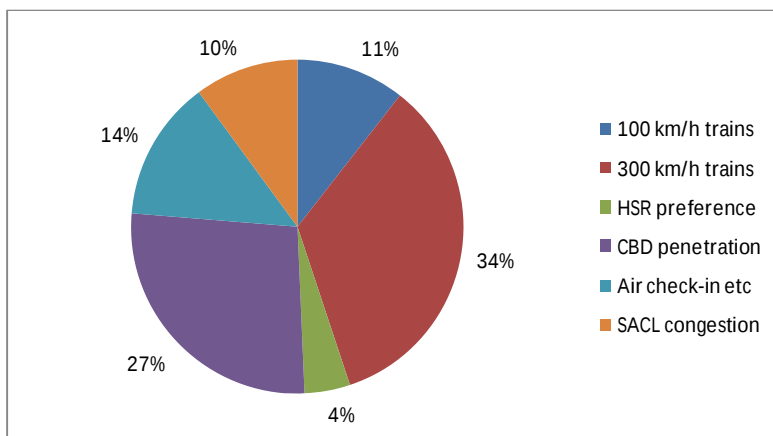
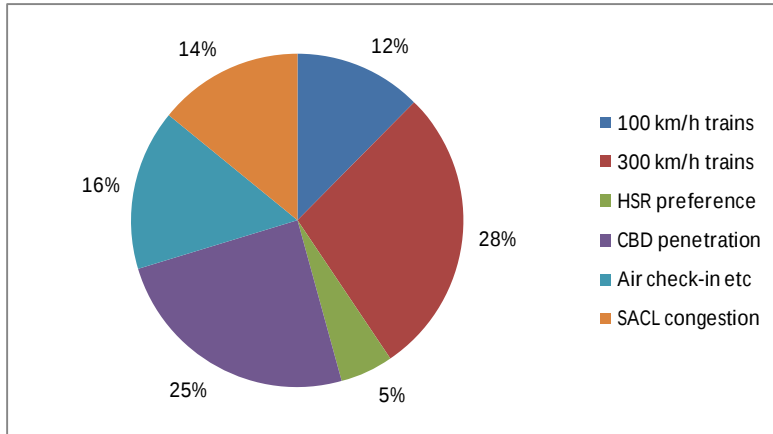


Figure 10 Source of HSR user benefits related to the competitive context



3.0 Scenario and sensitivity tests

In forecasting the impacts of a new mode of transport 20-70 years in the future, there are significant uncertainties, and indeed these are evident in the experience of other HSR forecasts. For this reason, in developing the demand forecasting procedures, a conservative approach has been taken. In addition, the risks and uncertainties associated with the HSR patronage forecasts have been evaluated in a limited risk analysis and a series of sensitivity tests.

3.1 Risk analysis

A review of the key risks for the risk assessment is summarised in **Table 6**. The risks identified are uncertainties relating to the description of the future scenarios including population and economic growth and the aviation base case, and uncertainties in the demand forecasts. These latter uncertainties are associated with the estimate of current travel demands, the projections of growth and the forecasts of the share of these travel demands that would be attracted to HSR.

There are other risks, for example the potential further investment in airport capacity and the level of HSR fares, which relate to government policy and are not encompassed in this overall analysis but which have been the subject of individual sensitivity tests.

Table 6 The risk scenarios

Risk factor	Assessment	Sensitivity test
Scenarios		
Economic growth	Gross state product/capita growth influences the overall growth in travel and travellers' willingness to pay transport costs/fares.	Gross domestic product (GDP)/capita: $\pm 0.3\%$ per annum. The Joint Study tested $\pm 0.5\%$ per annum on GDP, which also encompasses population variations. As these variations are included independently in the risk analysis, a lower variation on GDP/capita was used.
Population	Population growth influences the overall growth in corridor travel.	High and low scenarios based on state and ABS projections (Appendix 1F).
Aviation scenarios	Alternative air fare scenarios are based on the aviation capacity study ⁴ . The low air fare scenario involves a continuing growth of low cost airlines, consistent with a possible competitive response to HSR. Airline service strategies are judged unlikely to have a significant effect on the forecasts.	Air fares: -18% reduction and +22% increase in air fares. Test assumes commensurate HSR fare response on inter-capital routes.
Vehicle operating costs (VOC)	Sensitivity tests show that, within the range of expectation, this is not a significant risk.	Cross-elasticity of HSR demand to vehicle operating costs is very much less than 0.01 and future high and low VOC variations differ by at most 26% (in 2065).
Coach and standard rail fares	These fares do not have a significant influence on HSR patronage.	-
HSR system risks	Delivered service times or patterns may differ from those planned. The risk is judged to be low.	Considered not to be significant.
Modal integration risk	The risk is judged to be low, with all metropolitan stations at existing multimodal terminals.	-
Modelling forecast uncertainties		
Current travel demands	There are uncertainties in the estimated current travel demands, as indicated by the validations against independent data.	Based on validation results, two sensitivity tests: (1) +10% on all markets (2) -20% on the car market
Projections of demand growth	There are uncertainties in the projections of growth in travel demands.	Low scenario: more rapid rate of maturing income elasticity for air, zero income elasticity for coach and rail, lower car income elasticity of 0.5. High scenario: slower rate of maturing of car, coach and rail elasticities.
Forecast HSR share of future travel demand	The model-estimated HSR share of travel demand is subject to uncertainty. The suggested scenarios are based on judgements from the history of HSR forecasts and validations.	Inter-capital: $\pm 15\%$ of the HSR share. Long regional: $\pm 20\%$ of the HSR share. Short regional: $\pm 25\%$ of the HSR share. Induced travel: test 15% reduction and 30% increase in induced travel.
Other revenue risks	These are a small proportion of total revenues.	-

⁴ Australian and NSW governments, *Joint study on aviation capacity in the Sydney region*, 2012.

The effects of these individual uncertainties on HSR demand and revenues based on the ranges are given in **Table 7**. The largest uncertainties relate to the base market, primarily the car market, aviation capacity and the diversion of car travel to HSR. Other factors are also significant, including population growth, the inter-capital share of travel demand and the extent of induced travel.

Table 7 The effects of the individual uncertainties, 2065

Risk factor	Range of uncertainty around HSR forecasts	
	HSR demand	HSR revenues
Scenarios		
Economic growth	-11.5% to +12.5%	-12.5% to +14%
Population	-11.5% to +17.5%	-11% to +16.5%
Aviation scenarios	±1%	-11% to +13%
Modelling forecast uncertainties		
Current travel demands	-5% to +10%	-5% to +10%
Projections of demand growth	-9% to +2%	-8.5% to +1.5%
Inter-capital share of future travel demand	±10%	±18.5%
Long regional share of future travel demand	±9%	±10%
Short regional share of future travel demand	±4%	±1.5%
Induced travel	-4% to +6%	-5% to 6%

These uncertainties have been combined to provide an overall measure of risk, the process requiring assumptions to be made on the shape of the distributions of uncertainty for each risk factor and on the correlations between the risk factors. For transparency, the implications of four different assumptions on these matters are given in **Table 8** for 2065⁵.

The tests suggest a 95 per cent confidence range in 2065 for the forecast HSR demand of -22 per cent/+32 per cent. For the financial risk analysis the 70 per cent confidence range was required for HSR revenues corresponding to a range of -16 per cent/+24 per cent in 2065.

⁵ The correlations assumed are between the uncertainties in the HSR shares for inter-capital, long and short regional journeys.

Table 8 The overall range of uncertainty around the HSR forecasts (relative to the base case)

Uncertainty profile assumptions	HSR demand		HSR revenues	
	Most likely*	95% confidence limits**	Most likely*	70% confidence limits**
Forecasts for 2065				
Narrow range, no correlations	+2%	-21%/+30%	+4%	-14%/+20%
Narrow range, correlation	+2%	-21%/+32%	+4%	-18%/+25%
Wide range, no correlations	+3%	-22%/+32%	+4%	-15%/+22%
Wide range, correlations	+3%	-23%/+34%	+4%	-18%/+28%
Proposed risk profile, 2065	±3%	-22%/+32%	+4%	-16%/+24%

*This is the variation from the base forecast due to an asymmetric risk distribution.

**The range within which there is a 70% chance that the outcome will lie, used in the financial risk analysis.

The overall distributions of the risks for passengers and revenues are illustrated in **Figure 11** and **Figure 12**.

