Zero Carbon Australia
High Speed Rail

MELBOURNE ENERGY INSTITUTE

beyond ZERO emissions

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Your High Speed Rail Timetable

Zero Carbon Australia **High Speed Rail**

Melbourne → Sydney → Brisbane

	SB	AU	SB	AU	SB	AU	SC	AU	AU	CAN	SB	MS	AU	AU	CAN	SB	MS	AU	SC	MC	AU	CAN	SB	MS	SC	AU	CAN	SB	MS	AU	AU
	AM																														
Melbourne (Southern Cross)														5:00			5:05			5:35	6:00			6:05		7:00			7:05	7:30	
Melbourne Airport														5:11			5:16			5:46	6:11			6:16		7:11			7:16	7:41	
Seymour														—			5:36			6:06	—			6:36		—			7:36	—	
Shepparton														—			5:53			6:23	—			6:53		—			7:53	—	
Albury												5:26		6:12			6:26			6:56	7:12			7:26		8:12			8:26	8:42	
Wagga Wagga												5:52		—			6:52			7:22	—			7:52		—			8:52	—	
Canberra							5:40			6:12		—		—	7:12		—		7:40	8:07	—	8:12		—	8:40	—	9:12		—	—	
Goulburn							5:59			—		6:37		—	—		7:37		7:59		—	—		8:37	8:59	—	—		9:37	—	
Moss Vale							6:15			—		6:53		—	—		7:53		8:15		—	—		8:53	9:15	—	—		9:53	—	
Glenfield							6:29			6:54		7:07		7:41	7:54		8:07		8:29		8:41	8:54		9:07	9:29	9:41	9:54		10:07	10:11	
Sydney (Central)							6:43			7:08		7:21		7:55	8:08		8:21		8:43		8:55	9:08		9:21	9:43	9:55	10:08		10:21	10:25	
Sydney (Central)		5:00	5:13	6:00	6:13	6:30		6:55	7:00		7:13		7:55	8:00		8:13		8:30			9:00		9:13			10:00		10:13			10:30
Hornsby		5:10	5:23	6:10	6:23	6:40		7:05	7:10		7:23		8:05	8:10		8:23		8:40			9:10		9:23			10:10		10:23			10:40
Central Coast Parkway		—	5:36	—	6:36	—		—	—		7:36		—	—		8:36		—			—		9:36			—		10:36			—
Newcastle Parkway		5:34	5:51	6:34	6:51	7:04		7:29	7:34		7:51		8:29	8:34		8:51		9:04			9:34		9:51			10:34		10:51			11:04
Taree		—	6:20	—	7:20	—		—	—		8:20		—	—		9:20		—			—		10:20			—		11:20			—
Port Macquarie	5:35	—	6:35	—	7:35	—		—	—		8:35		—	—		9:35		—			—		10:35			—		11:35			—
Coffs Harbour	6:02	—	7:02	—	8:02	—		—	—		9:02		—	—		10:02		—			—		11:02			—		12:02			—
Grafton	6:22	—	7:22	—	8:22	—		—	—		9:22		—	—		10:22		—			—		11:22			—		12:22			—
Lismore	6:47	—	7:47	—	8:47	—		—	—		9:47		—	—		10:47		—			—		11:47			—		12:47			—
Gold Coast (Nerang)	7:10	7:33	8:10	8:33	9:10	9:03		9:28	9:33		10:10		10:28	10:33		11:10		11:03			11:33		12:10			12:33		13:10			13:03
Brisbane (Roma Street)	7:33	7:57	8:33	8:57	9:33	9:27		9:52	9:57		10:33		10:52	10:57		11:33		11:27			11:57		12:33			12:57		13:33			13:27

	SC	MC	AU	CAN	SB	MS	AU	MS	AU	CAN	SB	MS	AU	SC	MC	AU	CAN	SB	MS	AU	CAN	SB	MS	AU	SC	AU	MC
	AM																										
Melbourne (Southern Cross)		7:35	8:00			8:05	8:30	8:35	9:00			9:05			9:35	10:00			10:05	11:00			11:05				11:35
Melbourne Airport		7:46	8:11			8:16	8:41	8:46	9:11			9:16			9:46	10:11			10:16	11:11			11:16				11:46
Seymour		8:06	—			8:36	—	9:05	—			9:36			10:06	—			10:36	—			11:36				12:06
Shepparton		8:23	—			8:53	—		—			9:53			10:23	—			10:53	—			11:53				12:23
Albury		8:56	9:12			9:26	9:42		10:12			10:26			10:56	11:12			11:26	12:12			12:26				12:56
Wagga Wagga		9:22	—			9:52	—		—			10:52			11:22	—			11:52	—			12:52				13:22
Canberra	9:40	10:07	—	10:12		—	—		—	11:12		—		11:40	12:07	—	12:12		—	—	13:12		—		13:40		14:07
Goulburn	9:59		—	—		10:37	—		—	—		11:37		11:59		—	—		12:37	—	—		13:37		13:59		
Moss Vale	10:15		—	—		10:53	—		—	—		11:53		12:15		—	—		12:53	—	—		13:53		14:15		
Glenfield	10:29		10:41	10:54		11:07	11:11		11:41	11:54		12:07		12:29		12:41	12:54			13:41	13:54		14:07		14:29		
Sydney (Central)	10:43		10:55	11:08		11:21	11:25		11:55	12:08		12:21		12:43		12:55	13:08		13:21	13:55	14:08		14:21		14:43		
Sydney (Central)			11:00		11:13				12:00		12:13		12:30			13:00		13:13		14:00		14:13		14:30		14:55	
Hornsby			11:10		11:23				12:10		12:23		12:40			13:10		13:23		14:10		14:23		14:40		15:05	
Central Coast Parkway			—		11:36				—		12:36		—			—		13:36		—		14:36		—		—	
Newcastle Parkway			11:34		11:51				12:34		12:51		13:04			13:34		13:51		14:34		14:51		15:04		15:29	
Taree			—		12:20				—		13:20		—			—		14:20		—		15:20		—		—	
Port Macquarie			—		12:35				—		13:35		—			—		14:35		—		15:35		—		—	
Coffs Harbour			—		13:02				—		14:02		—			—		15:02		—		16:02		—		—	
Grafton			—		13:22				—		14:22		—			—		15:22		—		16:22		—		—	
Lismore			—		13:47				—		14:47		—			—		15:47		—		16:47		—		—	
Gold Coast (Nerang)			13:33		14:10				14:33		15:10		15:03			15:33		16:10		16:33		17:10		17:03		17:28	
Brisbane (Roma Street)			13:57		14:33				14:57		15:33		15:27			15:57		16:33		16:57		17:33		17:27		17:52	

	AU	CAN	SB	MS	AU	AU	CAN	SB	MS	AU	SC	AU	MC	AU	CAN	SB	MS	AU	AU	CAN	SB	MS	AU	AU	SC	MC	AU	CAN	SB	MS	AU
	PM																														
Melbourne (Southern Cross)	12:00			12:05		13:00			13:05				13:35	14:00			14:05		15:00			15:05	15:30			15:35	16:00			16:05	16:30
Melbourne Airport	12:11			12:16		13:11			13:16				13:46	14:11			14:16		15:11			15:16	15:41			15:46	16:11			16:16	16:41
Seymour	—			12:36		—			13:36				14:06	—			14:36		—			15:36	—			16:06	—			16:36	—
Shepparton	—			12:53		—			13:53				14:23	—			14:53		—			15:53	—			16:23	—			16:53	—
Albury	13:12			13:26		14:12			14:26				14:56	15:12			15:26		16:12			16:26	16:42			16:56	17:12			17:26	17:42
Wagga Wagga	—			13:52		—			14:52				15:22	—			15:52		—			16:52	—			17:22	—			17:52	—
Canberra	—	14:12		—		—	15:12		—		15:40		16:07	—	16:12		—		—	17:12		—	—		17:40	18:07	—	18:12		—	—
Goulburn	—	—		14:37		—	—		15:37		15:59			—	—		16:37		—	—		17:37	—		17:59		—	—		18:37	—
Moss Vale	—	—		14:53		—	—		15:53		16:15			—	—		16:53		—	—		17:53	—		18:15		—	—		18:53	—
Glenfield	14:41	14:54		15:07		15:41	15:54		16:07		16:29			16:41	16:54		17:07		17:41	17:54			18:11		18:29		18:41	18:54		19:07	19:11
Sydney (Central)	14:55	15:08		15:21		15:55	16:08		16:21		16:43			16:55	17:08		17:21		17:55	18:08		18:21	18:25		18:43		18:55	19:08		19:21	19:25
Sydney (Central)	15:00		15:13		15:55	16:00		16:13		16:30		16:55		17:00		17:13		17:55	18:00		18:13			18:30			19:00		19:13		
Hornsby	15:10		15:23		16:05	16:10		16:23		16:40		17:05		17:10		17:23		18:05	18:10		18:23			18:40			19:10		19:23		
Central Coast Parkway	—		15:36		—	—		16:36		—		—		—		17:36		—	—		18:36			—			—		19:36		
Newcastle Parkway	15:34		15:51		16:29	16:34		16:51		17:04		17:29		17:34		17:51		18:29	18:34		18:51			19:04			19:34		19:51		
Taree	—		16:20		—	—		17:20		—		—		—		18:20		—	—		19:20			—			—		20:20		
Port Macquarie	—		16:35		—	—		17:35		—		—		—		18:35		—	—		19:35			—			—		20:35		
Coffs Harbour	—		17:02		—	—		18:02		—		—		—		19:02		—	—		20:02			—			—		21:02		
Grafton	—		17:22		—	—		18:22		—		—		—		19:22		—	—		20:22			—			—		21:22		
Lismore	—		17:47		—	—		18:47		—		—		—		19:47		—	—		20:47			—			—		21:47		
Gold Coast (Nerang)	17:33		18:10		18:28	18:33		19:10		19:03		19:28		19:33		20:10		20:28	20:33		21:10			21:03			21:33		22:10		
Brisbane (Roma Street)	17:57		18:33		18:52	18:57		19:33		19:27		19:52		19:57		20:33		20:52	20:57		21:33			21:27			21:57		22:33		

	MS	AU	CAN	SB	MS	AU	SC	MC	AU	CAN	SB	MS	AU	MS	AU	SB	MS	SC	CAN	AU	MS	MS	SC	MC	MS	MS
	PM																									
Melbourne (Southern Cross)	16:35	17:00			17:05	17:30		17:35	18:00			18:05	18:30	18:35	19:00		19:05		19:35	20:00	20:05	21:05		21:35	22:05	23:05
Melbourne Airport	16:46	17:11			17:16	17:41		17:46	18:11			18:16	18:41	18:46	19:11		19:16		19:46	20:11	20:16	21:16		21:46	22:16	23:16
Seymour	17:05	—			17:36	—		18:06	—			18:36	—	19:05	—		19:36		20:06	—	20:36	21:36		22:06	22:36	23:36
Shepparton		—			17:53	—		18:23	—			18:53	—		—		19:53		20:23	—	20:53	21:53		22:23	22:53	23:53
Albury		18:12			18:26	18:42		18:56	19:12			19:26	19:42		20:12		20:26		20:56	21:12	21:26	22:26		22:56	23:26	0:25
Wagga Wagga		—			18:52	—		19:22	—			19:52	—		—		20:52		21:22	—	21:52	22:52		23:22	23:52	
Canberra		—	19:12		—	—	19:40	20:07	—	20:12		—	—		—		—	21:40	22:07	—	—	—	23:40	0:07	—	
Goulburn		—	—		19:37	—	19:59		—	—		20:37	—		—		21:37	21:59		—	22:37	23:37	23:59		0:37	
Moss Vale		—	—		19:53	—	20:15		—	—		20:53	—		—		21:53	22:15		—	22:53	23:53	0:15		0:53	
Glenfield		19:41	19:54		20:07	20:11	20:29		20:41	20:54		21:07	21:11		21:41		22:07	22:29		22:41	23:07	0:07	0:29		1:07	
Sydney (Central)		19:55	20:08		20:21	20:25	20:43		20:55	21:08		21:21	21:25		21:55		22:21	22:43		22:55	23:21	0:21	0:43		1:21	
Sydney (Central)		20:00		20:13							21:13					22:13										
Hornsby		20:10		20:23							21:23					22:23										
Central Coast Parkway		—		20:36							21:36					22:36										
Newcastle Parkway		20:34		20:51							21:51					22:51										
Taree		—		21:20							22:20					23:20										
Port Macquarie		—		21:35							22:35					23:34										
Coffs Harbour		—		22:02							23:02															
Grafton		—		22:22							23:22															
Lismore		—		22:47							23:47															
Gold Coast (Nerang)		22:33		23:10							0:10															
Brisbane (Roma Street)		22:57		23:33							0:33															

CONTINUED INSIDE BACK COVER

Services

- **AU** Australia Express
- **MS** Melbourne ⟷ Sydney stopping
- **MC** Melbourne ⟷ Canberra stopping
- **SC** Sydney ⟷ Canberra stopping
- **CAN** Sydney ⟷ Canberra express
- **SB** Sydney ⟷ Brisbane stopping

NOTE: Central Coast and Newcastle shuttle services not shown, and times shown can differ from travel times determined later by simulations

Zero Carbon Australia

High Speed Rail

Beyond Zero Emissions

Melbourne Energy Institute, The University of Melbourne

German Aerospace Centre

The Zero Carbon Australia High Speed Rail report is an important contribution to building the case for the prompt introduction of this transport mode in Australia.

HSR has been adopted around the world, providing safe, fast transport which serves both major cities and regional centres. Australia is one of only two continents without HSR or plans for its construction - the other is Antarctica.

With one of the world's busiest air routes between Sydney and Melbourne, and other corridors with intensive travel, Australia is long overdue for HSR. The Zero Carbon Australia High Speed Rail report helps to confirm that this is a transport system which we should be implementing without further delay.

— Dale Budd

Member of the reference group for the Commonwealth Government's 2010-2013 high speed rail study

HSR is a visionary and transformative infrastructure investment in the future of Australia. There is a debate to be had about the details, the timing, and the cost, but the decision to start, and to invest in this proposal is essential and urgent.

The ideas in the Zero Carbon Australia Transport Project report are convincing and a substantial contribution to the debate. In light of their report, I encourage the government to keep the discussion going and to take immediate action to protect the route so that this opportunity is not lost to Australia.

— Sue Holiday

Former member of the HSR advisory committee

On the eve of the 50th Anniversary of the Shinkansen Bullet train operating Tokyo Osaka, with no fatalities and profitable operations from near inception, I salute this work that further raises the profile of High Speed Rail for Australia. Better fifty years late than never for HSR Melbourne Tullamarine Canberra Sydney Newcastle and later Brisbane.

— Tim Fischer

Former Deputy Prime Minister of Australia and former member of the HSR advisory committee

High speed rail along the east coast of Australia has been studied for three decades including a recent report into its feasibility commissioned by governments. In analysing the introduction of a new technological system the long-term economic, social, health and environmental impacts represent key information for decision makers.

I commend this report with its focus on energy and greenhouse gases as essential reading for governments, industry and the community. When a national vision for high speed rail - backed up by science translated into policy - is implemented then society will be able to reflect on the real champions of change.

— John Black

Emeritus Professor of Transport Engineering Research Fellow, Institute of Environmental Studies UNSW Australia

High speed rail is an intergenerational project that will transform our nation. Fast east coast connections will effectively shrink the size of Australia, connecting regional centres with cities, changing where our population lives and how it travels for work and pleasure.

High speed rail must become a reality in Australia. The Beyond Zero Emissions report is a valid contribution to the high speed rail debate and I commend them for the effort.

— Bryan Nye

Chief Executive Officer,
Australasian Railway Association

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German Aerospace Center

INSTITUTE OF ENVIRONMENTAL STUDIES

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This report was able to be printed thanks to a generous donation from Mr Robin Friday.

You can help us produce climate solutions

Researching Zero Carbon solutions for Australia is a hard job.

The fact is that Beyond Zero Emissions relies on donations from hundreds of donors, both small and large. People like you. We don't get Government backing. We are very careful to ensure that our research is independent.

To do the research that needs to be done, to get the word out there, to empower Australians by providing them with scientifically sound facts, all costs money.

Your help will allow us to continue researching our Zero Carbon Australia solutions. And every cent helps.

Who are Beyond Zero Emissions?

Beyond Zero Emissions is a not-for-profit research & education organisation.

We are working to deliver a zero carbon Australia, relying on the support of people like you.

What is the Zero Carbon Australia project?

The Zero Carbon Australia (ZCA) project is an exciting initiative of Beyond Zero Emissions and the University of Melbourne's Energy Research Institute. The project is a road map for the transition to a decarbonised Australian economy.

The latest and most credible science tell us such a transition is necessary in order to reverse climate disruption.

The project draws on the enormous wealth of knowledge, experience and expertise within Beyond Zero Emissions and the community to develop a blueprint for a zero carbon future for Australia. There's more about the ZCA project on the back of this page.

How can you help?

Please tear out the donations form to the right, fill it in, seal the edges and send it to Beyond Zero Emissions, Suite 10, 288 Brunswick Street, Fitzroy, Vic 3065

Go to www.bze.org.au/donate

or fill out, detach, seal & send

DETACH ALONG HERE

Donations over $2.00 are tax-deductible

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My details

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First name

Surname

Address

P'code

Surname

Phone

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FREQUENCY Monthly ☐, Once only ☐

AMOUNT $25 ☐, $55 ☐, $105 ☐, $205 ☐

Other $

My credit card details

Visa ☐, Mastercard ☐, American Express ☐

Name on card

Card number

Verification no. Expiry /

My signature

I'll take the Direct Debit option

☐ *Beyond Zero Emissions Fund*
BSB 633-000
Account 139914402

Please include your name with your direct debit details.

SEAL ALONG HERE

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Beyond Zero Emissions
Suite 10, 288 Brunswick Street
Fitzroy, Vic 3065

SEAL ALONG HERE

SEAL ALONG HERE

FOLD ALONG HERE

DETACH ALONG HERE

The Zero Carbon Australia project

Six ZCA plans will provide a detailed, costed and fully researched road map to a zero-carbon economy for Australia. Following seven guiding principles, each plan will use existing technology to find a solution for different sectors of the Australian economy.

Stationary Energy plan

The plan details how a program of renewable energy construction and energy efficiency can meet the future energy needs of the Australian economy.

Transport plan

The plan will show how Australia could run a zero fossil fuel transport system. The main focus is on the large-scale roll-out of electrified mass transit and vehicles, with the application of sustainable bio-fuels where appropriate, based on availability and competing needs.

Buildings plan

The plan details how all existing buildings can reach zero emissions from their operation within ten years. It sets out how Australia can transform its building stock to reduce energy bills, generate renewable energy, add health and comfort to our living spaces, and make our workplaces more productive.

Industrial Processes plan

The plan will show how our industrial energy requirements can be supplied primarily from 100% renewable grid and investigate replacing fossil fuels with chemical equivalents.

Land Use, Forestry & Agriculture plan

With a significant proportion of Australia's emissions from land-use change, forestry and agriculture, the plan will also address broader issues like land-use efficiency and competition for different uses of land for different purposes and products.

Renewable Energy Superpower plan

As Australia and the world move away from fossil fuels and other sources of greenhouse gas emissions, the nature and volume of imported and exported goods will also change. This report will investigate the opportunities for Australia's balance of trade in a zero carbon world.

ZCA Guiding Principles

1. Australia's energy is provided entirely from renewable sources at the end of the transition period.
2. All technology solutions used are from proven and scaleable technology which is commercially available.
3. The security & reliability of Australia's energy is maintained or enhanced by the transition.
4. Food and water security are maintained or enhanced by the transition.
5. The high living standard currently enjoyed by Australians in maintained or enhanced by the transition.
6. Other environmental indices are maintained or enhanced by the transition.

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Key findings

This study proposes a High Speed Rail (HSR) network connecting the major capital cities and regional centres along the Australian east coast corridor between Melbourne, Sydney and Brisbane. It is proposed to commence services by 2025, reaching full passenger capacity by 2030.

Key findings of this study are:

45% of Australian regional travel is contained within the proposed High Speed Rail network corridor

Domestic regional travel in Australia is highly concentrated in the corridor between Melbourne and Brisbane. In 2010 Australian passengers travelled around 145 billion kilometres across the country; just under half of this was from journeys contained within a corridor approximately 100km either side of the proposed HSR line.

21 High Speed Rail stations connecting 12 regional centres and six major cities

Regional stations are proposed for: Seymour, Shepparton, Albury-Wodonga, Wagga Wagga, Goulburn, Moss Vale, Central Coast, Taree, Port Macquarie, Coffs Harbour, Grafton and Lismore. With HSR, these regional centres would be no more than one and a half hours from one of six major cities on the network: Brisbane, Gold Coast, Newcastle, Sydney, Canberra and Melbourne.

Ten minute train frequencies required during peak hours at Sydney station

From Sydney, the busiest station, high speed trains in both north and south directions would be departing platforms every 10 minutes in peak hour. Meeting the passenger demand estimated for the proposed HSR network would require a fleet of 87 trains. The average train occupancy is estimated to be 85%.

Journey times of less than three hours from the centre of Sydney CBD, to the CBD of Melbourne or Brisbane

Both express and stopping trains are proposed for the HSR network. Express trains will take less than 3 hours to travel from Sydney to both Melbourne and Brisbane. To travel the full length of the corridor, from Melbourne to Brisbane, will take 5 hours and 56 minutes.

60% of Australian population within 50km of a High Speed Rail station on proposed network

The proposed HSR network features a station less than one hour from 12.5 million Australian residents.

Three million fewer domestic passengers at Sydney Airport in 2030 than current levels

With the proposed HSR network fully operational in 2030, the reduced air travel demand would require 82 fewer daily aircraft movements than the current average of 850. The need for another airport to service Sydney will be greatly influenced by the proposed High Speed Rail network.

HSR becomes the dominant mode of transport for journeys between 350 and 1,300 kilometres in length

Once High Speed Rail is operational it is estimated that it will account for 30% of passenger kilometres travelled. Most of this travel is estimated to be transferred from current air services, and longer car journeys. Journeys shorter than 350 km remain dominated by car travel, whilst those longer than 1300 km remain mostly on air travel.

Over three times more passengers are expected to travel by HSR than air within the east coast corridor in 2030

68 million passengers are expected to travel by HSR in the year 2030, compared to 20 million by air (down from 55 million in 2010).

100% renewable energy powered HSR allows zero emissions journeys

The proposed HSR network can be powered by 100% renewable energy. This will allow passengers the choice of travelling with zero emissions for journeys that are appropriate to substitute with HSR. It is estimated that greenhouse gas emissions from regional travel would be reduced by 150 million tonnes of carbon dioxide equivalent over 40 years of operation compared with business-as-usual. Emissions created from the HSR construction would be offset after 5 years.

$84 billion total estimated construction cost including rolling stock, project management and contingency

Melbourne-Sydney is estimated to cost $40 billion, and Sydney-Brisbane $44 billion. Of this, $18 billion of the total estimated construction cost is required for entering the cities of Melbourne, Canberra, Sydney, Gold Coast and Brisbane.

$7 billion estimated fare revenue when fully operational in 2030

The passenger demand estimated would generate $7 billion of gross operating revenue in the year 2030, with HSR fares priced cheaper than the equivalent average air fares. Operating costs are estimated to total $2.3 billion for the same year. The net operating profit is $4.6 billion.

40 year capital repayment from operating profits

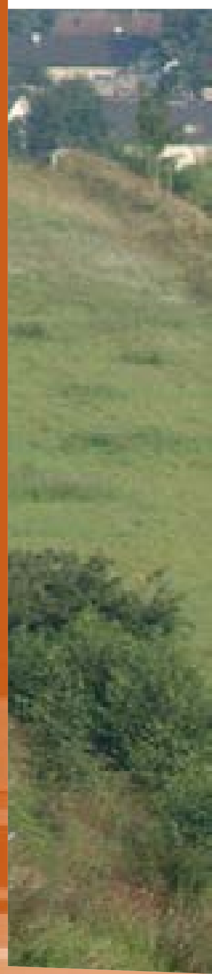
The significant operating profits would allow repayment of the capital costs after 40 years of operation. This takes into account expected growth in passenger demand, with a 4% real discount rate on future cash flows.

1,799km of High Speed Railway requiring 81km of tunnels (4.5%) and 98km of elevated sections (5.5%)

90% of the proposed HSR network is on track at ground level, in cuttings or on embankments. The alignment has been carefully designed to balance the need for expensive infrastructure such as tunnels and bridges, with the need to limit impacts on people and the natural environment.

Internationally, comparable HSR projects have been delivered in less than 10 years

HSR projects of similar or greater complexity have been completed in other countries in less than 10 years from commencing construction to beginning services. If Australia proceeds with HSR and achieves a similar pace of project delivery, the proposed network could be operational by 2025.



Cologne-Frankfurt high speed train parallel to Autobahn 3, Germany PHOTO: SEBASTIAN TERFLOTH

Executive summary

This study proposes a High Speed Rail (HSR) system running from Melbourne to Brisbane via Canberra and Sydney, to be developed as part of a zero emissions transport strategy for Australia. Once operational in 2025 it can become a dominant mode of transport within the busy east coast corridor, providing a superior service over flying or driving for a major portion of regional journeys. 60% of Australia's population would live within 50 km of a HSR station.

With estimated patronage expected to generate $4.6 billion/year in operating profits within five years of commencing services, growing over time, the $84 billion capital investment could be repaid by this profit from fare sales.

By powering the HSR network with renewable electricity, people could continue to travel the east coast of Australia without contributing to global warming.

Today's travel

Currently, 153 billion passenger-kilometres are travelled each year between cities, towns and locations around Australia. In this study, only regional travel (journeys which begin and end in different towns) is considered. Journeys within the same town are excluded. Despite Australia's size, the majority of travel is concentrated in the east coast corridor between Melbourne and Brisbane, visualised by passenger concentrations in Figure I. This travel within the east coast corridor represents 65% of all journeys, 45% of all passenger-kilometres travelled and 44% of all greenhouse gas emissions generated by regional travel passengers across Australia.

This demand has led to Melbourne-Sydney being ranked the fifth busiest city pair in the world by aviation passenger movements for 2012 (Table I).

TABLE I **2012 global top five busiest air travel city pairs by passenger volume (measured in origin to destination journeys travelled)**

Rank	Route		Passengers (million/yr)
1	Jeju	Seoul	10.2
2	Sapporo	Tokyo	8.2
3	Rio de Janeiro	Sao Paulo	7.7
4	Beijing	Shanghai	7.2
5	Melbourne	Sydney	6.9

HSR alignment

The High Speed Rail network proposed in this study has been configured to service this concentration of travel. Express and stopping-all-stations trains would directly connect 18 cities and towns along the Australian east coast.

The HSR express travel times are less than three hours between Sydney Central Station and both Southern Cross Station in Melbourne and Roma Street Station in Brisbane.

FIGURE I **Australian regional travel passenger distribution (2010)**

Transport system impact

When HSR is operating, the mode share of passenger travel is expected to change significantly. HSR will become the dominant mode in the east coast corridor in journeys between 350 km and 1,300 km in length (Figure II). Shorter journeys would continue to be served mainly by car travel and longer journeys by air.

It is estimated after five years of operation, the proposed HSR network will attract 68 million passengers/year and 30% of passenger-kilometres/year (Pkm/yr) travelled in the east coast corridor (Figure III). This means that HSR would then transport three times more passengers, and 35% more passenger-kilometres, than air (Table II).

FIGURE II **Estimated east coast corridor transport mode share after five years of HSR becoming available**

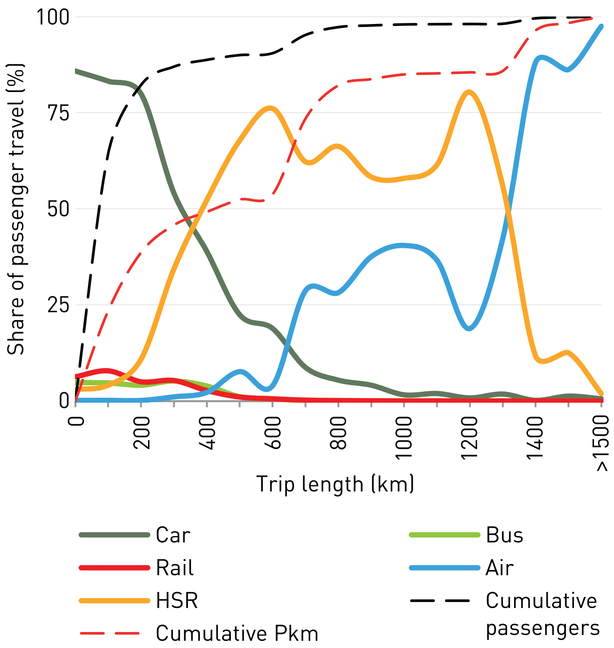


FIGURE III **Change in mode share of east coast corridor passenger travel in 2010, and after five years of HSR becoming available**

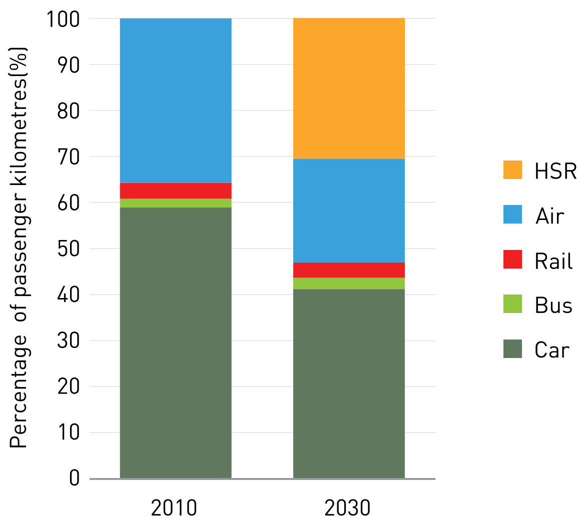


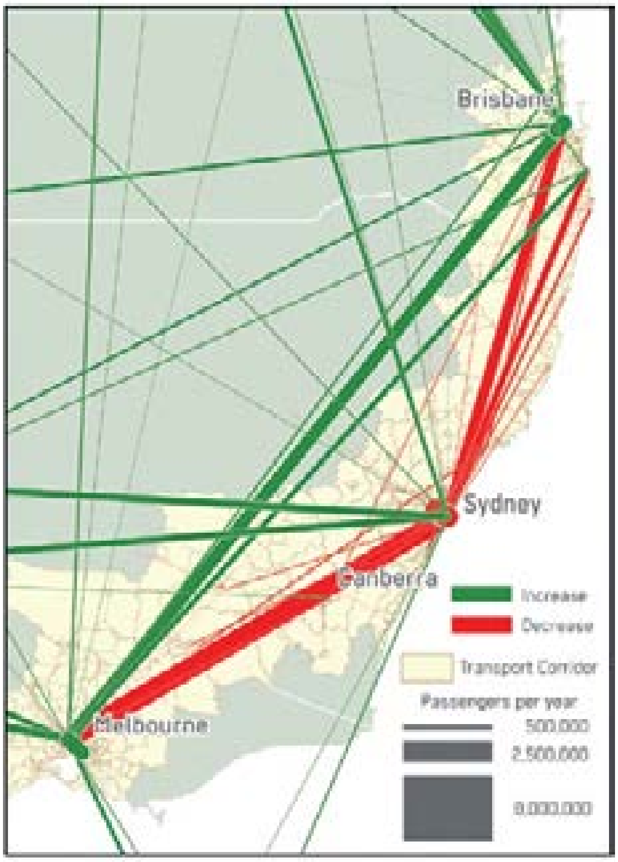
TABLE II **Annual mode share of east coast corridor passenger travel after five years of HSR becoming available. HSR passenger total is 63 million for journeys totally within the corridor, 68 million including journeys passing through the corridor**

Mode	Passengers (million/yr)	Share	Pkm (billion/yr)	Share
Car	340	72%	37	41%
Bus	19	4%	2	2%
Rail	30	6%	3	3%
Air	20	4%	20	23%
HSR	63	13%	28	31%
Total	**473**		**90**	

Australia's busy air routes are expected to experience a significant reduction in passenger volumes (Figure IV). Considering only the air and HSR passenger travel market, HSR is estimated to attract 65% of the Melbourne-Sydney and Sydney-Brisbane market. Melbourne-Brisbane HSR is expected to attract fewer passengers (11% of the market) due to the greater time required for this long distance journey. Air travel between Canberra and Sydney would be all but eliminated.

As a result, Sydney airport is expected to see three million fewer domestic passengers in 2030 than it did in 2012. This translates to approximately 82 fewer daily aircraft movements in 2030, than the current daily average of 853.

FIGURE IV **Change in air passenger travel from 2012 to 2030 with HSR available**



Comparison with existing transport options

The HSR fare structure is designed to be cheaper than the equivalent average airfare for all but the longest journeys (Figure V). This is the case with many HSR networks operating internationally, and is one of the key reasons for the expected shift by passengers from air to HSR.

For journeys between major cities, HSR will provide a competitive door-to-door travel time at lower cost.

For regional centres, HSR will not only be faster and safer than driving long distances, but also cheaper and more convenient than regional flights. As a result, HSR is expected to attract significant patronage from passengers who would otherwise be driving, and even 'induce' trips that would otherwise not have been taken.

Travel emissions impact

The High Speed Rail system is expected to consume 2.2 terawatt-hours of electricity in 2030. For context, this is approximately equal to the volume of renewable energy consumed in 2012 under the voluntary GreenPower initiative. HSR can use 100% renewable energy, allowing the operation of the system to generate zero greenhouse gas emissions.

The passenger diversion estimated to result from introducing the HSR service, from existing modes powered by fossil fuels to HSR powered by renewable energy, would reduce the emissions of regional travel in the east coast corridor by 28%. Greenhouse gas emissions from regional travel could be cut by 150 million tonnes of carbon dioxide equivalent (CO_2-e) over 40 years of operation. The emissions generated from manufacturing and constructing the HSR network would be offset within the first five years of operation.

Provision of the HSR system will allow passengers the choice of travelling with zero emissions for journeys that are appropriate to substitute with HSR. If all passengers travelling by the mass transit modes of bus, rail and air chose to switch to HSR where it services their journey, regional travel emissions within the east coast corridor would be halved. Further emissions reductions in the corridor will be possible by providing more alternatives to address the remaining travel demand still met by driving, and reducing the emissions intensity of the Australian vehicle fleet. Investigation of such options is outside of the scope of this study, but will be addressed in future work as part of the Zero Carbon Australia Transport Project.

Network operation

A total of 87 trains will be required to meet the expected demand. Sydney Central HSR platforms would see departures every 10 minutes in each direction during peak hour, with departures from Melbourne and Brisbane every 15 minutes. Express and stopping trains will cover 66 million kilometres in 2030. Figure VI shows the available services for the HSR network with a combination of express trains, and trains stopping all stations.

FIGURE V **Non-business air fare and HSR Economy fare price structure. Surveyed air fare range (2013 fares) is shown by bars. The low end is internet discount and the high end is flexible economy**

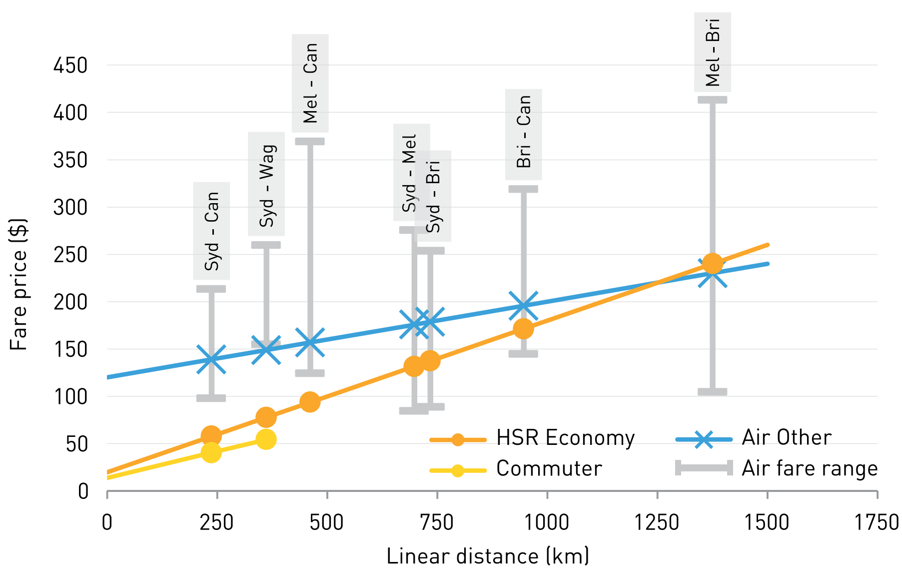
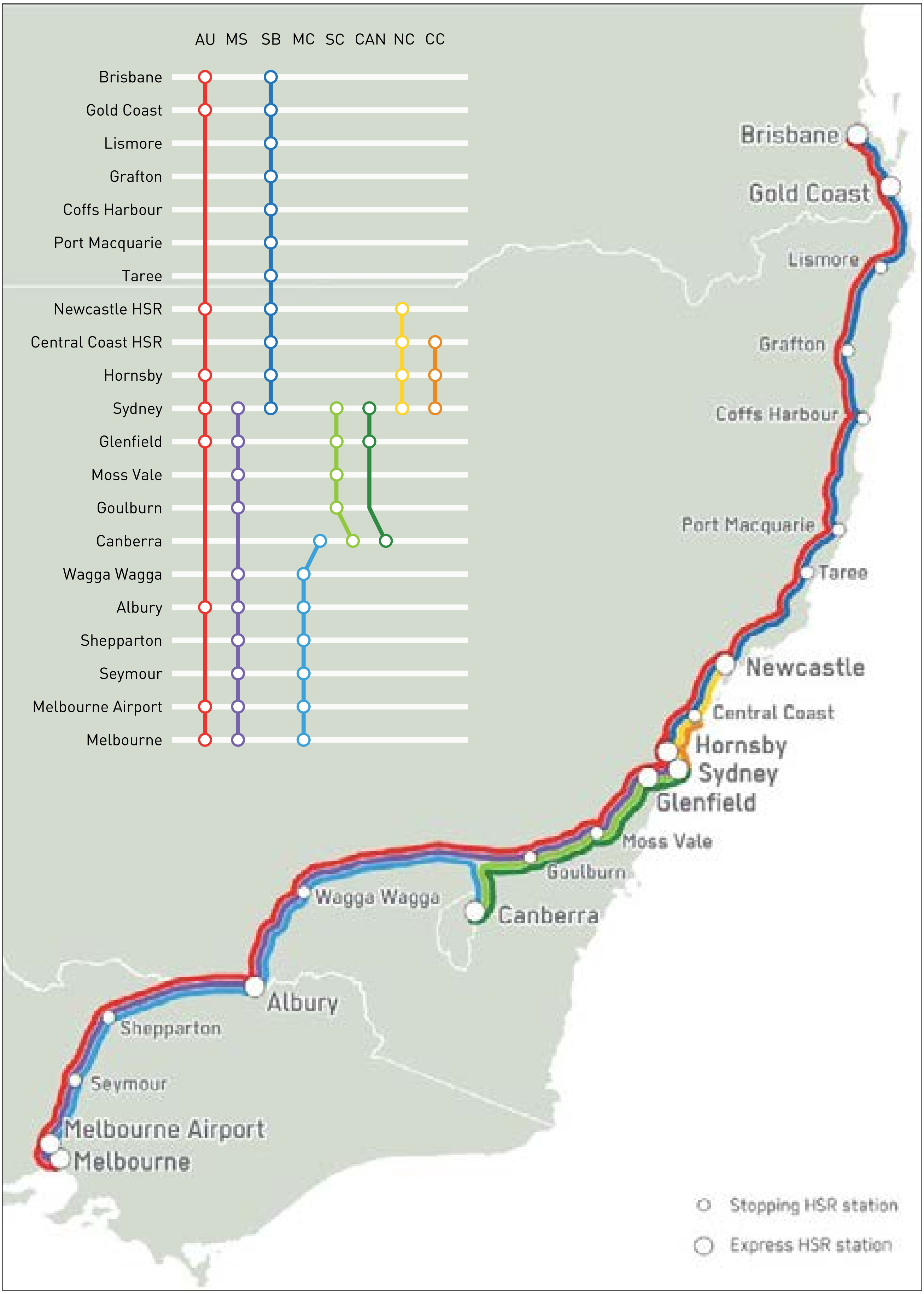


FIGURE VI **Operating schedule for Melbourne-Brisbane HSR network**



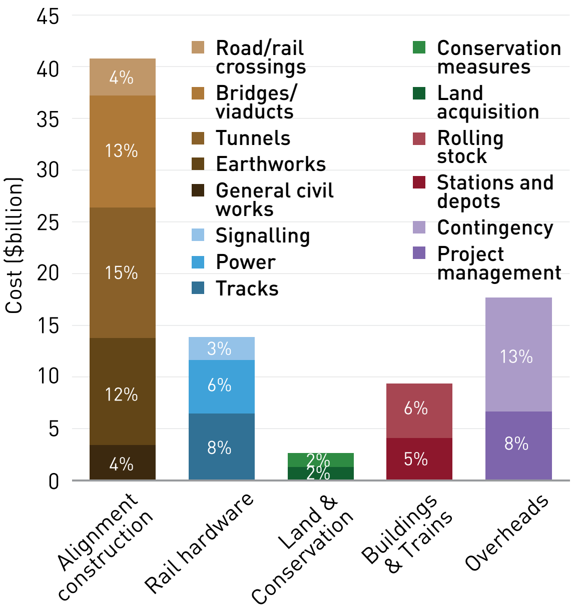
Capital cost

The estimated total cost for the HSR system, including construction, rolling stock, management and contingencies is $84 billion. The different cost components are broken down in Figure VII. Of this total, accessing major cities accounts for $18 billion (21%), while the required 87 high-speed train sets accounts for $6.6 billion (8%).