Figure 11 The overall distribution of HSR demand for 2065

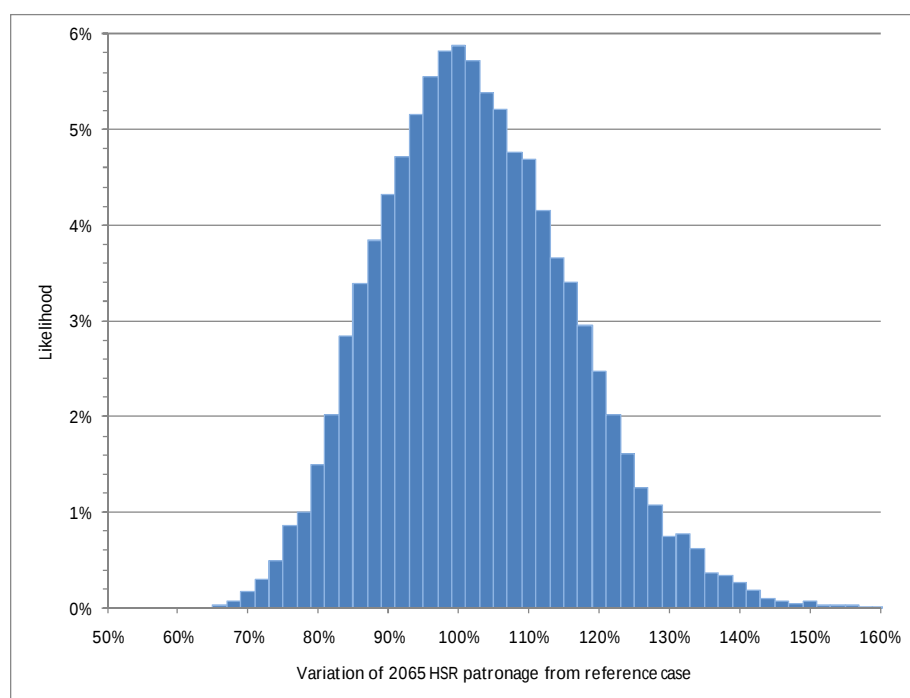
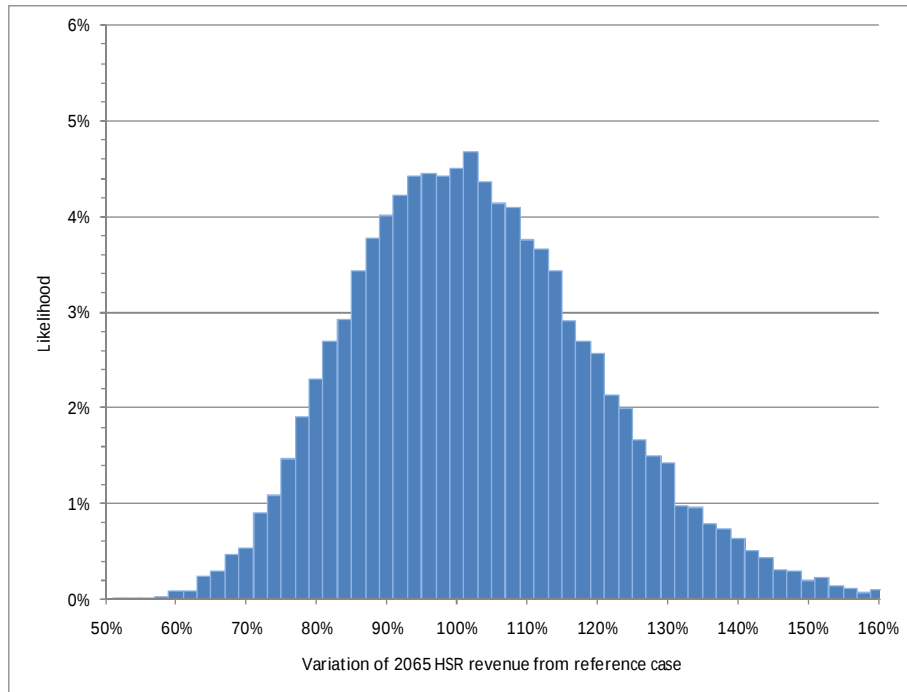


Figure 12 The overall distribution of HSR revenue for 2065



3.2 Sensitivity tests

In addition to the overall risk analysis, individual sensitivity tests have been run to illustrate specific uncertainties. These are:

- Low and high growth scenarios, in which the low scenario combines the low population and low economic growth scenarios and the high scenario combines the high population and high economic growth scenarios⁶.
- A high HSR fares scenario (a 30 per cent higher fare⁷ and a 50 per cent higher fare than assumed in the base case).
- Additional aviation capacity that assumes no there is no unmet aviation demand in the Sydney region.
- A combined test with additional aviation capacity and HSR fares +30%.
- Tests involving variations to the demand forecasting procedures:
 - HSR ASCs set to zero (these are the preferences for HSR relative to air for intercity and long regional trips, and relative to rail for short regional trips, over and above the measurable improvements in level-of-service).
 - An access/egress weighting of 1.0 (in the reference forecasts a weight of 1.4 is used).
 - Increased scaling parameters for regional trips, giving greater sensitivity in the HSR forecasts to differences in the generalised costs of travel by HSR and the competing modes (mainly car).

⁶ In the risk analysis, the population and economic growth uncertainties were assumed to be uncorrelated.

⁷ This is a larger fare variation than that used in the Joint Study on aviation capacity for the Sydney region and the financial risk analysis.

- A fixed value of time after 2035 (in the reference forecasts the values of time increase with income).
- A low combined scenario in which the low growth, additional aviation capacity and 50 per cent higher HSR fare scenarios were combined.

The forecasts shown in **Table 9** are most sensitive to the low and high scenarios of population and economic growth, their effects accumulating over the forecast period 2035 to 2065. The HSR fares increases also impact significantly on HSR patronage.

The low combined scenario linking low population and economic growth with greater aviation capacity and higher HSR fares therefore results in the largest decline in HSR patronage, of 45 per cent.

The effects of the model sensitivity tests are relatively minor with only the removal of the HSR ASCs having a significant impact on patronage (a decline of seven per cent).

Table 9 Impacts of the sensitivity tests on HSR patronage and revenues for 2065

Sector	2065
Low growth	-22%
High growth	+33%
HSR fares + 30%	-11%
HSR fares + 50%	-19%
Additional aviation capacity	-8%
Low combined scenario	-45%
Combined aviation capacity and HSR fares + 30%	-20%
HSR ASCs set to zero	-7%
Access/egress weighting of 1.0	-2%
Constant value of time after 2035	-3%
Regional scaling parameters	+4%

Appendix 1H

Analysis of rural light vehicle traffic growth in the Brisbane-Sydney-Melbourne corridor

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Analysis of rural light vehicle traffic growth in the Brisbane-Sydney-Melbourne corridor

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March 2013

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March 2013

Quality information

Document	Appendix 1H
Ref	60238250-1.0-REP-0101-1H
Date	March 2013

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1.0 Introduction

Diverted car travel is an important component of the High Speed Rail (HSR) patronage forecasts and so estimates of future growth in car trips in the corridor can have a significant effect on the estimated size of the potential HSR travel market.

Initial analysis of the National Visitors Survey (NVS) data for the period 2000–2011, conducted by the HSR study team, suggested there had not been significant growth in car holiday travel in the HSR corridor over that time and research by Tourism Research Australia in 2011 suggested car travel for holidays was declining in Australia, as people elected to travel overseas in greater numbers. International advisers confirmed that future car travel demand projections were also a concern in forecasts of High Speed 2 in the United Kingdom.

Clarification of the issue was sought through an analysis of trends in light vehicle traffic on the major interurban highways on the corridor. The principal purpose of the analysis was to determine the significance and magnitude of any relationship between light vehicle traffic growth in the corridor and gross domestic product (GDP) growth, allowing for the impact of population, travel costs and infrastructure improvements. The analysis was undertaken by the Bureau of Infrastructure, Transport and Regional Economics (BITRE).

This appendix outlines the methodology, data and results of the BITRE analysis. The structure of the paper is as follows. **Section 2** provides a brief overview of the traditional theoretical underpinning of rural highway traffic growth models, and derives a general empirical formulation for modelling total light traffic growth on rural highways. **Section 3** describes the data sources and briefly summarises growth in rural light vehicle traffic volumes in the corridor. **Section 4** describes the empirical analysis and results, and discusses the implications of the empirical results for implied growth in rural car travel in the HSR corridor. Some brief concluding remarks are made in **Section 5**.

2.0 Rural highway traffic growth

Rural highway traffic volumes comprise a mix of vehicle types and travel purposes. Heavy vehicles are generally a higher share of traffic on rural highways than in urban areas. Rural passenger vehicle movements generally encompass a variety of different trip types, including trips by rural residents to/from the local rural hamlet or town, inter-town trips, inter-regional (i.e. longer distance trips) and inter-capital trips. Modelling growth in total light vehicle traffic in the corridor ideally would entail separately modelled growth in passenger car travel for different trips between all origin/destination (OD) pairs, and validating against measured on-road traffic volumes. However, lack of up-to-date comprehensive OD travel data (the NVS does not provide reliable data on shorter-distance trips) precludes OD-based analysis. Consequently, the empirical analysis was restricted to relating growth in total light traffic volumes, observed at multiple points across the corridor, to factors contributing to growth in OD rural car travel demand, and inferring from that analysis plausible estimates of the relationship between car trips of interest to the study and household income and population growth. This section provides a brief overview of rural road travel models and derives a general specification for modelling corridor traffic growth.

2.1 Central place theory and modelling rural OD traffic volumes

Bullock discusses early rural travel models in Australia in the mid-1970s with a view to developing simple models to predict the effect of route realignment of parts of the then National Highway System¹. The paper adopts a hierarchical framework for modelling rural travel based on the type and location of travel, based on a five-tier urban centre hierarchy comprising:

- Capital cities (Level A).
- Provincial urban centres, e.g. Ballarat, Bendigo, Geelong, Launceston – corresponding roughly with population centres of 40,000 persons or more (Level B).

¹ D Bullock, undated, *Rural travel in Australia*, unpublished manuscript.

- Other urban centres, e.g. Horsham, Euroa, Echuca, which roughly corresponds with population centres of between 1,000 and 40,000 persons (Level C).
- Localities, which roughly corresponds with population centres of less than 1,000 persons (Level D).
- Farms and single dwellings not part of an urban centre or locality (Level E).

and four trip types:

1. Local rural travel – trips between farms and the local town (levels D and E in Bullock's urban centre hierarchy).
2. Inter-rural centre travel – trips to and from provincial urban centres (trips to level B from levels C, D and E).
3. Inter-regional travel – trips between capital cities and provincial urban centres.
4. Inter-capital trips (Bullock calls this 'non-trade area travel').