The precise route of the HSR line has been designed to balance the needs of providing a fast, affordable and convenient service while minimising the impacts on people and the natural environment. The 1,799 km alignment, shown in Figure X, is composed of 81 km of tunnel (4.5%), 99 km of elevated track (5.5%) and 1619 km of track at ground level, on embankments and in cuttings (90%).

The estimated cost of the Melbourne-Sydney segment is $40 billion and the Sydney-Brisbane segment is $44 billion, inclusive of the railway, stations, trains, management and contingency.

FIGURE VII **Breakdown of $84 billion capital cost estimate for Melbourne-Brisbane HSR system**



Operating profit and cost recovery

Operating revenue from ticket sales is expected to be three times greater than operating costs on an annual basis. This allows the initial capital cost to be repaid by the surplus operating profit. Figure VIII shows the projected operating cash flows for the year 2030 after five years of commencing services, with $7 billion of gross revenue and $4.6 billion of operating profit.

In net present value terms, capital costs would be recovered after 40 years of operation, as shown by the discounted cash flow in Figure IX.

Based on the experience of other countries, having the HSR network operational by 2025 is achievable. High Speed Rail will pay for itself financially whilst enabling Australia to reap the unquantifiable benefits of a clean, comfortable, modern transport service. It will bring regions and cities closer, change the way we work and live in the 21st century.

FIGURE VIII **Operating cash flows estimated for HSR operation in 2030**

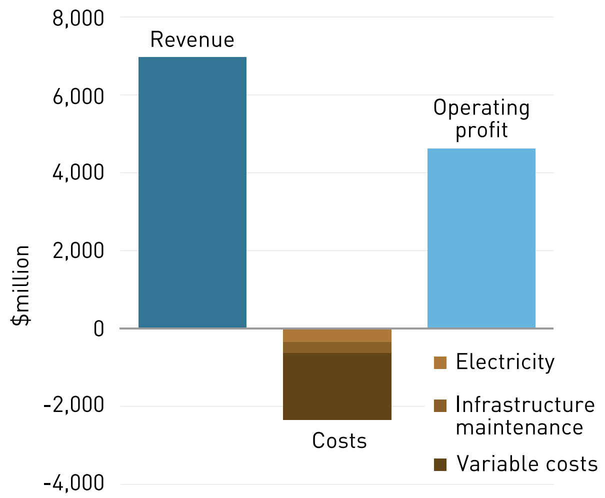


FIGURE IX **Annual costs and revenue (undiscounted 2012 dollars), and net present value (discounted, 4% real discount rate) for HSR network**

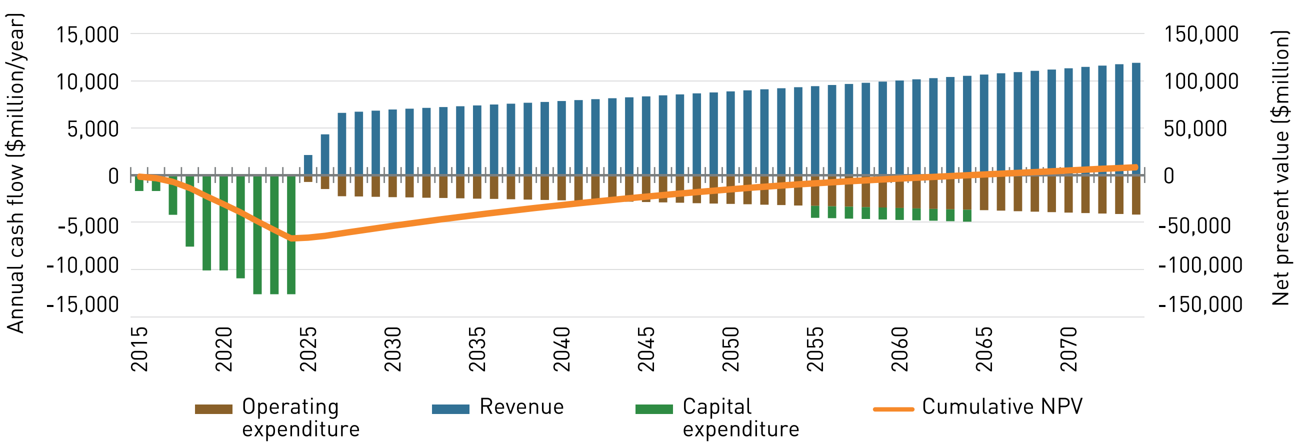
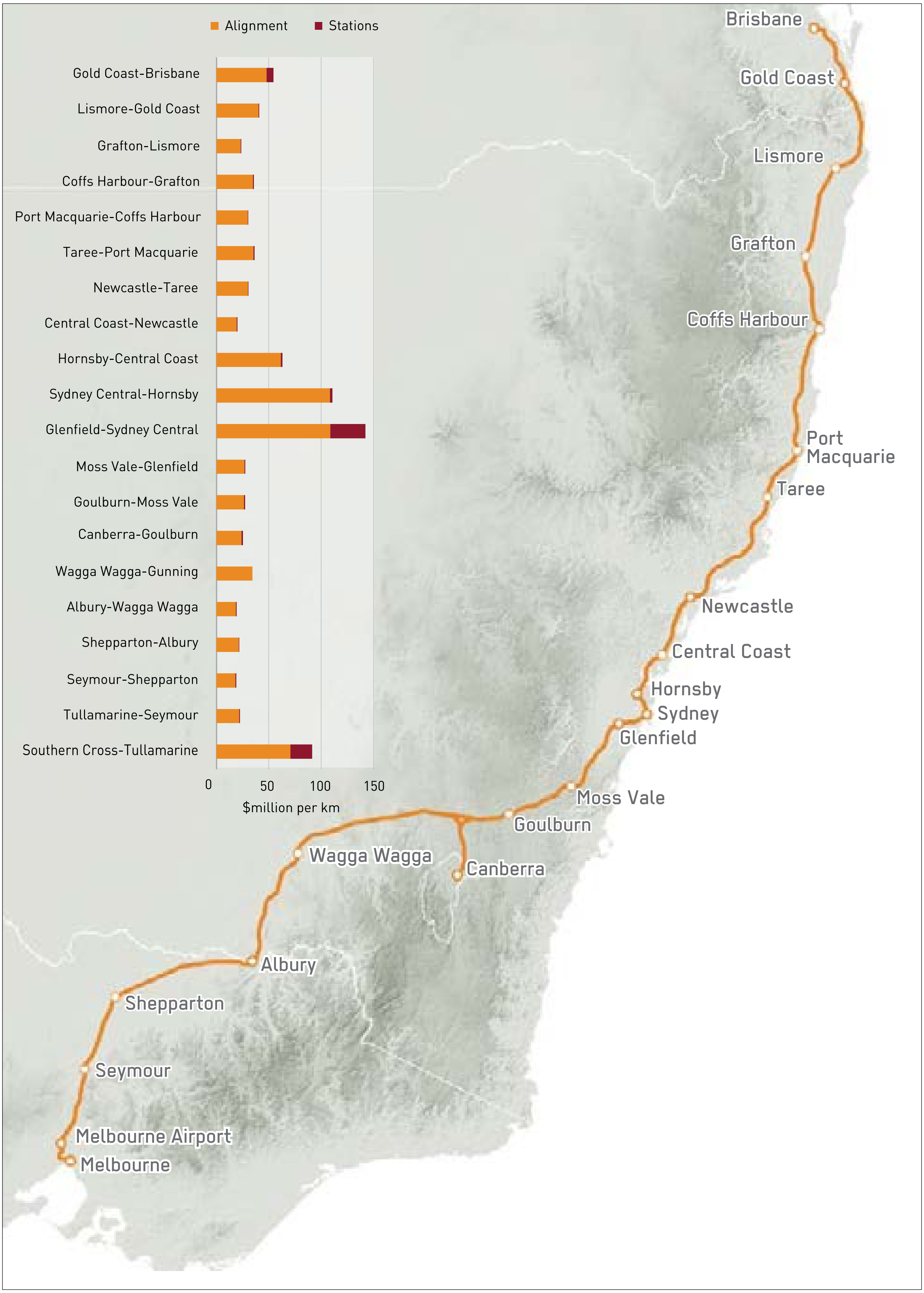
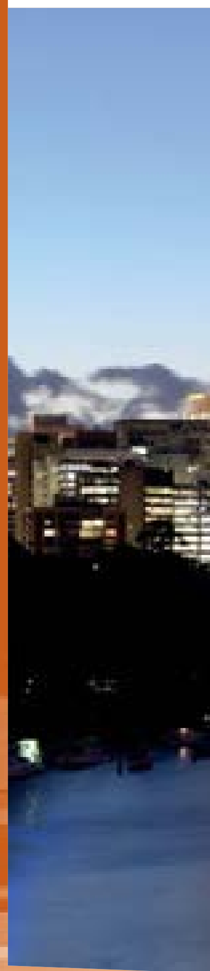


FIGURE X **HSR alignment with terrain data, and cost of railway construction and stations averaged over the length of each segment**





Brisbane during twilight, Brisbane River PHOTO: KONGERIGET KALLISUIT

Introduction

1

This report investigates the performance of a High Speed Rail service operating from Melbourne to Brisbane via Sydney and Canberra. It is the result of a joint investigation by researchers from Beyond Zero Emissions (BZE), a non-profit climate solutions research organisation, the University of Melbourne's Energy Institute and the German Aerospace Centre's (DLR) Institute of Vehicle Concepts and Institute of Transportation Systems.

High Speed Rail (HSR) in Australia has been discussed for decades. It is widely recognised as a desirable and exciting nation-building project. Yet Australia's HSR has been held back by misconceptions regarding population density, short-sighted political decision making and lack of public awareness about the potential benefits.

Objective

The objective of this study is to analyse the demand for HSR and compare the potential returns with the costs of construction and operation.

In addition, this study aims to identify the change in greenhouse gas emissions from Australia's business-as-usual trajectory with the inclusion of HSR operating on renewable energy.

This High Speed Rail study is the first of a number of transport studies to be conducted as part of the Zero Carbon Australia Transport Project. Each of the individual studies will address a piece of the Australian transport system. When completed these will provide a combination of solutions to remove greenhouse gas emissions from transport in this country.

Scope

This study encompasses all regional travel in Australia in order to provide context for a service which will service a limited area. For the convenience of comparison, travel within an area corresponding to the proposed HSR alignment has been examined separately where appropriate. This corridor includes all Statistical Area Level 2 (SA2) regions within 100 km of the proposed HSR alignment.

The reference year for current travel is 2010. Projected travel has been modelled for the year 2030. The year 2030 was chosen as it was considered possible for the service to be fully operational by this time and to limit the unreliable nature of assumptions over long time frames. Another consideration was that assessing the potential demand and returns sooner rather than later will be conservative by nature, due to Australia's trend of increasing population. The trend observed over the period 2010 to 2030 is extrapolated in order to estimate the ongoing patterns of passenger travel, emissions and financial flows. These assessments span 40 years of operation which is assumed to begin in full in 2025.

Due to the energy intensive nature of transport, conservative estimates of future fuel and electricity prices have been incorporated into the operating cost estimates of all transport options.

This study does not include a quantitative analysis of the wider economic costs and benefits of HSR such as travel time savings, reduction in transport related trauma, improved social amenity or reduced congestion.

Also excluded is examination of regional development potential, though it is recognised to be a significant opportunity. There are many factors which will influence the success of regional development and will best be served by an investigation incorporating the relevant communities and governing bodies. It would be valuable for such an investigation to include population and development redistribution which was beyond the scope of this study.

Policy, ownership structures and implementation were also excluded.

Unless otherwise stated, all prices are in 2012 Australian dollars. When indicating the net present value, a discount rate of 4% (real) has been applied.

Approach

A systematic approach was taken to estimate the performance and cost of a HSR service operating from Melbourne to Brisbane via Sydney and Canberra. This involved the following sequence of investigation:

- Existing and future travel demand
- Impact of HSR on travel patterns
- Network operation
- Route design
- Construction costing
- Commercial performance

In report Sections 1 and 2, Australia's current travel patterns are mapped out to determine the potential market for HSR and identify an appropriate corridor for the railway.

Following this in more detail, the regional transport system, including the major roadways, railways, air routes and the proposed HSR network, is simulated in order to estimate the effect HSR would have on passenger travel decisions. This analysis provides a robust estimate of how many passengers will switch travel modes to using HSR once it is operating. The relationship of patronage share for air or HSR is internationally observed to follow a strong trend proportional to travel distance, which has been applied to the Australian scenario. The redistribution of passengers is used to estimate the overall change in transport service use and the related effect on greenhouse gas emissions.

In Section 3, the estimated demand has been used as the basis for developing an operating concept of the HSR network. The network operation matches the performance of a modern train fleet to the expected passenger flows. A functional timetable is produced as a result of this, providing information on required fleet size, train frequencies, energy consumption and operating hours among other operational considerations. HSR operating revenue is determined based on estimated patronage numbers and a fare structure matching the relationship of international air and HSR fares.

In Sections 4 and 5, with a corridor of operation identified, specific placement of the railway is examined. This process involves negotiating the numerous obstacles presented by the Australian terrain while meeting the design limitations of a high speed railway. Avoiding unfavourable terrain has a significant effect on reducing capital costs of constructing the HSR alignment.

In Section 6, the construction required for the complete HSR alignment has been investigated to determine the indicative capital cost of the network. Each item of construction required has been allocated to the appropriate section of the alignment. The HSR component cost database sources up-to-date industry information on unit costs from Australian and international projects, and covers major items such as tunnels and bridges, down to minor items such as fencing and sound barriers.

A financial analysis has been carried out examining the cumulative balance of capital costs, operating costs and operating revenues.

Deutsche Bahn high speed ICE train at station PHOTO: SIEMENS PRESS PICTURE

Boxing day cricket, Melbourne Cricket Ground PHOTO: SIMON HELLE NIELSON

1. High speed rail demand in Australia

This section contains:

- **Passenger movements mapped across Australia**
- **The likely change in transport mode passenger distribution as a result of HSR**
- **Estimated HSR passenger volumes for 2030**
- **The effect that HSR would have on Australia's greenhouse gas emissions**

Overview

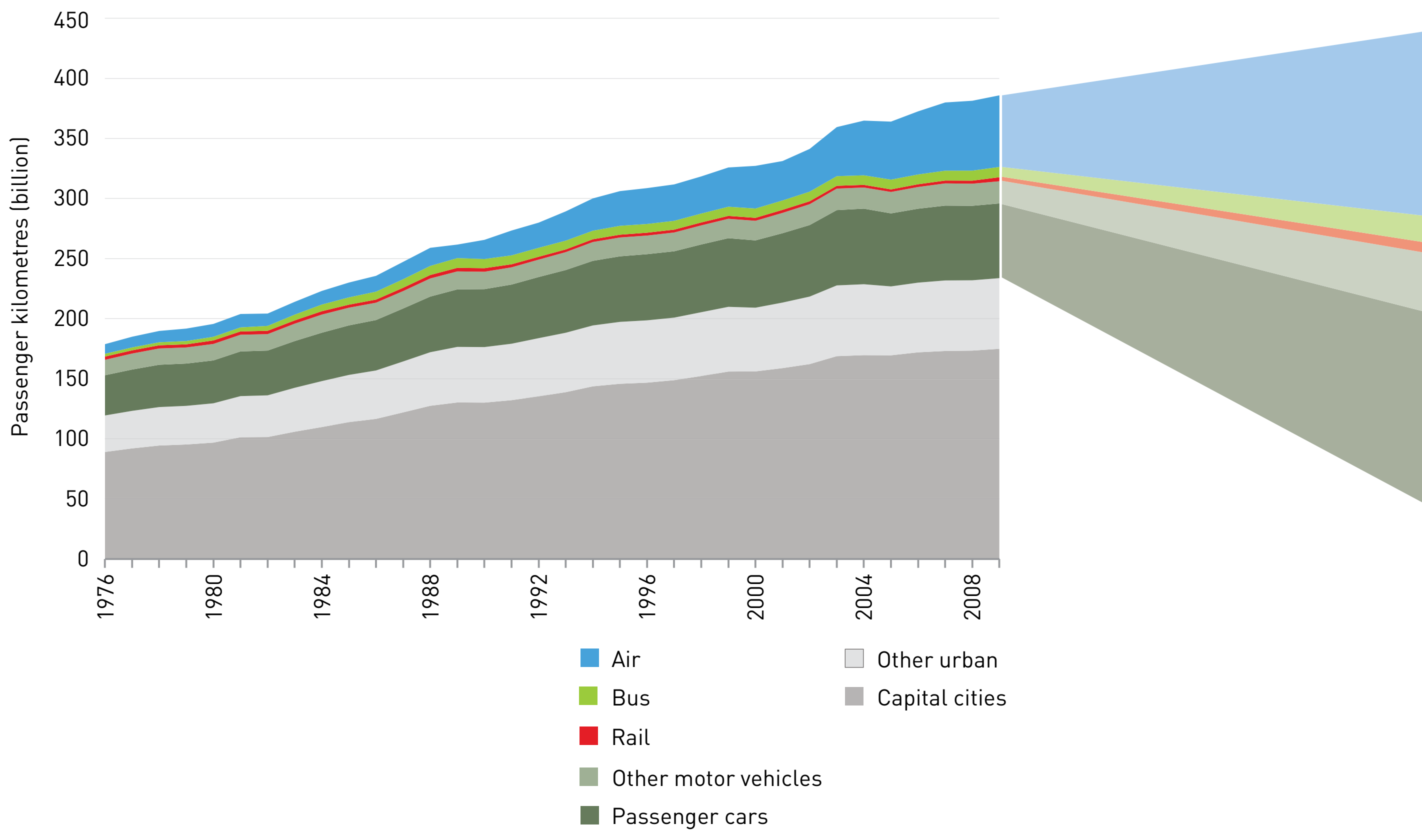
Currently, 153 billion kilometres are travelled each year by passengers between the regions around Australia. That is the equivalent of every person in the country travelling from the western tip to the eastern tip of the country, and back again every year.

Current passenger movements are heavily concentrated in the south-east of the country in the corridor between Melbourne and Brisbane. Sixty-five per cent of all Australian regional travel is contained within this south-east corridor. HSR is estimated to cause a very significant change to how Australians make these journeys.

HSR is estimated to attract 68 million passengers in 2030 and cover 30% of kilometres travelled in the corridor. This is a major departure from the situation today where car and air travel dominate the short and long journey markets. HSR provides a competitive alternative for both short and long journeys and will clearly dominate the middle range. By powering these HSR journeys with renewable energy, Australia's transport greenhouse gas emissions could be cut by 152 million tonnes of carbon dioxide equivalent (CO_2-e) over 40 years of operation. Construction emissions would be offset after only five years of operation.

Further detail is available in Appendix A.

FIGURE 1 **Annual passenger kilometres travelled by mode and region**

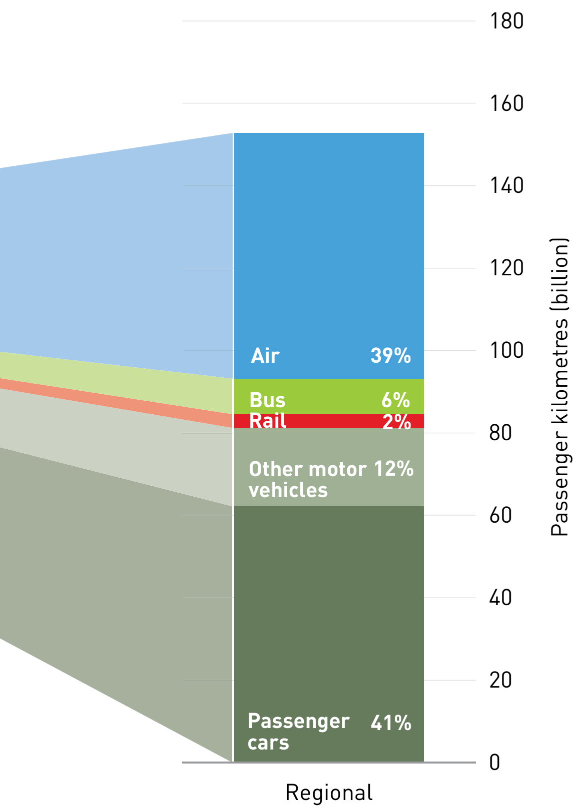


Current national passenger demand

Travelling is an important aspect of life in Australia. We currently have 1,800 towns thinly spread across Australia's 7.7 million square kilometres. The population of Australia has been spread like this to make use of the natural wealth discovered here. Agricultural potential, water, minerals or natural beauty were all factors which produced the towns established to date.

Though these towns are largely clustered within 200 km of the south and east coasts, the distances between towns are large by world standards. This has contributed to a psychological barrier in Australia where population density is the common justification for not improving services for long journeys we travel on a daily basis.

Travel is so much part of our lives that it accounts for almost one quarter of the total energy Australia consumes[1], 16% of household expenditure[2] and 12% of greenhouse gas emissions[3].



When Australians pack up for a holiday at the beach over the New Year, head interstate for a business meeting, skip town for the long weekend or visit relatives out of town, they are accumulating a large amount of the total kilometres we travel each year. According to Australian Bureau of Infrastructure, Transport and Regional Economics (BITRE), 54% of the kilometres covered are beyond the metropolitan areas of Australia's eight State and Territory capitals[4], and 40% of all kilometres travelled are regional – that is beyond the boundaries of urban habitation.

The annual kilometres travelled by Australians (passenger kilometres, Pkm) over the past 35 years is shown in Figure 1. Currently regional travel is dominated in almost even proportions by the family car (41%) and air travel (39%). Other motor vehicle travel accounts for 12% of passenger kilometres (primarily non-business use of light commercial vehicles with contributions from motorcycles, ferries and non-business use of trucks). Regional train and coach services share the remaining 8% of regional travel (Figure 1).

Regional travel accounts for approximately 42% of passenger transport emissions and 4.2% of Australia's total carbon footprint. In 2012, regional travel consumed around 6.2 billion litres of petroleum-based fuel at a cost of $5.7 billion (excluding taxes).

In this study, only regional travel (journeys which begin and end in different towns) is considered. Journeys within the same town are excluded.

Travel distribution

The distribution of travel across regional areas of Australia is shown in Figure 2. The density of passenger travel is shown by the line thickness and the different transport modes by colour. Despite Australia's size, the vast majority of travel is concentrated in the south-east corridor between Melbourne and Brisbane. The travel within this corridor, shown in Figure 3, represents 65% of journeys, 45% of kilometres and 44% of emissions accumulated by passengers across all regional Australia.

This demand has led to the Melbourne-Sydney air route being the fifth busiest route in the world today, by total passenger movements between cities[5] (Table 1). Ranked by seat capacity between individual airports, Australia holds the world ranking of fourth, 13th, and 36th busiest airport pairs for Melbourne-Sydney, Sydney-Brisbane and Melbourne-Brisbane respectively[6] (Table 2).

TABLE 1 **2012 global top 10 air travel busiest city pairs by passenger volume (measured in origin to destination journeys travelled)**[5]

Rank	Route		Passengers (million)
1	Jeju	Seoul	10.2
2	Sapporo	Tokyo	8.2
3	Rio de Janeiro	Sao Paulo	7.7
4	Beijing	Shanghai	7.2
5	Melbourne	Sydney	6.9
6	Osaka	Tokyo	6.7
7	Fukuoka	Tokyo	6.6
8	Hong Kong	Taipei	5.5
9	Okinawa	Tokyo	4.6
10	Cape Town	Johannesburg	4.4

FIGURE 2 **Australian regional passenger travel distribution (2010)**

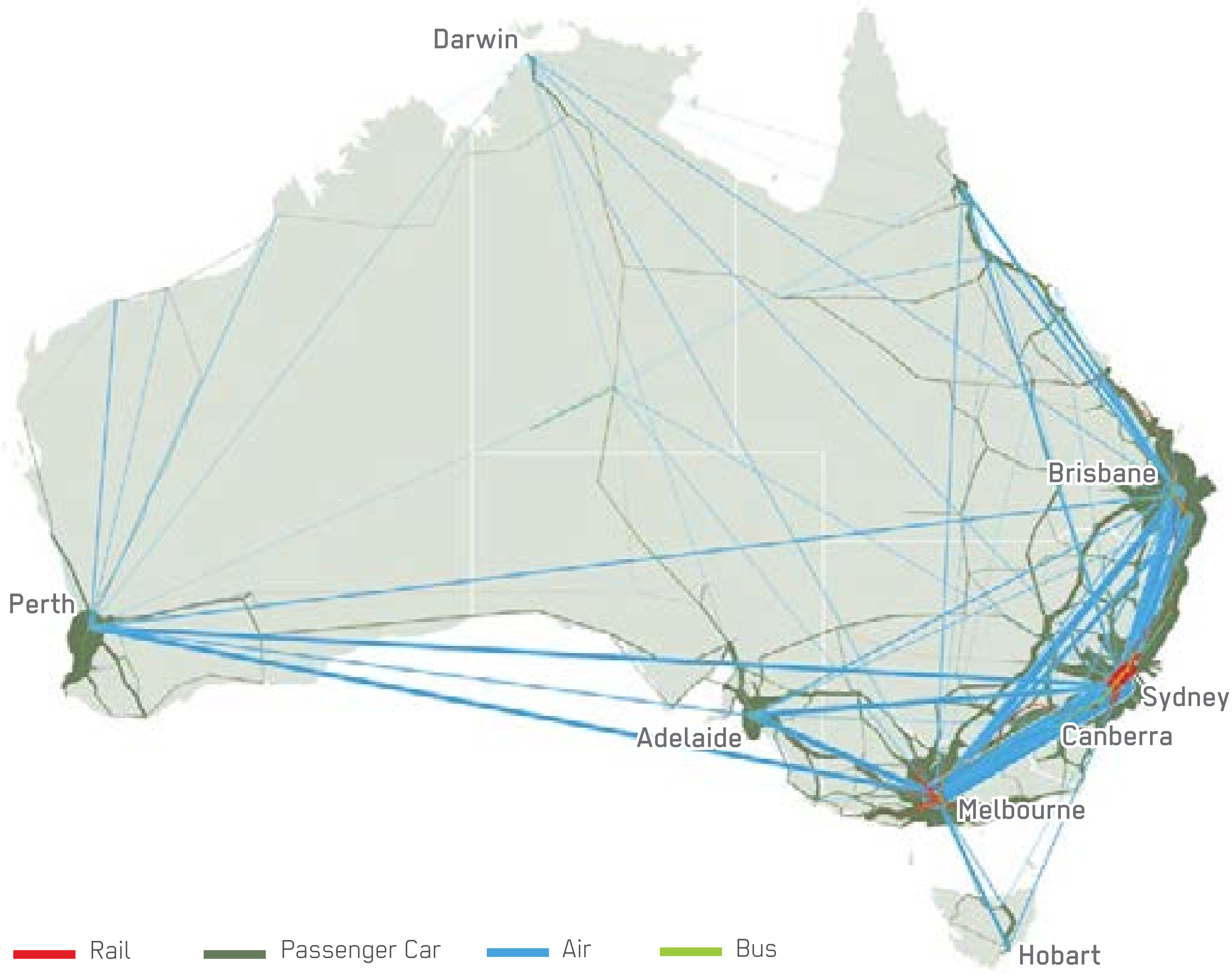
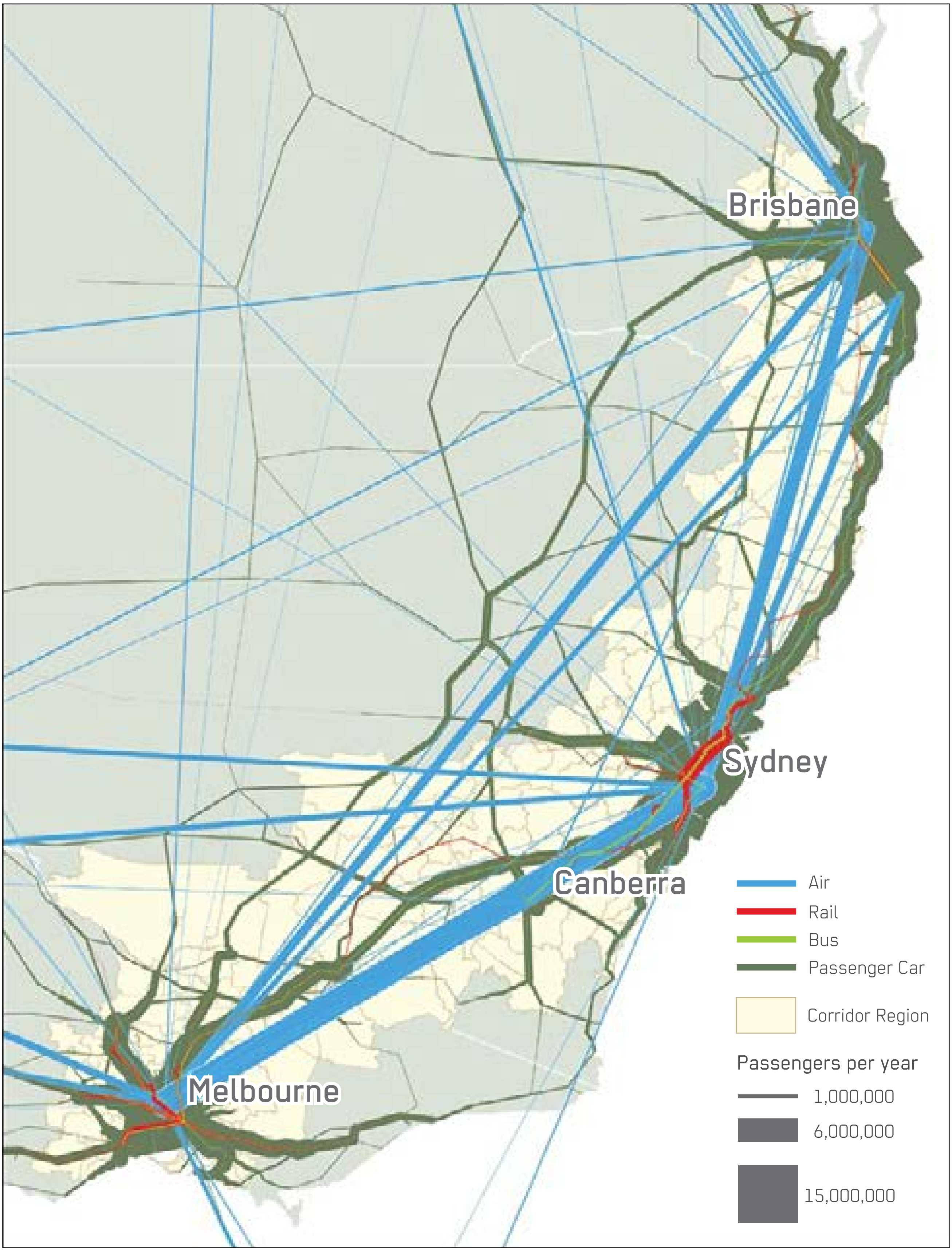


FIGURE 3 **South east Australia passenger travel distribution (2010)**



Considering only journeys where the travel time by HSR would be approximately equal to or better than by air (up to distances of 800 km), the current air traffic alone in this corridor would fill 100 high speed trains with a capacity of 500 seats every day.

Road trippers will not be surprised at the high concentration of traffic on the Hume Highway between Melbourne and Sydney and on the Pacific Highway between Sydney and Brisbane.

By stopping at many of the towns under these busy flight paths, HSR can deliver the regular and cost effective travel that city passengers already enjoy to regional centres that currently miss out. This characteristic of HSR travel is the reason it is a bridge between the service level of the car and the aircraft, and why it is an excellent fit for the nation's current travel profile.

TABLE 2 **2011 global top 50 air travel busiest routes by seat capacity**[6]

Rank	Airport code	Origin	Destination	Seats per week
1	HND-CTS	Tokyo	Sapporo	269,500
2	CJU-GMP	Jeju	Seoul	258,305
3	FUK-HND	Fukuoka	Tokyo	200,787
4	SYD-MEL	Sydney	Melbourne	172,629
5	HKG-TPE	Hong Kong	Taipei	146,014
6	HND-OKA	Tokyo	Okinawa	144,158
7	PEK-SHA	Beijing	Shanghai	142,520
8	DEL-BOM	Delhi	Mumbai	140,956
9	ITM-HND	Osaka	Tokyo	123,780
10	SIN-CGK	Singapore	Jakarta	112,640
11	JNB-CPT	Johannesburg	Cape Town	104,288
12	CGK-DPS	Jakarta	Denpasar	100,739
13	SYD-BNE	Sydney	Brisbane	96,648
14	SGN-HAN	Ho Chi Minh City	Hanoi	90,890
15	HKG-SIN	Hong Kong	Singapore	87,275
16	HKG-PVG	Hong Kong	Shanghai	86,616
17	SIN-KUL	Singapore	Kuala Lumpur	86,140
18	LAX-SFO	Los Angeles	San Francisco	84,263
19	CGK-SUB	Jakarta	Surabaya	83,738
20	HKG-BKK	Hong Kong	Bangkok	79,923
21	CGK-MES	Jakarta	Medan	78,758
22	CTU-PEK	Chengdu	Beijing	75,383
23	PEK-CAN	Beijing	Guangzhou	74,953
24	BKK-HKT	Bangkok	Phuket	74,836
25	CAI-JED	Cairo	Jeddah	74,414
26	JNB-DUR	Johannesburg	Durban	74,380
27	JFK-LAX	New York	Los Angeles	73,970
28	PEK-SZX	Beijing	Shenzhen	73,816
29	SDU-CGH	Rio De Janeiro	Sao Paulo	71,656
30	JED-RUH	Jeddah King	Riyadh	71,529
31	SZX-SHA	Shenzhen	Shanghai	70,556
32	JFK-LHR	New York	London	70,306
33	SIN-BKK	Singapore	Bangkok	69,790
34	MNL-CEB	Manila	Cebu	69,670
35	ORD-LGA	Chicago	New York	68,852
36	BNE-MEL	Brisbane	Melbourne	68,804
37	KOJ-HND	Kagoshima	Tokyo	68,787
38	DEL-BLR	Delhi	Bengaluru	68,700
39	CAN-SHA	Guangzhou	Shanghai	67,976
40	DXB-DOH	Dubai	Doha	67,588
41	PUS-GMP	Busan	Seoul	67,255
42	HKG-PEK	Hong Kong	Beijing	66,718
43	CGK-JOG	Jakarta	Yogyakarta	66,626
44	IST-ADB	Istanbul	Izmir	66,576
45	BKI-KUL	Kota Kinabalu	Kuala Lumpur	66,426
46	MTY-MEX	Monterrey	Mexico City	65,705
47	YVR-YYZ	Vancouver	Toronto	63,887
48	KUL-KCH	Kuala Lumpur	Kuching	63,845
49	CGK-UPG	Jakarta	Ujung Pandang	63,547
50	MAD-BCN	Madrid	Barcelona	63,305

Transport mode share of passenger travel

Although Australia has a very strong domestic aviation industry, travel by car has the highest share of current passenger journeys. As shown in Table 3, the share of passenger travel within the east coast corridor in 2010 was 58.9% car, 35.7% air, 1.9% bus and 3.5% rail, on a per passenger-kilometre basis.

TABLE 3 **Mode share of 2010 east coast corridor passenger travel**

Mode	Passengers (million)	Share	Pkm (billion)	Share
Car	246.7	85.8%	32.0	58.9%
Bus	5.2	1.8%	1.0	1.9%
Rail	13.6	4.7%	1.9	3.5%
Air	22.0	7.6%	19.4	35.7%
HSR	0.0	0.0%	0.0	0.0%
Total	**287.6**		**54.3**	

This is not surprising considering 85% of all journeys are less than 300 km (Figure 4) – a convenient distance for car travel. Beyond this distance, air travel begins to be used and is the dominant mode for journeys greater than 600 km.

Considering only the travel within the east coast corridor, a similar pattern is evident (Figure 5). The distribution of air travel is strongly tied to the availability of airports which accounts for some disturbance to the overall trend.

FIGURE 4 **Transport mode share relationship to journey length for all Australian regional travel in 2010**

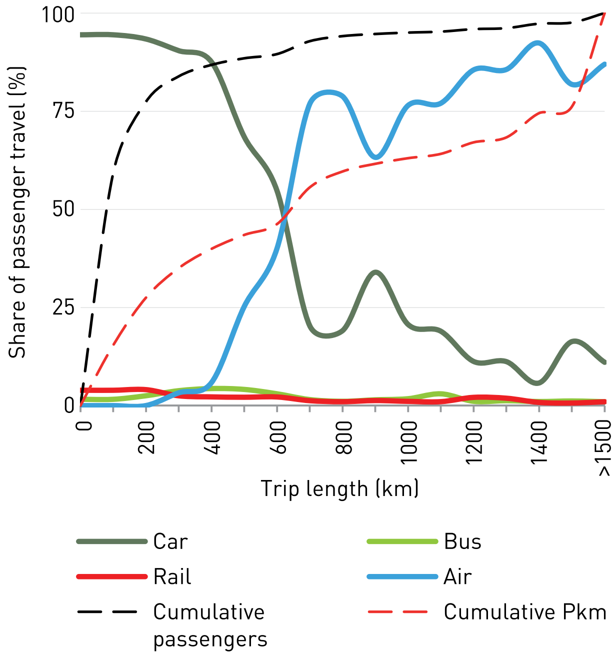
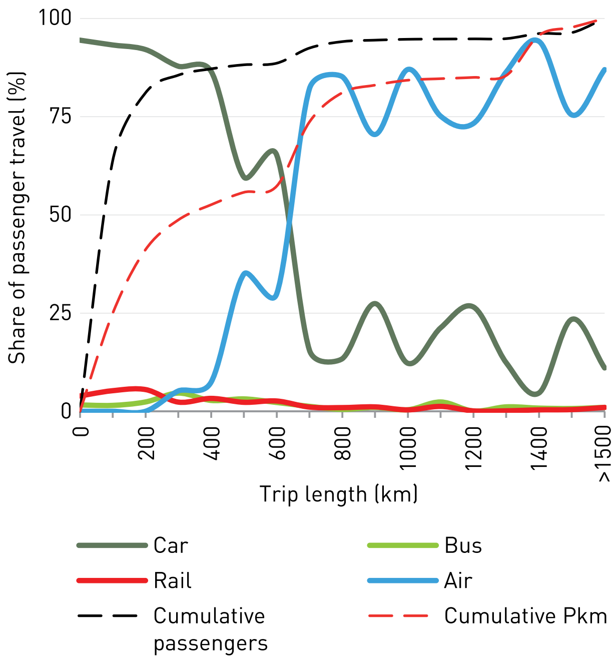


FIGURE 5 **Transport mode share relationship to journey length for east coast corridor regional travel in 2010**



Impact of HSR on passenger travel

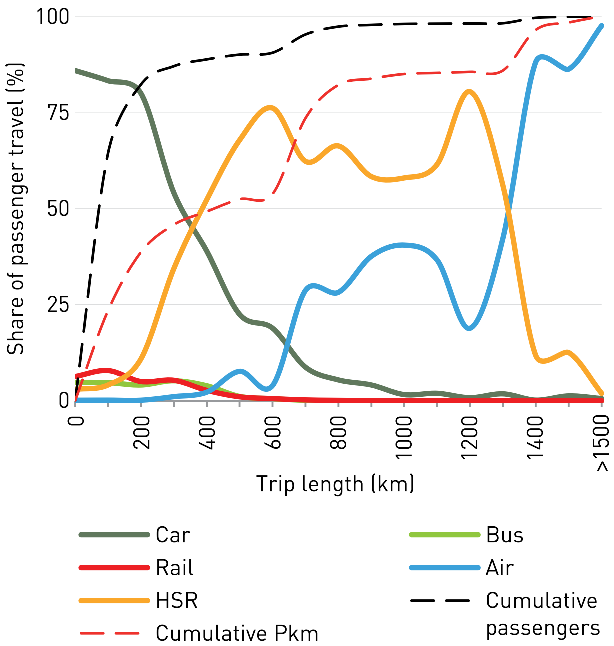
HSR is estimated to carry 68 million passengers in 2030 and dominate passenger share over much of the east coast corridor. This section summarises the results of the Regional Travel Model developed for this study, which analyses the impact of a Melbourne to Brisbane HSR network on Australia's travel patterns. It is further explained in Section 2.

Change in transport mode shares with HSR

When the option of HSR is made available, the mode share of passenger travel is estimated to experience a significant change. As Figure 6 shows, HSR begins to attract passengers when the journey is longer than 200 km. HSR becomes the dominant mode for journeys in the east coast corridor between 350 km and 1,300 km. For journeys greater than this, air travel remains the dominant mode.

HSR is competitive for journey distances between 200 km and 1,400 km. Importantly, this range covers 60% of the passenger kilometres travelled within the east coast corridor. This corresponds to approximately the same fraction (60%) of energy and emissions from travel in the corridor. Because of this performance window, HSR can contribute a great deal to lowering the carbon footprint of regional travel.

FIGURE 6 Estimated east coast corridor transport mode share relationship to journey length with HSR available in 2030



The share of both passengers and passenger kilometres within the corridor is shown in Table 4. The introduction of HSR significantly reduces the share of car and air passenger travel compared with the current levels given in Table 3.

When HSR patronage is compared with all travel across the country, it is still a major factor even though the network is confined to the east coast (Figure 7). Due to the popularity of travel between Sydney and both Melbourne and Brisbane, HSR would be the dominant transport mode in the country for journey lengths in the vicinity of 800 km.

TABLE 4 Mode share of 2030 east coast corridor passenger travel with HSR available

Mode	Passengers (million)	Share	Pkm (billion)	Share
Car	340.3	72.0%	37.2	41.2%
Bus	19.4	4.1%	2.2	2.4%
Rail	29.6	6.3%	3.0	3.4%
Air	20.0	4.2%	20.3	22.5%
HSR	63.2	13.2%	27.6	30.5%
Total	**472.6**		**90.3**	

FIGURE 7 Estimated total Australian regional transport mode share relationship to journey length with HSR available in 2030

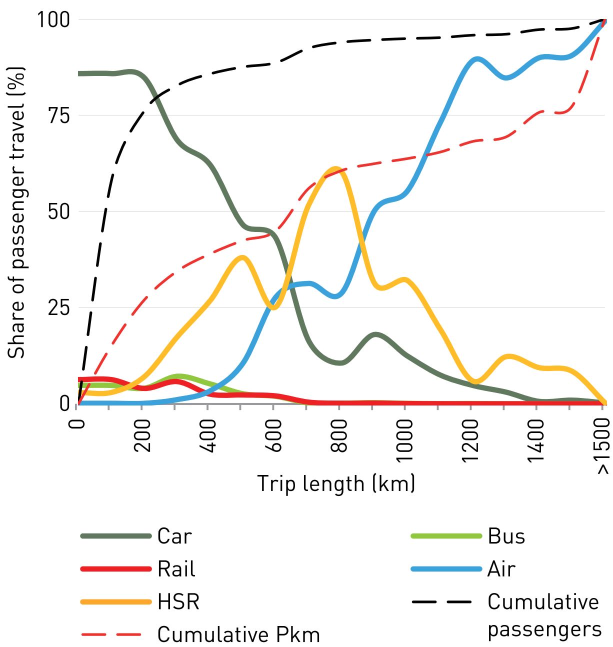
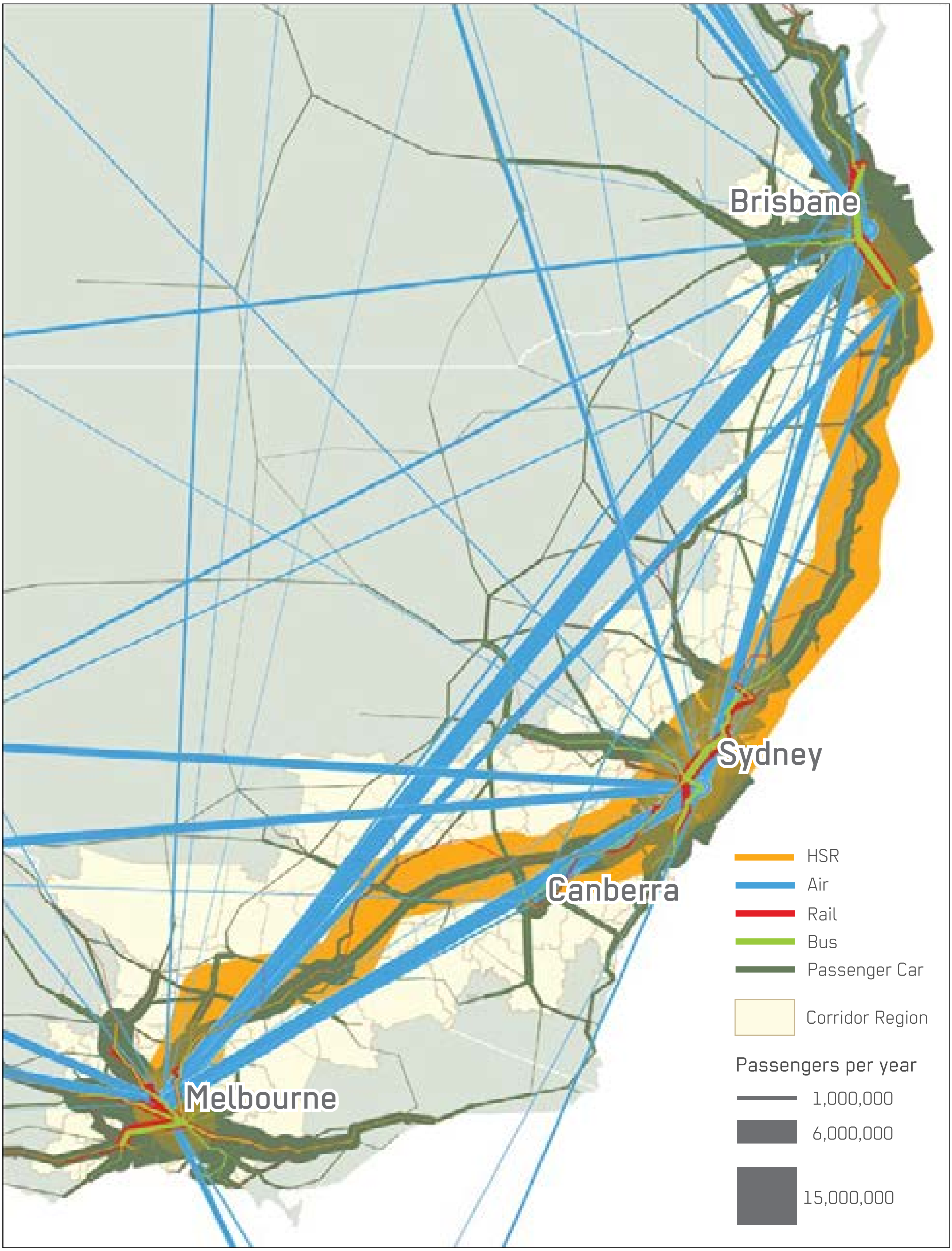


FIGURE 8 **Estimated 2030 passenger traffic distribution across south east Australia with HSR available**



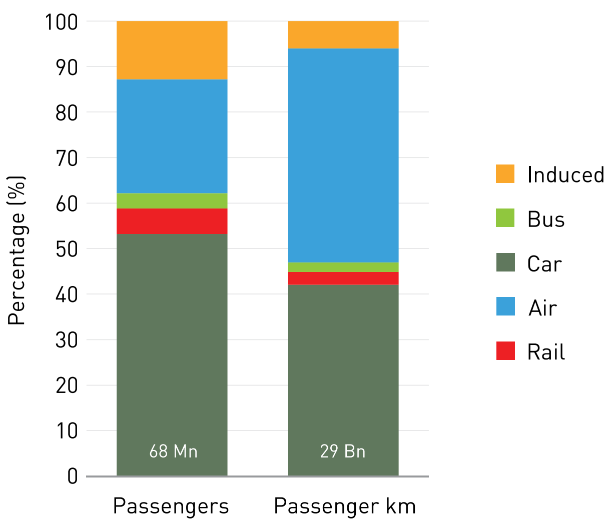
The scenario of passenger travel in the year 2030 with HSR available was estimated with the Regional Travel Model and the distribution of traffic across south-east Australia is shown in Figure 8. The model indicates that HSR will be a major service provider along the full corridor between Melbourne to Brisbane.

When considering the effect of HSR in Australia it is important to separate the added travel HSR would encourage from the redistribution of current travel. HSR can generate new travellers by improving the access to places relative to current levels.

The major cities of this country are well serviced by air travel, allowing fast and cost effective travel to most other cities and large towns. However, many places in the HSR corridor are not well connected by air services and much of the travel to and from these places is by road. With the introduction of the HSR service, travel times to and from towns near stations will be significantly reduced. The likely effect of this reduction in travel time is an increase in the number of people willing to take the journey. This is referred to as induced demand, and it generates passenger movements beyond what would be expected with no major change to the transport system.

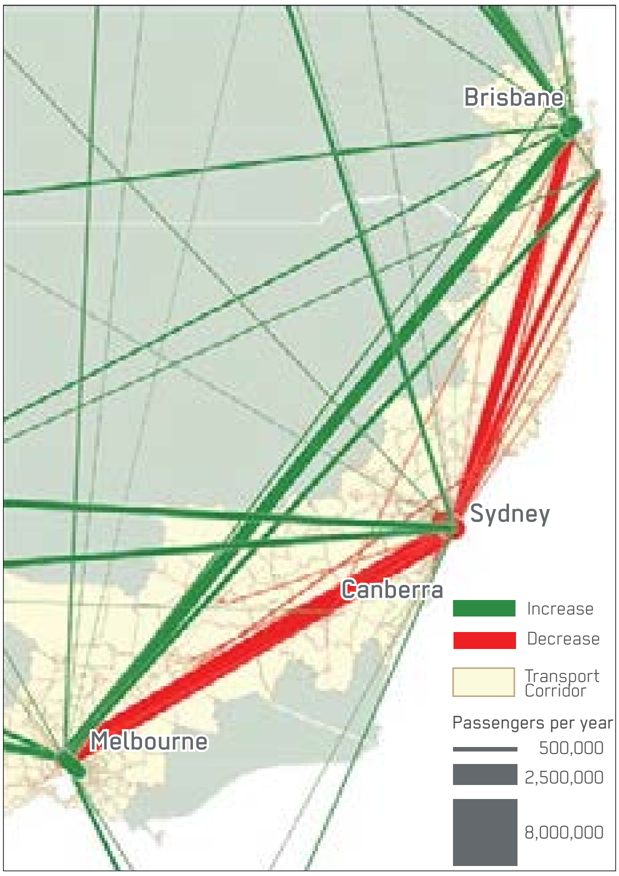
The new travellers from induced demand account for 13% of the 68 million HSR passengers and 6% of passenger kilometres travelled on the HSR service (Figure 9). The remaining 87% of passengers estimated to travel by the HSR service would be diverted from the services currently available. Around half of the HSR passengers would be diverted from the car and one quarter from current air services. Passengers diverted from bus and rail services combined would contribute 9%. As journeys by air are longer than by car, passenger kilometres are predominantly sourced from air (47%) followed by car (42%).

FIGURE 9 **Source of HSR passengers**



The change in air and road traffic is shown in Figure 10 and Figure 11. These figures show the difference in 2030 in passenger traffic with HSR available compared to 2012 levels. The figures show that while most parts of the transport network will experience substantial increases in traffic (green), HSR will cause the main north-south highways and flight paths to carry less traffic in 20 years' time than they do today (red).

FIGURE 10 **Change in air passenger travel from 2012 to 2030 with HSR**



The most substantial change is seen at Sydney airport. While Melbourne and Brisbane airports are estimated to see an increase in 2030, many passengers to these two major destinations from Sydney will be carried by HSR. Sydney airport is estimated to see three million fewer domestic passengers in 2030 than it did in 2012. That translates to approximately 82 fewer daily aircraft movements in 2030, than the average of 853 daily aircraft movements[7].

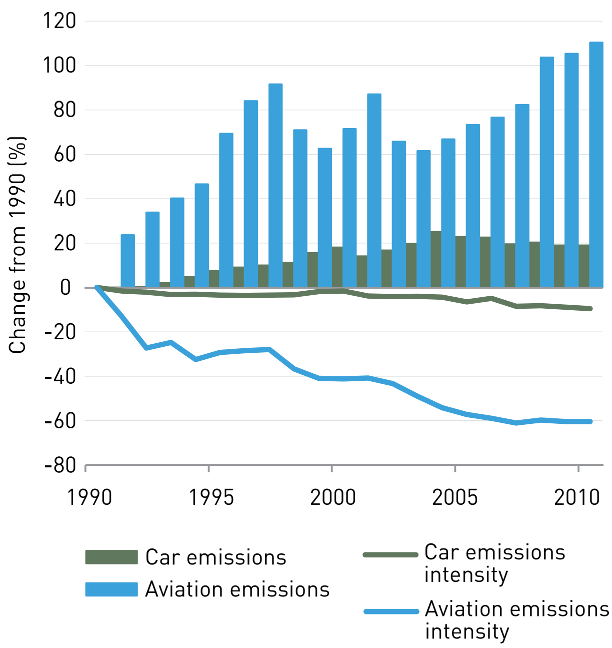
FIGURE 11 Change in car passenger travel from 2012 to 2030 with HSR

Change in transport emissions

Transport in Australia is almost entirely dependent on fossil fuel energy and the bulk of this is oil-based fuel. Though our current transport system is becoming more energy efficient, growth in travel is maintaining an increase in annual emissions. Figure 12 shows the relative change in absolute emissions as well as emissions intensity of passenger cars and aviation since 1990 according to the National Greenhouse Gas Inventory (NGGI)[3].

While new passenger cars have made significant improvements in fuel efficiency, the improvement of the Australian vehicle fleet as a whole lags behind considerably due to the gradual replacement of older vehicles with inferior performance. This trend is assumed to continue with no significant regulation or targets in place.

FIGURE 12 Relative change in passenger car and aviation emissions as well as emissions intensity (CO_2-e per Pkm) since 1990[3]



Great improvements are seen in aviation emissions intensity from 1990 to 2007. It is likely that many factors have contributed to this beyond technological improvements. Disciplined use of aviation fuel is a result of increasing market competition and higher fuel prices. With respect to new aircraft efficiency improvements, the same lag phenomenon will affect the Australian aviation fleet but to a much lesser extent due to the smaller size of the aircraft fleet. According to the International Civil Aviation Organisation (ICAO), technology and operational efficiency improvements make aviation emissions reductions of 2% per year achievable up to 2020[8]. Savings beyond this will require further measures such as alternative fuels and regulation.

It is worth noting here that the NGGI uses the Kyoto Protocol Accounting Framework which does not incorporate the radiative forcing amplification of combustion emissions understood to occur at cruise altitude. This converts to approximately 1.9 times the radiative forcing of the equivalent emissions at ground level[9]. Aviation emissions in this study have been calculated using the UK Department of Environment and Climate Change (DECC) guidelines which do account for the additional radiative forcing caused by combustion emissions at high altitude[10].

HSR offers the possibility of transporting a large number of passengers across the east coast corridor using renewable energy. The expected energy consumption of the HSR system, operating at full capacity, in 2030 is approximately equal to that consumed in 2012 under the Australian Government accredited GreenPower initiative[11].

By subscribing to a renewable energy supply either through the GreenPower initiative or by direct power purchasing agreements, the HSR system can accelerate Australia's renewable energy implementation.

The transport mode emission intensities used for this study are shown in Table 5. These values apply to the year 2012. An annual rate of improvement has been included for both car and air to reflect the continuing development of these transport modes. HSR is assumed to run on renewable energy allowing no improvement in emission intensity. Improvement for both bus and rail was disregarded due to the relatively small contribution by these modes.

With HSR operating on renewable energy in 2030, it is expected to reduce the emissions of regional travel within the east coast corridor by approximately 28%. Australia's total regional travel is expected to exceed 26 million tonnes of CO_2-e in 2030. The reduction in emissions resulting from HSR, totalling 3.5 million tonnes of CO_2-e for the year, lowers the carbon footprint of Australia's total regional travel, by 13.7% (Figure 13).

With the construction of the HSR infrastructure estimated to generate 13 million tonnes CO_2-e, the operation of the network would offset this within five years. Beyond this point emission reductions accumulate year on year to save 150 million tonnes of CO_2-e compared with the business-as-usual trajectory after 40 years of operation (including construction emissions).

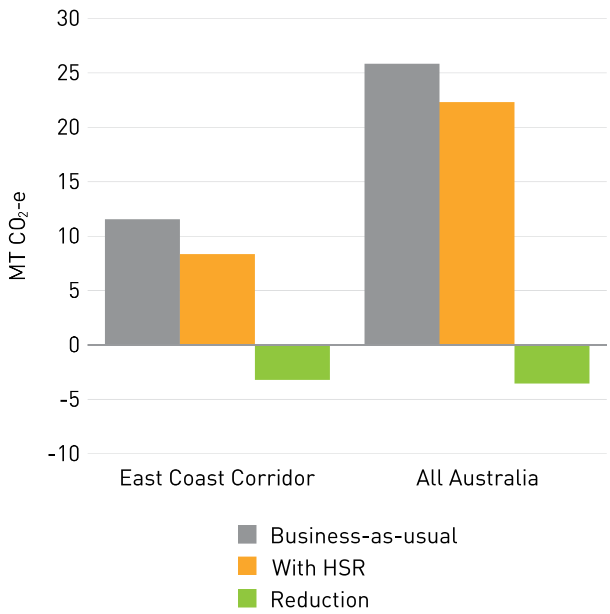
If all passengers travelling by the mass transit modes of bus, rail and air switched to HSR where it services their journey, emissions from these passengers would be reduced to zero and total regional travel emissions would decrease by around 50% (further detail of this is available in Appendix A). The remaining travel demand, still met by car travel, is characterised by journeys not suited to replacement by this HSR proposal. To pursue further emission reductions within the east coast corridor and elsewhere in Australia will require a more comprehensive set of alternatives for meeting this remaining travel demand, and reducing emissions from the vehicle fleet itself. Investigation of these options will be part of future work of the Zero Carbon Australia Transport Project.

Train crossing Viaducto Martin Gil, Spain, with wind turbines in background PHOTO: DAVID GUBLER

TABLE 5 **Emissions intensity of transport modes for year 2012 and annual reduction rates assumed**

Mode	Tonnes CO_2-e per million Pkm	Annual improvement in emission intensity
Car	158	0.5%
Bus	27	0%
Rail	19	0%
Air		
← 500km	310	2.0%
500-3,700km	180	2.0%
→ 3,700km	210	2.0%
HSR	0	0%

FIGURE 13 **Change in Australia's total regional passenger transport emissions for 2030 with HSR**

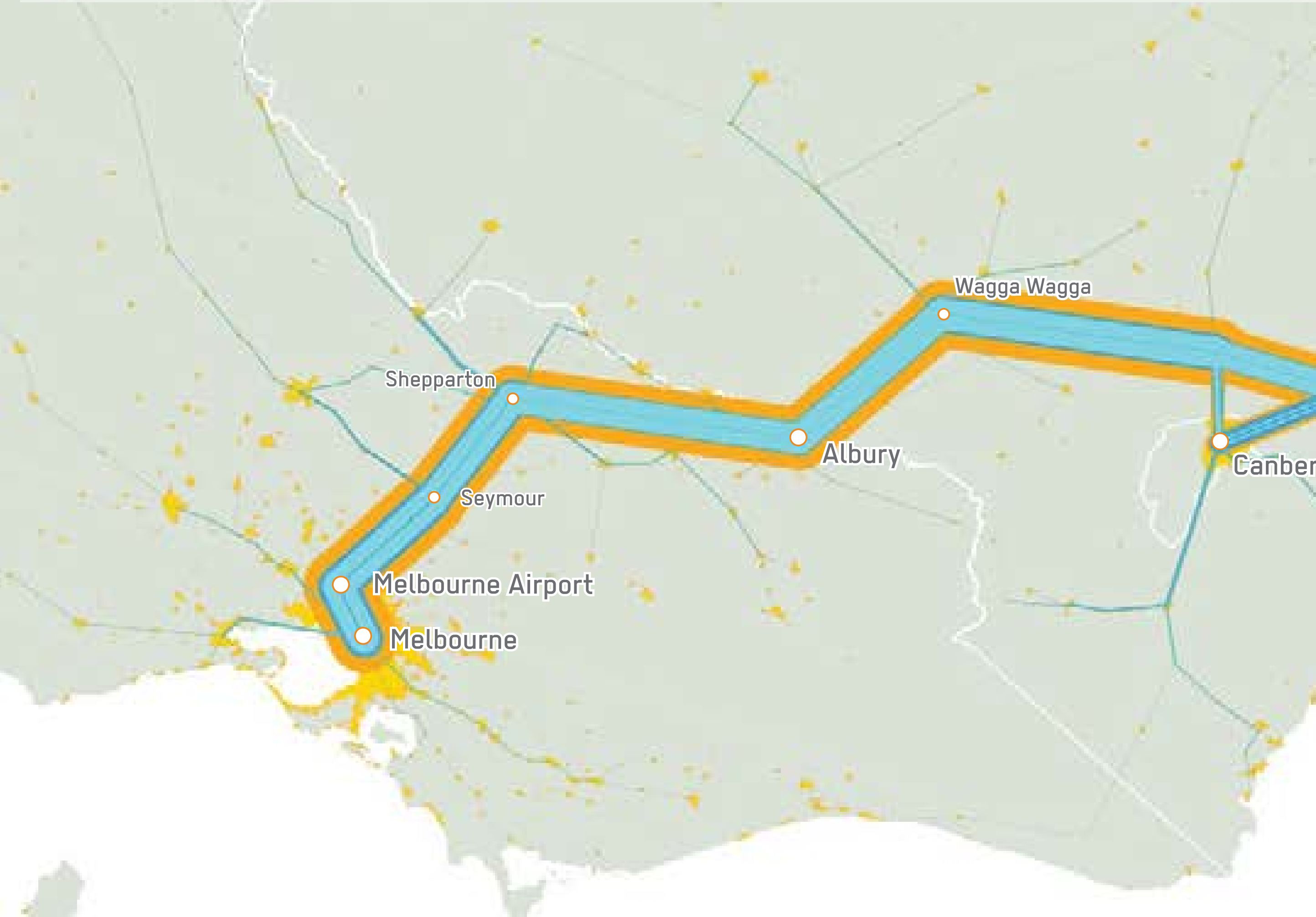


HSR demand

FIGURE 14 **Distribution of HSR passenger groups in 2030**

TABLE 6 **Travel matrix of 2030 HSR passengers (thousand)**

	Melbourne	Seymour	Shepparton	Albury	Wagga Wagga	Canberra	Goulburn	Moss Vale	Sydney	Central Coast	Newcastle
Melbourne	-	510	1,096	584	207	805	18	267	4,606	123	189
Seymour	510	-	40	17	4	17	-	2	25	-	4
Shepparton	1,096	40	-	90	45	77	3	29	203	22	20
Albury	584	17	90	-	86	103	10	62	245	32	70
Wagga Wagga	207	4	45	86	-	217	16	117	463	41	63
Canberra	805	17	77	103	217	-	75	265	1,735	101	198
Goulburn	18	-	3	10	16	75	-	18	128	14	17
Moss Vale	267	2	29	62	117	265	18	-	1,040	62	97
Sydney	4,606	25	203	245	463	1,735	128	1,040	-	2,191	1,775
Central Coast	123	-	22	32	41	101	14	62	2,191	-	330
Newcastle	189	4	20	70	63	198	17	97	1,775	330	-
Taree	33	-	2	1	18	20	5	15	334	37	99
Port Macquarie	36	-	10	9	53	41	15	15	625	59	141
Coffs Harbour	26	-	1	8	25	31	1	30	489	52	118
Grafton	22	-	8	1	4	25	-	22	216	51	81
Lismore	24	-	6	5	4	48	-	19	436	30	94
Gold Coast	162	10	49	23	16	94	13	78	1,505	117	214
Brisbane	285	11	90	50	48	255	8	133	2,886	129	333
Total	**8,993**	**640**	**1,792**	**1,395**	**1,428**	**4,109**	**341**	**2,272**	**18,901**	**3,392**	**3,842**



Taree	Port Macquarie	Coffs Harbour	Grafton	Lismore	Gold Coast	Brisbane	**Total**
33	36	26	22	24	162	285	**8,993**
-	-	-	-	-	10	11	**640**
2	10	1	8	6	49	90	**1,792**
1	9	8	1	5	23	50	**1,395**
18	53	25	4	4	16	48	**1,428**
20	41	31	25	48	94	255	**4,109**
5	15	1	-	-	13	8	**341**
15	15	30	22	19	78	133	**2,272**
334	625	489	216	436	1,505	2,886	**18,901**
37	59	52	51	30	117	129	**3,392**
99	141	118	81	94	214	333	**3,842**
-	82	58	35	31	73	53	**897**
82	-	96	39	128	97	110	**1,556**
58	96	-	129	92	197	220	**1,575**
35	39	129	-	107	89	175	**1,003**
31	128	92	107	-	144	219	**1,386**
73	97	197	89	144	-	3,385	**6,266**
53	110	220	175	219	3,385	-	**8,390**
897	**1,556**	**1,575**	**1,003**	**1,386**	**6,266**	**8,390**	**68,177**

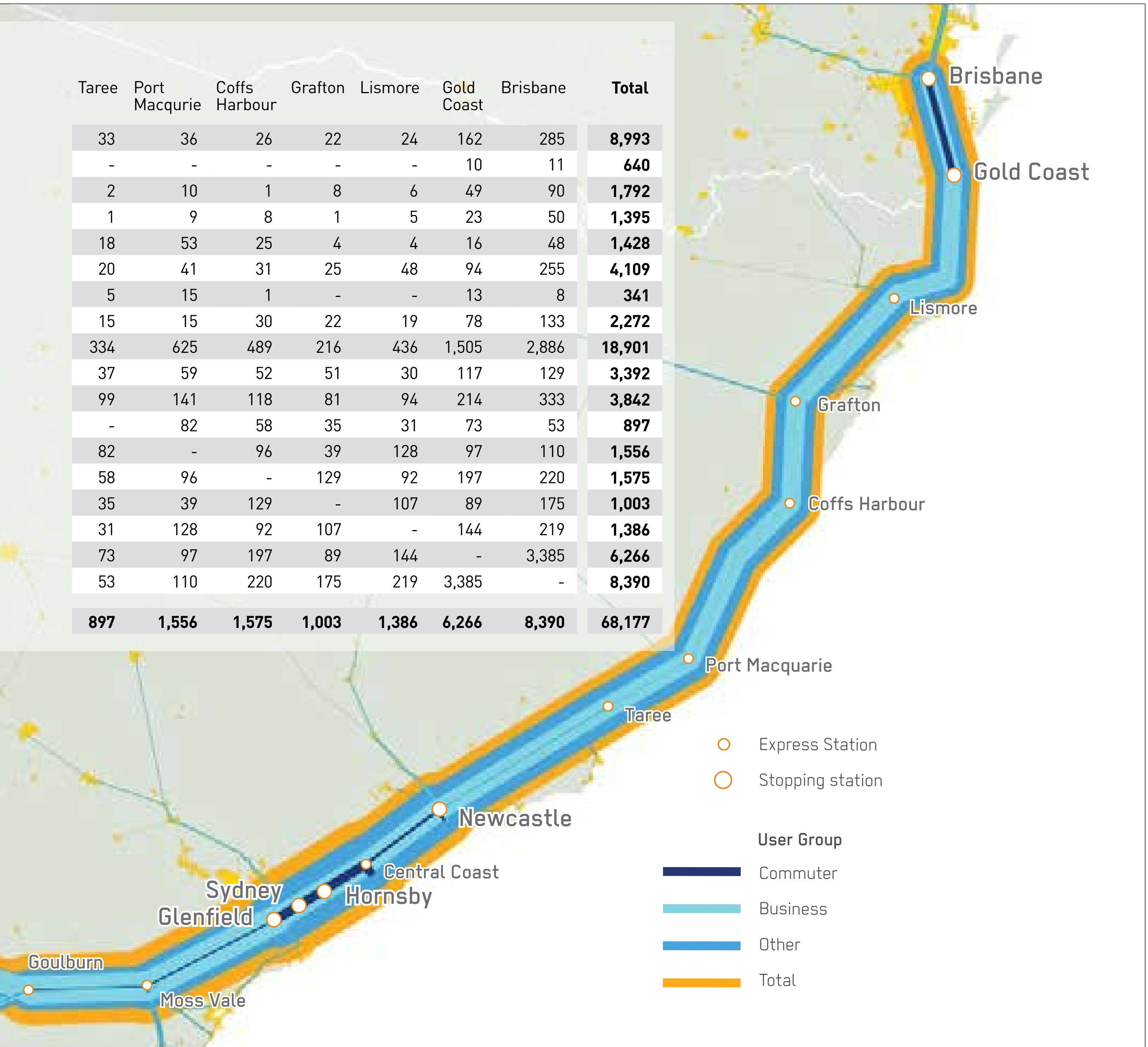
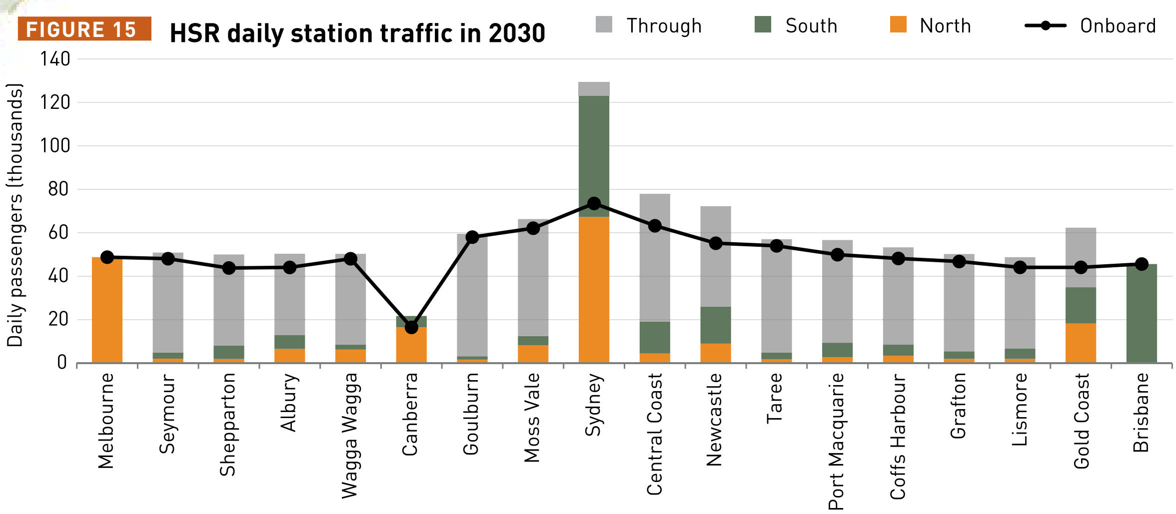
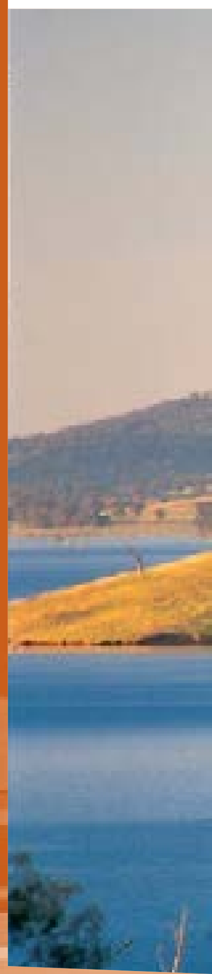


FIGURE 15 **HSR daily station traffic in 2030**





View of Lake Hume from Table Top, Albury PHOTO: ALBURYWODONGAAUSTRALIA.COM

2. Regional Travel Model

This section contains:

- **An overview of the Regional Travel Model developed for this study to analyse where and how people travel in Australia now and in the future**
- **HSR fare structure**
- **Details of journey simulation approach**

Overview

In order to understand the effects of a change to the Australian transport system such as HSR, a good understanding of the existing system performance and travel behaviour is needed. The Regional Travel Model was developed for this study to quantify where and how Australians travel now and in the future. This model considers 12,000 unique journeys across Australia to estimate the number of passengers taking each journey in the future and the mode of transport they are likely to use based on current behaviour. By evaluating the trade-off between time and cost (among other factors) for each travel option, the likely response to a new option is generated.

Further detail is available in Appendix B.

Current travel

The best information on where and how passengers move across Australia comes from the National Census for work commuting and the National Visitor Survey for all other purposes. The Census is a reliable indicator because all households in the country contribute information about where they live, where they work and how they choose to get there.

The National Visitor Survey samples the recent non-commuting travel of 250,000 people each year and is carefully scaled-up to reflect the movements of the entire population. This survey includes information about where we visit, why we choose to visit these places and how we travel there.

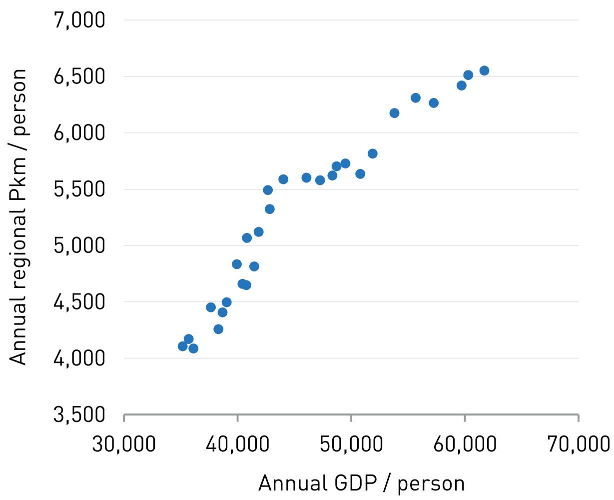
The Census and the National Visitor Survey together provide the best indication of the distribution of travel across regional areas of Australia.

Future travel

Travel activity in Australia has increased steadily over the past 30 years. Since 1980, non-metropolitan passenger kilometres have increased by 47% on a per person basis[4] as can be seen in Figure 16.

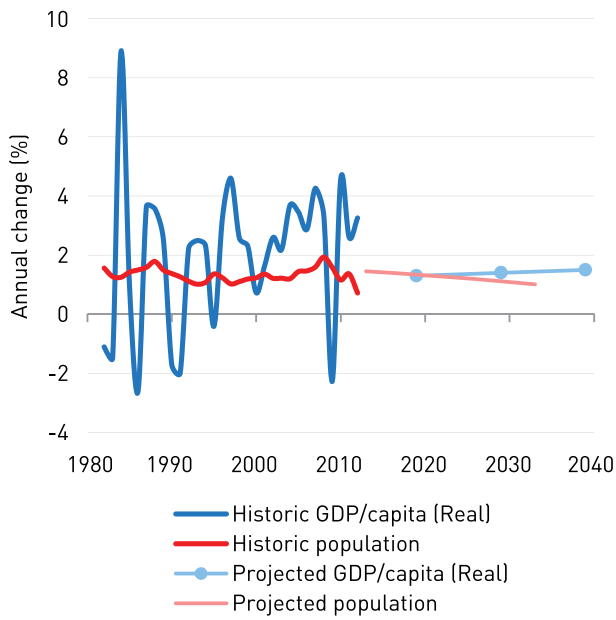
The growth experienced in passenger travel over the past 30 years is the result of both an increasing population and increasing wealth. As shown in Figure 17, this growth in passenger travel is likely to continue in line with expected, steady increases in Australia's population and incomes over the next 20 years and beyond[12, 13].

FIGURE 16 Average annual regional passenger kilometres travelled per person (1980-2010) [4,14,15]



Adding to this increase in passenger travel is the effect of induced travel in response to HSR's improvement to current transport options. This effect has been included in the Regional Travel Model by modifying the travel projection model used by the Federal Transport Department (Bureau of Infrastructure, Transport and Regional Economics, BITRE)[17] to consider any changes in journey time and cost.

FIGURE 17 Historic and projected annual change in GDP/capita and population[12–16]



The time and cost of travel

Anybody planning a trip will be aware of the trade-offs in how they choose to travel from one place to the next. The transport options to choose from are referred to as modes, and in this study include car, bus, conventional rail, air and HSR. There are often many things to consider: the price of a ticket, the waiting time before departure or after arrival, getting around after arrival, travel time, arrangements for children, disability access, safety... The list can go on and on. While it is possible to estimate the time and cost of a journey, many other considerations cannot be quantified directly. To account for these important factors, the evidence of current travel behaviour is used to best match the inclination to use one mode in favour of others when the travel time and cost may be equal.

There are many reasons why people choose to travel: to holiday, visit friends or relatives, a meeting with a client, get to work and more. In this study, passengers have been divided into three categories reflecting each group's travel purpose: work commuters, business travellers, and all others. These three groups typically consider the time and cost of travel differently. By treating these groups separately we can estimate more accurately the mode a passenger is likely to choose for their journey. The time and cost composition varies for different modes as can be seen in Table 7.

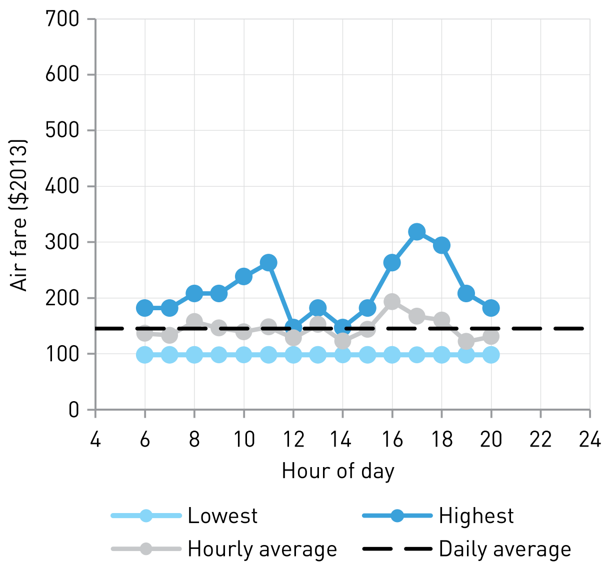
Travel time is converted into a time cost by applying a value ($/hr) to the time spent travelling. The value of time varies between user groups. Business travellers generally have higher constraints on their time, often making day trips, and as a result have a higher value of time than a tourist on a two-week holiday. Although car travel does not incur a fare in most cases, the equivalent cost is considered to be the operating cost which is shared by the vehicle occupants. Table 8 shows the factors contributing to the cost of travelling by car for each of the three passenger groups. For decision-making purposes only the cost of fuel consumed[18] is considered by most travellers. Business travellers often factor some of the expense associated with wear and tear. The vehicle occupancies shown are the average occupancy rate from Census[19] and National Visitor Survey[20] data.

For bus, rail and air fares, a survey of current ticket prices was conducted on numerous routes[21–30]. This was used to approximate the fare pricing rate proportional to the distance travelled. Air fare evidence shows a high upfront cost with a relatively small increase with journey distance. This is typically due to the disproportionate fuel burn associated with take-off and landing as well as the aircraft down time during ground activity (passenger boarding, taxiing and preparation cycles). The results of the air fare survey for Sydney-Canberra and Melbourne-Brisbane flights are shown in Figure 18 and Figure 19. These air fares cover the distance range of the east coast corridor. The trend observed has been represented by an upfront flag fall combined with a linear per kilometre rate. This is shown in Figure 20 for business travellers and Figure 21 for other travellers.

TABLE 7 **Factors affecting fare and time-related costs modelled for each mode**

Mode	Fare related costs		Time-related costs	
Car	Operating cost	Occupants	Travel time	
Bus	Bus fare		Travel time	
Rail	Train fare		Travel time	
Air	Air fare	Transfer/ parking	Flight time	Transfer/ connecting time
HSR	HSR fare	Transfer/ parking	Train time	Transfer/ connecting time

FIGURE 18 **Sydney–Canberra daily air fares (July-December 2013)**[30]



Because HSR is not subject to the same operating penalty at stops experienced by aircraft for take-off and landing, the flag fall cost may be significantly lower. This was set to be similar to current rail fares of similar length, making short journeys by HSR more competitive with land based modes (car, bus and rail). The fare pricing rate for HSR is based on the relative cost with air ticket prices from a survey of international city pairs serviced by both air and HSR as shown in Table 10. As shown in Figure 20 and Figure 21, a linear rate was adopted intercepting the flag fall price and the average relative fare price applied to air fares at the mid-point of the HSR distance range (approximately Sydney to Brisbane).

A transfer/parking cost has been estimated to be $30. This cost item is an average of parking, taxis, shuttle bus transfers, car hire or any other variation of how passengers choose to connect to and from terminals. In the case of air travel it has been assumed that this applies to both ends of a journey ($60 in total) and one end of a HSR journey due to the convenient location of HSR stations.

A summary of the 2012 fare structure for each of the modes considered in this study is shown in Table 9. Fares in future years change in proportion to projected changes in energy prices and are detailed in Appendix B.