Each of these trip types is typically modelled using a 'gravity type' model formulation – generally including regional population and/or income and travel distance or cost. For example, early empirical estimates of local rural travel were modelled as a function of the population of and distance from the local town, and travel between regions was modelled using a traditional gravity model formulation. Typical functional specifications for different rural trip types, for example, are:

Local rural travel: $T_i = k d^\alpha P^\beta$

Inter-rural centre travel: $T_{ij} = k P_i^\alpha P_j^\beta D_{ij}^{-\gamma}$

Travel between region 'j' and state capitals: $T_j/P_j = k D_j^\alpha C_j^\beta$

Non-trade area travel: $T_{ij} = k P_i^\alpha P_j^\beta D_{ij}^{-\gamma}$

where T – denotes travel, P – denotes population (or income), C_j – denotes 'competing' population (income) in travel to/from state capital model, and D – denotes distance.

These suggest a more general gravity model specification, covering all different hierarchical trip types and with separate parameters for each hierarchical trip type (k), of the following general functional form:

$$T_{ijkt} = A_{ij} P_{it}^{\alpha_k} P_{jt}^{\beta_k} D_{ijt}^{\gamma_k}$$

2.2 OD trips and rural highway traffic volumes

Total traffic volumes at any given point on a rural highway (V_a) is simply the sum of all OD pair traffic across that road section. That is:

$$V_{at} = \sum_q n_{qa} T_{qt}$$

where $n_{qa} > 0$ if highway link a on route between OD pair q and zero otherwise.

Substituting for OD trips gives the following functional form relating traffic at a point on the highway to population/household income and cost/distance:

$$V_{at} = \sum_q n_{qa} A_q P_{q(i)t}^{\alpha_k} P_{q(j)t}^{\beta_k} D_{qt}^{\gamma_k}$$

This functional specification is akin to an OD estimation problem, but without the prior OD flows that are usually required for that technique. However, it suggests that growth in traffic volumes at any point on the highway should be a distance-weighted sum of population/income growth across all regions contributing to travel on that road section. Accordingly, we adopt a specification that includes separate measures of growth in Statistical Local Area (SLA) population/household income and an inverse-distance weighted sum of population/income across all 'catchment' areas outside the local area, as well as trends in real travel costs.

The general model specification is:

$$V_{at} = A_a P_{i \in a,t}^\alpha \left(\sum_{j \neq a} P_{jt} D_{ij}^\gamma \right)^\beta C_t^\gamma \quad (1)$$

where $P_{i \in a,t}$ denotes the SLA population (income), $\left(\sum_{j \neq a} P_{jt} D_{ij}^\gamma \right)$ is the distance-weighted sum population (income) outside the local area but within the catchment area and C_t is real travel cost. Restricting $\beta = 0$ provides the simple local area population/income specification.

3.0 Data

Light and heavy vehicle annual average daily traffic volume data for the Hume and Pacific Highways was provided by New South Wales Roads and Maritime Services (RMS) and VicRoads (Victoria). The supplied data included all traffic counts from available count sites between 1989 and 2011. Data availability varies across sites, with data available nearly every year at some sites but for fewer than four years in 20 at other sites.

3.1 Traffic count data

3.1.1 Victorian count site data

VicRoads supplied data for 63 separate count site station locations across Victorian sections of the Hume Highway between 1989 and 2011. The data included separate traffic counts of light vehicles and heavy vehicles for each of the morning peak, afternoon peak, 12 hour and 24 hour periods, by travel direction. The data also included information about the count site location and the number of sampled days. **Figure 1** illustrates the location of Victorian Hume Highway count sites.

The supplied data appears to include a mix of 'permanent' count sites, for which an extended time series of traffic counts is available, and 'temporary' sites for which fewer annual observations were available. Where several temporary sites were located in relatively close proximity and the available data covered different years, BITRE pooled the data to derive a longer time series set of observations. At some count sites there were insufficient observations to enable trend growth estimation and these sites were excluded from the analysis. Several count sites located just within the Melbourne Statistical Division were also excluded from the analysis.

Figure 1 Victorian traffic count site locations



Source: State traffic count data (VicRoads).

3.1.2 Light and heavy vehicle traffic volumes

The Victorian traffic count data provides reasonably comprehensive information about light and heavy vehicle traffic volumes on the Hume Highway, in only a handful of cases were separate heavy vehicle counts not available. Heavy vehicles generally comprise between 25 and 40 per cent of total traffic on the Hume Highway in Victoria.

3.1.3 Inter-capital and inter-regional traffic volumes

As already noted, there is relatively little information available about the contribution of different traffic components to total rural light vehicle traffic volumes on Australian highways. What limited information is available provides some information about inter-capital and inter-regional traffic shares.

For example, data from the NVS and the road-side automatic number plate recognition (ANPR) survey of the Hume Highway conducted for the HSR study², both imply that inter-capital trips account for approximately 10 per cent of total rural traffic, the exact share varying with site location³. The ANPR survey results also suggest that approximately 30–40 per cent of traffic is medium to long distance travel (that is, trips involving travel of at least 100–200 kilometres along the highway). The highway distance within each SLA, the geographic spatial unit used in this analysis, is typically much shorter than this. There is no readily available time series information on how the OD composition of rural traffic volumes on these highways has changed over the last two decades.

3.1.4 Traffic growth – Victorian count sites

Averaged across all count sites on the Hume Highway in Victoria, total vehicle traffic grew by approximately 2.75 per cent a year between 1991 and 2011– with growth ranging from around one per cent a year on the Benalla–Glenrowan section to over 4.8 per cent a year on the Seymour–Avenel section⁴. Heavy vehicle numbers grew, on average, by approximately 2.4 per cent per annum between 1990 and 2011 across these sites, with growth ranging from as little as 0.8 per cent per annum within Wangaratta township (off the Hume Freeway) to as high as 3.94 per cent a year between Seymour and Avenel. Light vehicle traffic grew by approximately 2.85 per cent per annum between 1990 and 2011, ranging from 0.7 per cent per annum between Benalla and Glenrowan to six per cent a year between Seymour and Avenel.

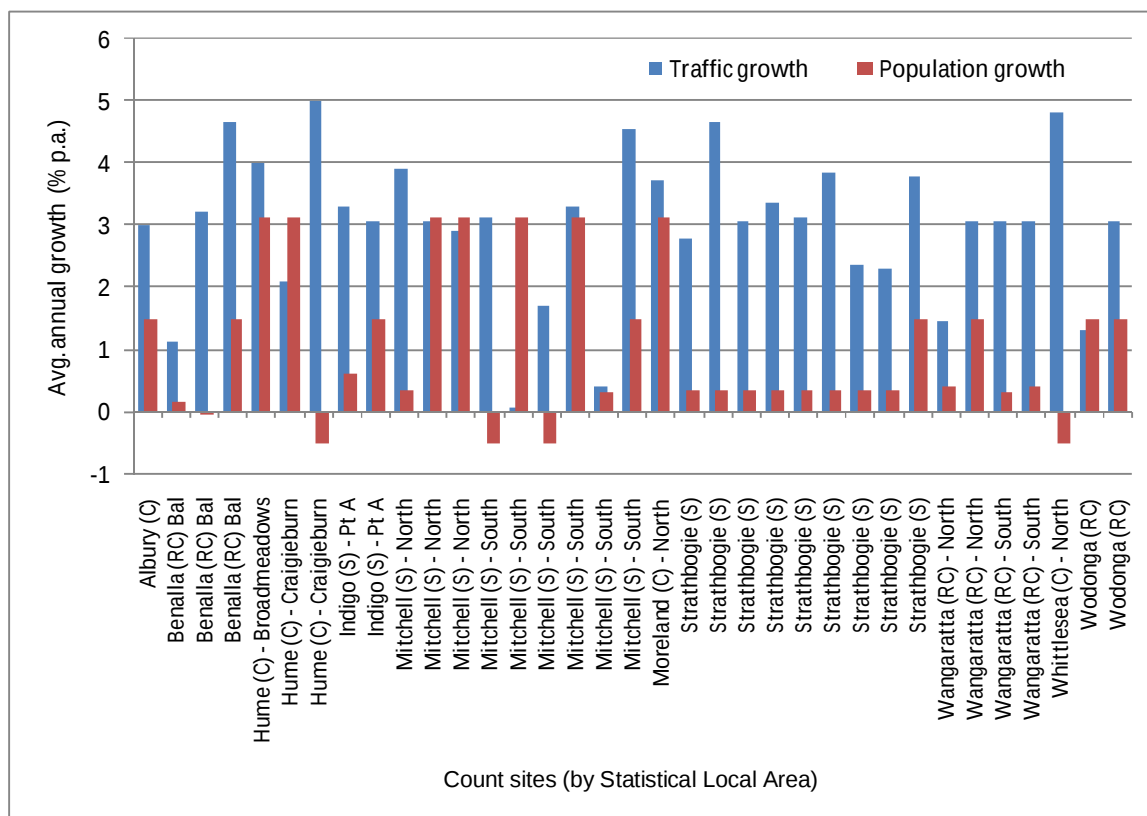
Figure 2 illustrates the growth in light vehicle traffic volumes between 1991 and 2011 for each of the grouped count sites in Victoria, as well as population growth in the corresponding SLA. Growth in light vehicle traffic volumes has generally exceeded local region population growth across most sites.

² Austraffic, *Hume Freeway Number Plate Study 7-11 December 2011*, Report prepared for Sinclair Knight Merz and the Department of Infrastructure and Transport, February 2012.

³ BITRE, *Passenger Movements between Australian Cities, 1970-71 to 2030-31*, Information Sheet 26, BITRE Canberra 2006. This document provides estimates of inter-capital car traffic volumes for major inter-capital city pairs, based on data from the NVS and IVS. The data implies that annual inter-capital car passenger numbers have fluctuated by around one million persons per annum between 1971 and 2010. This would be equivalent to around 1,100 vehicles per day (both directions), assuming an average vehicle occupancy of 2.5 persons per vehicle. Combined with the Victorian traffic count data, the BITRE (2006) estimates imply that inter-capital light vehicles comprised around 13–17 per cent of all light vehicles north of Seymour and nine per cent south of Wodonga. Recent survey evidence collected from a road-side ANPR survey on the Hume Highway suggests that inter-capital (Melbourne–Sydney) light vehicles as a share of all light vehicles was around nine per cent of light vehicles at Seymour, eight per cent south of Albury, 10 per cent north of Albury, eight per cent at Yass and four per cent at Goulburn and two per cent at Campbelltown.

⁴ Estimated traffic growth based on a simple log trend model of traffic volumes.

Figure 2 Trend average annual light vehicle traffic growth and local population growth, Victorian Hume Highway count sites, 1991-2011



Sources: VicRoads traffic count data, Australian Bureau of Statistics (ABS)⁵ and BITRE estimates.

3.1.5 NSW count site data

NSW RMS supplied count site data for seven separate count sites on the Hume Highway and 21 separate count sites on the F3 and Pacific Highways. The supplied data included 11 count sites located within the Sydney metropolitan and Gosford urban areas along the old Pacific Highway alignment, which were excluded from the analysis. As well as count site data, RMS also supplied traffic counts sourced from seven weigh-in-motion (WIM) sites on these two highways, with one site on the Hume Highway and six separate sites on the F3/Pacific Highways. Several of the Pacific Highway WIM sites cover mutually exclusive periods, and data from proximate WIM sites was combined into a longer time series. Additionally, one WIM site was only commissioned in 2008 and so was excluded from the analysis. These issues reduced the effective number of WIM sites available for use in the analysis of Pacific Highway traffic growth to three. Further, WIM site traffic count data was available only from 1995 onwards. The NSW supplied count and WIM site locations are illustrated in **Figure 3**.

3.1.6 Light and heavy vehicle traffic volumes

The NSW traffic count data included total vehicle counts for every available year, but only heavy vehicle traffic volume information from 2000, 2003 and 2004, and for only a subset of count sites. Consequently, across most years no separate heavy vehicle traffic volume information was available and separate light vehicle traffic counts could not be derived.

⁵ ABS, *Regional Population Growth, Australia, Electronic Delivery*, June 2003, Catalogue no. 3218.055.001, 2004. ABS, *Regional Population Growth, Australia*, Catalogue no. 3218.0, 2007. ABS, *Regional Population Growth, Australia*, Catalogue no. 3218.0, 2012.

WIM data includes counts of both light vehicles (Austroads Class 1 and 2 vehicles), which are detected but not weighed at each site, and heavy vehicles. While consideration was given to applying growth in heavy vehicle shares measured at WIM sites to regular count sites missing heavy vehicle count information, few of the count sites and WIM sites are located in sufficient close proximity to guarantee robust inferences about trends in heavy vehicle traffic volumes at those sites. In lieu of reliable heavy vehicle traffic volume data, heavy vehicle traffic shares were simply assumed to have remained more or less unchanged over the sample period and applied to missing years. For count sites located relatively close to Sydney or other major urban centres, heavy vehicle traffic shares are generally less than 15 per cent, so this assumption is unlikely to significantly affect implied light vehicle traffic growth. For other sites, where heavy vehicles can comprise between 30 and 40 per cent of total traffic, the inclusion of WIM data in the estimation of light vehicle traffic growth provides a measure of comparison.

Figure 3 NSW traffic count site locations and weigh-in-motion



Source: RMS traffic count data.

3.1.7 Inter-capital and inter-regional light traffic volumes

Section 3.1.1 provided an outline of inter-capital light vehicle traffic volumes on the Hume Highway and is not repeated here. Comparison of traffic count data and NVS data implies that inter-capital travel is generally less than 10 per cent of measured light vehicle traffic volumes on the Pacific Highway, with the share again varying by site location⁶. Consequently, local and shorter-distance inter-regional traffic are likely to account for the majority of measured growth in total light vehicle traffic volumes on this highway.

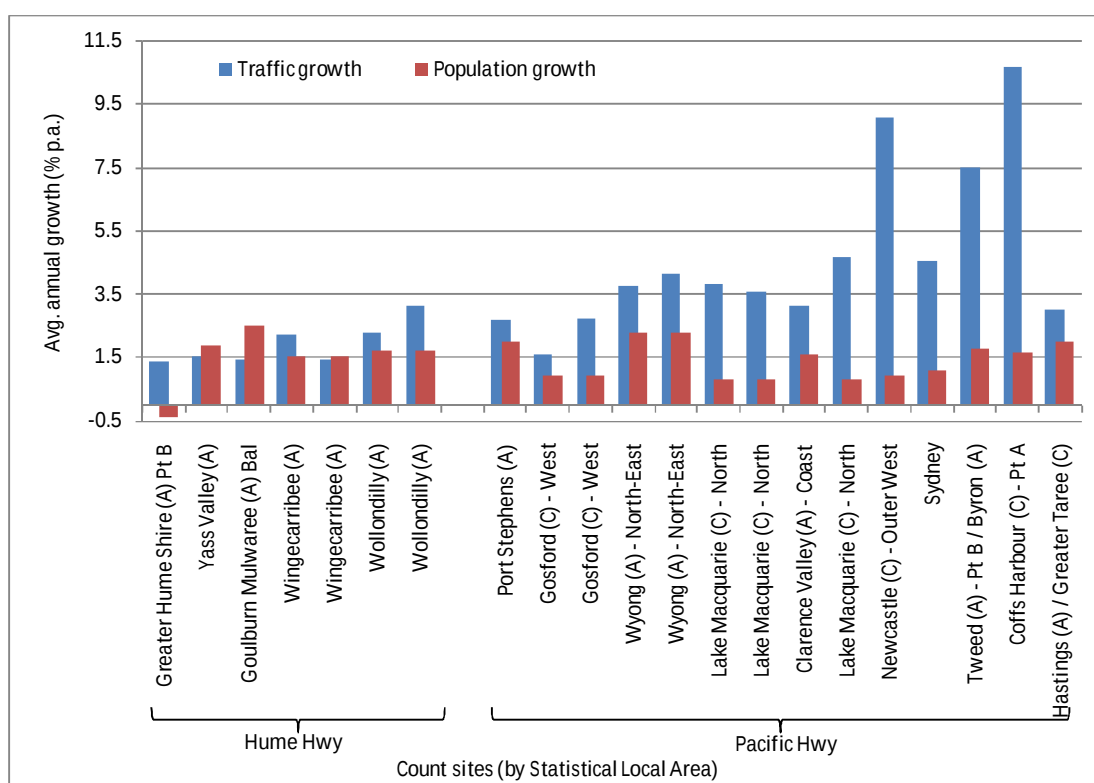
3.1.8 Traffic growth – NSW count sites

Averaged across all sites, total traffic grew by approximately 2.7 per cent a year between 1991 and 2011 on the Hume Highway in NSW. Light vehicle traffic grew by approximately two per cent per annum between 1991 and 2011 on the Hume Highway, with growth ranging from 1.4 per cent per annum at sites south of the Southern Highlands in NSW up to 3.2 per cent per annum on the outskirts of Sydney.

Averaged across all sites on the Pacific Highway, total traffic grew by approximately 4.6 per cent a year between 1991 and 2011. However, this appears to be inflated by measured traffic growth at three sites. Across other sites, traffic growth has varied between 1.6 and 4.5 per cent a year over this period.

Figure 4 shows the implied growth in light vehicle traffic volumes at NSW traffic count and WIM sites and local SLA population growth between 1991 and 2011. Similar to sites on the Hume Highway in Victoria, traffic growth has generally exceeded local population growth at most sites over that period.

Figure 4 Trend average annual light vehicle traffic growth and local population growth, NSW Hume and Pacific Highway traffic count sites, 1991–2011



Sources: State traffic count data, ABS (2004, 2007, 2012) and BITRE estimates.