FIGURE 19 **Melbourne–Brisbane daily air fares (July-December 2013)**[30]

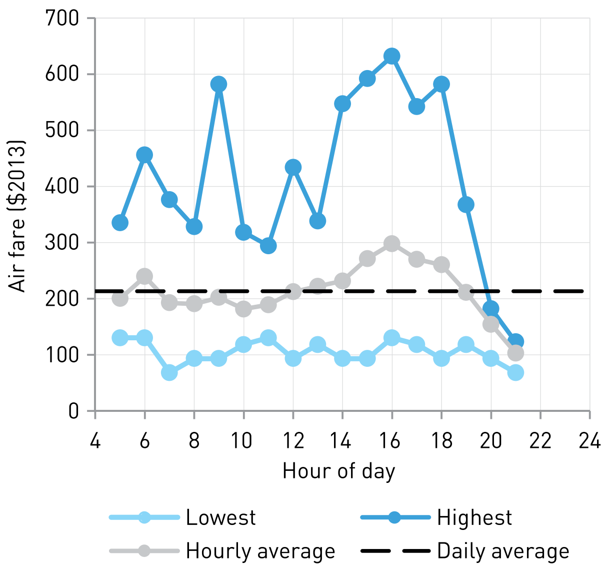


TABLE 8 **Car passenger vehicle operating cost factors**

	Fuel price ($/L)	Fuel cons. (L/km)	Wear ($/km)	Operating cost ($/km)	Vehicle occupancy	Passenger fare ($/km)
Commuter	1.523	0.11	0.00	0.168	1.1	0.153
Business	1.523	0.11	0.052	0.219	1.2	0.183
Other	1.523	0.11	0.00	0.168	2.5	0.067

TABLE 9 **Transport mode fare cost per kilometre for year 2012**

Mode	Commute ($/km)	Flag fall ($)	Business ($/km)	Flag fall ($)	Other ($/km)	Flag fall ($)
Car	0.153	—	0.183	—	0.067	—
Bus	0.170	—	0.210	—	0.210	—
Rail	0.130	—	0.210	—	0.160	—
Air	—	—	0.170	220	0.080	120
HSR	0.112	14	0.250	30	0.160	20

FIGURE 20 **Business passenger air fare and HSR Premium fare price structures. Surveyed air fare range is shown by bars. The low end is flexible economy and the high end is business class.**

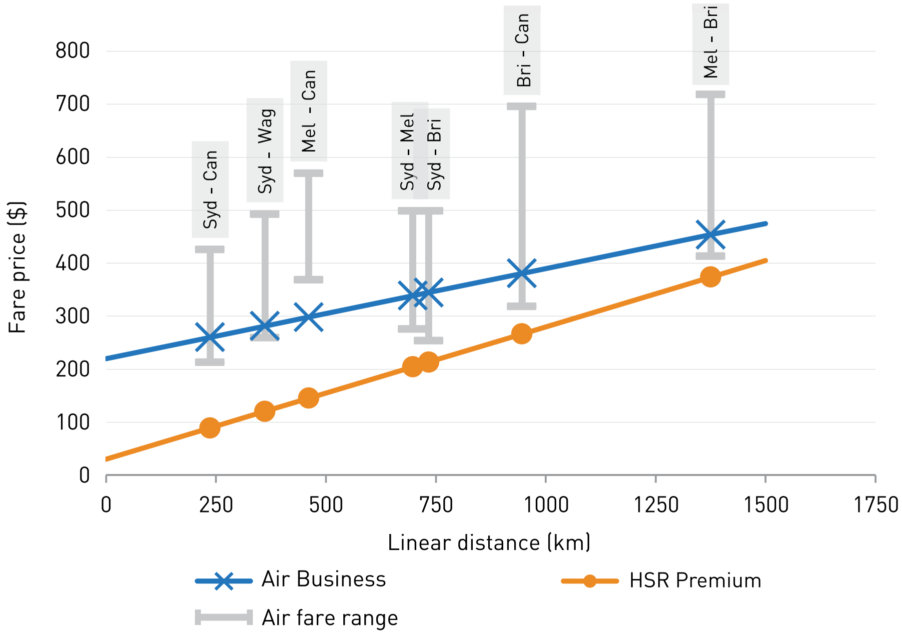


FIGURE 21 **Other passenger air fare and HSR Economy fare price structure. Surveyed air fare range is shown by bars. The low end is internet discount and the high end is flexible economy.**

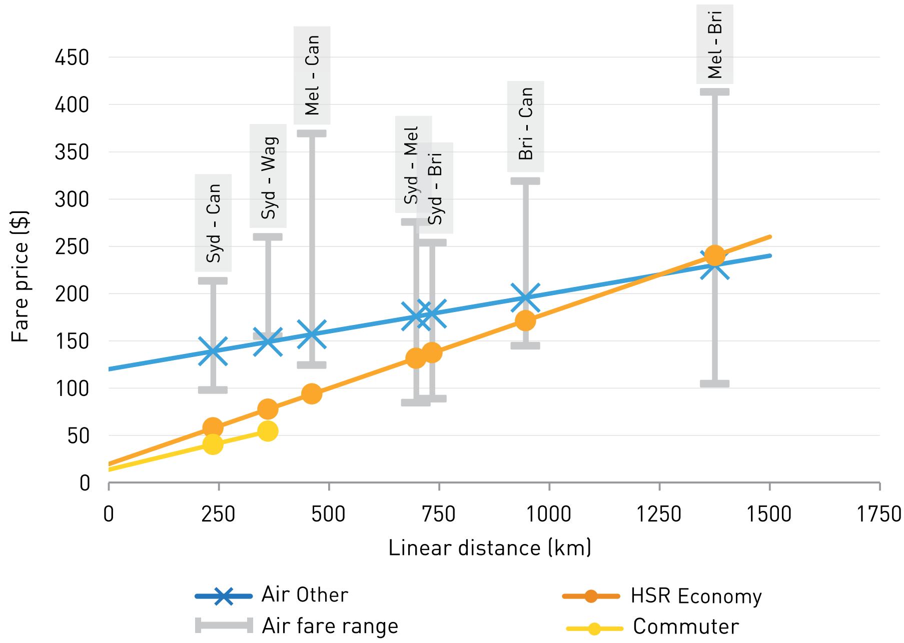


TABLE 10 **HSR and air fare comparison**[31-40]

		HSR			Air			Relative price	
Origin	**Destination**	**Operator**	**2nd Class**	**1st Class**	**Operator**	**Econ.**	**Business**	**Other**	**Business**
London	Paris	Eurostar	£107	£276	BA	£158	£339	67.7%	81.4%
Berlin	Köln	DB	€49	€117	Air Berlin	€49	€249	100.0%	47.0%
Madrid	Sevilla	Renfe	€85	€127	Vueling	€84	€332	101.2%	38.3%
Paris	Marseille	SNCF	€72	€96	AF	€98	€304	73.5%	31.6%
Tokyo	Osaka	JR	¥8,510	¥10,180	ANA	¥12,170	¥21,370	69.9%	47.6%
Tokyo	Hiroshima	JR	¥11,340	¥14,140	ANA	¥16,170	¥26,670	70.1%	53.0%
							Average	**80.4%**	**49.8%**

Traffic assignment

In order to simulate journeys taken around the country it was necessary to construct a model of Australia's regional transport network. This task was undertaken in partnership with the German Aerospace Centre (DLR). Australia's major roadways and ferries (Figure 22), railways (Figure 23), and flight paths (Figure 24) have been included along with travel times and speeds. The modelled network connects 99% of the population living in towns across the country. An overview of the network model is given in Table 11 and Table 12.

The combined passenger movements provided by the Census and National Visitor Survey include almost 42,000 unique journey combinations. This was processed to remove journeys with low passenger levels (less than 1,000 passengers annually) which reduced the unique combinations substantially while still accounting for 84% of passenger movements. These remaining passenger movements were the basis for all simulations throughout the network.

By calculating the fastest pathway from a journey's origin to destination – much like satellite navigation provides us with directions – the sequence of each journey can be approximated. By combining the passengers for all journeys, the traffic on every part of the network can be approximated. The journey sequence shown in Figure 25 is the fastest pathway for the case study from Parkes, New South Wales to Toowoomba, Queensland.

TABLE 11 **Network statistics**

Network	Australia	Urban	Model
Population	19.8 Mn	17.9 Mn	17.5 Mn
Towns	1,752	-	1,125
Road km	-	-	54,000
Flight pairs	-	-	88
Rail km	-	-	15,400
Unique journeys			1.27 Mn

TABLE 12 **Passenger data statistics**

Passenger Data	Ref Data	Model	
Unique journeys	41,874	12,952	31%
Journeys	530 Mn	445 Mn	84%
NVS Samples	592,782	478,348	81%

FIGURE 22 **Road and ferry network**

FIGURE 23 **Rail network**

FIGURE 24 **Flight network**

Journey case study: Parkes to Toowoomba

This case study presents a journey between two of Australia's regional towns. The modelled journey segments are captured, demonstrating the accumulation of travel time and cost. Actual costs for this particular journey are compared to the costs produced by the generic costing structures calculated in the Regional Travel Model, detailed earlier. The generic costing—shown in **bold**— represents the average, which will in some cases involve more than one member of a travelling group sharing costs.

Patty is an agricultural engineer who lives in Parkes and has been invited to speak at the University of Southern Queensland in Toowoomba. The university has offered to cover her travel costs so Patty decides to take whatever is the fastest option. In this case it is by plane and includes two flight legs. She books the flexi-saver fares online in case her presentation is rescheduled:

Dubbo to Sydney

- Actual ticket price $310
- **Estimated price**
  $220 flag fall + 309 km x $0.17/km = $273

Sydney to Brisbane

- Actual ticket price $289
- **Estimated price**
  $220 flag fall + 753 km x $0.17/km = $348

Patty leaves home early in the morning, at 6:37 am exactly, in order to catch the only flight from Dubbo, the nearest airport, that will allow her to reach Toowoomba before midnight. After tossing her hastily packed overnight bag into her car Patty sets off for Dubbo. At 129 km from home (**11.3 L fuel x $1.53/L / 1.2 occupants = $14.4**), Patty brings along her iPod to keep her awake and liven up the 98 minute journey through the central New South Wales countryside on Highway 39. After hearing 24 of her favourite tunes, it is 8:15 am and Patty arrives at Dubbo airport car park where the charge is $9 per day (**$30 for transfer/parking**).

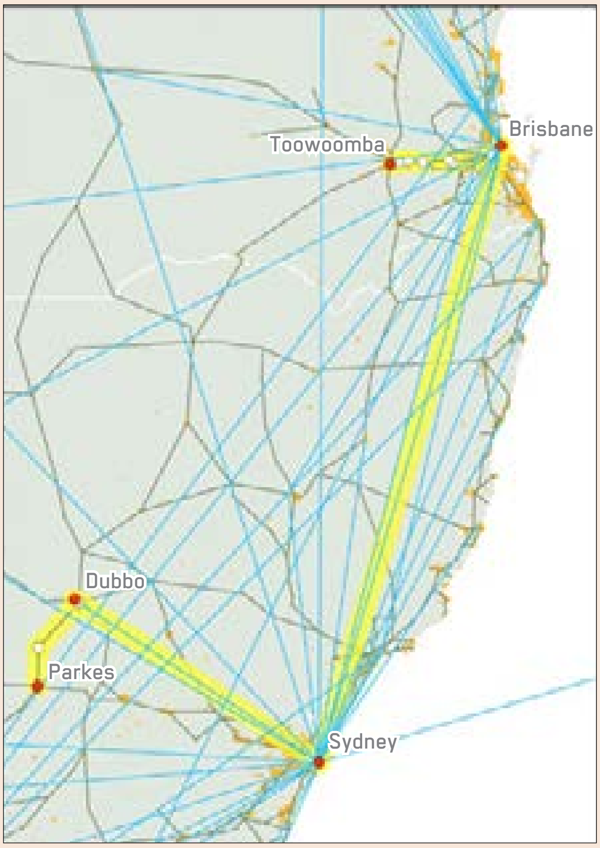
Patty grabs her bag and checks in. With 45 minutes to wait before her flight departs it's time to finally have breakfast and read the news in Dubbo's Daily Liberal. While boarding the 9:00 am flight Patty starts thinking about how she might make her presentation on soil fertility interesting. She spends the 70 minute flight trying to think of an amusing introduction and when the plane lands at 10:10 am still has no idea. The gate for Patty's next flight is at the opposite end of the terminal and her name is being called by the time she arrives. At 10:55 am her flight to Brisbane leaves the gate. She spends another 90 minutes trying to think of a catchy first line and still has no idea when the plane reaches the terminal at Brisbane at 12:25 pm.

Patty eats a sandwich for lunch as she arranges her $45 per day rental car (**$30 transfer/parking**) before leaving the airport at 1:10 pm. Like many other people in Brisbane, Patty decides she doesn't want to use the toll roads and takes the M3, M5 and M2 before reaching the A2 Warrego Highway where she can relax. For the remainder of the 137 km (**12.0 L fuel x $1.53/L / 1.2 occupants = $15.3**) and 137 minute drive to Toowoomba she revisits her dilemma. As she nears the crest of the Toowoomba escarpment it's 3:27 pm and Patty has a brainwave:

"It goes without saying that if you try and fertilise every square inch of your block, your prospects for reproduction will often not work out. If you want success, you need the right ingredients in the right place. It's the same story with crops."

The full 8 hour and 50 minute journey has a total actual cost of $712. **The total estimated cost is $710.70**.

FIGURE 25 **Fastest pathway from Parkes to Toowoomba**



Model validation

It is possible to estimate the share of passengers travelling on each available mode by modelling the sequence of each journey and approximate the related fare and time cost. This is important when a change is made to the transport network, such as introducing the option of HSR. The estimated share of passengers has been compared with current evidence of passenger travel from the Census and National Visitor Survey (Figure 26). A good correlation can be seen up to 800 km. Beyond this, air becomes more favourable than the reference data indicates.

HSR passenger shares are compared with international evidence in Figure 27. This shows a very good fit with HSR services currently in operation, particularly the major city pairs which are well serviced by airlines. HSR is seen to be more favourable than the international trend. This is in part due to the HSR service delivering a better level of service, faster and more frequent, than airlines currently provide.

The major travel pairs of Melbourne-Sydney and Sydney-Brisbane are estimated to attract approximately 65% of the air and HSR market. Melbourne-Brisbane attracts fewer passengers (11%) due to the greater time of this long distance journey.

Of passengers travelling the Canberra-Sydney route, 89% are estimated to travel by HSR. A drop in patronage of this scale would likely cause airlines to stop services between these two cities. Passenger numbers would drop so significantly that the cost of operating flights would increase on a per passenger basis, further reducing the number of passengers likely to make this journey by air.

FIGURE 26 **Comparison of estimated passenger mode shares with Census and National Visitor Survey**

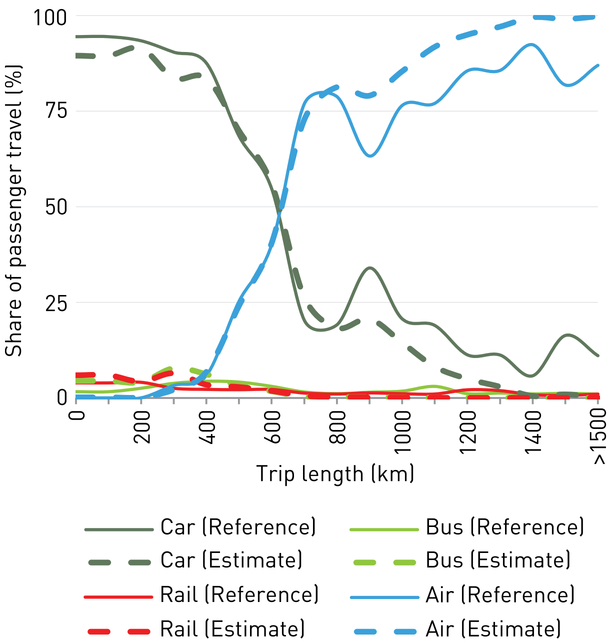
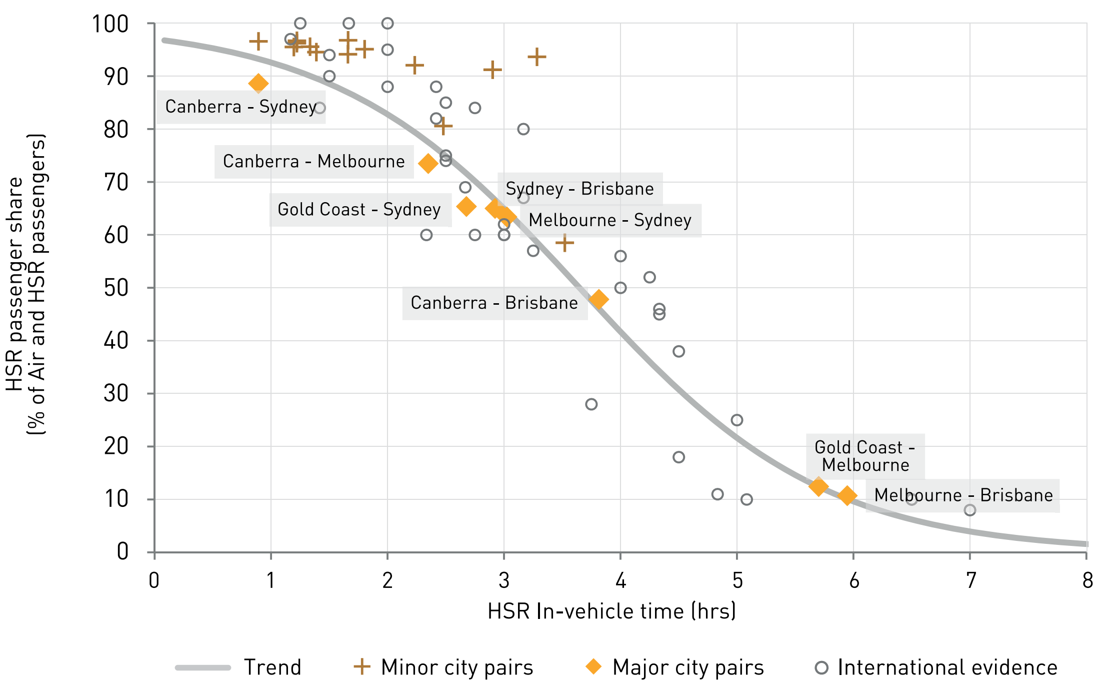


FIGURE 27 **Estimated HSR passenger share of HSR and air passengers with change in HSR journey time**[41,42]



Vivid Sydney, lighting the sails, Sydney Opera House PHOTO: DANIEL BOUD

3. Network operation

This section contains:

- **Travel times modelled for express and stopping HSR services**
- **A HSR operating schedule to meet the passenger flows projected from the Regional Transport Model**
- **Annual operating statistics for the HSR network including total kilometres travelled, energy consumption and revenue generation from ticket sales in 2030**

Overview

Train performance and passenger flows are combined in this section to produce an HSR service schedule for 2030, including a complete timetable. A total of 87 trains will be required to meet the expected demand. Sydney HSR platforms will see departures every 10 minutes in each direction during peak hour, with departures from Melbourne and Brisbane every 15 minutes. Express and stopping trains will cover 66 million kilometres in 2030. Fare revenue for this year is estimated to total $7 billion dollars.

Further detail is available in Appendix C.

Train performance

The design speed for the majority of the HSR alignment is 400 km/h. However, on the basis of currently available technology, the maximum operating speed recommended is 350 km/h. When stops, speed restrictions and steep gradients are added, the average speed of the high speed train is somewhat lower than this maximum – just under 290 km/h for express services, or 255 km/h for stopping services.

Once the preferred alignment was finalised, simulations were made to accurately calculate the performance of the network. This includes accelerations, speeds and times as well as energy consumed and potentially regenerated.

As an example, the performance of the train for the Melbourne-Sydney section of the network (bypassing Canberra) is shown in Figure 28-Figure 30. The speed and time chart (Figure 28) shows the speed profile as well as the average speed and cumulative time for both the express service and stopping all stations service. The energy chart (Figure 29) shows the instantaneous power demand as well as the energy consumed en route. Negative values of instantaneous power demand indicate points where the train has excess momentum and is able to reverse the flow of energy back to the supply line. This capability can save significant amounts of energy, particularly when trains are stopping frequently. The vertical alignment chart (Figure 30) shows the elevation of the rail alignment. The main performance measures for the Melbourne-Sydney section are given in Table 13.

These main performance measures for all sections are included in Appendix C, and an overview of travel times is shown in Figure 31.

TABLE 13 Main performance measures Melbourne–Sydney section (Canberra bypass)

Melbourne-Sydney		North/South		South/North	
Performance		**Express**	**Stopping**	**Express**	**Stopping**
Distance	km	852	852	852	852
Journey time	h:mm	2:57	3:21	2:56	3:21
Average speed	km/h	288	253	289	254
Gross energy	kWh	32,172	32,906	32,177	33,036
Regenerated energy	kWh	2,055	4,510	1,888	4,553
Net energy used	kWh	30,117	28,396	30,289	28,483
Net energy per km	kWh/km	35.4	33.3	35.6	33.4
Stopping times					
Sydney (Central)		0:00	0:00	2:56	3:21
Glenfield		0:14	0:14	2:41	3:06
Moss Vale		–	0:35	–	2:47
Goulburn		–	0:52	–	2:30
Wagga Wagga		–	1:37	–	1:43
Albury		1:49	2:04	1:07	1:17
Shepparton		–	2:33	–	0:47
Seymour		–	2:52	–	0:28
Melbourne Airport		2:46	3:11	0:09	0:09
Melbourne (S. Cross)		2:57	3:21	0:00	0:00

FIGURE 28 **Speeds and times of Melbourne–Sydney express and stopping trains (Canberra bypass)**

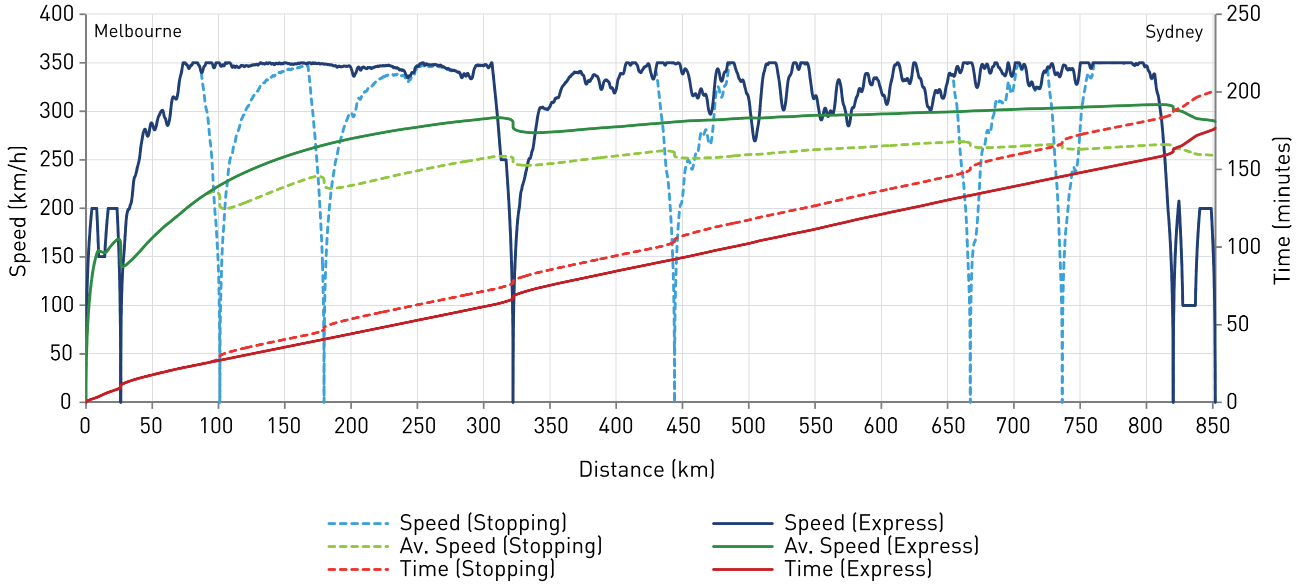


FIGURE 29 **Power use and energy consumption of Melbourne–Sydney express and stopping trains (Canberra bypass)**

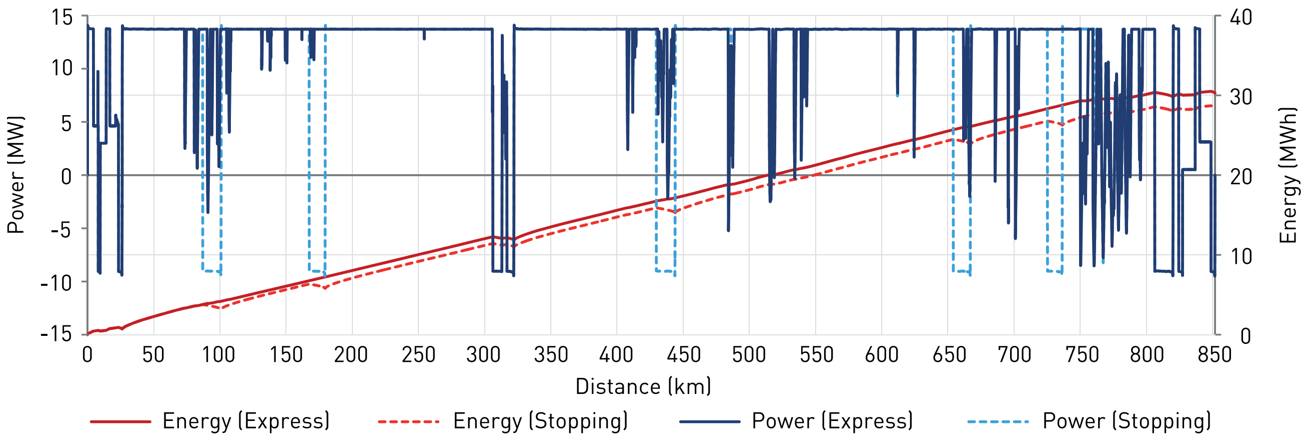


FIGURE 30 **Melbourne–Sydney vertical rail profile (Canberra bypass)**

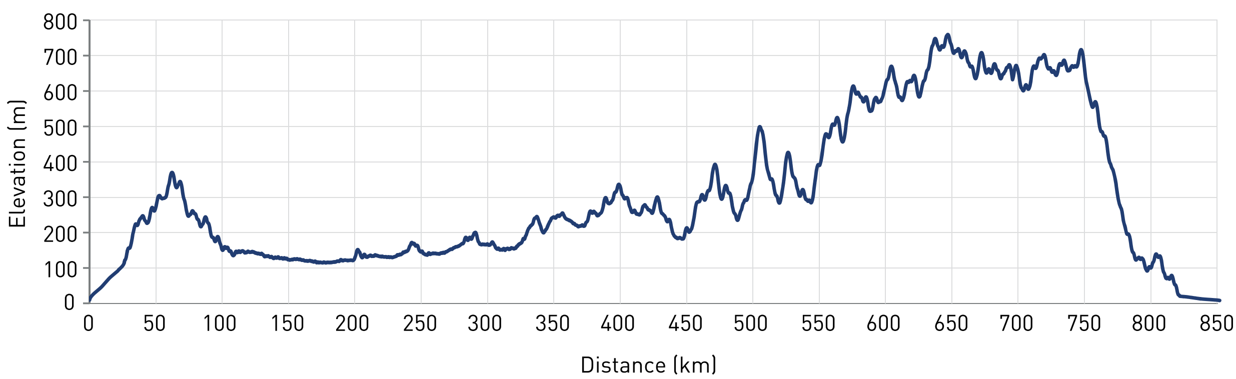
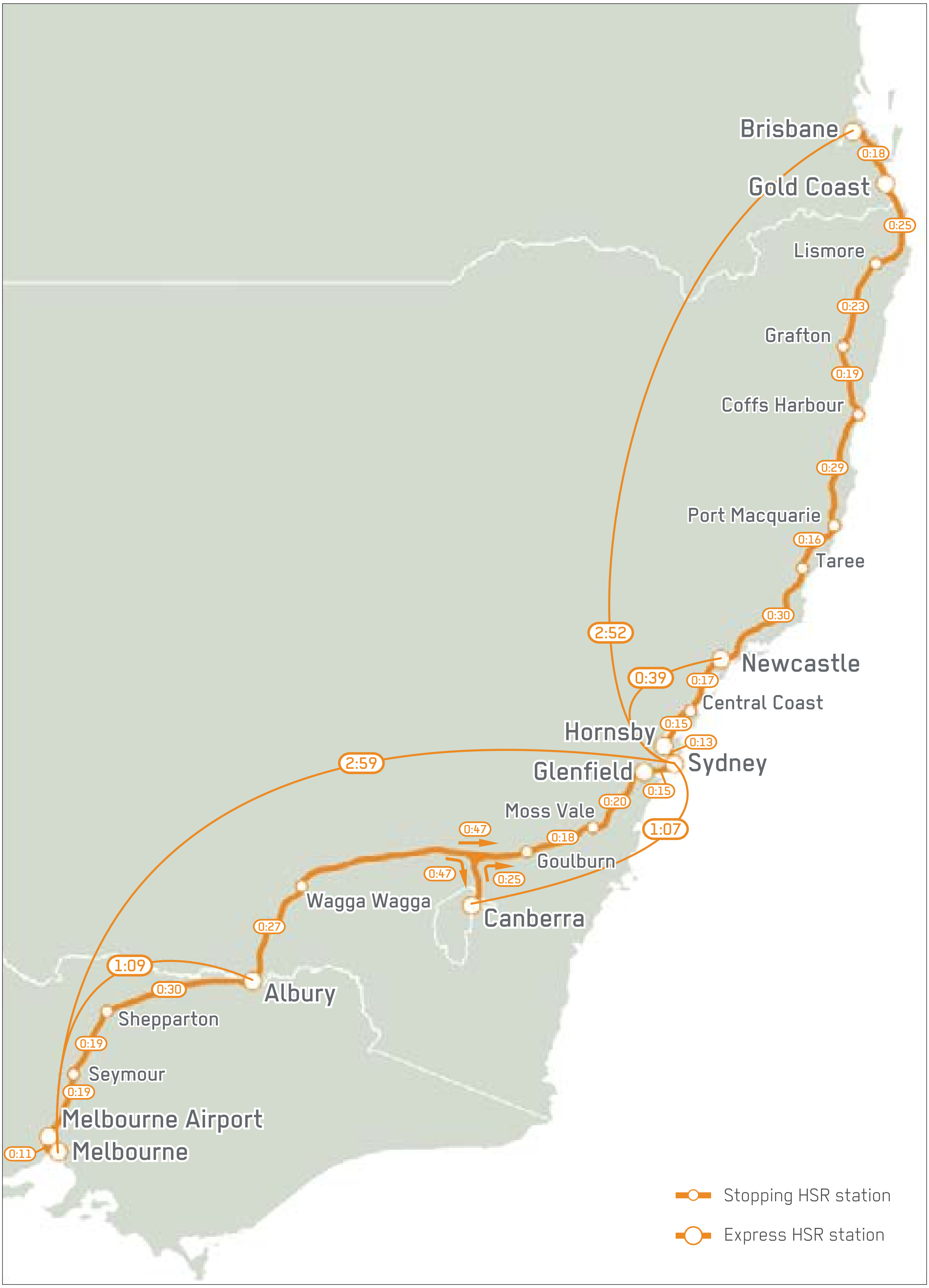


FIGURE 31 **HSR travel time overview**



Train demand and operating schedule

The average daily passenger demand estimated for 2030 was converted to an hourly average patronage to determine the number and frequency of trains required to service the network. The hourly passenger movements at the long distance HSR terminal in Hanover, Germany[43], were used as a guide for peak and off-peak passenger flows (Figure 32).

Using a train capacity of 500 passengers, the resulting hourly train demand (both directions) for the full Australian HSR network can be seen in Figure 33.

With the exception of the Canberra branch line towards the south, there is demand for a minimum of two to three trains per hour for the full network from 6am through 7pm. For the morning and evening peak periods, three to four trains per hour are required for the full network with four to six trains per hour required between Canberra and Newcastle. The Canberra branch line towards the south would require fewer than two trains per hour through the day.

FIGURE 32 **Hourly proportion of daily passengers at Hanover HSR station, Germany**

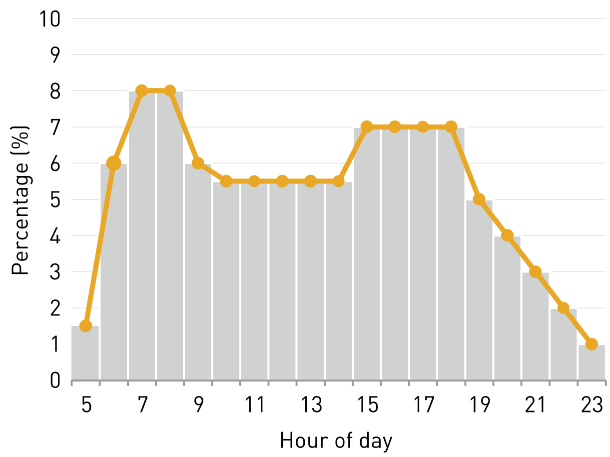
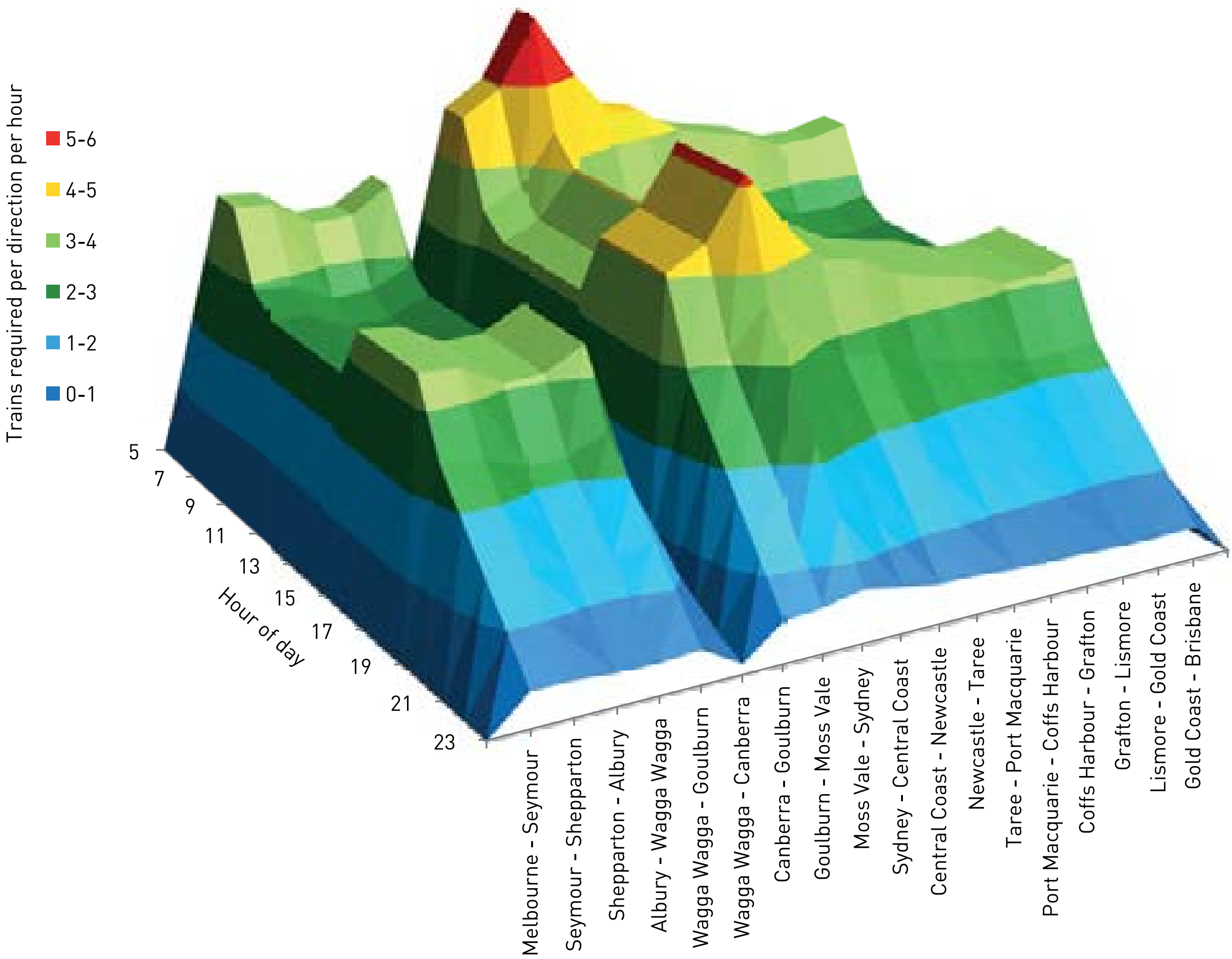


FIGURE 33 **HSR network hourly train demand**



Because a large number of passengers are travelling long distances it is important to determine the mix of express and stopping trains to match. The morning peak period demand was used to determine the mix needed at this critical time. The schedule for peak hour train services is shown in Table 14 and the corresponding passenger loadings in Figure 34.

There are many passengers travelling between the major cities of the east coast which makes the Australia Express (AU), travelling the full length of the network, the busiest train service. The Australia Express requires three trains per hour in each direction during the morning peak. Additionally, there is one service per hour in each direction stopping all stations for Melbourne-Sydney (MS) and one and a half services per hour in each direction stopping all stations for Sydney-Brisbane (SB).

Separate services are required for passengers travelling to Canberra due to the spur line. Between Canberra-Sydney one express service per hour in each direction (CAN) and one stopping all stations service (SC) per two hours in each direction is required. Between Canberra-Melbourne demand is relatively low and only one stopping all stations service (MC) is required in each direction every two hours.

Passenger demand for the Sydney-Newcastle route is very high and requires one additional short distance shuttle service per hour in each direction between both Sydney-Central Coast (CC) and Sydney-Newcastle (NC). These shuttle services have the option to continue from the high speed station and join the existing rail line. The Central Coast (CC) service can then stop at Gosford and Woy Woy stations. The Newcastle (NC) service can stop at the University and the existing Newcastle main station. The possibility remains for the CC and NC shuttle services to stop at any of the intermediate local stations to collect passengers before continuing to Sydney at high speed.

TABLE 14 **Australian HSR peak hour train service schedule**

	Service	Trains per hr per direction
AU	Australia Express	3
MS	Mel-Syd Stopping	1
MC	Mel-Can Stopping	0.5
CAN	Syd-Can Express	1
SC	Syd-Can Stopping	0.5
SB	Syd-Bri Stopping	1.5
CC	Syd-Cen Shuttle	1
NC	Syd-New Shuttle	1

FIGURE 34 **Estimated Australian HSR morning peak train service passenger loading (train layout diagram courtesy of Bombardier)**

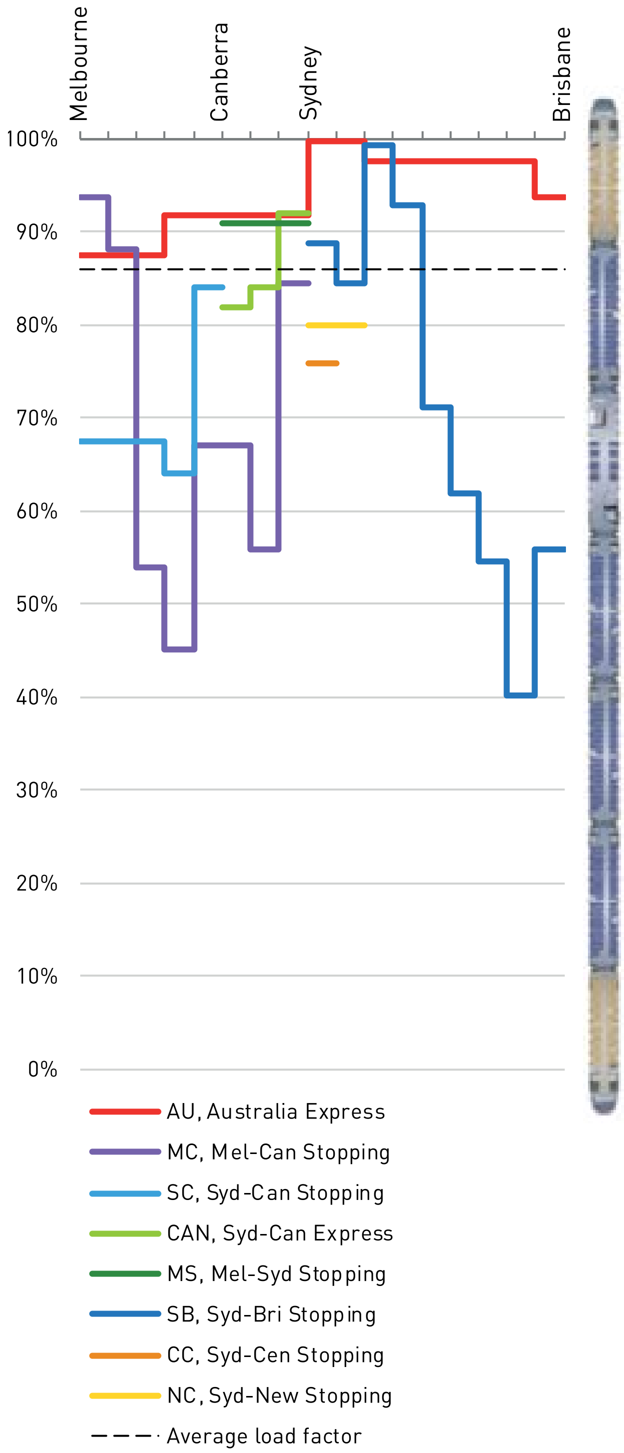
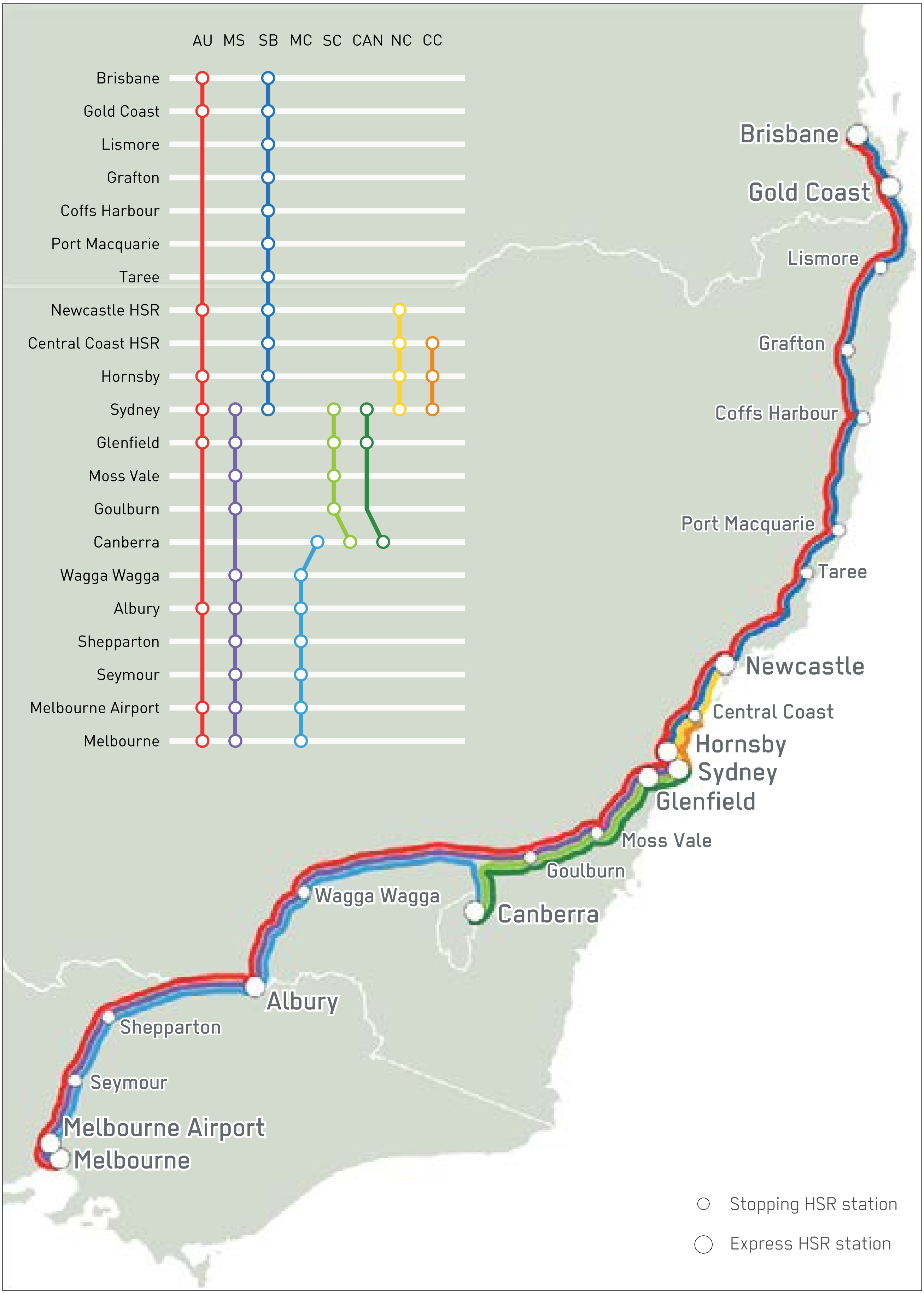


FIGURE 35 **Operating schedule for Melbourne–Brisbane HSR network**



The morning peak period determines the number of trains required by the HSR network. Using the service schedule of Table 14 and the return trip and turn-around time for each service the minimum number of trains can be calculated. In this case 79 train sets with 500 seats each are required. An additional 10% buffer has been assumed to rotate trains through their maintenance programs. This brings to 87 the total number of train sets required to service the estimated patronage for 2030 and operate the HSR network.