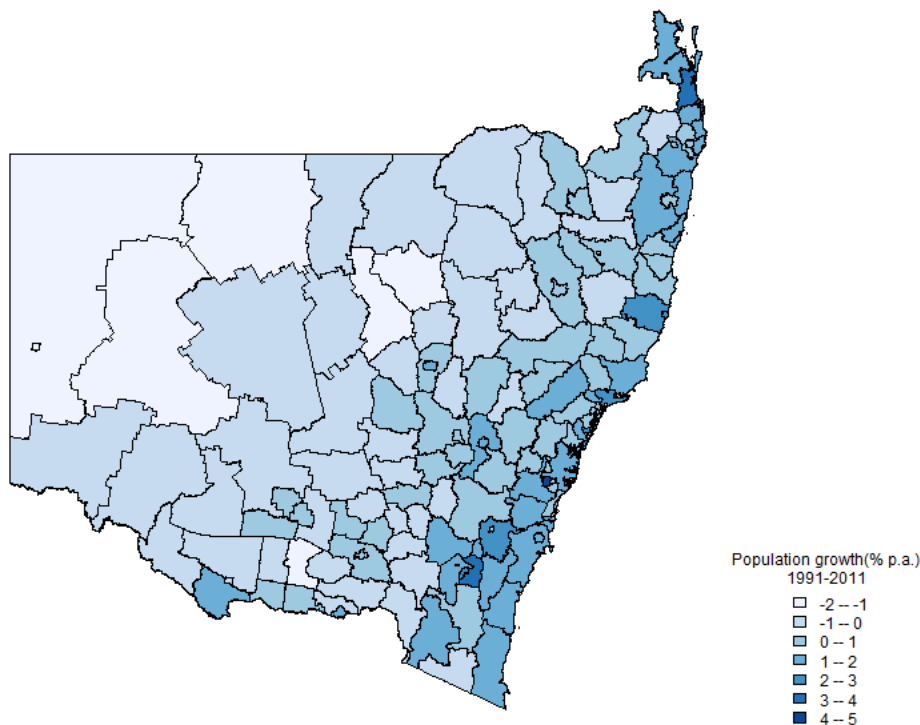
⁶ BITRE (2006) estimates of inter-capital car traffic volumes for major inter-capital city pairs implies annual inter-capital car passenger numbers between Sydney-Brisbane, Sydney-Melbourne and the Gold Coast have generally been around 600,000 persons per annum between 1971 and 2010. Assuming an average vehicle occupancy of 2.5 persons per vehicle for inter-capital trips implies around 650 vehicles per day (both directions).

3.2 Regional population

SLA-level regional population data was sourced from ABS Regional Population Growth statistical releases in 2004, 2007 and 2012. Changes in statistical boundaries over that period were handled by first standardising all regional population estimates to the 2006 SLA boundaries, using ABS-supplied SLA-level population concordances, and then spatially matching regional areas to count sites.

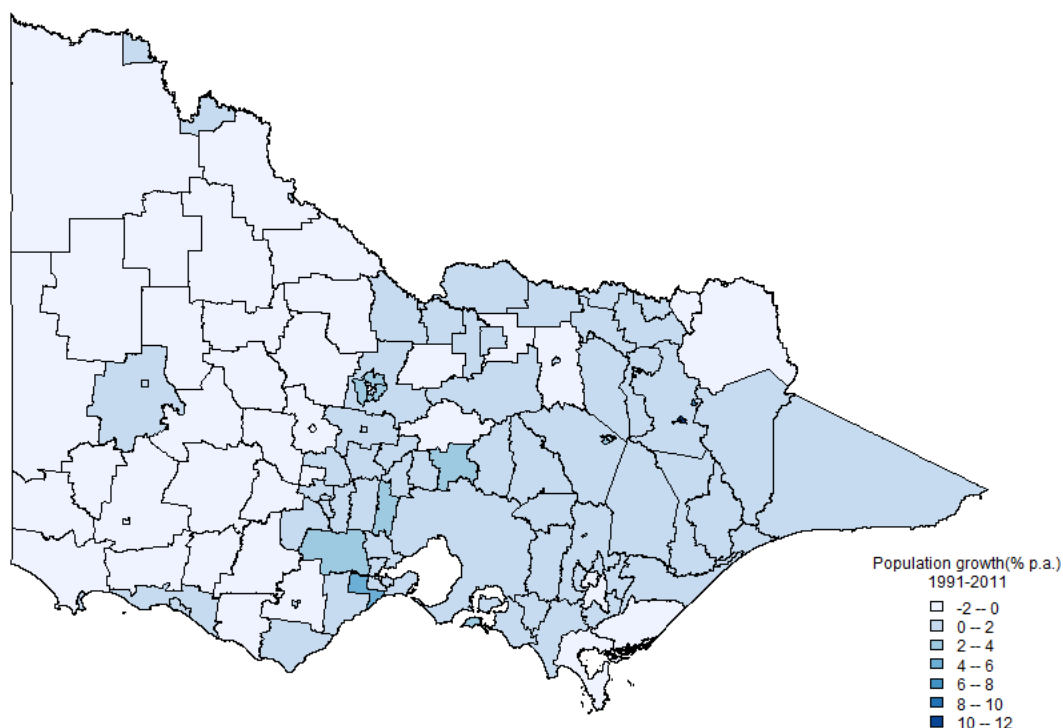
Between census years, the regional population estimates are an approximation to the actual resident population, derived from the last census year population measurement and data and/or assumptions about fertility, mortality and regional migration patterns. This may affect the estimated travel elasticities. **Figure 5** and **Figure 6** show average annual population growth between 1991 and 2011, for NSW and Victorian SLAs.

Figure 5 NSW average annual regional population growth, 1991–2011



Sources: ABS (2004, 2007, 2012) and BITRE estimates.

Figure 6 Victorian average annual regional population growth, 1991–2011



Sources: ABS (2004, 2007, 2012) and BITRE estimates.

3.3 Household income

Consistent with the demand analysis in the HSR study, household income growth was proxied by growth in real GDP per capita⁷. BITRE also estimated the models using real gross national expenditure which measures real expenditure by Australian households. While real gross national expenditure grew approximately half a percentage point per year faster than real GDP between 1989 and 2011, and produces slightly different income elasticities, it did not improve the statistical performance of the models.

3.4 Travel costs/fuel prices

Two alternative measures of travel cost were used in the empirical analysis: i) the private motoring price index, and ii) automotive fuel price index, both sourced from the Consumer Price Index collection and deflated by movements in the Consumer Price Index All Groups index⁸. While the choice of travel cost variable does affect the size and significance of the parameter estimate, the real automotive fuel price index has been used to align with wider assumptions in the HSR study.

3.5 Network changes

Since 1991, there have been several major expansion and/or realignment projects along the Hume and Pacific Highways.

Construction of the Wangaratta (1994) and Albury-Wodonga (2007) bypasses have been main changes to the Hume Highway in Victoria over that time. Dummy variables were included in the analysis to account for the impact of these projects on the level of light vehicle traffic at nearby traffic count sites.

⁷ ABS, *Australian System of National Accounts, 2010-11*, Catalogue no. 5204.0, release date 28 October 2011.

⁸ ABS, *Consumer Price Index Collection*, 2012.

Along the Hume Highway in NSW, the main infrastructure upgrades since 1991 have been alignment changes, mainly the addition of the following town bypasses: Goulburn (1992), Yass (1994), Bookham (Northbound 1991, Southbound 1998) and Coolac (2007). Work is currently being completed to duplicate the remaining single carriageway sections in southern NSW and bypass Holbrook. With the exception of Goulburn and Yass, none of the count sites for which data was available are very close to these locations, and for Goulburn and Yass the available data does not overlap with the upgrade period, so these network changes were not explicitly accounted for in this analysis for this section of the corridor.

There have also been significant enhancements applied to the Pacific Highway over the sample period. These include duplication of highway sections at Bonville (9.6 kilometres, opened 2008), Brunswick Heads to Yelgun (8.6 kilometres, 2007), Nabitac (10 kilometres, 2006), Yelgun to Chinderah (14.5 kilometres, 2002) and bypass of Karuah (2004). Dummy variables were included in the models to account for the impact of these projects on the level of light vehicle traffic at count sites near the Yelgun-Chinderah section. No explicit adjustment was made for other upgrades sections as no count sites are located in close proximity to these sections.

4.0 Estimation specification and empirical analysis

4.1 Empirical specification

BITRE modelled growth in traffic volumes across the available count sites using three separate empirical specifications, all based on the general formulation given in equation (1):

- i. A simple 'in-levels' specification (equation 2).
- ii. 'Lagged-differences' specification, around a base year T (equation 3).
- iii. An error correction mechanism (ECM), which incorporates dynamic effects (equation 4).

$$\log V_{at} = A_a + \beta_1 \log P_{i \in a t} + \beta_2 \log(\sum_{j \neq a} P_{jt} D_{ij}^\lambda) + \beta_3 \bar{Y}_t + \beta_4 \log C_t + \varepsilon_t \quad (2)$$

$$\log V_{at} - \log V_{aT} = (\beta_1 \log P_{i \in a t} - \beta_1 \log P_{i \in a T}) + \beta_2 (\log(\sum_{j \neq a} P_{jt} D_{ij}^\lambda) - \log(\sum_{j \neq a} P_{jT} D_{ij}^\lambda)) + \beta_3 (\bar{Y}_t - \bar{Y}_T) + \beta_4 (\log C_t - \log C_T) + \varepsilon_t \quad (3)$$

$$\Delta \log V_{at} = \gamma_0 + \gamma_1 \Delta \log P_{i \in a t} + \gamma_2 \Delta \log(\sum_{j \neq a} P_{jt} D_{ij}^\lambda) + \gamma_3 \Delta \bar{Y}_t + \gamma_4 \Delta \log C_t + \phi(\log V_{at-1} - \beta_1 \log P_{i \in a t-1} - \beta_2 \log(\sum_{j \neq a} P_{jt-1} D_{ij}^\lambda) - \beta_3 \bar{Y}_{t-1} - \beta_4 \log C_{t-1}) + \varepsilon_t \quad (4)$$

Most variables are as defined in **Section 2**. The estimating specifications include separate population – P_{it} , denotes population in region i – and GDP per capita – $\bar{Y}_t$ denotes national per capita income – terms. The ECM specification includes short-run (γ) and long-run (β) impacts (the in-levels specification is a restricted version of the ECM model). The parameter estimates were tested for statistical significance in order to derive the most parsimonious empirical specification. Separate 'in-levels' estimates were derived using both: 1) the raw traffic count data, which contained missing observations; and 2) 'multiply-imputed' traffic count data set, where missing traffic count observations were imputed using multiple imputation techniques (Rubin 1987, see discussion below)⁹. The 'lagged differences' specification was estimated using only the raw data and involved the use of different base years (T) across sites, due to differences in temporal data availability. Although the base year should be essentially arbitrary from the point of view of the analysis, it may have some effect on the results. The base year was chosen as close as possible to 2000–01 (the mid-point of the analysis period). The lagged differences specification effectively removes the site-specific constant terms from the regression. The ECM model estimates used the multiply-imputed data sets.

For each of the similar linear and ECM specifications, BITRE derived two sets of results: i) using a simple linear model with separate fixed effects for traffic volumes, and ii) including random effects to account for variation in the relationship between traffic growth and population/income across different

⁹ DB Rubin, *Multiple Imputation for Nonresponse in Surveys*, J Wiley and Sons, New York, 1987.

sites¹⁰. Owing to differences between jurisdictional data and potential differences in traffic growth across the Hume and Pacific Highways, separate estimates were made of traffic growth across each of the Hume Highway in Victoria, and the Hume Highway and the Pacific Highway in NSW. For all models, separate estimates were produced using unweighted data and weighting each observation by the number of recording/sampling days, to reflect the relative reliability of the measured count data. Weighting accords greater weight to observations based on a higher number of recording days, which should, in theory, exhibit less count variability. The Victorian data included the number of sampling days for all count sites. The NSW data, however, did not include the number of sampling days at non-WIM traffic count sites. Where this was the case, the number of sampling days was assumed equal to the total number of days in the year. The consequence of this assumption is that the days-weighted model results tend to be little different to the unweighted model results for NSW sections.

As already mentioned, all specifications included dummy variables to account for changes in network alignment over the period (for example, Wangaratta bypass c.1994 and Albury-Wodonga bypass 2007 at Victorian sites), and to also other account for other non-measurable effects such as unavailability of heavy vehicle counts at several sites between 1992 and 1994. These dummy variable parameter estimates are not reported in the estimation results. Models were also estimated using light vehicle traffic growth less BITRE-estimated inter-capital road-based trips¹¹. However, as inter-capital passenger car trips typically represent less than 10 per cent of total road traffic volumes, removal of these trips did not significantly affect the estimation results.

4.2 Multiple imputation of missing data

Multiple imputation methods were used to impute missing vehicle count and pre-1991 SLA-level populations, in order to estimate the ECM model specification which requires annual observations. For Victorian sites, missing vehicle count data comprised approximately 62 per cent of the annual number of records across all count sites and 58 per cent of total annual light vehicle counts across sites included in the analysis. Accordingly, BITRE generated 10 multiply-imputed data sets for the Victorian analysis.¹² For NSW sites, the rate of missing vehicle count data was approximately 44 per cent on the Hume Highway and 42 per cent on the Pacific Highway, and again 10 imputations were generated. All imputations were generated using the Amelia II package¹³.

The impact of imputation was 'tested' by comparing the raw and multiply imputed data based 'in-levels' estimation results. In general, imputation had little impact on the sign and magnitude of the estimated parameters across Hume Highway sites, but did have a more significant impact on the Pacific Highway results. The multiply imputed data generally provided less variable and more sensible results than the raw data.

4.3 Estimation results

4.3.1 'In-levels' specification results

Table 1 shows the 'preferred' specification model results for the raw data based 'in-levels' specification (equation 2). In all cases, the dependent variable is the natural logarithm of average daily light vehicle traffic volumes. The reported results include separate estimates based on the Hume Highway in Victoria, and the Hume Highway and the Pacific Highway in NSW, and separate estimates based on unweighted and recorded days-weighted estimation. The results reported were based on linear mixed effects (LME) specification, with site-specific fixed effects to account for variation in average traffic volumes across sites and site-specific random effects to account for site-specific variation in the relationship between traffic growth and the independent factors. All specifications are linear in logs, so the parameter estimates may be directly interpreted as (long-run) elasticities.

¹⁰ Use of the mixed effects specification allows for fixed variation in traffic levels across sites and random effects to capture average trend and variation in traffic growth from across the sample of available count sites. In other words, the count sites are treated as a sample of traffic growth across the road corridor of interest.

¹¹ BITRE, op. cit.

¹² The efficiency of estimates based on multiple imputations is $(1 + \gamma/m)^{-1}$ where γ is the rate of missing information and m the number of imputations (Rubin op. cit.). For a missing information rate of between 50 and 70 per cent, the efficiency of 10 imputations is between 93 and 95 per cent and that of 20 imputations is between 97 and 98 per cent.

¹³ J Honaker, G King, M Blackwell, *Amelia II: A Program for Missing Data*, *Journal of Statistical Software*, 2011.

Table 1 'In-levels' raw data based results

	Hume Highway – Victoria		Hume Highway – NSW		Pacific Highway – NSW	
	Unweighted	Days weighted	Unweighted	Days weighted	Unweighted	Days weighted
<i>Parameter estimates (fixed effects)</i>						
Local population	0.046	0.100	0.081	0.065	0.922	4.70
	(0.095)	(0.018)	(0.150)	(0.008)	(0.385)	(2.67)
GDP per capita	0.694	0.519	1.181	1.141	1.329	–0.889
	(0.145)	(0.023)	(0.133)	(0.007)	(0.216)	(0.169)
Fuel cost	0.002	–0.068	–0.367	–0.345	–0.087	–0.321
	(0.089)	(0.016)	(0.067)	(0.003)	(0.083)	(0.010)
Catchment population	1.161	1.446	NA	NA	NA	NA
	(0.215)	(0.023)				
Catchment distance	0.447	0.494	NA	NA	NA	NA
<i>Random effects (standard deviation)</i>						
Intercept	0.061	0.029	0.001	0.021	0.042	0.014
Local population	0.500	0.084	0.054	0.012	1.138	1.124
GDP per capita	0.383	0.100	0.008	0.002	0.047	0.710
Fuel cost	0.500	0.076	0.003	0.0002	0.15	0.041
Catchment population	NE	NE	NE	NE	NE	NE
<i>Summary statistics</i>						
σ	0.1040	0.05	0.002	0.042	0.082	0.034
R^2	0.9862	0.9841	0.9984	0.9984	0.9956	0.9993
Log likelihood	282.7	–263.3	107.8	–125.3	126.8	–319.5

NA denotes not applicable.

NE denotes not estimated.

Note: Standard errors in parentheses. Intercept, site-specific constants and dummy variable parameter estimates not shown.

Source: BITRE estimates.

4.3.2 Victorian Hume Highway results

Columns 2 and 3 in **Table 1** list the preferred raw model results for light vehicle traffic growth across Victorian traffic count sites between 1991 and 2011 (population data for 1989 and 1990 which was not readily available, so these years were excluded from the analysis). For both the weighted and unweighted results, the inclusion of the catchment population term is statistically significant, with the catchment population distance weighting approximately 0.5. The inclusion of catchment population reduces the magnitude of the local population term. The parameter estimates for local population, GDP per capita and fuel costs are all of the expected sign and nearly all are statistically significant. The mean per capita GDP elasticity is statistically significant and approximately 0.7 in the unweighted model, with a standard deviation across sites of approximately 0.4, and 0.5 in the days weighted specification, with a standard deviation across sites of 0.1. The fuel cost elasticity was generally negative and small (below -0.1) across most specifications and not statistically significant in the unweighted specification.

4.3.3 NSW Hume Highway results

Columns 4 and 5 in **Table 1** list the preferred raw data based 'in-levels' model results for light vehicle traffic growth at NSW Hume Highway count sites. In contrast to the Victorian Hume Highway results, the catchment population term was not statistically significant across NSW Hume Highway sites. There is little difference between the unweighted and days weighted specifications. Information on the number of recording days was available for only a small number of NSW sites. The parameter estimates for local population, GDP per capita and real fuel costs are of the expected sign and generally statistically significant. Local population was not statistically significant in the unweighted specification. The results imply a GDP per capita elasticity of around 1.1 to 1.2, which is significantly higher than that derived for Victorian Hume Highway sites. The implied fuel cost elasticity is around – 0.35 to –0.40, which implies travel is relatively inelastic to movements in fuel prices, but higher than the fuel price elasticity implied by the Victorian data.

4.3.4 NSW Pacific Highway results

Columns 6 and 7 in **Table 1** list the preferred raw model results for light vehicle traffic growth across NSW Pacific Highway count sites. The estimation results exhibit significantly more variation across the different model specifications than for either of the two Hume Highway data sets. This variation disappears when the multiply-imputed data is used instead of the raw data, suggesting the small number of observations and variation affects the results. The equivalent results derived using the multiply-imputed data are listed in **Sub appendix 1H.1, Table 4**. The wider catchment-area population term was generally not statistically significant for data from this corridor. The parameter estimates for local population and fuel prices are of the expected signs, with rural traffic volumes being relatively inelastic with respect to fuel prices and local population having a more significant effect. The GDP per capita parameter estimate is of completely different signs depending on whether the estimates are weighted or not. The multiply-imputed parameter estimates, by contrast, are reasonably consistent and imply a GDP per capita elasticity of around 1.1 to 1.2 on the Pacific Highway (see **Appendix 1H.1, Table 4**).