A timetable was developed to allocate train services over a full day to determine the annual utilisation of each train set. The complete daily timetable is available in Appendix 3. Table 15 shows that just less than 66 million kilometres would be covered by the HSR fleet in 2030, an average of 756,000 km for each of the 87 train sets. Approximately 2.2 Terawatts of energy would be consumed by the HSR fleet in 2030.

TABLE 15 HSR service annual operation statistics for year 2030

Service	Services per day	Services per year	Service distance (km)	Service time (min)	Energy per service (MWh)	Kilometres per year (000's)	Operating hours per year (000's)	Energy consumed per year (MWh)
AU	38	13,870	1,674	347	64	23,218	4,813	827,957
MS	18	6,570	852	201	33	5,598	1,321	186,846
MS*	14	3,640	852	201	33	3,101	732	103,519
SB	36	13,140	822	199	32	10,801	2,615	357,981
SB**	38	11,780	822	199	32	9,683	2,344	320,930
CAN	34	12,410	290	67	11	3,599	831	120,702
SC	18	6,570	290	76	11	1,905	499	60,122
MC	18	6,570	674	151	26	4,428	992	152,157
CC**	63	19,530	72	25	3	1,406	488	38,572
NC**	48	14,880	138	42	6	2,053	625	60,949
Total	**325**	**108,960**				**65,794**	**15,260**	**2,229,735**
Per train set						756	175	25,629

* Weekdays only
** Fewer services on weekends
All other services are daily for the 365 days of the year

Operating revenue

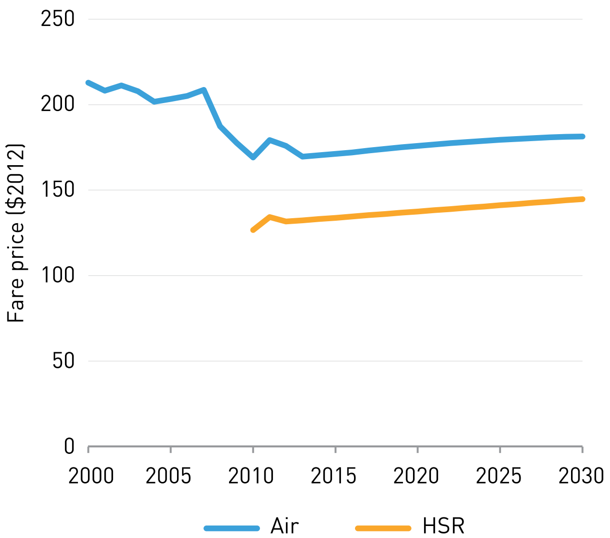
There are a number of potential revenue streams from the HSR network. These include:

- HSR fare sales
- Access charges
- Rent from commercial space at stations
- Advertising
- On-board services and catering

In this study only the revenue from HSR fare sales is considered. The estimated passenger demand has been used as a basis for fare sales on the Australian HSR network. Combining this with the fare structure developed provides the estimated passenger revenues. As an indicator, a HSR ticket to travel between Melbourne and Sydney is estimated to cost, on average, $204 for premium class and $132 for economy class. In practice fares tend to fluctuate with discount offers in order to smooth out demand variability associated with seasonal travel and peak activity as well as other factors. It is likely that a range of HSR fares lower and higher than the average fares estimated would be offered to passengers.

Energy prices make up a significant portion of the fare price of both air and HSR services. Future fares have been estimated based on fuel and electricity price projections. As shown in Figure 36, both air and HSR are expected to increase in real terms at a similar rate.

FIGURE 36 **Comparison of Melbourne–Sydney air and HSR fare price projection**

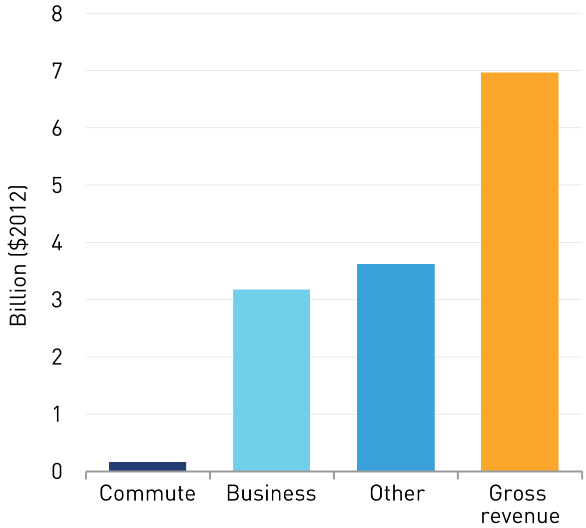


The total fare revenue estimated for 2030 is $7 billion (2012 dollars). The proportion of revenue estimated from each user group is shown in Table 16 and a summary of passengers and fares for 2030 is given in Figure 37.

TABLE 16 **Summary of Australian HSR revenue for year 2030**

User	Passengers (million)	Revenue kilometres (million)	Fare revenue (million)	Percentage of revenue
Commute	6.2	572	$165	2.3%
Business	17.6	9,437	$3,175	45.6%
Other	44.5	15,010	$3,620	52%
Total	**68.2**	**25,018**	**$6,960**	

FIGURE 37 **Australian HSR revenue in 2030 by user group**



Kay Hull Veterinary Teaching Hospital, Charles Sturt University Wagga Wagga PHOTO: BIDGEE

4. Designing the HSR line

This section contains:

- **The requirements for designing a HSR line, including track geometry and construction cost trade-offs**
- **The principles that have been used for minimising environmental and social impacts**
- **The detailed methodology used to design the proposed HSR alignment for this study**

Overview

The precise design of a rail alignment for HSR requires detailed examination of the terrain it must pass through and areas to be avoided. Trains running at high speeds can turn only on long, gentle corners, which make it difficult for the route to avoid every obstacle in its path. Trade-offs are made between finding the shortest route, keeping construction costs low, and limiting the impact on people and nature while providing a convenient service.

Further detail is available in Appendix D.

Design considerations

The major issues considered while determining the final alignment include the design specifications of HSR, landscape topography, environmental and social impacts and station integration – all of which influence where the rail line is built and therefore how much it costs. This section provides an overview of how these considerations were incorporated into the final alignment design, while a detailed discussion of costs is outlined in Section 6.

Railway design specifications

One of the major differences between HSR and conventional rail lines is the geometry of the track. While there are various technical specifications that apply to high-speed lines, the gradient and curvature are the most significant ones affecting how the alignment navigates across the landscape.

The gradient design limits applied in this study are a maximum of 2.5% for a sustained slope, and 3.5% for short sections (up to 6 km). These limits are based on what high-speed trains can operate on from stationary to full speed, developed from international experience. When the terrain exceeds this gradient, earthworks or structures are required to stay within these design limits.

Curvature design limits apply to both horizontal curves, as the rail line turns left or right, and vertical curves, as it rises over crests or dips across valleys. A tight curve radius allows the greatest design flexibility for avoiding obstacles. However curves must be gentle enough to avoid derailment and passenger discomfort. Curves cause ‘G-forces’ like those experienced on a rollercoaster or from sharp turns in a car or aircraft. Horizontal curves produce a lateral acceleration, experienced as a sideways force. Vertical curves produce vertical acceleration, experienced as a decrease or increase in weight. Internationally, operators of HSR have developed design specifications for HSR curve radii based on operating speeds to ensure adequate safety and passenger comfort. These are shown in Figure 38, from the European Technical Standards for Interoperability[44].

The sideways force generated by horizontal curves can be counteracted to a degree by tilting the train in the direction of the turn. Referred to as the cant of a track, the outside rail is raised slightly, causing the vehicle to tilt inwards. The cant is also limited to avoid passenger discomfort and instability at low speeds.

The recommended curve radii relative to design speed shown in Figure 38 take into account both the curvature and cant parameters.

A track designed to operate at 400 km/h will have a minimum curve radius over five times greater than one designed to operate at 200 km/h, and 21 times greater than a track designed today to operate at 100 km/h. Many existing rail lines in Australia are still limited to 100 km/h due to the geometry of alignments built roughly a century ago.

FIGURE 38 Minimum curve radius for given design velocity for general HSR traffic[44]

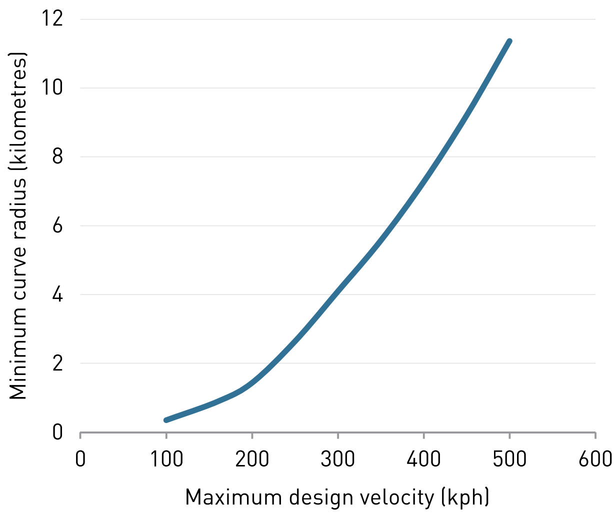
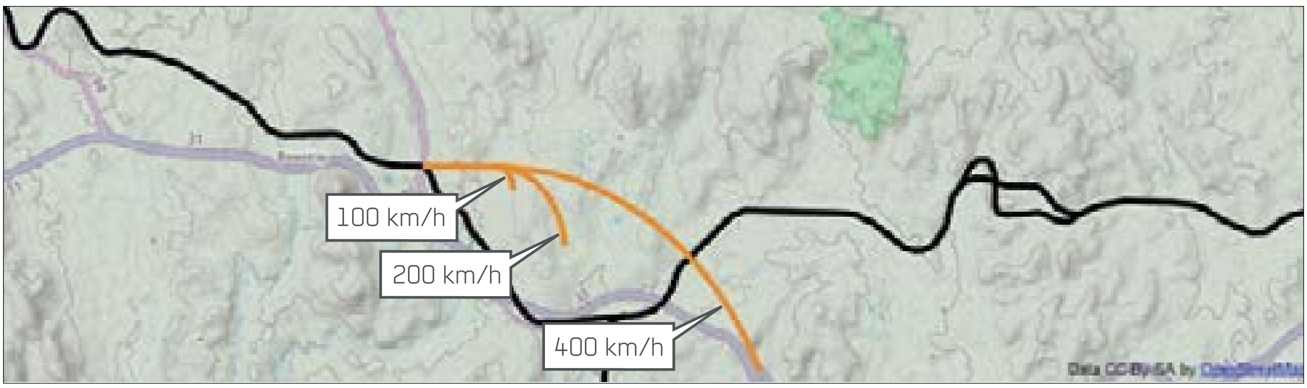


Figure 39 Figure 38 demonstrates how this affects the design of a rail alignment. The existing Melbourne-Sydney rail line is shown in black passing near Yass in New South Wales. The allowable minimum curves are shown in red for design speeds of 100 km/h, 200 km/h and 400 km/h. Obstacles such as terrain variations, roads, and rivers are shown in relation to these allowable curves. Historically rail lines were able to avoid difficult sections of terrain easily by travelling at low speeds. However, when faster speeds are desired, avoiding these obstacles is more difficult. This results in the need for more earthwork and structures for HSR which has a substantial effect on the construction cost.

The maximum operating speed for the proposed HSR system assumed for when operations begin is 350 km/h. This is the fastest service currently operating or planned in the world[45]. Over the 50-year history of HSR, technological improvements have allowed operating speeds to increase from 210 km/h on the first Japanese Shinkansen in 1964[46] to 350 km/h today. The current speed record under controlled experimental conditions (without passengers) is 574.8 km/h, by a specially modified Alstom TGV in 2007[47]. While this speed is not expected to be used in commercial operations in the near future, it is reasonable to expect continuous improvements in HSR. Trains are already available for operational speeds of 350-380 km/h from leading technology providers including Alstom[48], Siemens[49] and Bombardier[50]. For these reason the rail alignment has been designed to allow for speed increases over time.

For regional sections of the alignment, the curve radius applied in this study is 10 km. This translates to a maximum operating speed of 450 km/h. In a select few cases, curve radii have been decreased to allow more design flexibility while still allowing operating speeds of 350 km/h. For urban sections of the alignment, a curve radius of 2.5 km has been targeted, which would allow for speeds up to 250 km/h, though complexities in urban areas requires further limitations on curve radii in some situations.

FIGURE 39 Curve requirements for 100 km/h, 200 km/h and 400 km/h in comparison to existing railway

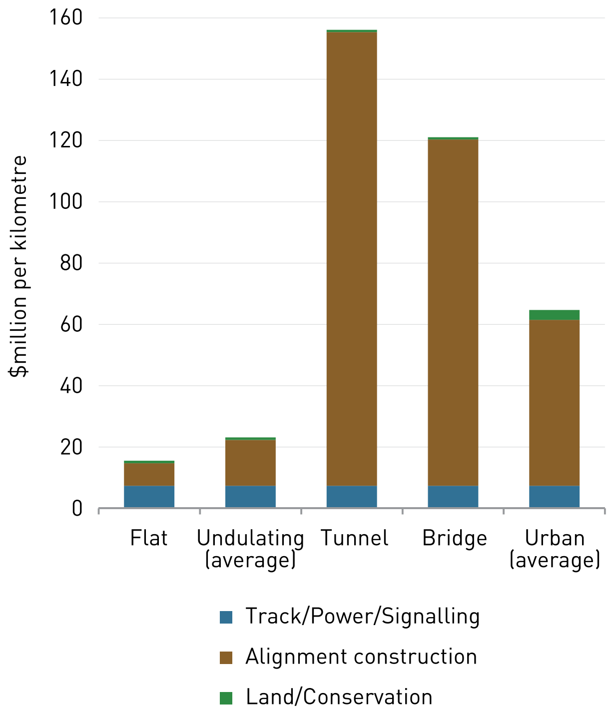


Landscape topography

The particular character of a landscape significantly affects the construction required and the resulting cost. On a per kilometre basis, the relative cost of building rail lines through difficult terrain requiring tunnels, bridges or dealing with the complexities of urban areas can be five to ten times greater than the cost of building the same kilometre through a flat paddock (Figure 40). Even undulating terrain requiring significant earthworks is an order of magnitude cheaper than tunnels or bridges. With this in mind, a great deal of care was taken to identify a pathway between Melbourne and Brisbane which made the best use of the landscape while still allowing high-speed travel.

A number of computational tools were developed to determine an alignment which avoided as much adverse terrain as possible while conforming to the design specifications required for high-speed travel. These are discussed later in this section.

FIGURE 40 **Indicative construction costs for HSR line over different terrain**



Environment and society

When designing the HSR alignment, one of the primary considerations is avoiding unnecessary impacts on the natural environment and communities.

Environmental considerations

While careful design can avoid the majority of areas sensitive to the local environmental effects of an HSR line, there will inevitably be some impact from the construction and operation. This includes land clearing, habitat severance and interference with the natural drainage system.

These initial negative impacts (kept to a discrete area around the HSR alignment) must be weighed against the long term positive impacts, including reduced pollution and avoidance of road and air infrastructure expansion which also intrude on the natural environment.

When designing HSR alignments, environmental issues along potential corridors were dealt with using three strategies:

1. **Avoidance** was the primary strategy for managing potential significant impact.
2. **Mitigation** measures were adopted in instances where the construction and operation of HSR may cause unavoidable environmental impacts affecting people, flora and fauna. These impacts often occur due to route selection constraints (geometric, topographic etc.). Examples of mitigation measures include providing habitat enhancement measures when passing through areas with significant protected species. In this phase of the study, specific mitigation measures along the entire route were not compiled. However an allowance of $750,000 per kilometre of alignment was factored into the capital cost to provide for them.
3. **Environmental offsets** were put in place in instances where any residual adverse impacts may remain after adopting avoidance and mitigation measures. Offsets provide environmental benefits to counterbalance these impacts. At this level of the study, offsets were simply costed as acquiring 10 times the amount of land adjacent to what was affected. However in more detailed studies, offsets should be tailored specifically to the attribute of the protected entity that is impacted in order to deliver a conservation gain.

The main legislation used for decisions on environmental issues was the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Cth)[51]. Alongside this, the Collaborative Australian Protected Area Database (CAPAD)[52] was used. The EPBC Act is designed to protect national environmental assets, and also to promote ecologically sustainable development, conservation of biodiversity, and to demonstrate adaptation to reasonable climate change scenarios. Published by the Australian Government, CAPAD is a geographical database of information on protected areas and is used to provide a national perspective of the conservation of biodiversity in protected areas.

The following 'check-list' of important environmental considerations for route selection was formed based on the EPBC Act and the CAPAD. Other relevant environmental issues were also incorporated if they were deemed relevant to this particular project:

Ecological resources

a. Ramsar wetlands – internationally recognised environmentally significant wetlands
b. EPBC listed communities and species – nationally listed as critically endangered or endangered communities and species
c. State/Territory listed communities and species – threatened communities and species specific to a State/Territory
d. Native vegetation

Cultural heritage

a. World Heritage Areas
b. Commonwealth Heritage List
c. State Heritage Registers
d. Native Title determinations

Water resources and flooding

a. Lakes and reservoirs
b. Water supply and reservoirs
c. Floodplains
d. Directory of important wetlands – nationally important wetlands
e. Acid sulfate soils – disturbance of these soils can have a destructive effect on aquatic ecosystems and infrastructure

Existing and proposed land uses

a. National parks
b. Prohibited areas – including defence and mining areas
c. Areas subject to mine subsidence
d. State forests and forestry reserves

For the purpose of mapping, the above check-list was consolidated to what was most relevant to the chosen HSR alignment, and grouped into the following areas: national parks or equivalent, state/other conservation areas, and wetlands. Specific environmental issues encountered along the selected HSR route are described in Appendix D.

Social considerations

A similar systematic approach has been applied to reduce the social impacts of the alignment, with avoidance as the key strategy. In general, the HSR alignment has endeavoured to avoid impacting existing settlements and infrastructure as much as possible before deviations significantly affect travel speed and cost. However, in order to provide passengers with convenient access to stations, the HSR line must pass close to or even enter towns and cities. In these cases, as much effort as possible is taken to limit any negative effects to the surrounding environment. Examples include using existing road and rail corridors to minimise the need for acquiring properties, and providing noise/visual screens when passing through built-up areas.

Access to major city destinations is covered in a separate section as part of the alignment design descriptions. Each city has its own unique constraints to providing this access.

All HSR services will stop in major capital cities, but there will also be express services that bypass intermediate stations. If the HSR line passes through urban areas, it is required to slow to a maximum 200 km/h for safety and noise reasons. Stations bypassed by express services will be designed to have the platforms on a siding separate from the mainline, to allow express trains to safely overtake at full speed past trains stopped at a station. These stations have been located on the periphery of the corresponding town so HSR express trains do not disturb residents.

Another measure to reduce urban disturbance is to make use of existing infrastructure corridors and reserves. There are many useable corridors along existing road or rail lines that correspond with the HSR alignment. It is particularly advantageous to make use of these corridors when penetrating built-up urban areas where land is at a premium. These corridors often feature curvatures which are too tight for full-speed HSR operation and can only be partially exploited. Where practical this has been done to reduce the cost of the HSR line and also reduce the imposition on the built environment.

Open consultation with stakeholders and communities that may be affected by the development of HSR is vital. It is a priority to ensure that people have an understanding of the proposed development well in advance of it going ahead and if or how it will affect their individual properties, residences or businesses. Prior to, and throughout the planning and construction phases, these groups must be consulted and kept informed of significant events or changes. For example, it would be important to hold stakeholder and community information sessions in towns where the proposed route will pass through, allowing them to be more involved in the process.

Station integration

Stations are the interface between travellers, communities and the proposed HSR network. There is no one-size-fits-all approach to integrating stations with existing urban development and a high-speed interstate alignment. The approach was simplified by considering four generic configurations when locating and accessing HSR stations:

Through configuration

In this configuration, the HSR mainline travels through the middle of the town to allow the most convenient direct stopping. This requires the express trains to slow down to 200 km/h in the town area.

Peripheral configuration

In the peripheral configuration, the HSR mainline skirts the outer edge of the corresponding town to allow the station to be located adjacent to the town without significant disruption and cost, and allowing full-speed 350 km/h bypass.

Side line configuration

In this configuration, the HSR mainline bypasses the town, while a separate loop enters and exits the town in a through configuration (Figure 41). There are some cases where existing rail lines could be effectively used for this purpose. This configuration allows express trains to bypass at 350 km/h.

Branch line configuration

This configuration also allows the mainline to bypass the town, but uses a single corridor for entry and exit as a dual track branching from the mainline (Figure 42). Existing infrastructure and corridors can also be used with this configuration.

Recommendations

For the HSR alignment proposed in this report, the stations for most regional towns have been designed as peripheral stations, putting the station close for functionality but allowing the track geometry to remain compatible with express trains bypassing at full speed. In a few select cases, a through or branch line configuration has been recommended for important stops.

No towns were identified where side line configurations would be a necessary pre-requisite for efficient HSR operation, so none have been designed or costed. There are several towns where this may be a future upgrade option if desired, to offer an even more convenient service. This would require rebuilding existing track to be compatible with high-speed trains.

FIGURE 41 Side line configuration

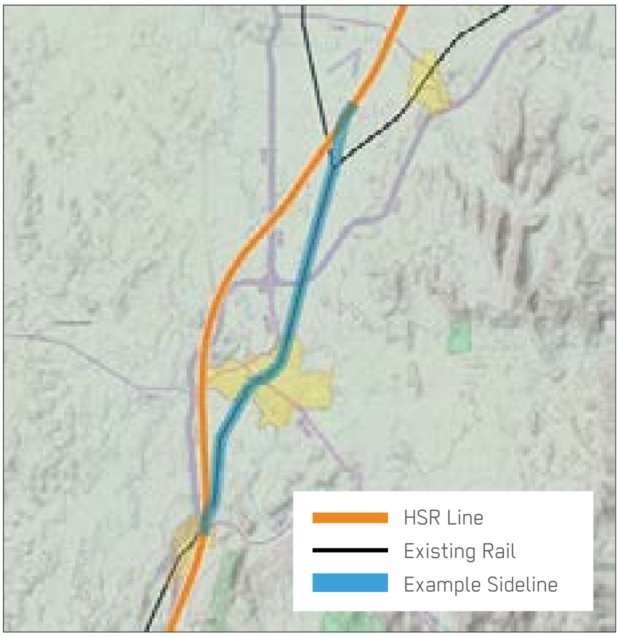
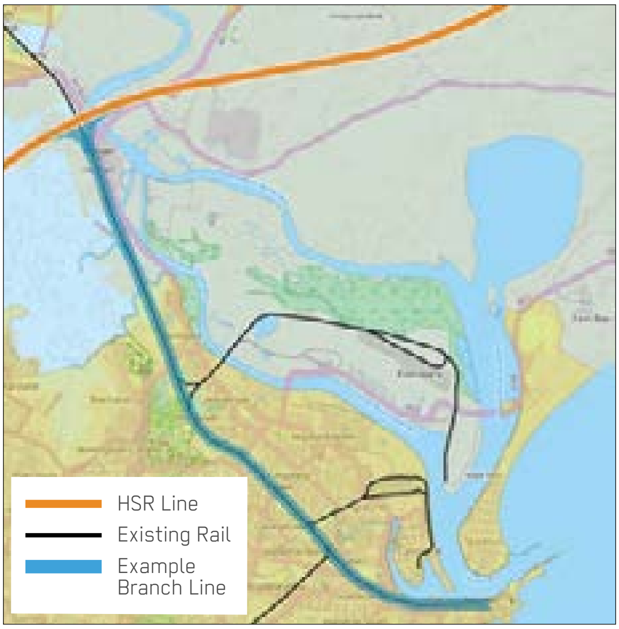


FIGURE 42 Branch line configuration



Alignment design methodology

The HSR alignment was designed by first specifying the horizontal alignment, then the vertical profile, using software techniques described in this section. The final alignment design is the product of many iterations of these steps to minimise construction costs while meeting design requirements.

Horizontal alignment design

Designing the HSR alignment involves finding a balance between:

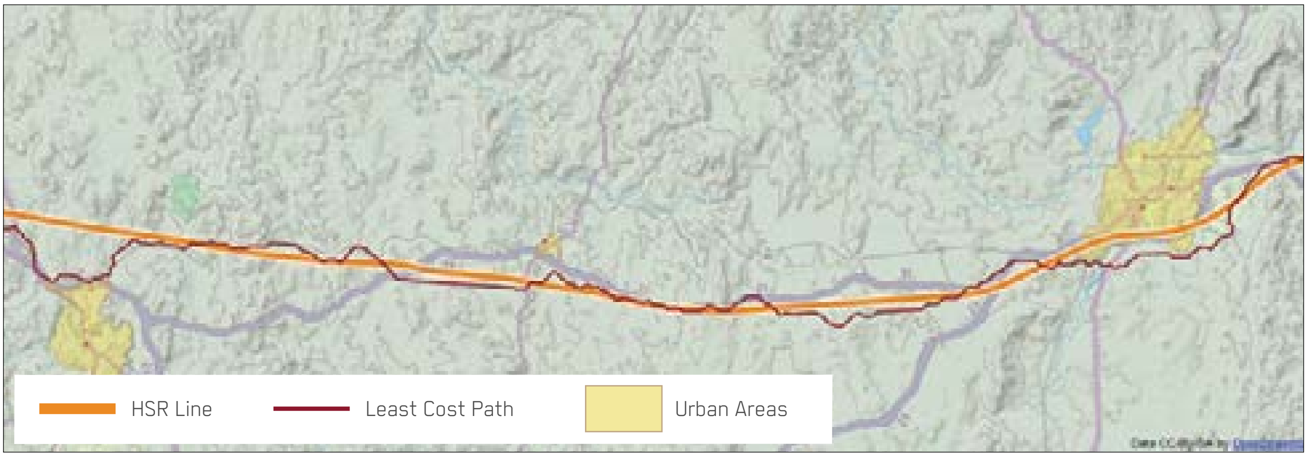
- The shortest distance between stations to minimise travel times
- Avoiding steeply sloping land, which results in high construction costs
- Avoiding obstacles such as environmentally sensitive areas and built-up areas
- Minimising high cost land acquisitions

Initial approximate routes were mapped out with indicative paths connecting proposed stations. These indicative paths were then refined using computational processes to determine the least cost pathway between stations.

This process uses Geographical Information Systems (GIS) software to map all relevant obstacles and associates a cost penalty for encroaching on each feature. Such obstacles include steep terrain, boundaries of environmentally sensitive areas (for example, National Park and conservation areas), water bodies and urban areas in addition to roads and other railways. The result is a path of least resistance between each point. As shown in Figure 43, this pathway can be very irregular and must then be reconciled with the horizontal curvature design specifications.

The least cost path was used as a starting point for software that smooths the path over many iterations until it conforms to the geometric design specifications. The resulting alignment is then reviewed and adjusted manually where necessary.

FIGURE 43 **Example of least cost path (dark red) and final HSR alignment (orange) conforms to design specifications through a section north of Canberra**



Vertical alignment design

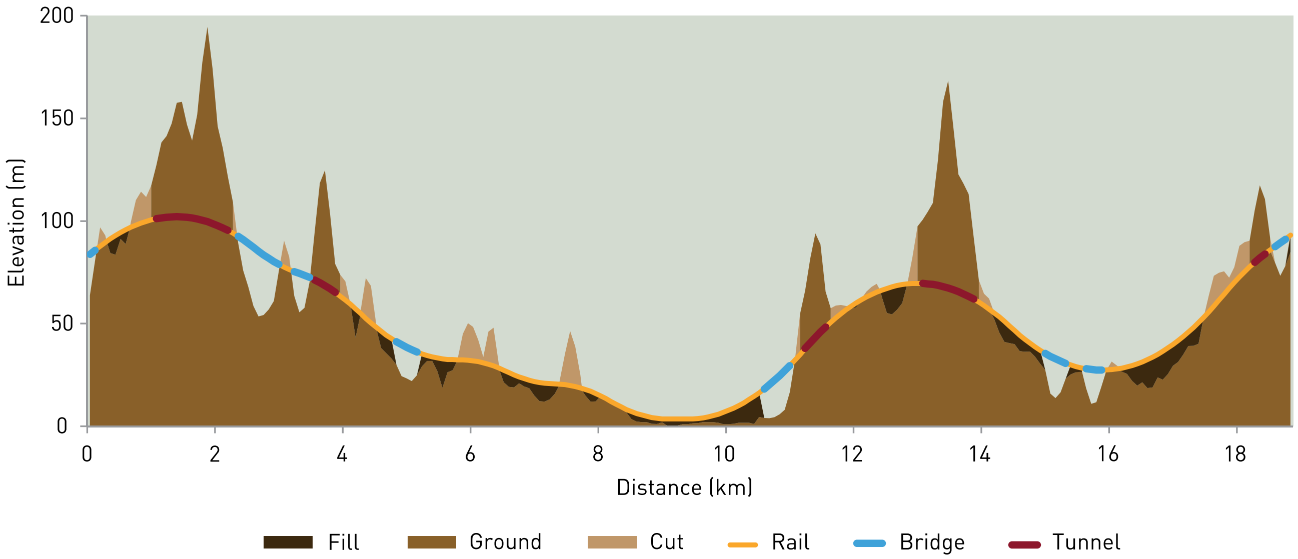
The allowable vertical alignment often requires building the HSR line above or below the ground level of the existing terrain. This requires earth moving where shallow cuttings and fills will suffice, or tunnels and bridges where the hills or valleys to be traversed are significantly higher or deeper than the required HSR line. The elevation profile of the horizontal alignment was used to determine the civil works required to fit the HSR to the terrain within the design limits. An example of this is shown in Figure 44.

The rail elevation profile was initially set as the ground elevation profile, and was then smoothed over many iterations until it conformed to vertical geometry specifications. This was processed with a variable elevation bias. This bias would raise or lower the rail line to adjust the mixture of earthworks, tunnels and bridges required. The civil construction costs are calculated by attributing unit costs to the cubic metres of earth to be moved and kilometres of track to be elevated on a structure or laid in a tunnel. Variation of the elevation bias allowed the lowest cost solution to be identified.

High speed train in Spain crossing the Rio Jalón bridge after exiting Tunel de las Mina, before entering a second tunnel

PHOTO: PETER HUERZELER

FIGURE 44 **Example of vertical alignment and civil infrastructure requirements from vertical profile analysis**



Up close turtle encounter, Coffs Harbour PHOTO: DOLPHIN MARINE MAGIC

5. Proposed HSR alignment

This section contains:

- **Detailed maps and descriptions of the proposed HSR alignment in four segments from Melbourne to Brisbane**
- **Cumulative construction costs and per-kilometre costs, demonstrating the effect of different terrain along the route**
- **Detailed examples of challenging segments of the HSR alignment**
- **Comparison of access options for major cities**

Overview

The pathway of the proposed railway is discussed in relation to natural features, built-up areas and existing infrastructure in the following four broad segments:

- Melbourne-Wagga Wagga
- Wagga Wagga-Sydney
- Sydney-Coffs Harbour
- Coffs Harbour-Brisbane

Costs provided in this section indicate the construction cost only, excluding management and contingencies, which are applied to the final cost estimate in Section 6.

A number of particularly challenging sections have been encountered in the process of selecting the proposed alignment. Three have been included in this section to highlight the complexity of this process:

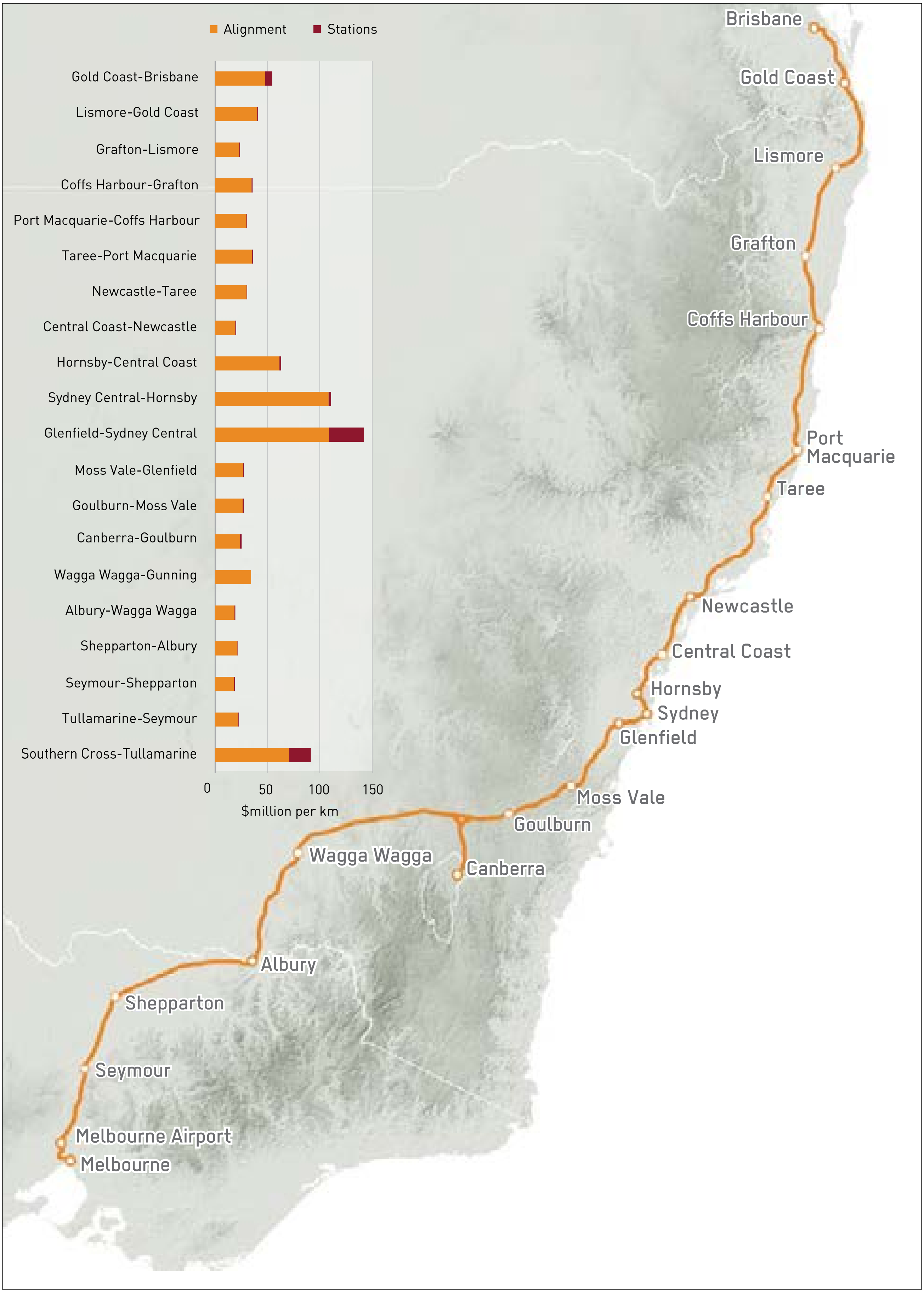
- Albury-Wodonga access
- Hawksebury River crossing
- Grafton floodplain

Accessing cities is a significant component of the overall capital cost. Each major city has its own unique challenges and trade-offs to be made between travel times and construction cost. The following five cities are presented in detail:

- Melbourne
- Canberra
- Sydney
- Gold Coast
- Brisbane

The 1,799 km HSR alignment directly connects 18 cities and towns along the Australian east coast. This is composed of 81 km of tunnel (4.5%), 99 km of bridges and viaducts (5.5%) and 1619 km of track at ground level, on embankments and in cuttings (90%). 60% of Australia's total population will live within 50 km of a HSR station.

FIGURE 45 **HSR alignment with terrain data and average cost per kilometre by segment**



Melbourne to Wagga Wagga

The 443 km segment from Southern Cross Station in Melbourne to Wagga Wagga HSR Station travels some of the easier terrain along the whole HSR alignment. Inclusive of stations, the raw construction cost estimate for this segment is $11.1 billion, an overall average of $25.1 million/km. After crossing the Great Dividing Range, the alignment can be built cheaply over flat farmland from Seymour to Albury, and remains on relatively easy ground from Albury to Wagga Wagga. The most expensive segments are the first 26.6 km exiting Melbourne via Tullamarine Airport, which incurs $2.5 billion and the segment through Albury-Wodonga with a viaduct over the Murray River.

Melbourne to Shepparton

From Southern Cross Station in Melbourne, the HSR alignment uses existing corridors via Footscray, Sunshine and part of the Albion-Jacana freight corridor to Tullamarine Airport.

The regional segment of the alignment meets Melbourne's urban fringe at Tullamarine Airport. Here the new HSR station connects air passengers with the city centre and all other stations en route to Brisbane. From here, the line heads north-east, passing west of Craigieburn. From Wandong to Seymour, the alignment stays close to the Hume Highway to minimise impact upon the surrounding built-up and rural areas, some of which contain protected species.

FIGURE 46 **Cost per kilometre of HSR segments from Melbourne–Wagga Wagga**

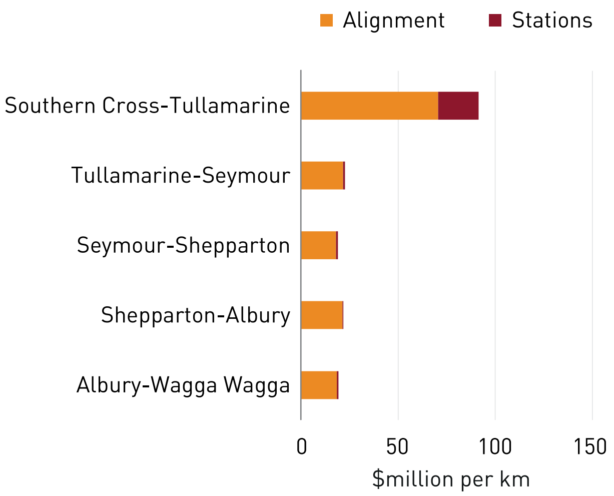


TABLE 17 **Length breakdown of HSR segment Melbourne–Wagga Wagga**

	Length (km)	Per cent of segment length
Tunnels	5.6	1.3%
Bridges	13.5	3.0%
Grade	424.0	95.7%
Total	443.1	

The HSR mainline skirts Seymour to the west, alongside the existing Hume Highway bypass. Seymour station is located approximately 2.5 km west of the town, close to the intersection of the Hume Highway and the Seymour-Tooborac Road.

The alignment heads directly from Seymour to Shepparton over flat, sparsely populated rural land. It runs adjacent to a straight segment of the Goulburn Valley Highway for 13 km to minimise the impact of land acquisition on rural properties. Shepparton station is located next to the Midland Highway, 3.6 km east of the town centre.

Shepparton to Albury

The alignment heads north-east, again across flat, sparsely populated rural land. The flat land either side of Shepparton makes construction cheaper than following the Hume Highway, where the hills around Glenrowan would be more expensive to traverse. The HSR alignment passes north of the Warby Range, which is part of the Warby-Ovens National Park. This national park also covers a large part of the Lower Ovens River, which must be crossed, involving an unavoidable impact on the area. The hills south-west and north of Albury-Wodonga, along with the Murray floodplain, leave limited options for passing outside the towns within a useful distance. Therefore the option was chosen to run the HSR line alongside the existing highway and rail alignments directly through the town, with an upgraded or new station located at the existing Albury railway station site. A 5.3 km viaduct is used to cross the Murray River floodplain and highway intersections entering Albury from the south.

Curvature restrictions are required to keep within the available corridor through the town, resulting in speed limits of 200 km/h, then 100 km/h in the vicinity of the station. Albury has been chosen as a stop for all services (including express) so the impact of these speed limits is minimal.

Albury to Wagga Wagga

The alignment runs alongside the Hume Highway north of Albury for approximately 40 km until reaching Culcairn, avoiding high ground to the east.

From here, the alignment heads north towards Wagga Wagga across mostly flat, sparsely populated rural land. Two deviations are made to avoid hilly terrain.

Wagga Wagga is passed on the east, with a 5.3 km viaduct over the Murrumbidgee River floodplain. The station is located 5 km from the town centre, by the Sturt Highway between East Wagga Wagga and Gumly Gumly. The station will be constructed with elevated platforms to meet the viaduct.

FIGURE 47 **HSR alignment: Melbourne–Wagga Wagga (highlighted segment corresponds to the profile shown in Figure 48)**

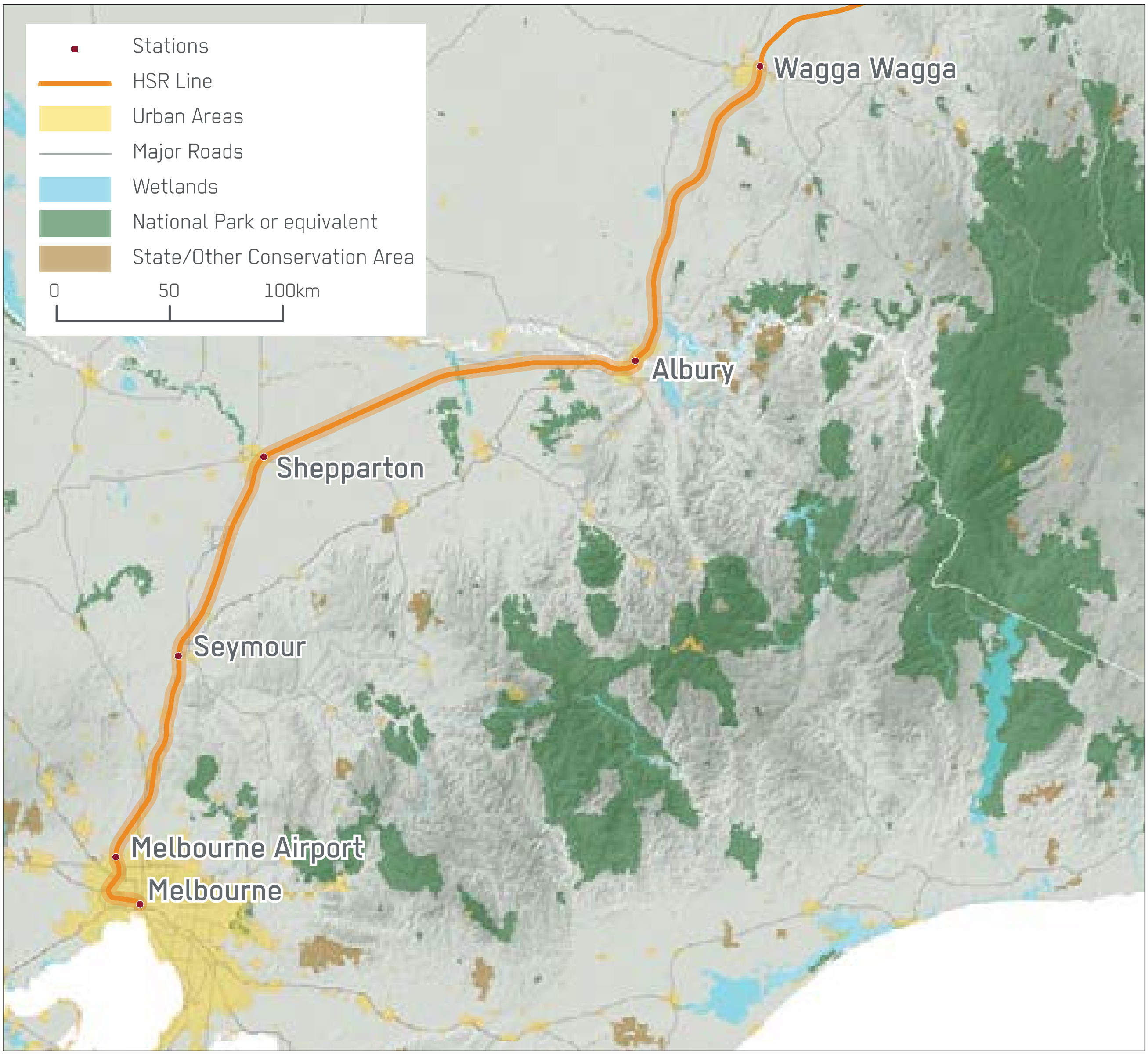
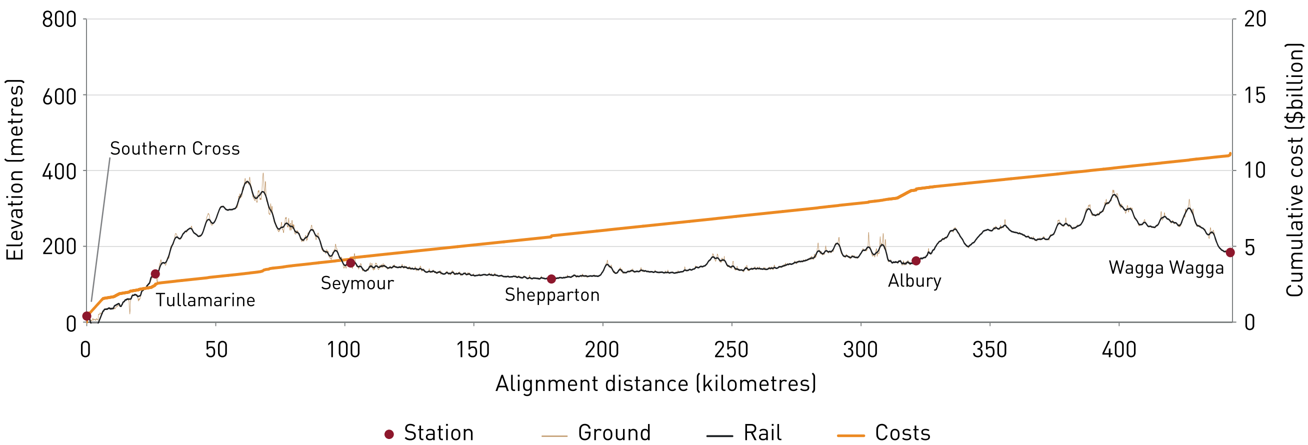


FIGURE 48 **HSR alignment profile and cost: Melbourne–Wagga Wagga**



Wagga Wagga to Sydney

The undulating highlands between Wagga Wagga and Sydney require more tunnelling than the Melbourne to Wagga Wagga segment. The total construction cost estimate for this section, is $18.1 billion for 408 km of mainline and 81 km of branch line to Canberra. The final 29.7 km into Central Station, including a $1 billion upgrade to create the HSR station, costs $4.2 billion. The cost of the 81 km branch line to Canberra is $2.3 billion, including Canberra HSR Station.

Wagga Wagga to Gunning

The next stops along the HSR route are due east of Wagga Wagga, and must traverse hilly terrain before reaching the Southern Highlands. The choice was made to run the alignment further north of Wagga Wagga and Gundagai, through wide but gentle hills and valleys. The terrain further south around the Murrumbidgee River valley is more variable and would require more tunnels and bridges.

From Jugiong the alignment runs along the northern side of the Hume Highway until just before Gunning. Here the line crosses the Highway to run along the southern side. The HSR mainline from Wagga Wagga to Gunning has been considered as a sub-segment because the Canberra branch line intersects near Gunning - there is no HSR station at Gunning.

FIGURE 49 **Cost per kilometre of HSR segments from Wagga Wagga–Sydney**

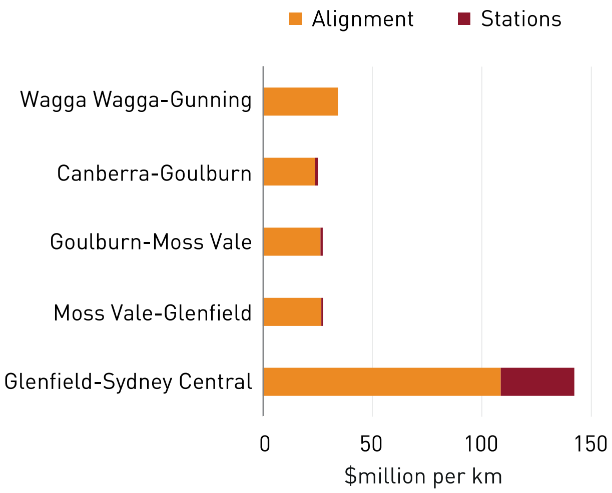


TABLE 18 **Length breakdown of HSR segment from Wagga Wagga–Sydney**

	Length (km)	Per cent of segment length
Tunnels	26.6	6.5%
Bridges	22.9	5.6%
Grade	358.5	87.9%
Total length	**408.0**	

Canberra branch line to Goulburn

Mountains directly west of Canberra make a direct path from Wagga Wagga very challenging and expensive. Avoiding this obstacle by directing the mainline south from Yass to pass through Canberra would represent a significant diversion. In addition, the passenger demand for Canberra is only a fraction of demand between Sydney and Melbourne. Therefore a branch line was chosen to connect Canberra to the main line. This branch line intersects near Gunning and allows a full-speed interchange between the Canberra line and the main line. Canberra HSR Station is located 70 km south of the main line at the current railway station site and enters the city from the east.

The profile of this branch line is not shown in Figure 51. However, the cost is added at the point on the mainline alignment where the branch line connects.

The costs for Canberra to Goulburn have been given as one segment to enable consideration of Sydney to Canberra as a discrete stage of HSR. It includes the whole Canberra branch line, and the HSR mainline from where the branch line joins just south of Gunning, to Goulburn, running on the south side of the Hume Highway. Goulburn station is located on the south side of the town next to the Hume Highway.

Goulburn to Sydney

Goulburn is on a plateau 640 m above sea level. The HSR alignment remains above 600 m elevation until past Moss Vale, where it gradually descends into the Sydney Basin. From Goulburn the alignment mainly follows a system of valleys on the north side of the Hume Highway. It then curves westward to pass between Moss Vale and Bowral, with a station on the north side of Moss Vale, 2.5 km north of central Moss Vale and 6.4 km from central Bowral. This station is located at the intersection of the existing rail line so that there is opportunity for interchange services.

The HSR line curves northwards again to pass through the hills on the east side of Bowral, then skirts the western edges of the Upper Nepean State Conservation Area past Yerrinbool. It remains very close to the Hume Highway on the entry to Sydney, to avoid some of the more challenging terrain and minimise the impact on built-up areas such as Douglas Park and Campbelltown.

Glenfield HSR Station is located 1 km northeast of the existing Glenfield rail station, providing good opportunities to interchange with existing rail services to the suburbs of the greater Sydney area and beyond. From Glenfield, the alignment approaches Sydney from the south alongside the East Hills railway line and then tunnels to Central Station.

FIGURE 50 **HSR alignment: Wagga Wagga–Sydney (highlighted segment corresponds to the profile shown in Figure 51)**

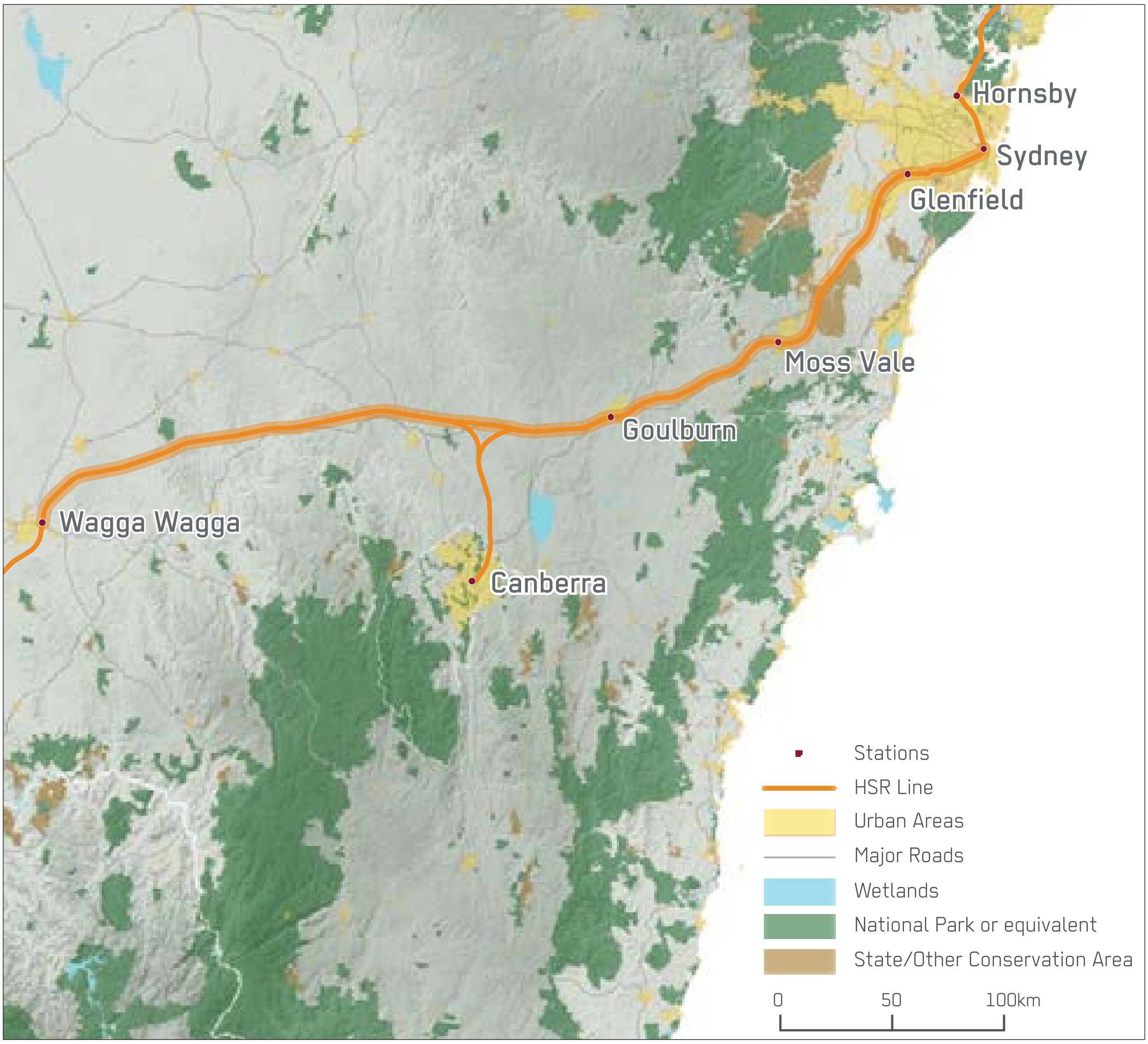
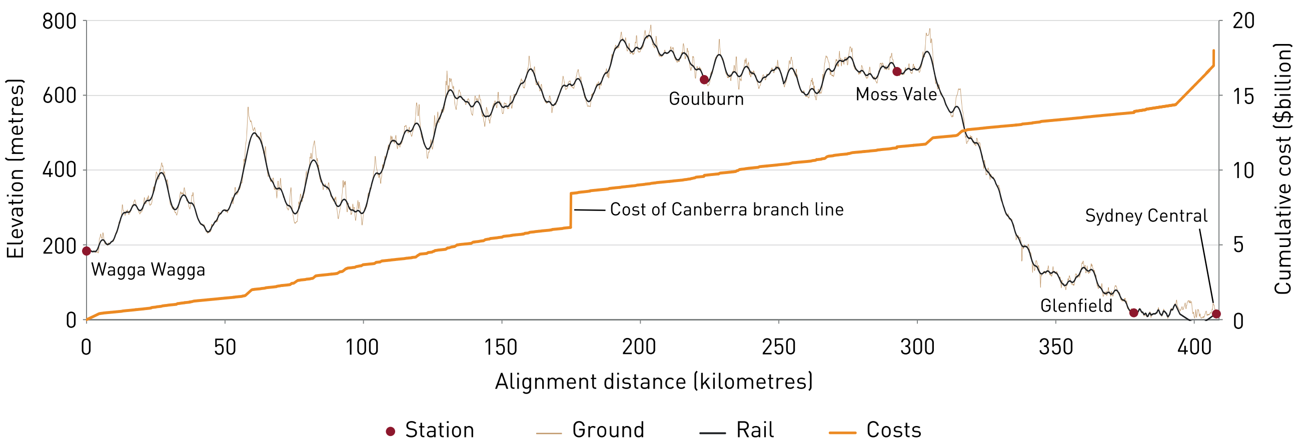


FIGURE 51 **HSR alignment profile and cost: Wagga Wagga–Sydney. Canberra branch line profile not shown, although the cost is included**



Sydney to Coffs Harbour

The segment from Sydney to Coffs Harbour contains some of the most challenging terrain of the whole HSR alignment. The Hawkesbury River crossing is particularly difficult, and the entire segment from Newcastle to Coffs Harbour requires navigating through sharply undulating terrain with a number of tunnels and bridges. The whole 480 km segment will cost $18.3 billion, of which $3.3 billion is for the first 29.8 km exiting Sydney.

FIGURE 52 **Cost per kilometre of HSR segments from Sydney–Coffs Harbour**

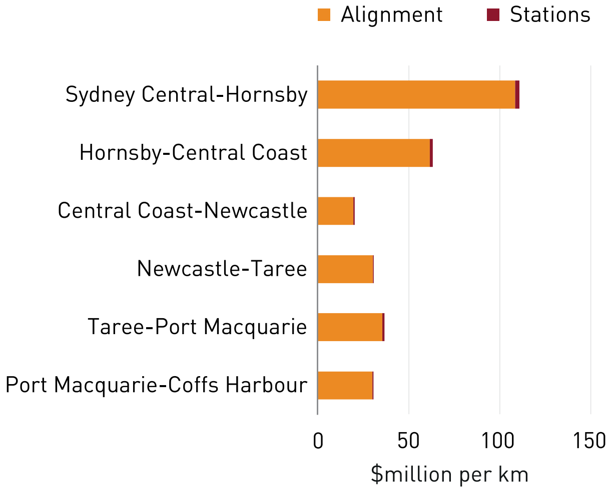


TABLE 19 **Length breakdown of HSR segment from Sydney–Coffs Harbour**

	Length (km)	Per cent of segment length
Tunnels	29.1	6.1%
Bridges	35.4	7.4%
Grade	415.1	86.5%
Total length	479.6	

Sydney to Central Coast

From Central Station, the alignment continues underground to the north. Surfacing near Lindfield, the HSR line follows the North Shore Line to Hornsby. Hornsby HSR Station joins the current railway station providing good opportunities to interchange with existing rail services.

Some of the most challenging terrain of the HSR alignment is encountered between Hornsby and the Central Coast. The minimum curve radius of this segment is relaxed to 7.1 km (compared to 10 km elsewhere), which still allows 400 km/h operating speeds[44]. Navigating the difficult ridges and valleys around the Hawkesbury River is made easier as a result.

From Hornsby the alignment continues north past the built-up area of Mount Kuring-gai, following the same ridgeline as the Sydney-Newcastle Freeway as it heads towards the Hawkesbury River. Several tunnels and bridges are required. The Hawkesbury River is crossed on a bridge 30 m above the water level. The alignment then continues close to the highway until Calga. Significant tunnelling is required in this segment, on either side of the river due to the mountainous terrain.

The alignment passes through 4.5 km of the Brisbane Water National Park as it cannot deviate as sharply as the existing highway. Central Coast HSR Station is located next to the Sydney-Newcastle Freeway north of Ourimbah, allowing central access to the many surrounding populated areas. Here an interchange is proposed as well as a branch line connecting the HSR line to the existing Newcastle Rail Line. Gosford and Woy Woy could then be serviced by a high-speed shuttle service between Central Station and the current local stations in addition to services on the main line. Local services collecting passengers from towns between Newcastle and Gosford would also be able to interchange with HSR services.

Central Coast to Newcastle

The alignment approximately follows the Sydney-Newcastle Freeway towards Newcastle. Passing Morisset and Dora Creek, high ground to the west is avoided. There is a potential issue with mine subsidence in this area, which would require remediation work.

After passing through approximately 6 km of the Sugarloaf State Conservation Area, the alignment continues to pass just north of the built-up area of Hexham. Newcastle HSR Station is located here, 15 km north-west of the centre of Newcastle. To better connect the city of Newcastle to the HSR service, a branch line is proposed using 17 km of the existing Hunter Line corridor. As with the Central Coast, the Newcastle city centre could be served by a high-speed shuttle service along this branch line stopping at existing local stations then directly to Sydney Central Station.

FIGURE 53 **HSR alignment: Sydney–Coffs Harbour (highlighted segment corresponds to the profile shown in Figure 54)**

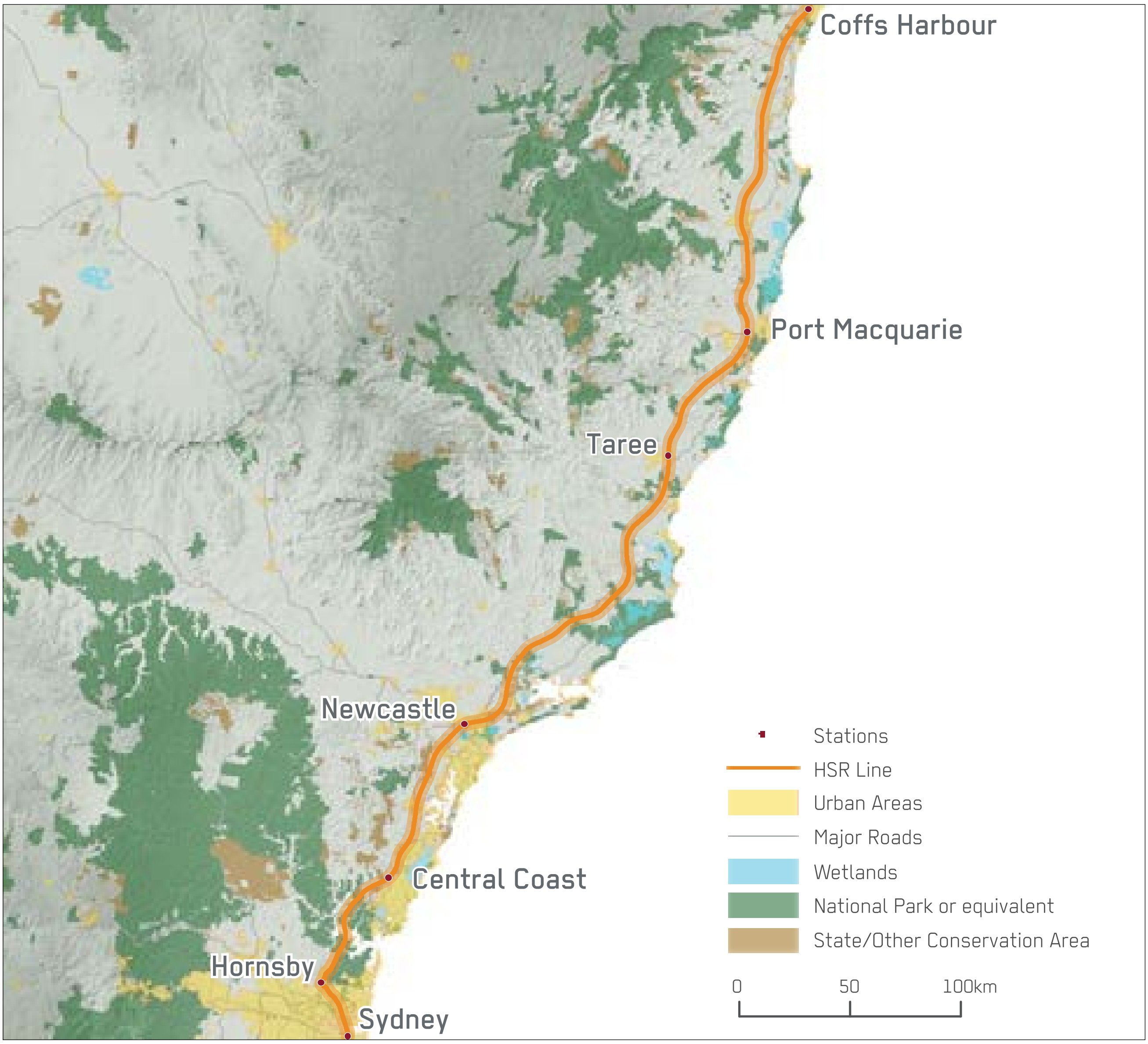
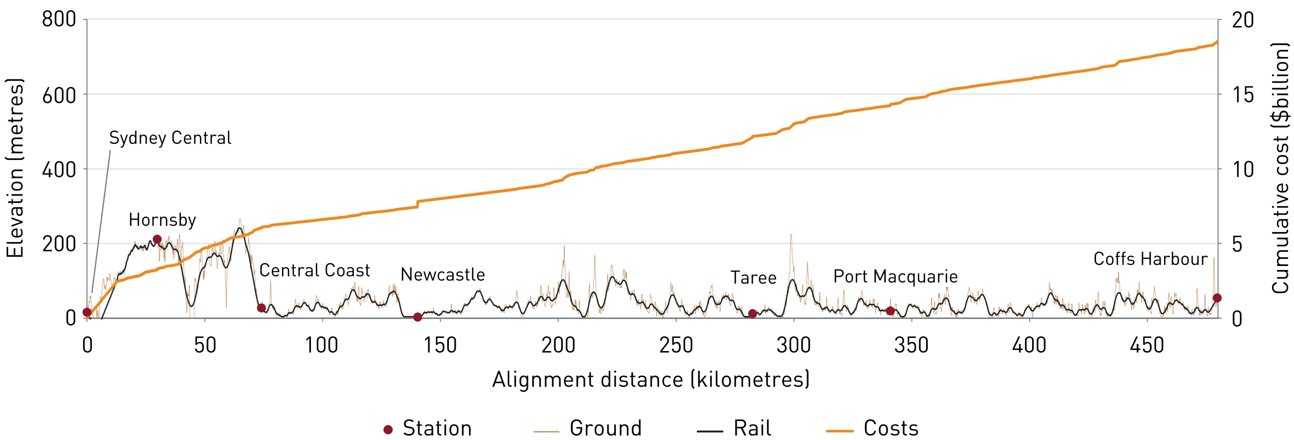


FIGURE 54 **HSR alignment profile and cost: Sydney–Coffs Harbour**



Newcastle to Taree

From Hexham, the alignment continues north-west, passing through Tilligerry State Conservation Area and skirting the eastern edge of Grahamstown Lake. It passes through Medowie State Conservation Area and some small parts of Karuah National Park, while staying close to the existing roads so as to have minimal impact on the national park. This avoids traversing west of the lake around the Hunter and Williams Rivers, which is a flood-prone area containing soft soils and acid sulfate soil. Disturbing these soils could damage the local waterways and construction costs would be increased.

Advancing towards Bulahdelah, the alignment avoids hilly terrain to the west just past Allworth. Two sections of the Myall Lakes National Park, part of the internationally protected Myall Lakes Ramsar site, are crossed. A total of 4.5 km of track through these national park sections will be tunnelled to reduce the disturbance on this sensitive environment. The HSR line, both surface and tunnelled segments, does not pass through the wetlands, but does pass through approximately 4 km of the national park associated with the Myall Wetlands catchment, several kilometres inland.

From here to Taree the alignment follows the Pacific Highway, within a few kilometres, avoiding the high ground on either side of Coolongolook and north of Nabiac. On approaching Taree to the east, the Manning River and its floodplain are crossed with a 4.3 km viaduct before reaching the Taree HSR Station on the northern bank of the river. The station is located close to Taree airport, approximately 5 km from the centre of the town, and 1 km from Cundletown. Public bus services may provide convenient transfers to the surrounding area.

Taree to Port Macquarie

From Taree, the alignment follows close to Lansdowne Road, crossing the Lansdowne river on a 3.2km viaduct just east of the town. A more coastal alignment here was not chosen due to the large expanses of soft soils, acid sulfate soil and waterways.

The alignment continues north-east avoiding steep ground as much as possible, passing Hannam Vale, Lorne, Upsalls Creek and Logans Crossing. The existing rail line and the Pacific Highway are then crossed close to Herons Creek. Part of Queens Lake State Conservation Area is crossed, before the alignment heads north to reach Port Macquarie HSR Station.

Port Macquarie HSR Station is located close to the intersection of the Pacific Highway and the recently upgraded Oxley Highway, approximately 8 km from the town centre. A public bus service may provide fast transfers to the city and surrounding towns.

Port Macquarie to Coffs Harbour

After Port Macquarie HSR Station, there is a 2.8 km viaduct across the Hastings River floodplain, as the HSR alignment closely follows the Pacific Highway. Further north there is another viaduct running 2.1 km across the Wilsons River floodplain just east of Telegraph Point.

The alignment continues in the vicinity of the Pacific Highway up to Kempsey, which it passes on the western side avoiding acid sulfate soil in the floodplain to the east of the town. It then continues north for 10 km before intersecting with the existing rail line and following its approximate alignment until Warrell Creek. Hilly terrain north of Eungai is avoided on either side. After passing west of Macksville, the HSR alignment continues 5-10 km inland from the coast, with some tunnelling required.

The alignment passes through 3.2 km of Bongil Bongil National Park. It passes Bonville and Boambee, before reaching the location of Coffs Harbour HSR Station near the intersection of the Pacific Highway and Stadium Drive. This location was chosen as it is only 6 km from central Coffs Harbour to the north and an equal distance to the built-up areas of Toormina and Sawtell to the south. To achieve this, the curve radius of this segment was relaxed to 5.6 km, making it possible to navigate the mountains which tower over the Coffs Harbour township without major tunnelling. This allows a maximum operational speed of 350 km/h[44], but would remain limited at this if operating speeds were increased in future.

Aerial view of Coffs Harbour PHOTO: DESTINATION NSW

Coffs Harbour to Brisbane

From Coffs Harbour to Brisbane the terrain is gentler than the preceding segment from Sydney. There are several points with notable challenges: the Clarence River floodplain at Grafton, hills and rivers either side of Lismore, and a set of ridges south of the Gold Coast requiring a sequence of tunnels. The total cost of this 358 km segment is $13.4 billion, of which $2.6 billion is the final 25.9 km into Roma Street Station in central Brisbane.

Coffs Harbour to Lismore

The alignment exits Coffs Harbour through the mountains to the west, passing Karangi and Coramba. From here it follows the Orara Valley, staying close to Orara Way until reaching Grafton, avoiding undulating terrain on either side of the road. Grafton is passed to the west over Susan Island and Carrs Island, with the Clarence River floodplain requiring a 7.5 km viaduct. Grafton HSR Station is located 5 km north of the town centre, adjacent to the existing rail line. The elevation is high enough here such that flooding should not affect the station. An alignment passing to the east of Grafton was not chosen due to the larger floodplain and extensive acid sulfate soils present in that area.

FIGURE 55 Cost per kilometre of HSR segments from Coffs Harbour–Brisbane

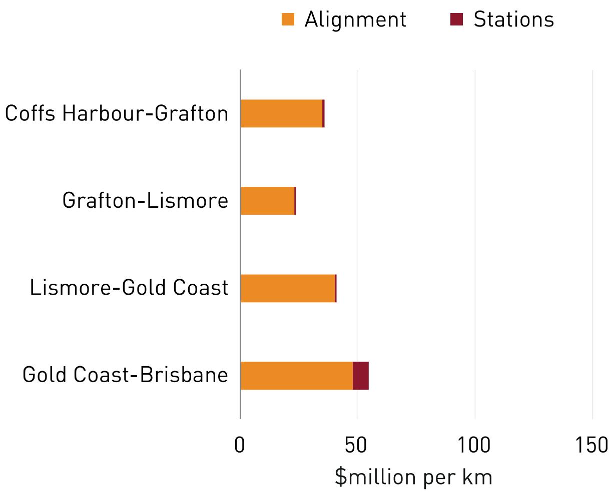


TABLE 20 Length breakdown of HSR segment from Coffs Harbour–Brisbane

	Length (km)	Per cent of segment length
Tunnels	20.0	5.6%
Bridges	26.8	7.5%
Grade	311.0	86.9%
Total length	**357.8**	

The alignment continues north, closely following the existing rail line. It diverges at Banyabba and continues north, before heading towards Lismore across flat and open rural land. Lismore HSR Station is located on the south side of Lismore Showgrounds, approximately 1 km north of the town centre. Lismore is central to the population centres of Casino, Ballina and Byron Bay and may develop as a hub to these areas. Public bus transfers may provide convenient transfers to these towns or the existing railway could be recommissioned to service to surrounding areas.

Lismore to Brisbane

The alignment heads north-east towards Bangalow, within a few kilometres of the existing rail line. It then continues north, passing east of Mullumbimby, avoiding the high ground to the west but passing through a small part of the Billinudgel Nature Reserve.

On reaching the Tweed River, there is a 5.3 km viaduct crossing the floodplain and over Stotts Island Nature Reserve. It could be possible to have the route encroach less on this environmentally sensitive area by shifting the alignment further to the west. This would increase the construction costs considerably and was not chosen in this study.

The alignment then heads parallel to the coast, following an inland corridor to avoid impacting the significant urban development closer to the coast. This segment runs through a number of east-west ridgelines, which must be tunnelled. It passes west of Bilambil Heights and east of Currumbin Valley before slowing to 200 km/h on entry to the Gold Coast. Speed is limited here to allow the alignment to keep within the existing rail corridor. This compromise was made to reduce the cost of this segment while allowing convenient access to the residents of the Gold Coast—Tweed Heads area.

There is a high level of passenger demand for the Gold Coast and all services (including express) will stop here. As a result, the time penalty associated with this speed restriction is minimal. The added advantage is the possibility of high-speed shuttle services stopping at current local stations then directly to Roma Street Station in Brisbane. This is only possible when the HSR alignment extends along the length of the Gold Coast urban area.

The Gold Coast HSR Station is co-located at the existing Nerang Station, which is central to the resident population, providing an interchange with existing rail and bus systems which service the coast.

Continuing alongside the existing rail corridor until Ormeau, the HSR alignment heads directly north through rural and peri-urban terrain, curving westward to avoid the Venman Bushland National Park. It enters Brisbane from the east side of the city, after following the Gateway Motorway for several kilometres north, then heading east to tunnel from Cannon Hill to Roma Street Station.

FIGURE 56 **HSR alignment: Coffs Harbour–Brisbane (highlighted segment corresponds to the profile shown in Figure 57)**

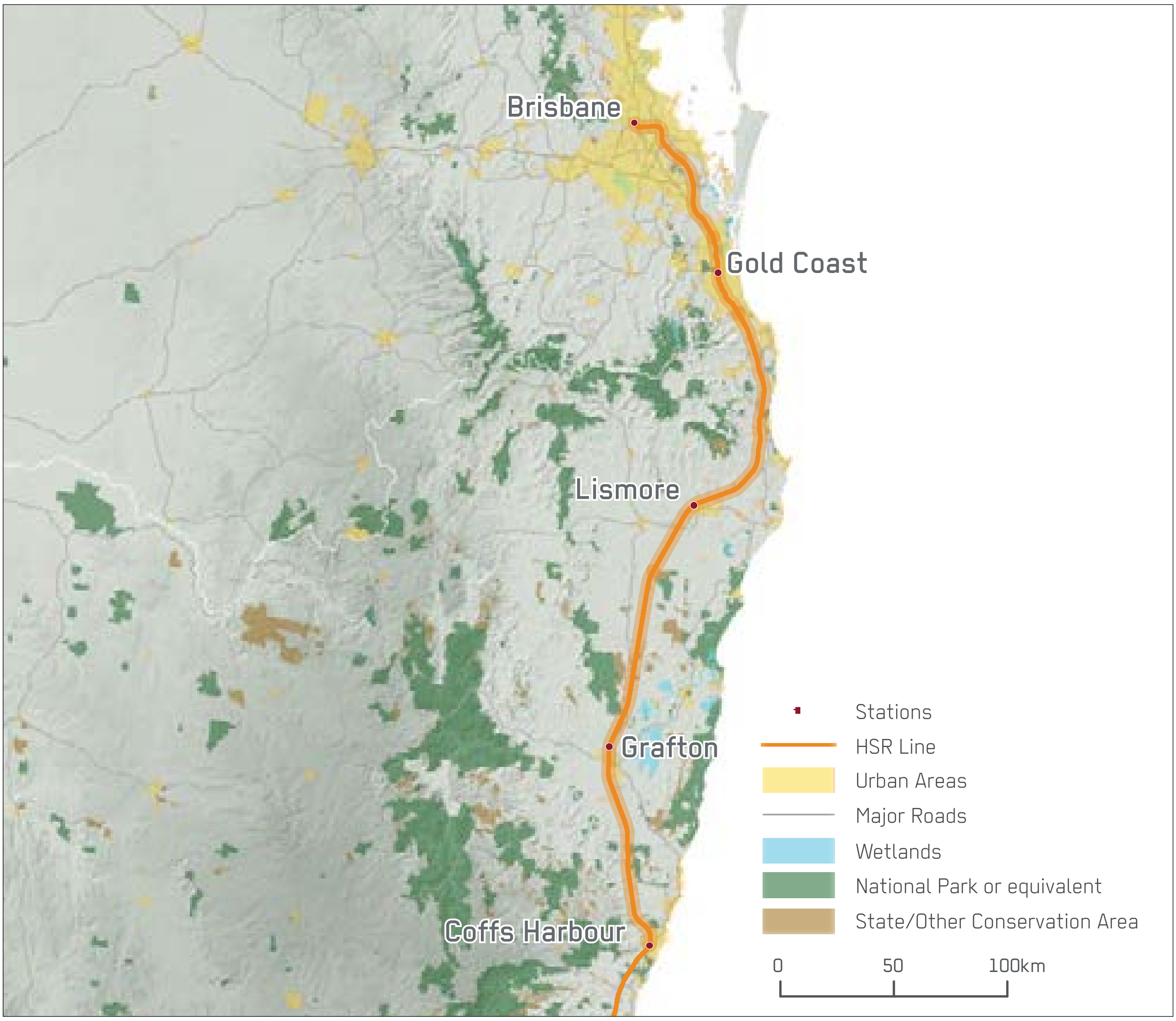
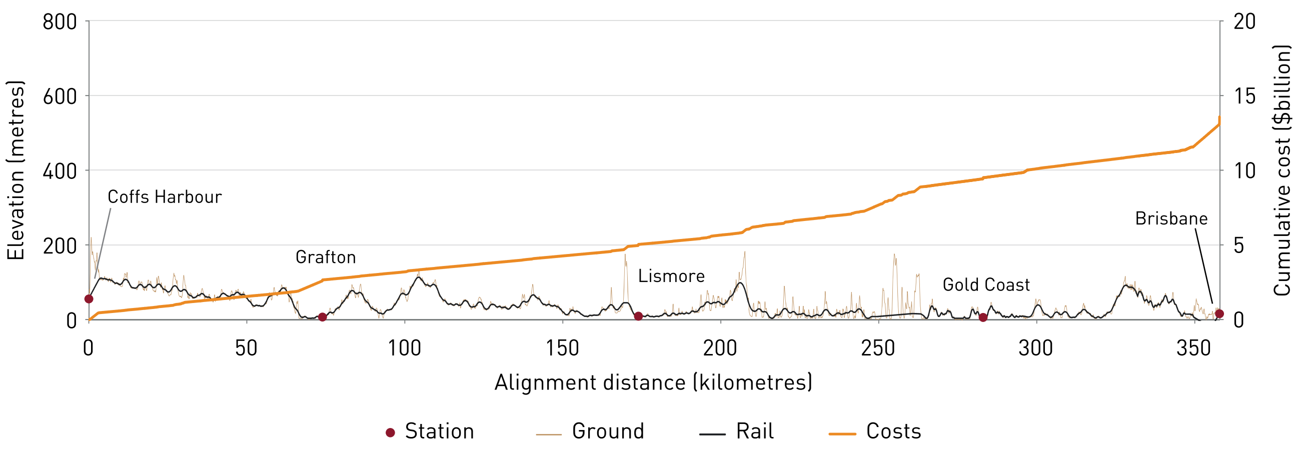


FIGURE 57 **HSR alignment profile and cost: Coffs Harbour–Brisbane**



Detailed examples of applying design principles

Several examples are provided to demonstrate the design principles, trade-offs and challenges as applied to particular segments of the HSR route. The segments chosen are the Albury-Wodonga town access, the Hawkesbury River crossing and the traverse of the Grafton floodplain.

Albury-Wodonga access

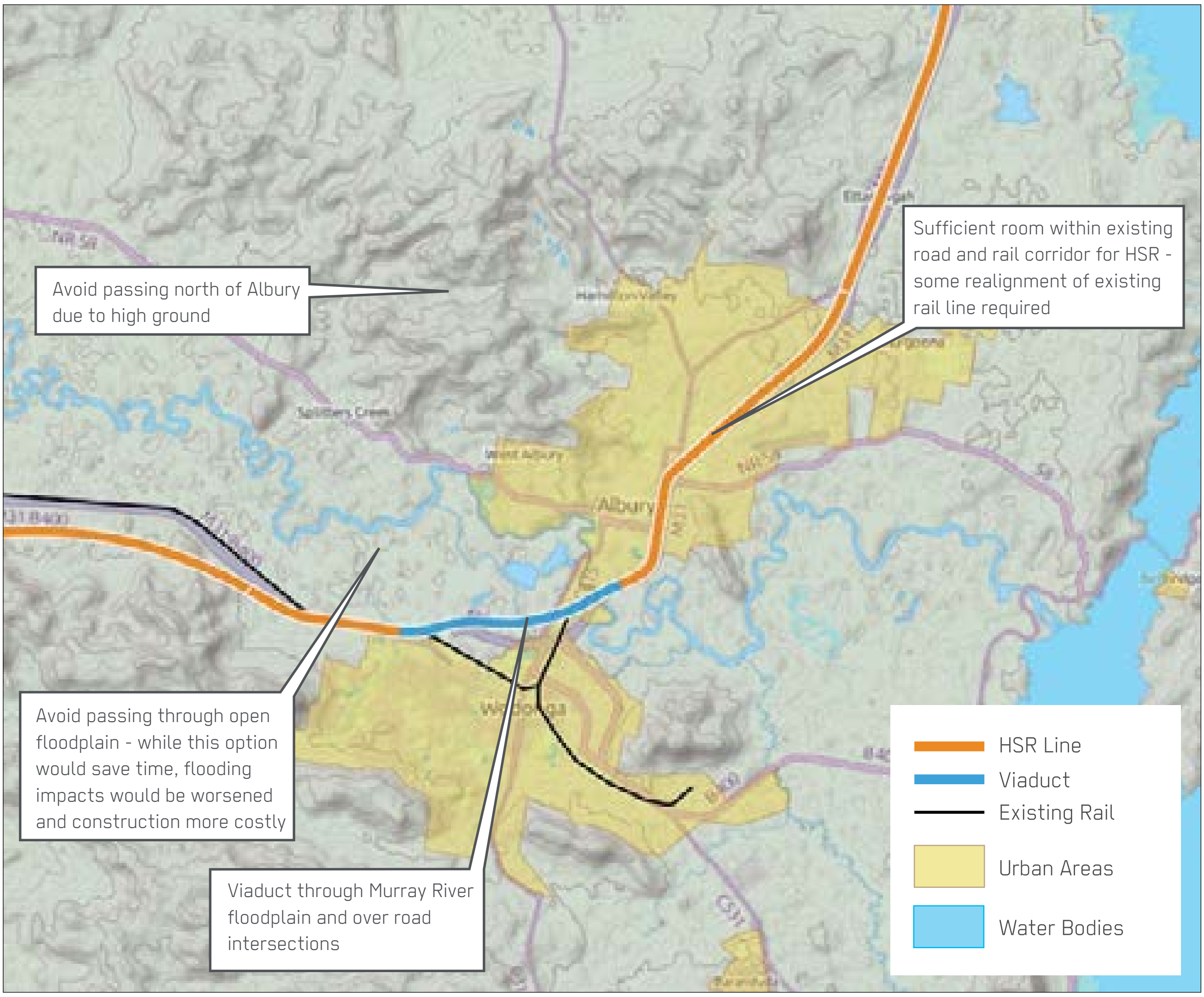
The border town of Albury, located in New South Wales and adjacent to its Victorian sister city of Wodonga, is one of only three major regional townships along the HSR alignment with a centrally located station (the others being Lismore and the Gold Coast).