4.3.5 'Lagged difference' model results

Table 2 shows the 'preferred' estimation results for the lagged difference specification (equation 2). The lagged difference specification removes site-specific variation in traffic volumes. For estimation purposes, constant terms were included in the linear regressions in order to facilitate ready interpretability of the summary statistics, but they were generally not statistically significant. As for the in-levels model, several different specifications were estimated, including unweighted and days-weighted regressions and allowing for random parameter variation across sites. The lagged difference income elasticity estimates are generally similar in magnitude and sign to the in-levels estimates.

Table 2 'Lagged-differences' raw data based results

	Hume Highway – Victoria		Hume Highway – NSW		Pacific Highway – NSW	
	Unweighted	Days weighted	Unweighted	Days weighted	Unweighted	Days weighted
<i>Parameter estimates (fixed effects)</i>						
Intercept	–0.012	0.0004	–0.014	–0.028	–0.071	–0.061
	(0.089)	(0.028)	(0.037)	(0.012)	(0.045)	(0.039)
Local population	–0.063	0.056	0.081	0.065	0.465	0.551
	(0.086)	(0.017)	(0.150)	(0.008)	(0.104)	(0.116)
GDP per capita	0.384	0.340	1.181	1.141	1.224	1.128
	(0.153)	(0.020)	(0.133)	(0.007)	(0.161)	(0.155)
Fuel cost	0.044	–0.038	–0.367	–0.345	0.074	0.053
	(0.080)	(0.006)	(0.066)	(0.003)	(0.099)	(0.091)
Catchment population	1.660	1.658	NA	NA	NA	NA
	(0.212)	(0.020)				
Catchment distance	0.911	0.847	NA	NA	NA	NA
<i>Random effects (standard deviation)</i>						
Intercept	0.056	0.025	0.022	0.013	NA	NA
Local population	0.381	0.070	0.231	0.012	NA	NA
GDP per capita	0.346	0.074	0.087	0.002	NA	NA
Fuel cost	0.364	0.020	0.059	0.0001	NA	NA
Catchment population	NE	NE	NE	NE	NA	NA
<i>Summary statistics</i>						
σ	0.092	0.041	0.023	0.041	0.118	1.965
R^2	0.9528	0.9402	0.8934	0.8908	0.8770	0.8781
Log likelihood	256.3	–166.1	107.8	–125.3	141.7	153.9

NA denotes not applicable.

NE denotes not estimated.

Note: Standard errors in parentheses. Intercept, site-specific constants and dummy variable parameter estimates not shown.

Source: BITRE estimates.

Victorian Hume Highway results

Columns 2 and 3 of **Table 2** show the lagged difference model results for light vehicle traffic growth for Victorian Hume Highway traffic count sites. The table includes unweighted and recording days weighted results. For both specifications, local population has little effect on traffic growth, but the catchment population parameter estimate, of approximately 1.6, is statistically greater than one. The optimal catchment distance is around 0.9, suggesting a surprisingly strong relationship between travel and regional population growth. The per capita GDP elasticity is around 0.35 to 0.40 implying that growth in travel on Victorian sections of the Hume Highway is relatively inelastic with respect to income. The estimates imply fuel cost has little effect on light travel on the Hume Highway in Victoria.

NSW Hume Highway results

Columns 4 and 5 of **Table 2** show the preferred unweighted and days weighted lagged difference model results for light vehicle traffic growth across NSW Hume Highway traffic count sites. Preferred specifications include random variation in the parameter estimates. The catchment population parameter is not statistically significant across these sites. Again, there is little difference in the parameter values across the two specifications and the parameter estimates are broadly similar to the in-levels estimates in **Table 1** (i.e. local population growth is marginally statistically significant, fuel prices have a statistically significant but relatively small impact on travel and the per capita income elasticity is quite significant and around 1.1 to 1.2).

NSW Pacific Highway results

Columns 6 and 7 of **Table 2** show the preferred specification results for the lagged difference model of light vehicle traffic growth across NSW Pacific Highway traffic count sites between 1991 and 2011. The preferred specifications do not include site-specific random parameter variation. The catchment population term is not statistically significant across these sites. Again, like the results for NSW Hume Highway sites, there is little difference between the weighted and unweighted regression results. The estimates imply a local population elasticity of around 0.5 and per capita income elasticity of 1.1 to 1.2 for rural car travel on the Pacific Highway. The real fuel price parameter is not statistically significant, implying rural car travel on this section is relatively unresponsive to fuel prices.

4.3.6 ECM model results

Table 3 shows the model results for various multiply-imputed ECM model results (equation 3). In all cases, the dependent variable is the first difference of light vehicles traffic volumes. Again, the results report estimates for two separate specifications: i) unweighted and ii) days weighted, estimated separately using linear (LM) and LME specifications. All specifications are linear in logarithms, so the parameter estimates can be readily interpreted as elasticities. The ECM specification enables identification of short- and long-run impacts.

Victorian Hume Highway results

Columns 2–5 of **Table 3** show the ECM model results for light vehicle traffic growth for Victorian Hume Highway traffic count sites between 1991 and 2011. The summary statistics imply that the LM specification results fit the data better than the LME specification, but there is generally little difference in the parameter estimates across the different specifications. The results shown in **Table 3** are based on the unit distance weighted catchment population term (the distance weighting parameter was not estimated for the ECM specification, but the results for the non-distance weighted catchment population term are broadly similar). With the exception of local population, the first difference parameter terms are generally not statistically significant. The short-run local population term is statistically significant only in the LM specification, with an elasticity of around +0.1. The lagged dependent variable is strongly significant and around –0.8 to –0.9 across the different specifications, implying only a slight lag in dynamic response of travel to changes in income and fuel prices. The long-run local and catchment population terms are also statistically significant, and imply long-run elasticities of 0.25–0.36 and 0.6–1.1, respectively. The GDP per capita term implies a long-run elasticity of between 0.3 and 0.5. The inclusion of the catchment population term reduces the GDP per capita elasticity. Excluding the catchment population term, the long-run GDP per capita elasticity is around 0.8. The estimates imply fuel cost has little effect on rural light vehicle travel on the Hume Highway in Victoria.

NSW Hume Highway results

Columns 6–9 of **Table 3** show the ECM model results for light vehicle traffic growth across NSW Hume Highway traffic count sites between 1991 and 2011. The summary statistics imply that the LME specification results fit the data slightly better than the LM specifications. The catchment population parameter is not statistically significant across these sites. With the exception of real fuel costs, the first difference variable parameter estimates are generally not statistically significant. The short-run real fuel cost term is statistically significant with an elasticity of around –0.27. The lagged dependent variable is strongly significant and around –1.0 across all specifications, implying a very short lag in rural travel response to changes in income and fuel prices. The GDP per capita term is strongly

significant, and implies a long-run income elasticity of around 1.1. The long-run fuel cost elasticity is around -0.4 .

NSW Pacific Highway results

Columns 10–13 of **Table 3** show the ECM model results for light vehicle traffic growth across NSW Pacific Highway traffic count sites between 1991 and 2011. Again, none of the first differences parameter estimates are statistically significant. The lagged dependent variable is strongly significant and around -0.9 in the LM estimates and -0.75 in the LME estimates, implying a short lag in long run rural travel response to changes in population, income and fuel prices. The lagged GDP per capita parameter estimate is strongly significant across all specifications, and implies a long-run income elasticity of around 1.5 to 1.6 across these sites (after allowing for lagged adjustment effects). The long-run local population and fuel cost elasticities are of the wrong sign, but generally not statistically significant.

4.4 Implications for long-term rural car travel growth

The empirical results imply quite a degree of variation in population and income elasticity estimates across the three modelled road segments: i) the Hume Highway in Victoria, ii) Hume Highway in NSW, and iii) Pacific Highway in NSW. Fuel price responsiveness of rural car travel appears relatively consistent across the different road sections and model specifications, suggesting rural car travel is relatively insensitive to fuel prices. Within each road section, however, the parameter estimates derived for each model specification (i.e. in-levels, lagged differences and error correction model) are relatively consistent.