The presence of high ground to the north and south of the towns makes bypassing on either side difficult and costly options, and the surrounding Murray River floodplain offers a unique challenge.

A wide existing road and rail corridor through the centre of Albury is available along the Hume Highway. This makes it possible to construct the HSR line through the town, providing convenient passenger access with minimal disturbance. The use of this corridor requires a speed limit of 100 km/h within 5 km on either side of the station. Given that all trains on the proposed service will stop in Albury (including express services) this speed restriction will not significantly affect journey times. This also means that the impacts on the Murray river floodplain can be minimised by putting the HSR line alongside the existing road and rail corridors. A 5.3 km viaduct spans the the river and floodplain.

FIGURE 58 **HSR alignment design accessing Albury-Wodonga**

BASE MAP: © OPENSTREETMAP CONTRIBUTORS



Hawkesbury River

The Hawkesbury River is located approximately 40 km north of the Sydney CBD. This proved to be one of the most challenging segments of the alignment. The surrounding area consists of steep, forested hills and deep valleys (Figure 59), much of which is protected by national park. Considering these issues along with the problem of construction access, the chosen alignment runs close to existing road and rail corridors as much as possible. It is one of the few examples along the HSR route where the decision was made to encroach on national park. The parts of national park that are impacted by the HSR line are directly adjacent to the existing freeway, which has already caused partial disturbance, instead of passing through relatively untouched areas of national park further to the east or west.

This is an example where environmental offsetting measures would be applied, purchasing land adjacent to the national park to increase the amount of land protected overall. The cost of this is included in the total land acquisition costs.

FIGURE 59 North-facing view of the Hawkesbury River crossing[53] PHOTO: DAVID NOBLE

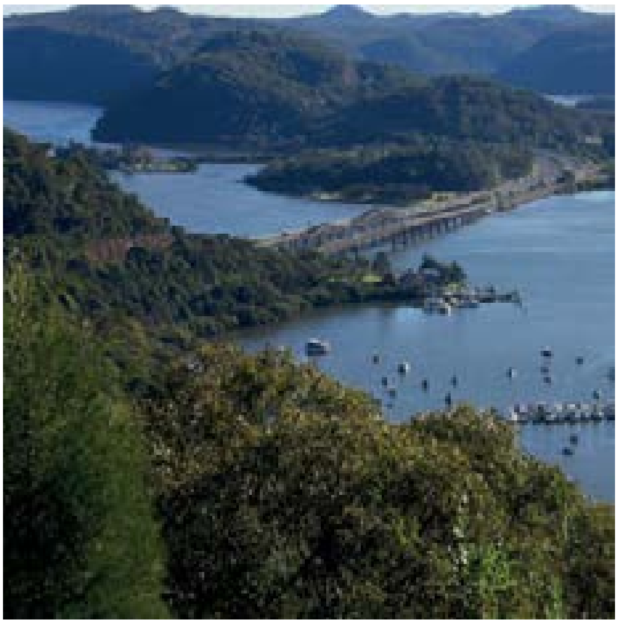
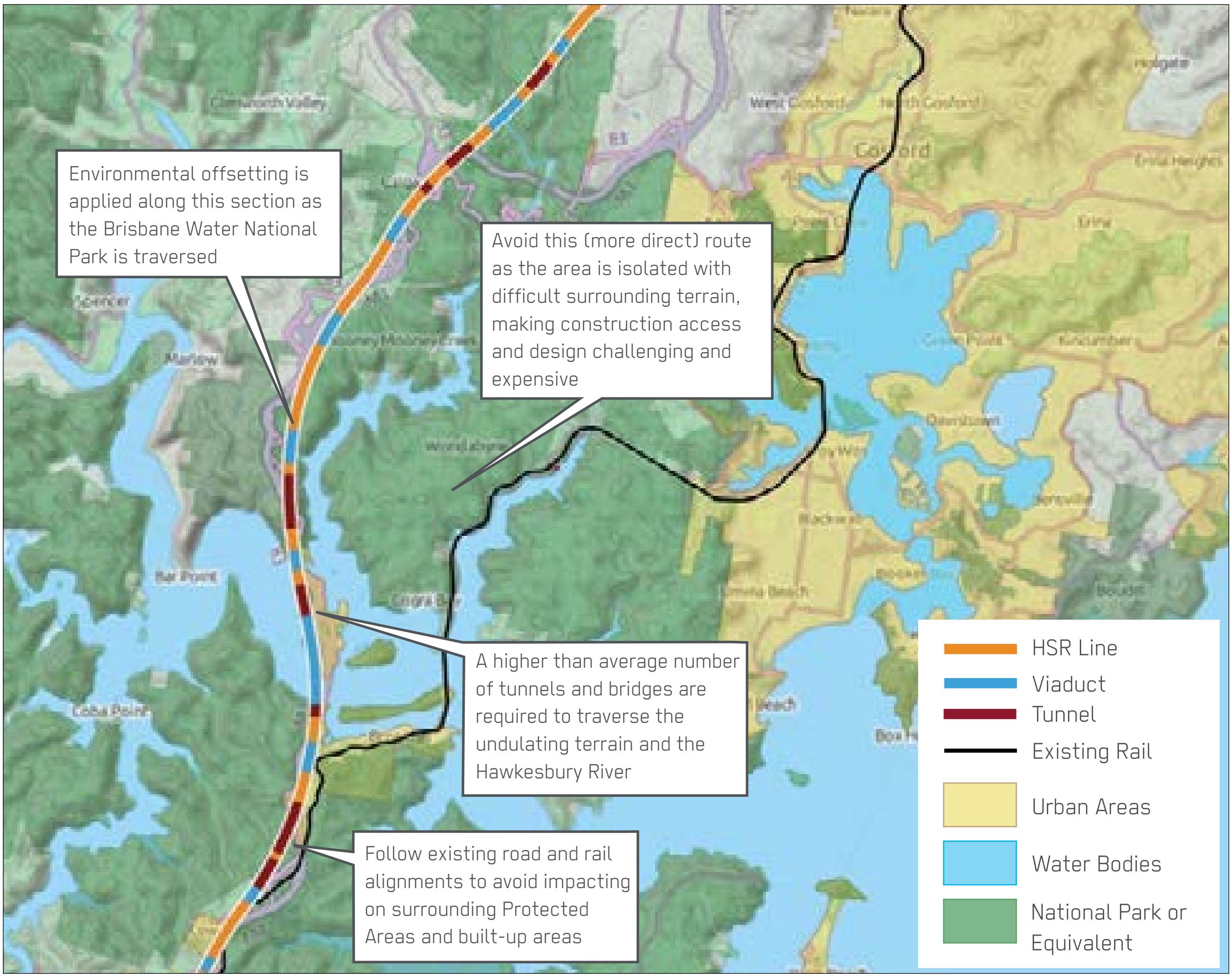


FIGURE 60 HSR alignment design crossing the Hawkesbury River, New South Wales

BASE MAP: © OPENSTREETMAP CONTRIBUTORS



Grafton floodplain

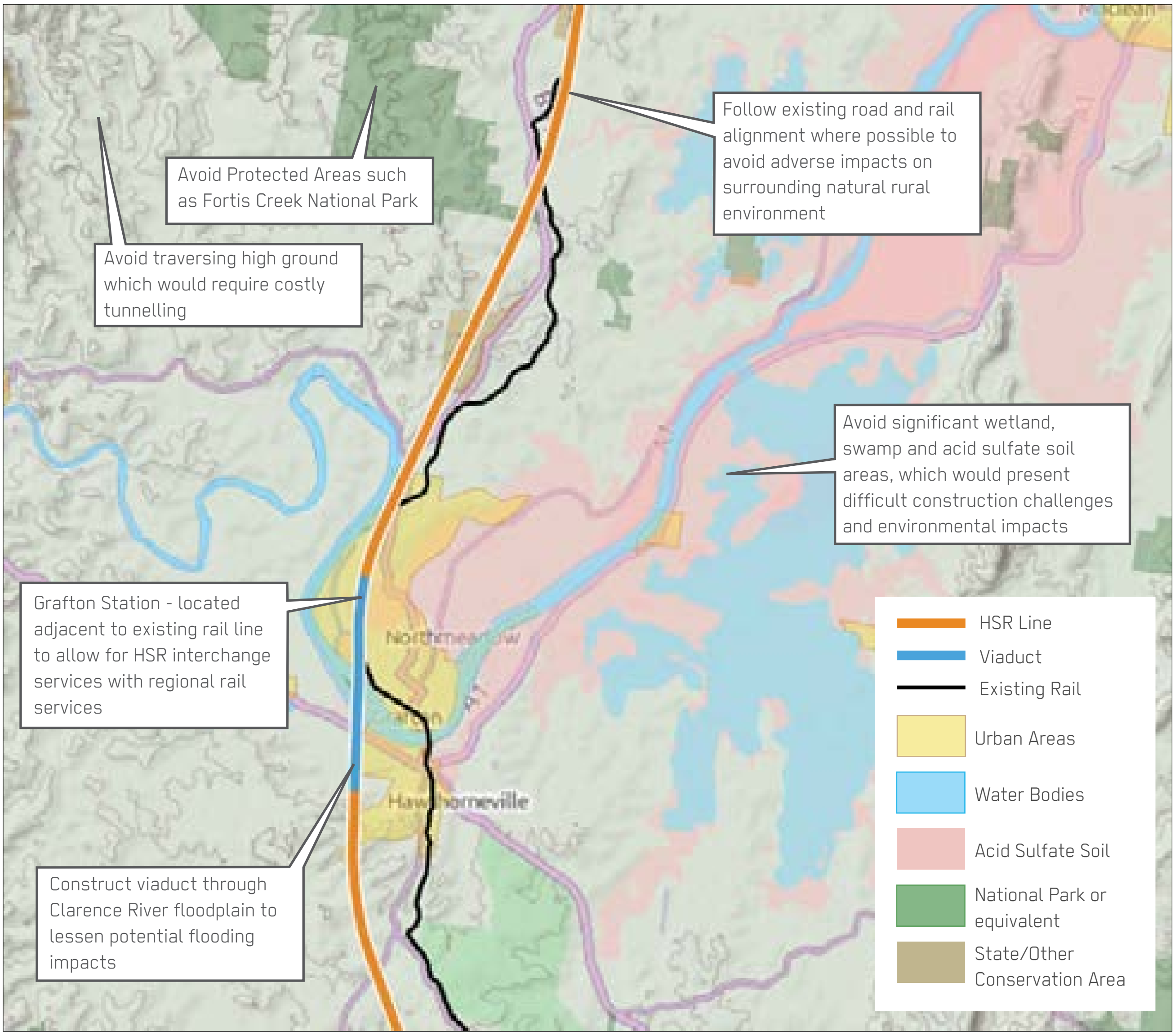
Grafton is located in northern New South Wales, approximately 40 km inland. It is situated on the floodplain of the Clarence River, a flat alluvial plain only a few metres above sea level. The HSR line runs along the western outskirts of the urban area. A viaduct 7.5 km long is provided to avoid inundation during flooding events and minimise disruption to the natural drainage. The location chosen for Grafton HSR Station is on high ground north of the river.

The option of passing to the east was decided against due to the presence of acid sulfate soils and wetlands. Disturbing acid sulfate soils would result in added cost, and uncertain environmental risks. Traversing the wetlands would result in extra flooding risk and harm to ecosystems.

The alignment then continues north, approximately following the existing railway line.

FIGURE 61 **HSR alignment design around Grafton, New South Wales**

BASE MAP: © OPENSTREETMAP CONTRIBUTORS



Major city access

The major cities of Australia's east coast provide the bulk of the estimated HSR patronage and providing convenient access to this service is important to realise this potential. The urban development of these cities presents a significant challenge to accommodate HSR infrastructure. Ideal station locations are typically central to the urban area and surrounded by dense housing.

As a result, city access represents a significant portion of the total cost of the HSR project. Many options were explored to reduce this cost including making use of existing infrastructure corridors. Opportunities to utilise existing transport or other infrastructure corridors are limited and a balance must be chosen between train speed and the cost-saving potential of using available corridors. The curvature restrictions to allow high speeds do not allow HSR infrastructure to keep entirely within the confines of the limited corridors that are available.

In addition to the physical placement of HSR infrastructure, other issues add to this challenge. Noise pollution, integration with existing transport services and environmental protection all factor in the decisions made.

Also considered was the geographic centre of city populations and the destinations popular for visitors when identifying locations for HSR stations. Typically passengers embarking on a journey can originate from any point in the city and the geographic centre of population is a good guide as a central location. However, visitors to a city often concentrate in a small number of locations.

An investigation of the compromise between the construction cost and travel speed was made for the cities of Melbourne, Canberra, Sydney, Gold Coast and Brisbane. These are quantified and explained in this chapter and a summary of the recommended options is provided in Table 21.

The average travel speed achieved for the city segments is 162 km/h with an average cost rate of $100 million per kilometre. Sydney is the most expensive city to access per kilometre and also has the longest pathway due to the approach from the south and the north. For these reasons more than half of the total city access cost is attributed to Sydney.

TABLE 21 Summary of the preferred access option for each city

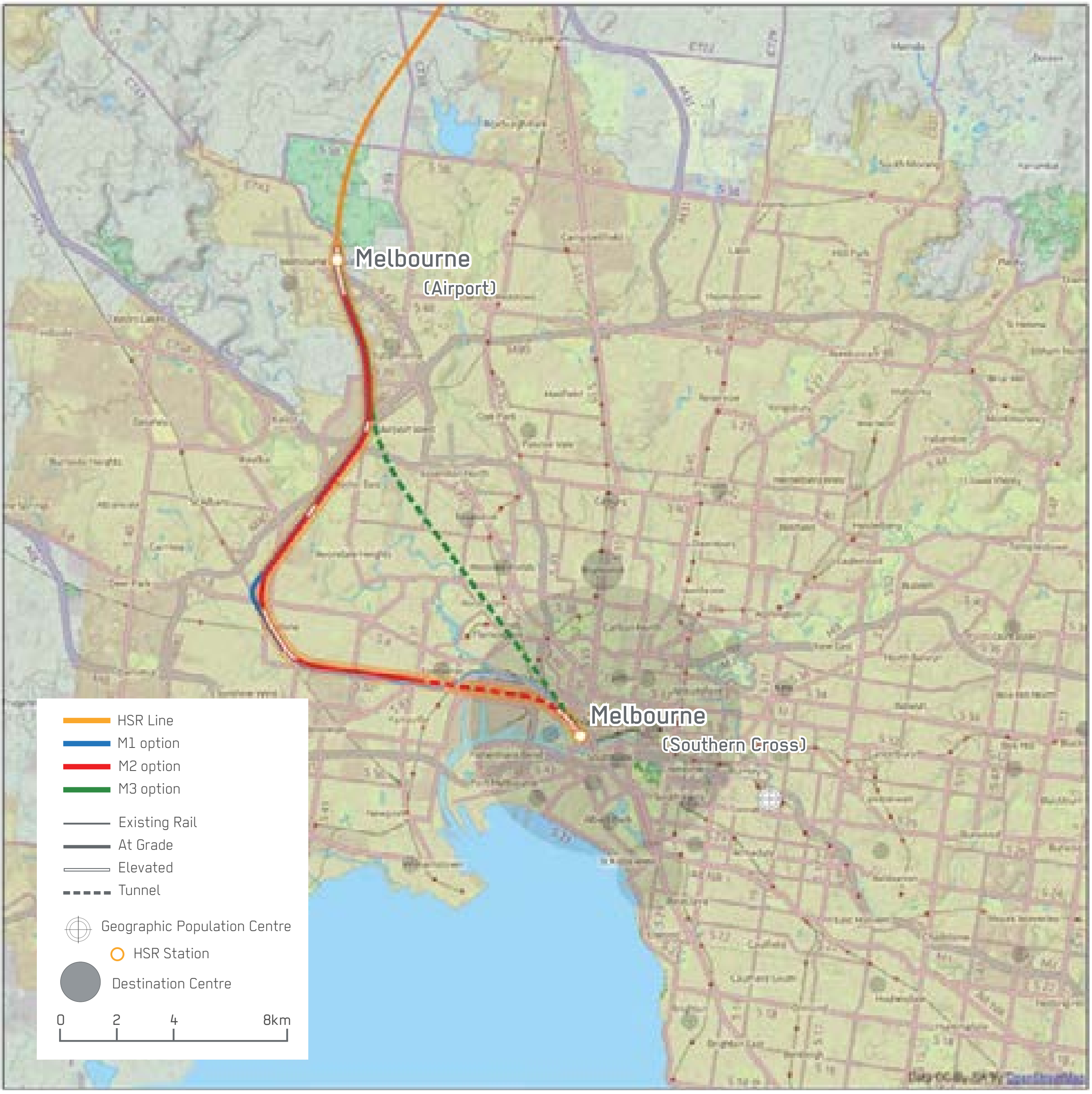
	Cost ($M)	Distance (km)	Cost rate ($M/km)	Time (minutes)	Average speed (km/h)
Melbourne	2,499	26.6	93.9	12	148
Canberra	409	9.7	42.2	4	173
Sydney	7,576	63.1	120.1	35	124
Gold Coast	361	32.6	33.8	12	169
Brisbane	2,619	25.0	104.7	8	198
Total	**14,567**	**157.0**	**79.0**	**71**	**162**

Melbourne

Melbourne is a fast-growing city with a population of 3.7 million and the largest urban area in the country, approximately 2,543 square kilometres[54]. Although the majority of Melbourne residents currently live east of the CBD, the CBD is relatively central and offers the best point of access to the greater city area. The HSR alignment approaches Melbourne from the north where there are two main areas where the urban fringe is within 15 km of the city centre: Campbellfield and Tullamarine. Access via Campbellfield was eliminated as an option early due to the opportunity to incorporate a rail link to Tullamarine Airport. Three alternatives were explored in detail: M1, M2 and M3 (Figure 62).

Option M2 is recommended as the preferred option. All options offer the opportunity to add a high-speed shuttle service from the city to the airport.

FIGURE 62 **Options investigated for access to Melbourne** BASE MAP: © OPENSTREETMAP CONTRIBUTORS



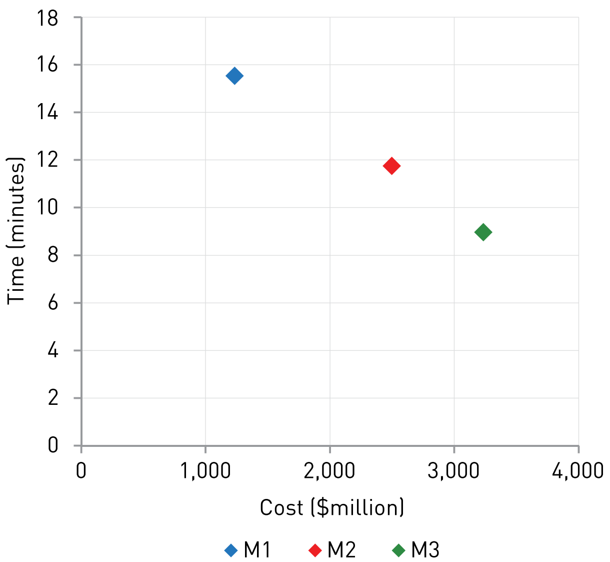
Melbourne M1

This option uses as much current infrastructure as is practically possible. From the Melbourne Airport HSR Station (located on a flyover above the Tullamarine Freeway) this alignment heads south, over the Western Ring Road and along the rail reserve from Airport West to Albion. Beyond Albion the alignment is suggested to merge with the soon-to-be-completed Regional Rail Link where it will continue to Southern Cross Station. This option would require speeds to be limited to 100 km/h from Albion to Melbourne CBD due to rail curvature constraints and mixed traffic with regional V/Line trains. M1 is estimated to cost $1.2 billion and offer a city-to-fringe travel time of 16 minutes, including a stop at Melbourne Airport Station. M1 is a low cost option which performs well in terms of travel time. However this was not chosen due to the unquantified complication caused by mixed traffic.

Melbourne M2

This option is a very similar alignment to M1. However, it involves constructing an entirely independent rail line. Changing course at Albion, the HSR alignment takes a more gentle turn to an elevated section past Sunshine Station. Allowing speeds of 150 km/h, the rail line returns to ground level before Tottenham and continues along the rail yard. From West Footscray the alignment tunnels to the North Melbourne rail yard. To avoid further congestion of the platform approach, the alignment is elevated from North Melbourne to first level platforms at Southern Cross Station. M2 is estimated to cost $2.5 billion and offer a city to fringe travel time of 12 minutes, including a stop at Melbourne Airport Station. M2 avoids the complication of mixed traffic and allows a shorter travel time, yet increases the construction cost. This compromise was chosen as the preferred option.

FIGURE 63 **Comparison of cost and travel time for Melbourne access options investigated**



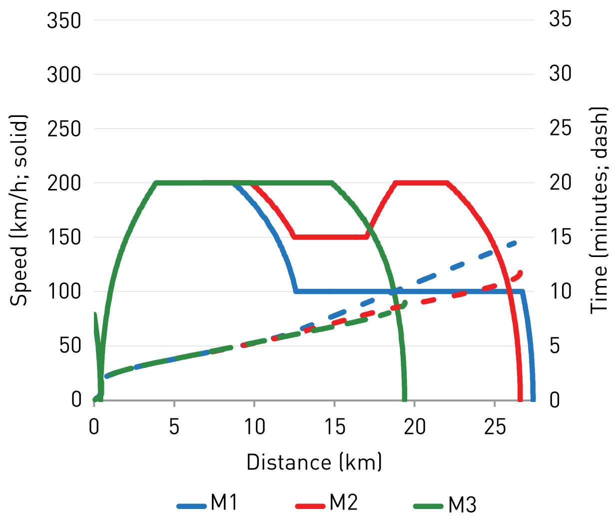
Melbourne M3

This option makes the least compromise in order to achieve the best possible journey time. Using the same corridor from Melbourne Airport Station to the Western Ring Road the alignment then tunnels all the way to an underground terminus at Southern Cross Station. This alignment is more costly due mainly to the long tunnelling required and the underground platforms. M3 is estimated to cost $3.2 billion and offer a city-to-fringe travel time of nine minutes, including a stop at Melbourne Airport Station. M3 is not recommended as the time saving of three minutes was not considered to justify the increased cost of $700 million.

TABLE 22 **Estimated cost of Melbourne access options**

	Estimated cost ($ million)		
Cost component	**M1**	**M2**	**M3**
Land acquisition	30	169	5
Substructure	92	130	38
Superstructure	58	99	72
Signalling	32	32	23
Power supply	71	72	51
Buildings and structures	360	1,407	2,463
Stations and depots	570	570	570
Conservation	21	21	15
Total	**1,234**	**2,499**	**3,236**

FIGURE 64 **Comparison of speed and time for Melbourne access options**

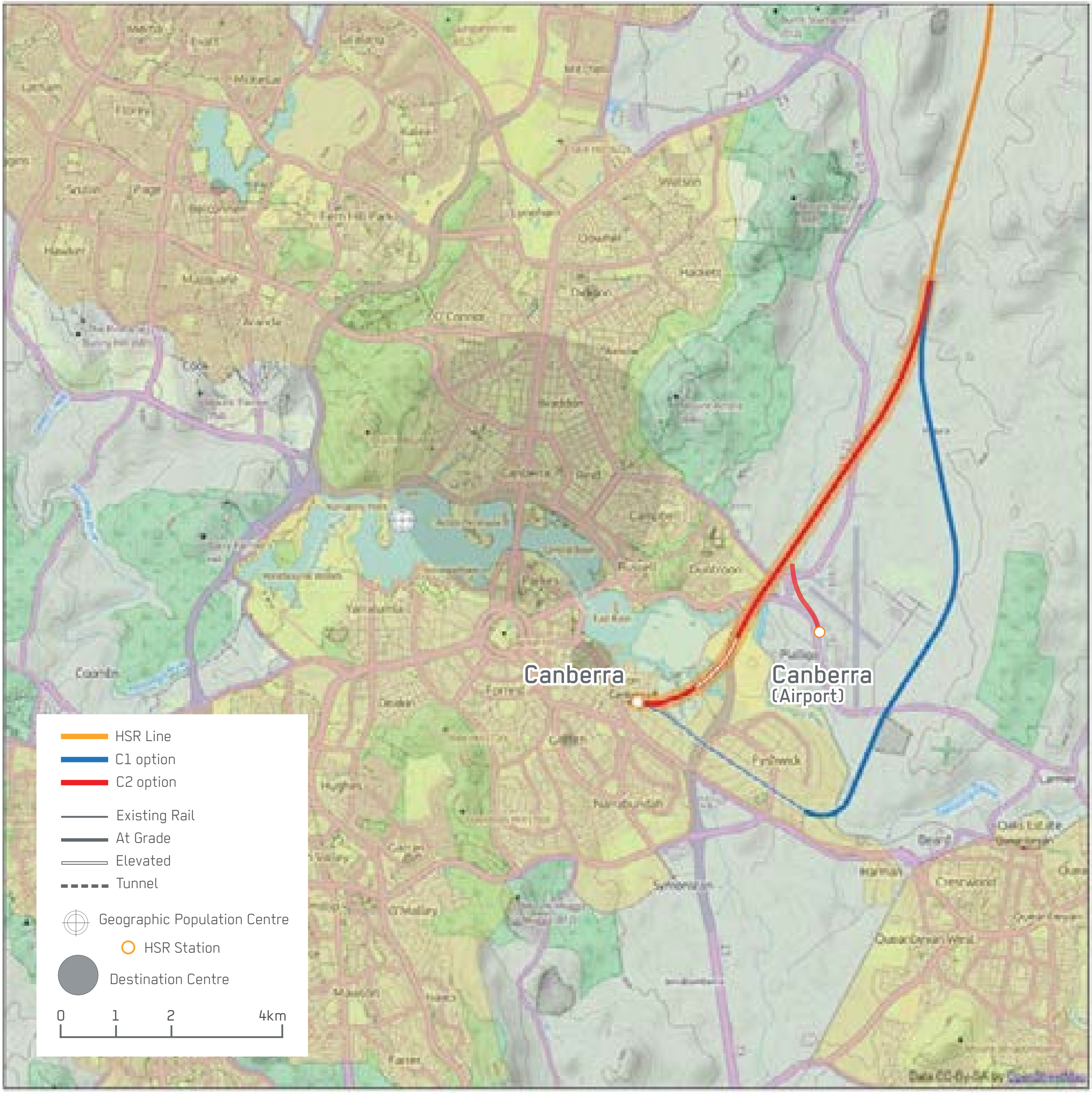


Canberra

Canberra is a city of two halves, split by Lake Burley Griffin. The urban areas to the north and south have approximately the same area and residential population so there is no clear preference in locating the HSR station. The aim was to select a central point for the station near to the activity centres of Capital Hill and Civic. Canberra Railway Station was chosen for the station location because of its proximity to the activity centre, connectivity with public transport services and ease of access. Canberra Airport was considered as an alternative HSR station location but the proximity of the current rail station was ultimately preferred.

The HSR branch line alignment approaches Canberra from the north-east where there is an undeveloped corridor to the east of Mount Ainslie. Two alternatives were investigated: C1 and C2 (Figure 65). Option C2 is recommended as the preferred option and could easily be altered to accommodate a Canberra Airport Station.

FIGURE 65 **Options investigated for access to Canberra** BASE MAP: © OPENSTREETMAP CONTRIBUTORS



Canberra C1

This option utilises the current rail corridor to access the city. Deviating at Majura, this alignment passes by the east side of Canberra Airport where the speed is then limited to 200 km/h. Prior to converging with the current rail track at Fyshwick the speed is then limited to 100 km/h all the way to Canberra Railway Station. C1 is estimated to cost $349 million and offer a travel time of 6 minutes.

FIGURE 66 Comparison of cost and travel time for Canberra access options investigated

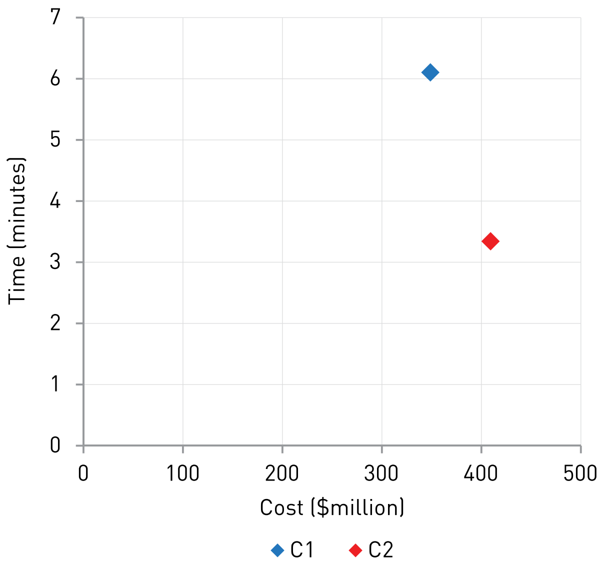


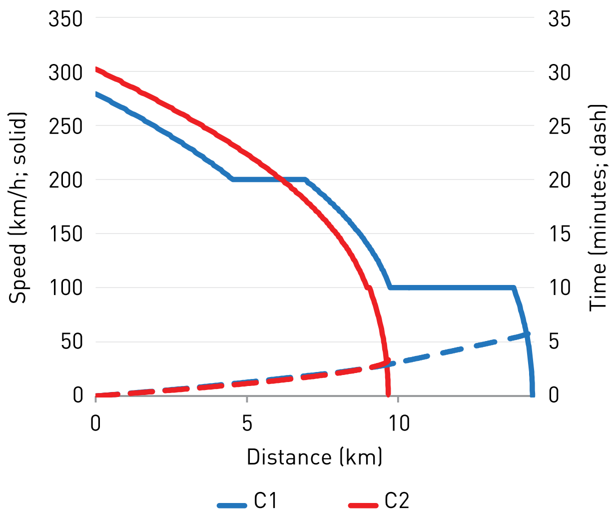
TABLE 23 Estimated cost of Canberra access options

	Estimated cost ($ million)	
Cost component	**C1**	**C2**
Land acquisition	0	14
Substructure	98	60
Superstructure	39	35
Signalling	17	11
Power supply	37	25
Buildings and structures	48	157
Stations and depots	100	100
Conservation	11	7
Total	**349**	**409**

Canberra C2

This option is the most direct route and approaches the city on the east side of Mount Ainslie via Majura. The alignment crosses the Molonglo River between the airport and the city. Passing over the Monaro Highway the rail line returns to ground level and heads directly to Canberra Railway Station. C2 is estimated to cost $409 million and offer a travel time of just over three minutes. Speeds of 350 km/h are possible up to the crossing of the Molonglo River, after which the speed is limited to 200 km/h. Option C2 may be easily redirected to a station at Canberra Airport should interchangeability between air and HSR travel be considered a higher priority than urban proximity.

FIGURE 67 Comparison of speed and time for Canberra access options



Sydney

Accessing the centre of Sydney with HSR is a challenging prospect. There are very limited opportunities to utilise existing infrastructure corridors and the terrain poses many problems, particularly to the north. An additional complication is deciding on the most suitable location for the HSR station. The geographic centre of Sydney's 3.9 million resident population is located in the vicinity of Homebush, which has good connectivity to the greater city area. However this is not a substantial activity centre of Sydney. Sydney CBD is identified in the National Visitor Survey as the major destination for visitors to Sydney and is also a place of major activity and employment. For this reason, as well as the connectivity to the greater Sydney area, Sydney Central Station was selected as the preferred location.

To narrow down the possibilities a high level comparison was made to quickly estimate the potential for a variety of approaches (Figure 69). The corresponding construction required and average train speeds were approximated for each segment. These travel time and cost characteristics for the possible combinations were then compared to provide an objective basis to proceed with a more detailed investigation of the most promising options. The results of this comparison are shown in Figure 68. Combinations H, J and B were used as the basis for further investigation.

FIGURE 68 **Comparison of cost and travel time for Sydney access: High level options**

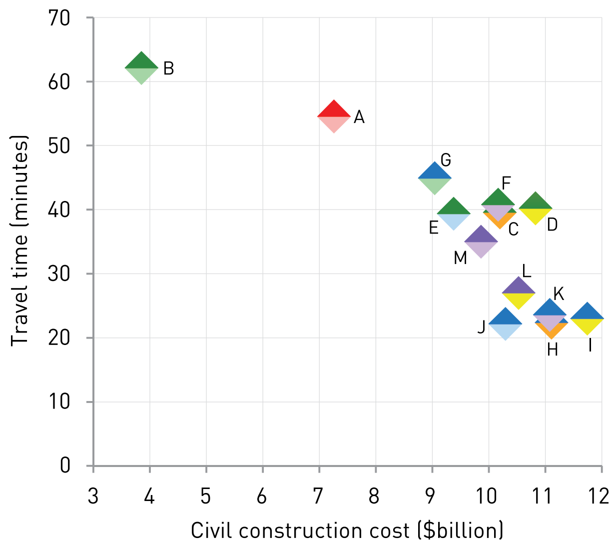
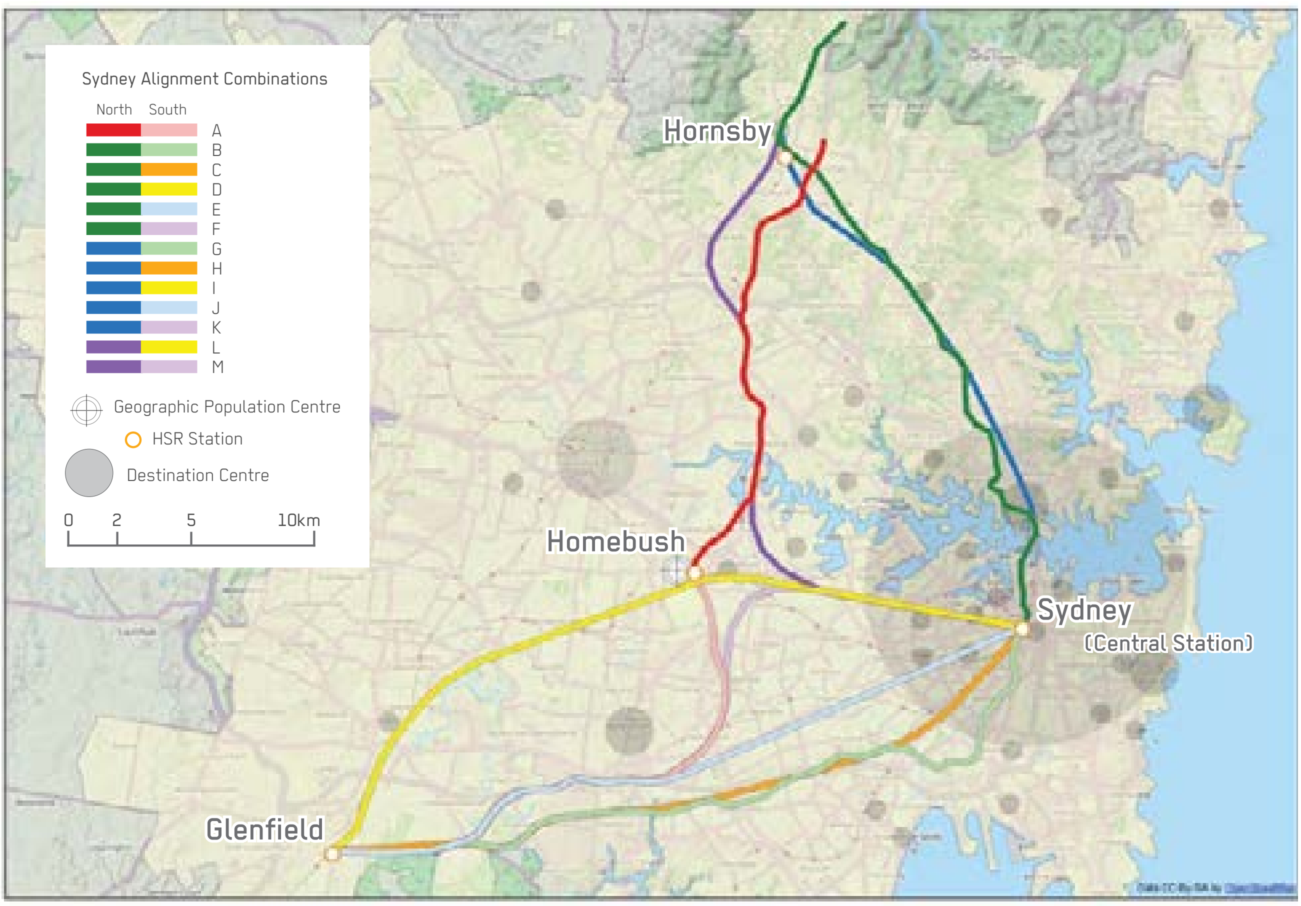


FIGURE 69 **Sydney access options initially investigated** BASE MAP: © OPENSTREETMAP CONTRIBUTORS



The southern HSR alignment approaches Sydney from the south-west via Narellan and Glenfield. A suitable corridor is available from Glenfield to Voyager Point, alongside the East Hills Railway line. A peripheral HSR station has been located in Glenfield where an interchange with the East Hills and Airport Line, South Line and Cumberland Line is possible. From here the southern options deviate.

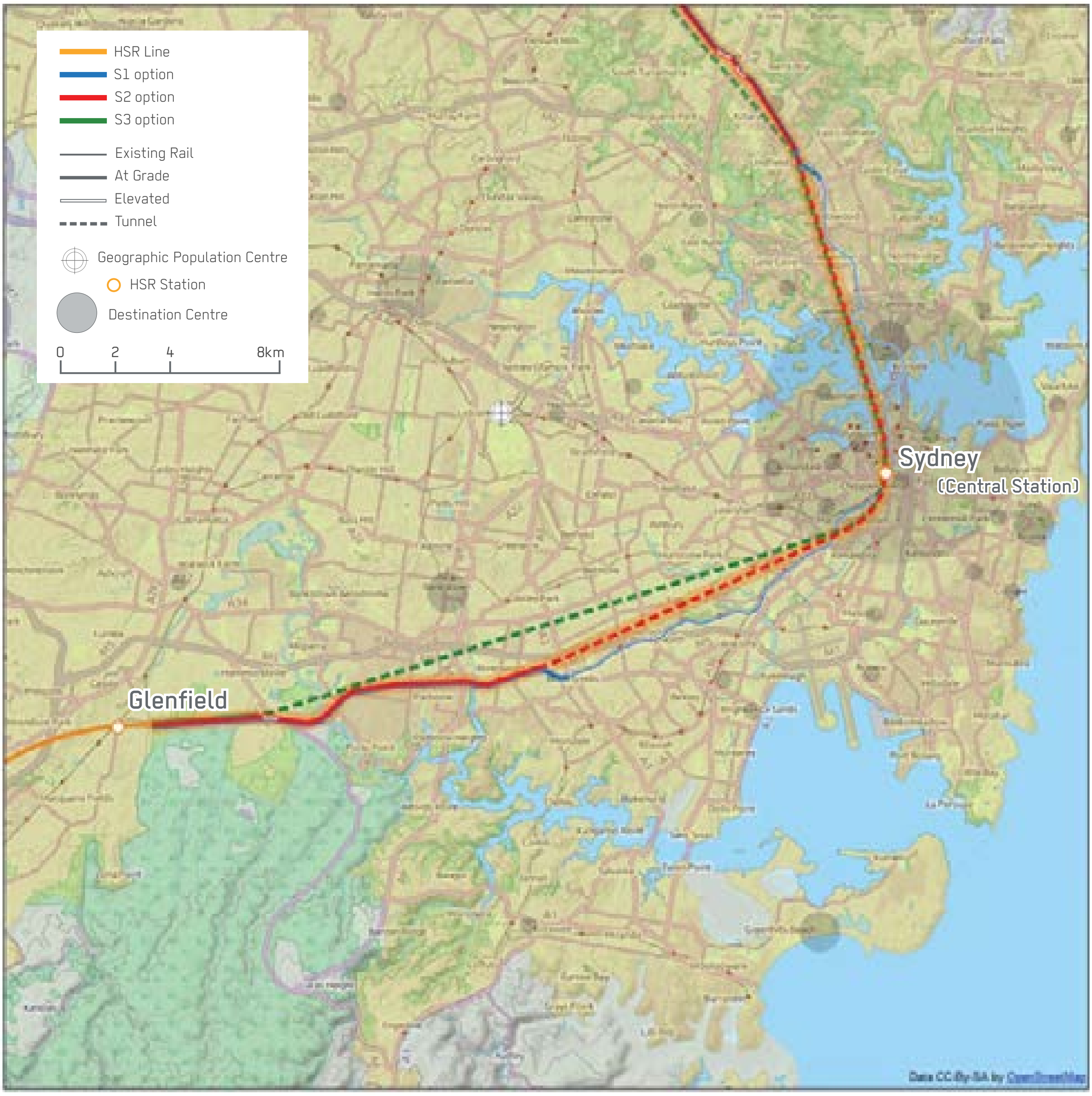
The northern HSR alignment approaches Sydney from the north, via Mount Kuring-gai along the Sydney-Newcastle Freeway. A peripheral HSR station has been located at Hornsby where an interchange with the North Shore and Western Line and Northern Line is possible.