Table 3 Preferred multiply-imputed ECM model results

	Hume Highway – Victoria				Hume Highway – NSW				Pacific Highway – NSW			
	Unweighed		Days weighted		Unweighed		Days weighted		Unweighed		Days weighted	
	LM	LME	LM	LME	LM	LME	LM	LME	LM	LME	LM	LME
<i>Parameter estimates (fixed effects)</i>												
<i>First differences</i>												
Local population	0.145	0.061	0.113	0.085	−0.097	−0.625	−0.045	−0.474	0.343	0.349	0.338	0.681
	(0.047)	(0.067)	(0.041)	(0.064)	(1.434)	(1.709)	(1.457)	(0.796)	(0.268)	(0.272)	(0.266)	(1.188)
GDP per capita	0.413	−0.393	−0.813	−0.721	0.338	0.293	0.324	0.296	0.874	0.330	1.020	0.465
	(0.713)	(0.510)	(0.559)	(0.633)	(1.181)	(1.215)	(1.144)	(0.863)	(1.427)	(1.995)	(1.236)	(0.904)
Fuel cost	−0.085	−0.024	0.077	0.030	−0.274	−0.273	−0.266	−0.267	0.094	0.092	0.057	0.070
	(0.063)	(0.081)	(0.104)	(0.113)	(0.127)	(0.131)	(0.134)	(0.092)	(0.175)	(0.182)	(0.157)	(0.095)
Catchment population	−1.764	−0.736	−0.208	0.587	NA	NA	NA	NA	NA	NA	NA	NA
	(4.535)	(3.781)	(0.582)	(0.457)								
Catchment distance	1	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA
<i>Lagged variables</i>												
LV AADT	−0.887	−0.768	−0.894	−0.761	−1.064	−1.084	−1.066	−1.080	−0.897	−0.743	−0.933	−0.733
	(0.059)	(0.054)	(0.050)	(0.055)	(0.127)	(0.153)	(0.152)	(0.135)	(0.124)	(0.100)	(0.113)	(0.068)
Local population	0.324	0.276	0.228	0.228	0.145	0.137	0.118	0.112	−0.296	−0.370	−0.268	−0.374
	(0.051)	(0.036)	(0.043)	(0.040)	(0.241)	(0.236)	(0.240)	(0.139)	(0.180)	(0.191)	(0.188)	(0.096)
GDP per capita	0.277	0.319	0.309	0.404	1.113	1.141	1.140	1.160	1.371	1.186	1.462	1.221
	(0.261)	(0.174)	(0.218)	(0.177)	(0.299)	(0.313)	(0.293)	(0.217)	(0.296)	(0.278)	(0.289)	(0.177)

Table 3 (continued)

	Hume Highway – Victoria				Hume Highway – NSW				Pacific Highway – NSW			
	Unweighed		Days weighted		Unweighed		Days weighted		Unweighed		Days weighted	
	LM	LME	LM	LME	LM	LME	LM	LME	LM	LME	LM	LME
Fuel cost	−0.012	0.003	0.057	0.038	−0.407	−0.411	−0.409	−0.411	0.238	0.239	0.143	0.165
	(0.100)	(0.097)	(0.098)	(0.103)	(0.157)	(0.161)	(0.160)	(0.117)	(0.192)	(0.194)	(0.174)	(0.091)
Catchment population	1.001	0.685	0.898	0.446	NA	NA	NA	NA	NA	NA	NA	NA
	(0.299)	(0.213)	(0.381)	(0.293)								
<i>Random effects (standard deviation)</i>												
Intercept	NA	0.045	NA	0.027	NA	0.031	NA	0.013	NA	0.064	NA	4.15e−07
Population	NA	0.025	NA	0.106	NA	1.943	NA	0.082	NA	0.008	NA	0.121
GDP per capita	NA	0.487	NA	1.682	NA	0.753	NA	0.030	NA	4.755	NA	0.177
Fuel cost	NA	0.039	NA	0.071	NA	0.065	NA	0.004	NA	0.222	NA	0.007
Catchment population	NA	NE	NA	NE	NA	NE	NA	NE	NA	NE	NA	NE
<i>Summary statistics</i>												
σ	0.5971	0.1380	0.1690	0.1772	0.090	0.087	1.662	0.087	0.197	0.197	3.150	0.181
R^2	0.4489	0.3680	0.4202	0.3857	0.5738	0.6051	0.5785	0.5983	0.3681	0.3886	0.4033	0.3701
Log likelihood	347.69	−1573.9	425.56	358.21	147.41	119.25	145.95	−289.51	73.61	21.87	102.29	−804.59

NA denotes not applicable.

NE denotes not estimated.

Note: Standard errors in parentheses. Intercept, site-specific constants and dummy variable parameter estimates not shown.

Source: BITRE estimates.

On Victorian Hume Highway sections, the (long-run) income elasticity is statistically significant, generally ranging between 0.4 and 0.7, depending on the empirical specification and variables included. If the distance-weighted catchment population term is excluded, the income elasticity on Victorian Hume Highway sections was around 0.8 to 1.0. Across all model specifications, however, the empirical results imply an income elasticity statistically significantly less than one. By contrast, the model estimates for count sites on the Hume and Pacific Highways in NSW imply a higher (long-run) income elasticity for rural car travel, typically around 1.1 to 1.2. The distance-weighted catchment population term was generally not statistically significant across these highway sections. Factors that might account for some of the estimated difference in the income elasticity of rural car travel across these different sections could include inherent differences in the mix and type of rural car trips, relative distribution of count sites and input data accuracy.

Travel mix and behaviour

Part of the difference in estimated income elasticities across different highway sections could be due to inherent differences in the type and mix of trips on the two highways. It may be that the mix of rural car trips on the Hume Highway in Victoria entail a greater share of shorter-distance, less discretionary trips than either of the Hume or Pacific Highways in NSW. However, as stated at the outset, there is little information available on the relative mix of rural car trip types and lengths.

Count site location impacts

Differences in the relative geographic distribution of available traffic count site data across the three different highway segments may contribute to some of the difference in the estimated income elasticity, particularly between NSW and Victorian sections of the Hume Highway. The Victorian data provides a more evenly distributed set of counts across the length of the highway, whereas the NSW count sites, both on the Hume and Pacific Highways, are predominantly located closer to Sydney. The more even geographic distribution may mean that the Victorian data includes more observations at sites where shorter-distance farm to local rural town trips are a greater proportion of the traffic stream, and hence affect the measured income and price elasticities. Again, with relatively little available information on the composition of car travel across different sites, it is not possible to determine how significant this effect is.

Population and household income measures

As noted in **Section 3**, between census years, regional population data is an approximation to the actual resident population, based on data and/or assumptions about trends in births, deaths and regional migration patterns. Intercensal disparity in regional population estimates may also explain some of the relative difference in estimated elasticities across the different corridors. In a similar vein, per capita GDP is a very blunt approximation to changes in household incomes, which may vary considerably across urban and rural regional areas. Were household income growth is available at a regional level, it might account for some of the estimated variation in the income elasticity across the different corridors.

Choice of long-run income elasticity

In considering the long-run income elasticity to apply to future rural car travel across the corridor, the separate Victorian and NSW section results present a choice between an income elasticity either slightly below one or slightly above one. For forecasting potential future rural car travel in the HSR corridor, a long-run income elasticity of 0.8 has been chosen for long-distance car trips, and about half that for shorter-distance rural car trips. Influential in opting for these values is the judged relative robustness of the Victorian-based estimation results, e.g. greater number of count sites, generally more observations per site and more evenly distributed geographic coverage of sites. These elasticity values also imply more conservative estimates of likely future rural car travel demand, which is generally consistent with the approach adopted across the HSR study.

5.0 Concluding remarks

This paper has outlined the methods and empirical results of analysis of the relationship between historical growth in light vehicle traffic on the Hume and Pacific Highways and growth in regional populations, per capita GDP, a proxy for household income growth, and real fuel prices. The primary purpose of the analysis was to determine the significance and size of the relationship between household income growth and rural light vehicle traffic volumes. The analysis estimated separate relationships for each of: i) the Hume Highway in Victoria; ii) the Hume Highway in NSW and iii) the Pacific Highway in NSW, using a range of different empirical specifications.

The empirical results imply a statistically significant and positive relationship between rural light vehicle traffic growth and per capita GDP across the corridor. The Victorian Hume Highway data implies an average income elasticity for light vehicle rural traffic volumes of around 0.5 to 0.8, depending on the estimation method, and the NSW Hume and Pacific Highway data implies an average income elasticity of around 1.1 to 1.2. The results also imply local and regional population growth has a small but positive effect on rural traffic volumes, but that rural travel is relatively insensitive to changes in fuel prices. For forecasting potential future rural car travel in the HSR corridor, a long-run elasticity of 0.8 would appear to be appropriate for long-distance rural travel, and a lower elasticity value for shorter-distance rural trips.

Sub appendix 1H.1 Additional empirical results

Table 4 Multiply-imputed 'in-levels' preferred specification estimates

	Hume Highway – Victoria		Hume Highway – NSW		Pacific Highway – NSW	
	Unweighed	Days weighted	Unweighed	Days weighted	Unweighed	Days weighted
<i>Parameter estimates (fixed effects)</i>						
Local population	0.209	0.252	0.125	0.114	0.549	0.573
	(0.077)	(0.072)	(0.231)	(0.116)	(0.450)	(0.169)
GDP per capita	0.982	0.965	0.990	0.991	1.216	1.159
	(0.124)	(0.113)	(0.246)	(0.143)	(0.326)	(0.148)
Fuel cost	0.132	0.081	−0.289	−0.279	0.113	0.107
	(0.093)	(0.091)	(0.122)	(0.089)	(0.143)	(0.075)
Catchment population	NA	NA	NA	NA	NA	NA
Catchment distance	NA	NA	NA	NA	NA	NA
<i>Random effects (standard deviation)</i>						
Intercept	0.032	0.027	0.041	0.031	0.050	0.049
Local population	0.220	0.046	0.089	0.007	0.829	0.039
GDP per capita	0.262	0.045	0.189	0.011	0.460	0.021
Fuel cost	0.155	0.042	0.087	0.005	0.322	0.018
Catchment population	NE	NE	NE	NE	NE	NE
<i>Summary statistics</i>						
σ	0.150	0.120	0.090	0.090	0.129	0.126
R^2	0.9325	0.9294	0.9919	0.9919	0.9860	0.9856
Log likelihood	506.06	−1229.2	122.37	−309.67	135.59	−755.45

NA denotes not applicable.

NE denotes not estimated.

Note: Standard errors in parentheses. Intercept, site-specific constants and dummy variable parameter estimates not shown.

Source: BITRE estimates.