Three alternatives were investigated in detail: S1, S2 and S3 (Figure 70). Option S2 is recommended as the preferred option.

Sydney S1 – South

This option uses as much of the current infrastructure as practically possible. From Glenfield to Beverly Hills a corridor allowing dual track is available alongside the East Hills line. From Glenfield to Voyager Point speeds are limited to 200 km/h and from Voyager Point to Beverly Hills speeds are limited to 100 km/h due to track curvature restrictions. From Beverly Hills the rail corridor is fully utilised with four tracks currently in place. The HSR alignment would merge with the current railway tracks here and operate with mixed traffic to Central Station.

FIGURE 70 **Options investigated for south access to Sydney** BASE MAP: © OPENSTREETMAP CONTRIBUTORS



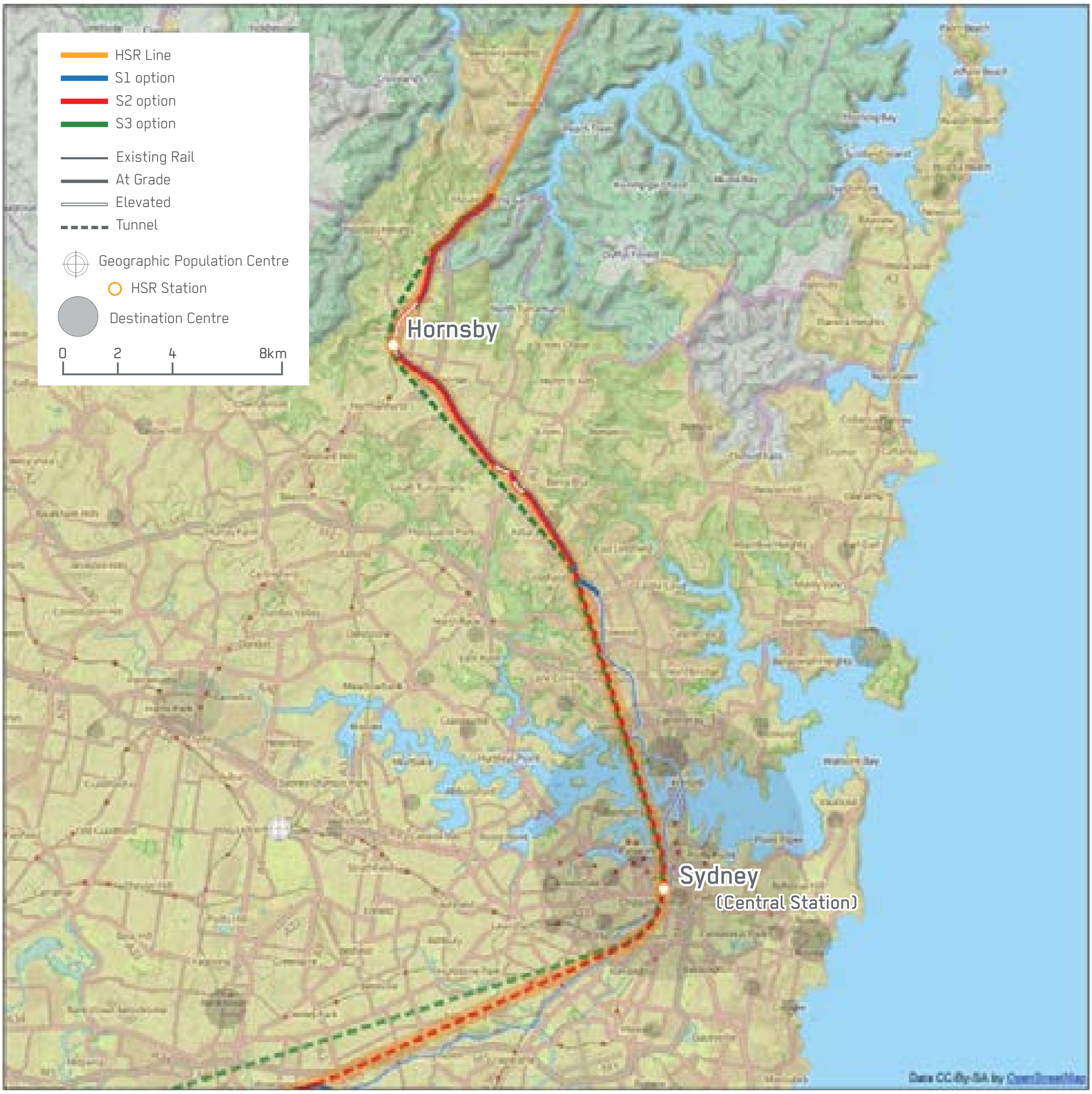
Sydney S1 – North

Again, as much of the existing infrastructure as possible is utilised in the northern section of this option. Beginning at Mount Kuring-gai, the HSR alignment uses the corridor alongside the North Shore rail line to Asquith. From Asquith the HSR track is elevated over the North Shore rail line on a viaduct to the peripheral Hornsby HSR station. From Hornsby the rail line returns to ground level and runs alongside the North Shore rail line to Roseville and requires upgrades to a number of road overpasses. While there is adequate land space for the majority of the alignment from Hornsby to Roseville, some land acquisition would be required. The speed would be limited to 100 km/h from Hornsby to Roseville, compared with 80 km/h for commuter trains currently running on the North Shore Line.

After Roseville the rail corridor is fully utilised with four tracks currently in place. The HSR alignment would merge with the current railway tracks here and operate with mixed traffic to Central Station.

S1 is estimated to cost $2.2 billion and offer a travel time of 66 minutes. S1 is a low-cost option but is highly compromised by the sharing of track. It must be assumed that HSR trains may be delayed behind commuter trains which would need to be factored into scheduling. HSR would add significant traffic to the shared rail track and this demand is expected to exceed capacity when fully operational. This unacceptably compromises the HSR service level.

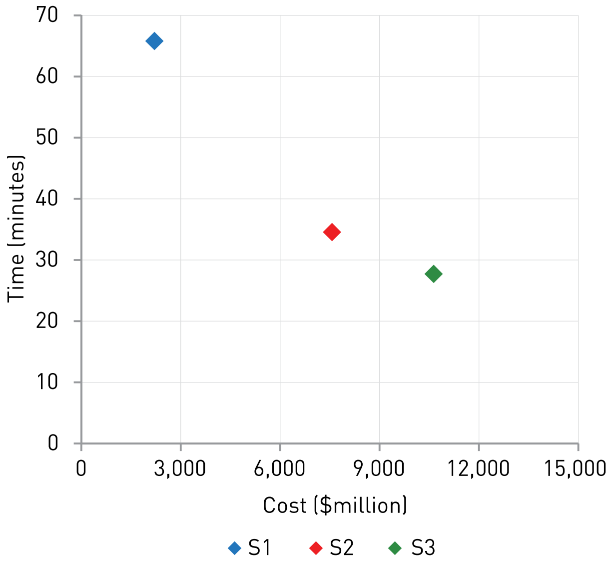
FIGURE 71 **Options investigated for north access to Sydney** BASE MAP: © OPENSTREETMAP CONTRIBUTORS



Sydney S2 – South

This option takes the same path as S1 alongside the East Hills line up to Riverwood. The HSR speed is limited to 200 km/h from the Glenfield peripheral station to Voyager Point and 100 km/h from Voyager Point to Riverwood due to track curvature restrictions. From Riverwood the HSR alignment heads underground and tunnels 15 km to Central Station. Speeds of 200 km/h are possible from Riverwood to Central Station.

FIGURE 72 Comparison of cost and travel time for Sydney access options investigated



Sydney S2 – North

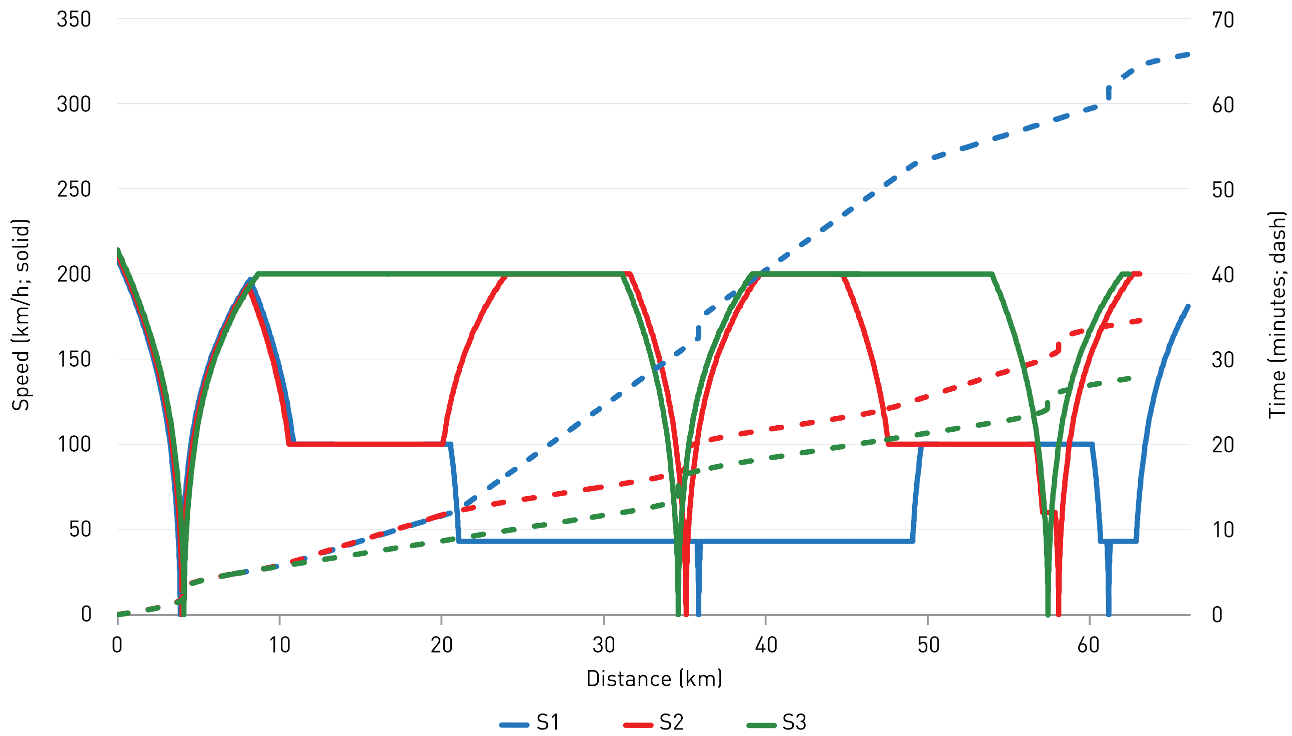
This option takes the same path as S1 along the North Shore Line up to Lindfield. The HSR alignment tunnels from Lindfield to Central Station where speeds of 200 km/h are possible.

S2 is estimated to cost $7.6 billion and offer a travel time of 34 minutes including stops at Glenfield, Central and Hornsby Stations. S2 avoids the complication of mixed traffic and allows a shorter travel time, yet increases the construction cost. This compromise was chosen as the preferred option.

TABLE 24 Estimated cost of Sydney access options

	Estimated cost ($ million)		
Cost component	**S1**	**S2**	**S3**
Land acquisition	10	10	0
Substructure	251	257	129
Superstructure	130	215	225
Signalling	78	70	73
Power supply	172	155	163
Buildings and structures	884	5,685	8,781
Stations and depots	640	1,140	1,220
Conservation	50	45	47
Total	**2,214**	**7,576**	**10,637**

FIGURE 73 Comparison of speed and time for Sydney access options



Sydney S3 – South

This option takes the same path as S1 alongside the East Hills line up to Holsworthy. Before reaching the Holsworthy railway station the HSR alignment enters a tunnel which extends 25 km to Central Station. The HSR speed is limited to 200 km/h from the Glenfield peripheral station to Central Station.

Sydney S3 – North

This option follows along the North Shore Line from Mount Kuring-gai to Mount Colah where tunnelling begins. An underground HSR station at Hornsby allows interchanges with two city lines. This tunnel continues and passes beneath Lindfield and descends below Sydney Harbour which is approximately 10 metres deep at this location. The tunnel continues to Central Station. The HSR speed is limited to 200 km/h from Mount Kuring-gai to Central Station.

S3 is estimated to cost $10.6 billion and offer a travel time of 28 minutes including stops at Glenfield, Central and Hornsby stations. S3 avoids the complication of mixed traffic and allows a shorter travel time, yet increases the construction costs.

This option makes the least compromise in order to achieve the best possible journey time. S3 avoids the complications of mixed traffic and surface construction in urban areas. It was decided that the time saving of six minutes was not considered to justify the increased cost of $3 billion.

Gold Coast

The Gold Coast is home to just under half a million people. The urban area is elongated in the north-south direction due to the natural confines of the ocean to the east and the hinterland to the west. Because the HSR service also runs north-south, the complication of accessing the city is increased. The many waterways and canals of the Broadbeach area add to the challenge of providing a convenient station location.

The current rail corridor was identified to have sufficient space available to accommodate the HSR line but curvature restrictions would limit the train speed to 200 km/h along this segment. The passenger demand for the Gold Coast was identified to be very high and it was decided that all trains, including express services, would stop here. The time penalty of this speed restriction was investigated and the result is shown in Figure 75. An additional three minutes is added to the journey time through this segment. The three minute travel time increase was considered to be acceptable.

Option G1 makes use of the existing rail corridor, allowing additional opportunities such as high-speed shuttle services between the Gold Coast and Brisbane. Shuttle services would be able to collect passengers from a number of Gold Coast stations, making commuting to Brisbane much more convenient for the population stretched along the coastline. Nerang and Robina railway stations were shortlisted as the best options for the main HSR station. Nerang was finally chosen as the preferred location due to its centrality to the residential population and proximity to the major tourism destination of Surfers Paradise. It is a marginal preference and with this configuration can be easily changed.

G1 is almost entirely at ground level with an elevated structure over the low-lying banks of the Coomera River. It is estimated to cost $1.1 billion and offer a travel time of 12 minutes from the beginning to the end of the 200 km/h speed zone.

FIGURE 74 **Option investigated for access to the Gold Coast** BASE MAP: © OPENSTREETMAP CONTRIBUTORS

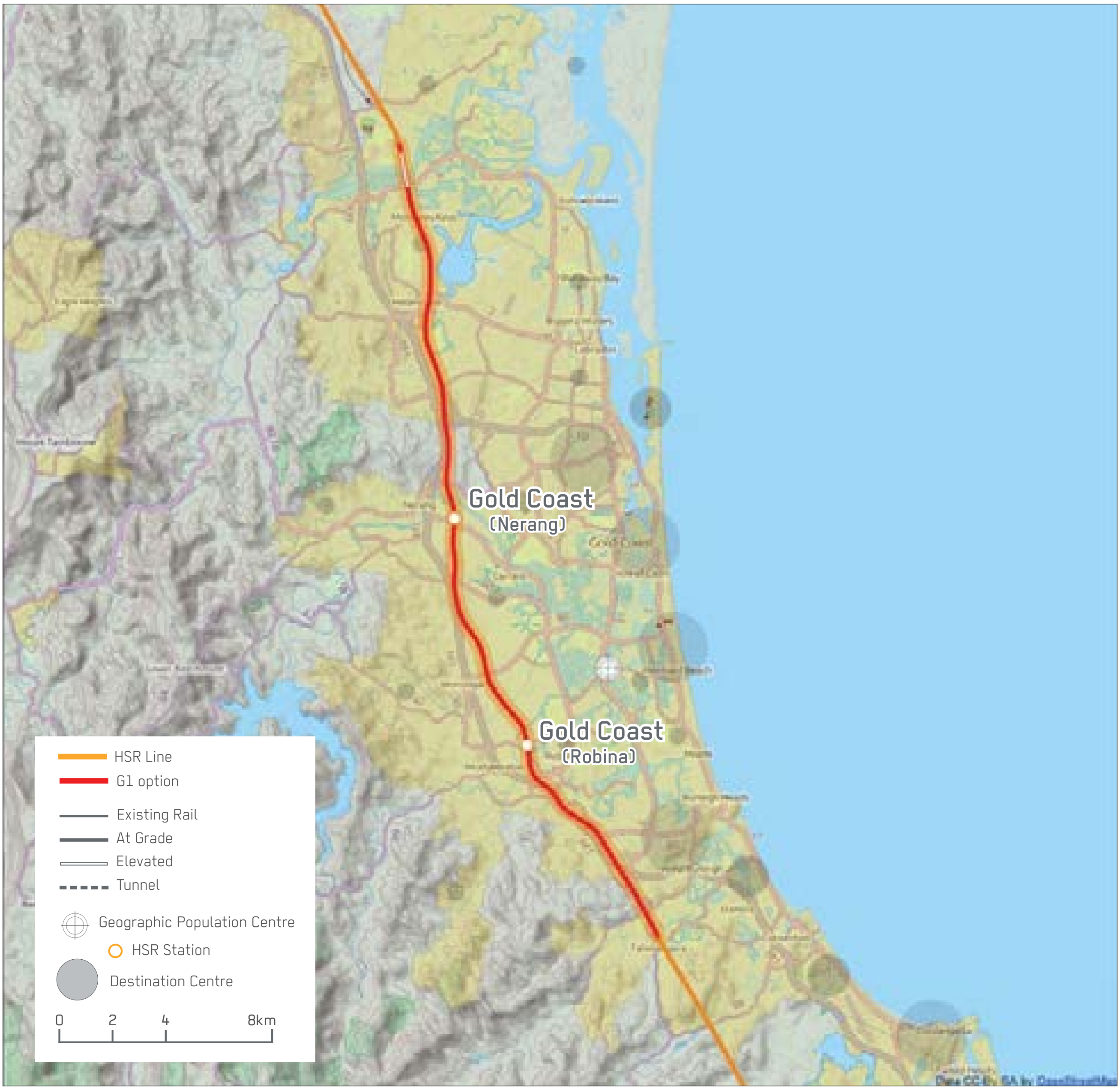


FIGURE 75 **Comparison of speed and time for Gold Coast access options**

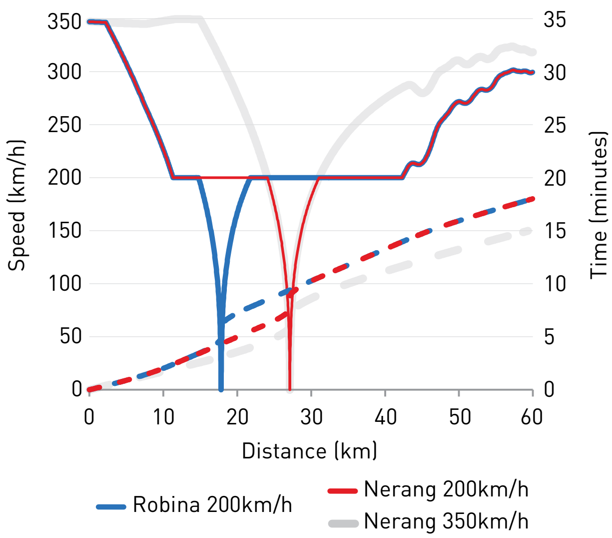


TABLE 25 **Estimated cost of Gold Coast access**

	Est. cost ($ million)
Cost component	**G1**
Land acquisition	31
Substructure	250
Superstructure	118
Signalling	38
Power supply	85
Buildings and structures	486
Stations and depots	70
Conservation	24
Total	1,101

Brisbane

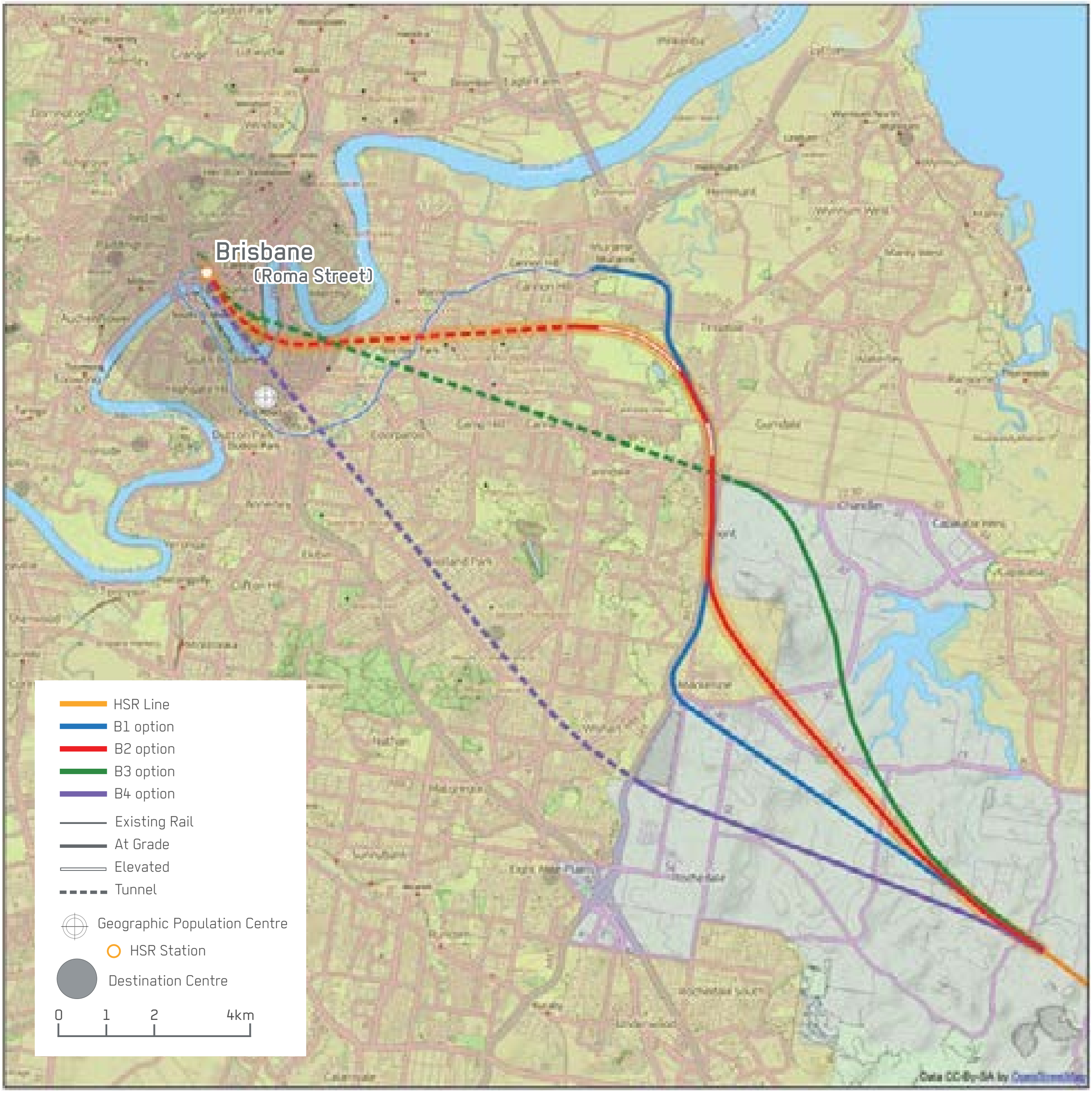
Brisbane is Australia's third largest city and is home to 1.9 million people. The urban area of Brisbane stretches roughly in three directions from the CBD (to Caboolture, Ipswich and Pimpama) and covers 1,971 square kilometres[54]. The CBD is central for both the population and activity of the city so it is the preferred location for the HSR station. Both Roma Street and Southbank railway stations were considered as possible HSR stations. Roma Street Station is the preferred option due to its superior connectivity to the existing public transport network, proximity to the CBD and the potential for redevelopment.

The HSR alignment approaches Brisbane from the south-east. The undeveloped expanse between Springwood and Victoria Point was identified as a suitable corridor, where the urban fringe reaches within 12 km of the city centre. Four alternatives were explored in detail: B1, B2, B3 and B4 (Figure 76). Option B2 is recommended as the preferred option.

Brisbane B1

This option uses as much of the current infrastructure as possible. The HSR alignment converges with the Gateway Motorway at Mackenzie and is restricted to 100 km/h as it continues parallel until reaching Old Cleveland Road. Here the HSR line crosses from the east to the west

FIGURE 76 **Options investigated for access to Brisbane** BASE MAP: © OPENSTREETMAP CONTRIBUTORS



motorway easement and continues to Murrarie. Here the HSR joins the Cleveland Line and would be limited to 40 km/h to Roma Street Station due to sharing track with the city train services. B1 is estimated to cost $1.2 billion and offer a travel time of 32 minutes. B1 is a low cost option but is highly compromised by the sharing of track. It must be assumed that HSR trains may be delayed behind commuter trains, and this would need to be factored into scheduling. HSR would add significant traffic to the shared rail track. This unacceptably compromises the HSR service level.

Brisbane B2

This option approaches Mount Petrie at full speed before slowing to 200 km/h as the alignment converges with the Gateway Motorway. After passing over Old Cleveland Road the alignment crosses from the east to the west motorway easement. The HSR line then heads west from the motorway on an elevated structure over the northern edge of the Minippi Parklands. Before reaching Creek Road the alignment enters a tunnel towards Kangaroo Point and on to Roma Street Station. B2 is estimated to cost $2.6 billion and offer a travel time of eight minutes. B2 avoids the complication of mixed traffic and allows a shorter travel time, yet increases the construction cost. This compromise was chosen as the preferred option.

Brisbane B3

This option passes to the east of Mount Petrie at full speed before slowing to 200 km/h at Chandler. Here the HSR line curves alongside Old Cleveland Road to head west and enters a tunnel before reaching the Gateway Motorway. From here the tunnel continues towards Kangaroo Point and on to Roma Street Station. B3 is estimated to cost $2.8 billion and offer a travel time of just over seven minutes. B3 avoids the complication of mixed traffic and allows a shorter travel time. The increase in construction cost is due mainly to the longer tunnelling required. This tunnelling avoids complications associated with using the motorway corridor and could be the preferred option despite its higher cost.

Brisbane B4

This option is the most direct approach and makes the least compromise in order to achieve the best possible journey time. Heading towards Upper Mount Gravatt at full speed the HSR slows to 200 km/h as it enters a tunnel before reaching the Gateway Motorway. From here the alignment heads directly to Roma Street Station. B4 is estimated to cost $3.1 billion and offer a travel time of just over seven minutes. B4 requires more tunnelling again which is responsible for the increase in cost. This option is not recommended considering it has an equivalent travel time performance but is $300 million more expensive than option B3.

FIGURE 77 Comparison of cost and travel time for Brisbane access options investigated

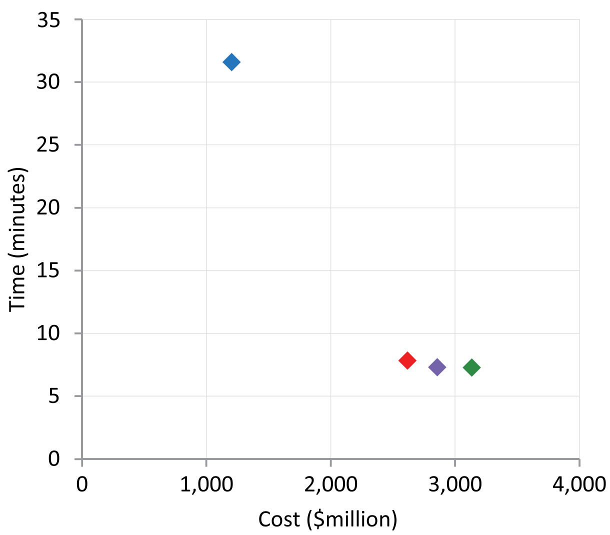


FIGURE 78 Comparison of speed and time for Brisbane access options

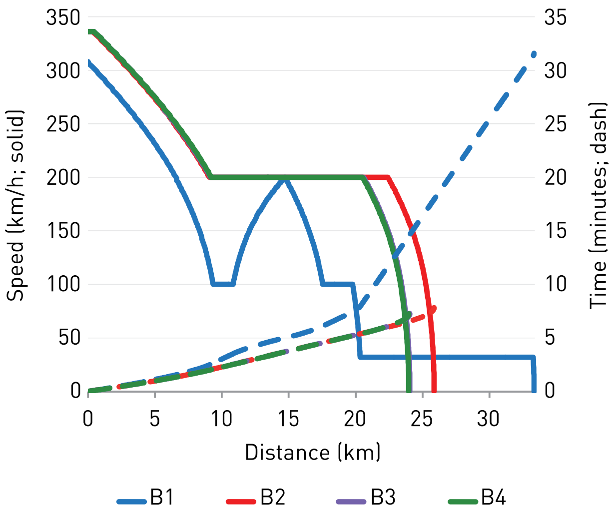
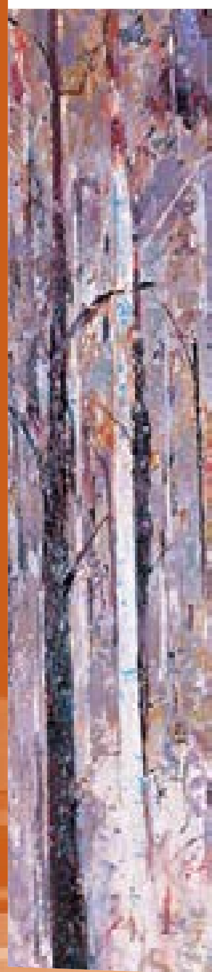


TABLE 26 Estimated cost of Brisbane access options

	Estimated cost ($ million)			
Cost component	**B1**	**B2**	**B3**	**B4**
Land acquisition	141	94	0	0
Substructure	151	163	99	81
Superstructure	73	94	87	86
Signalling	39	30	28	28
Power supply	87	68	63	63
Buildings and structures	188	1,650	2,063	2,360
Stations and depots	500	500	500	500
Conservation	25	19	18	18
Total	**1,205**	**2,619**	**2,858**	**3,136**



Untitled (Shoalhaven Landscape), detail from the design for the Great Hall tapestry, Parliament House Canberra PAINTING: ARTHUR BOYD

6. Costs and financial analysis

This section contains:

- **Details of the construction cost inputs**
- **Breakdown of the final construction cost estimate**
- **Operating costs and revenue**
- **Financial analysis of the payback on the initial capital cost**

Overview

A high speed rail system from Melbourne to Brisbane requires significant capital investment, most of which is required for constructing the alignment itself on which the track is laid. The raw construction cost estimate is $61.3 billion for the railway and stations, with train sets costing a further $5.2 billion. The final budget estimate with management costs and contingency included comes to $84.3 billion.

Once operational, the system has relatively low running costs and high revenues. For example, in 2030, revenue from ticketing would be $7 billion, with operating costs of $2.3 billion, leaving a surplus operating profit of $4.6 billion, 66% of revenue.

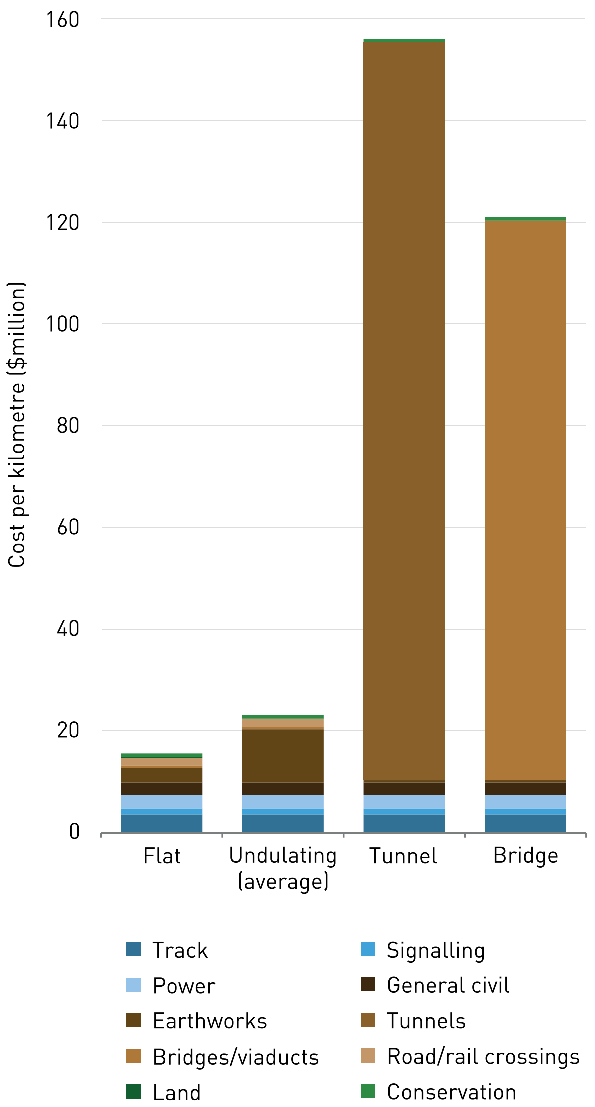
From the perspective of an entity building and operating the HSR network, this operating surplus would be able to repay the initial capital construction cost after 40 years of operation (calculated at a real discount rate of 4%).

Further details are available in Appendix E.

Construction cost methodology

As discussed above, the particular landscape characteristics significantly affect the construction required and in turn the cost. On a per-kilometre basis, the indicative construction costs are shown in Figure 79 for track requiring earthworks (at grade), tunnelling or on a bridge. Tunnels and bridges are respectively, ten and eight times more expensive per kilometre than track at grade on flat ground. HSR across undulating terrain can be in the order of 50% more expensive due to extra earthworks requirements, with the actual cost dependent on the profile of each individual section.

FIGURE 79 **Indicative examples of per-kilometre cost breakdown of HSR track through different terrain**



Costs for the HSR system have been estimated based on a cost database developed in partnership with the German Aerospace Centre. Benchmarked to Australian and international sources, the database contains information to the level of sub-components of civil works, track, signalling, electrification, auxiliary buildings, rolling stock, operational costs, and management. International unit prices have been normalised to 2012 Australian dollars using historical exchange rates, purchasing power parities (PPP) and construction price indices (CPI).

Unit costs have been applied on a per-kilometre or per-item basis. Elements on a per-kilometre basis were applied to the length of the alignment that requires it. Per-item elements were applied either through discrete counting (for example, the number of railway stations or major road crossings), or through assumptions on the frequency of items required (for example, the assumed spacing between electrical substations).

Full details of the unit rates, sources and costing methodology can be found in Appendixt 4. Some of the main cost elements are briefly described below.

Construction

Earthworks – Associated with major levelling of terrain with cuttings and filled sections, earthworks keep the alignment within the required gradient and curvature parameters.

Tunnels – The cost of excavating and preparing rail tunnels, generally twin bore (i.e. two separate parallel tunnels, one for each direction), not inclusive of general rail-specific items covered elsewhere in this list. Tunnels in urban and rural environments are costed at different rates.

Bridges/viaducts – Bridges are required to cross rivers and large valleys in terrain where the height is too great and it is therefore impractical to use earthworks to raise the alignment. Viaducts that raise the alignment above the surface of the terrain may be required to allow for sufficient water flow in floodplains, and in urban areas to reduce impacts.

Road/rail crossings – The entire HSR alignment must be grade-separated with the track passing over or under existing road or rail lines. A GIS-based analysis has been used to count the number of crossings major roads and existing rail lines. For minor roads and streams, an average cost has been applied based on estimates of their frequency along the line. In urban areas, the frequency and complexity of grade-separating roads from the HSR line is a significant cost, and they have been counted individually.

General civil – Additional infrastructure works including drainage, temporary roads, fencing and noise barriers. This is applied on a per-kilometre basis.

Land and conservation

Land acquisition – Purchase of land in regional areas was based on a 60 metre corridor width and applying average land values for different categories of land (rural, semi-urban, regional urban). In major cities, the actual areas of land to be acquired were mapped out manually and costed on a per-square metre basis. This category includes extra land acquired to offset in cases where the alignment intrudes on protected areas such as national parks.

Environmental conservation – Mitigating or offsetting unavoidable negative environmental impacts with measures such as revegetation, or providing special fencing and wildlife bridges when passing through areas with protected species.

Track hardware

Track – The cost of dual slab track, including regularly spaced turnouts and crossovers. This is applied on a per-kilometre basis.

Signalling – Trackside infrastructure required for implementing European Train Control System (ETCS) Level 2 signalling, with Global System for Mobile Communications–Railway (GSM-R). This is applied on a per-kilometre basis.

Power – Overhead electrical cables, or catenary, to deliver power to trains, along with regularly spaced substations and grid connection. Catenary is applied on a per-kilometre basis and substation with grid connections is applied on a per-item basis.

Discussion

As shown in Figure 79, there is effectively a constant fixed cost per kilometre for track hardware. Alignment construction costs are highly variable and depend entirely on the specific terrain encountered.

The baseline cost of dual HSR track on relatively flat ground requiring only minor earthworks is approximately $16 million/km.

As an indicative example, a segment of line on undulating terrain requiring significant earthworks, but not requiring tunnels or bridges, costs approximately $23 million/km, with the exact cost depending on the amount of earthworks required for individual sections of terrain.

The total cost of a rail line in twin-bore rail tunnels in a rural setting is $156 million/km. An urban tunnel is $176 million/km (not shown).

The total cost of an average HSR rail bridge, inclusive of fixed rail costs, is $121 million/km. A lower value of $81 million/km is used for modular viaducts in urban or floodplain settings.

Final construction cost breakdown

A summary of the HSR system costs is given in Table 27 and Figure 80. This provides the construction cost, overheads and per kilometre cost for each segment of the proposed alignment as well as the cost of purchasing rolling stock.

The basic cost of constructing the HSR alignment is estimated at $61.4 billion. The Melbourne to Sydney segment would be $29.3 billion, including the full cost of upgrading Sydney Central Station. Sydney to Brisbane is $32.1 billion. Rolling stock, the set of 87 high speed trains, is a further $5.2 billion. The costs associated with engineering, procurement and construction management are estimated as a further 10% of construction costs, bringing the total to $73.3 billion. An allowance of 15% of this total is included as a contingency for unforeseen risks, resulting in a final capital budget estimate of $84.3 billion, in real 2012 dollars. Of this full final estimate, inclusive of management and contingency overheads, with half of the rolling stock allocated to each segment, Melbourne to Sydney would cost $40.3 billion and Sydney to Brisbane would cost $43.9 billion.

A breakdown of the capital construction costs are shown in Figure 81. The most significant cost is in preparing the actual alignment for the track to run along: earthmoving, tunnels, bridges and crossings (river crossings are included in the bridges/viaducts category). Averaged over the whole alignment, land acquisition is a relatively small cost, although in sections within cities and towns it is more significant. The category 'stations and depots' includes all stations and ticketing costs as well as maintenance depots for infrastructure and rolling stock at set locations along the route.

Further explanation of the costing methodology and detailed cost breakdown can be found in Appendix E.

FIGURE 80 **Capital cost and length breakdown of HSR system, from station to station**

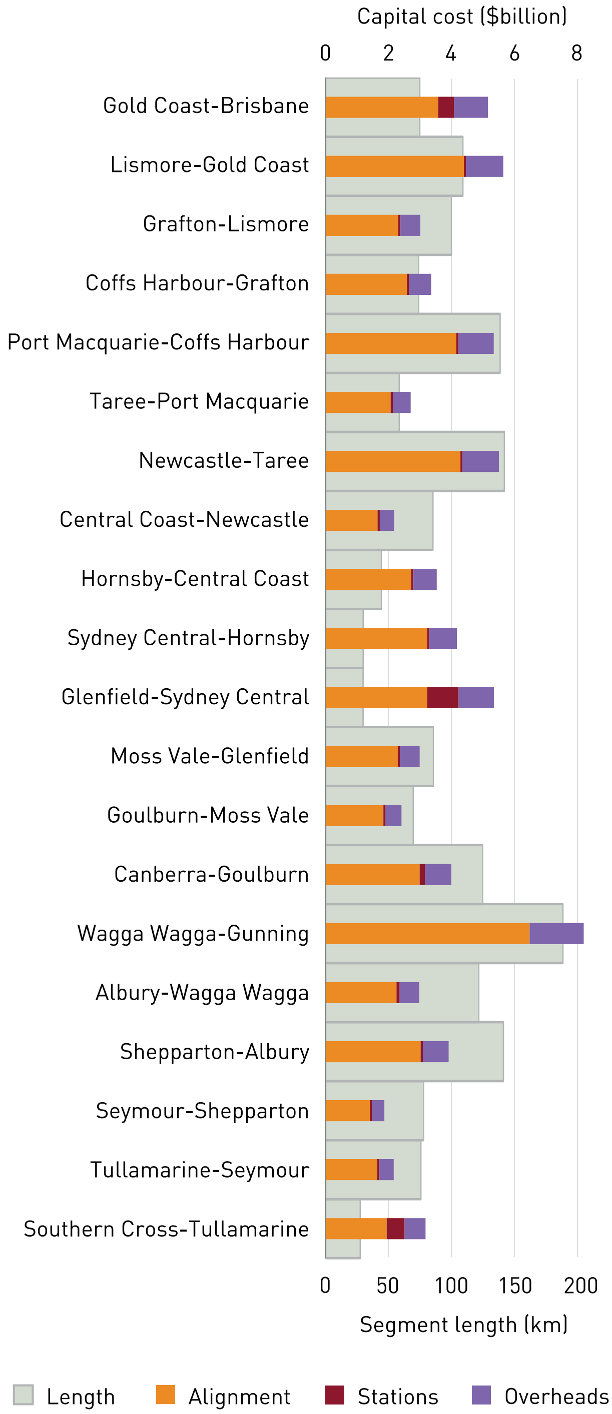
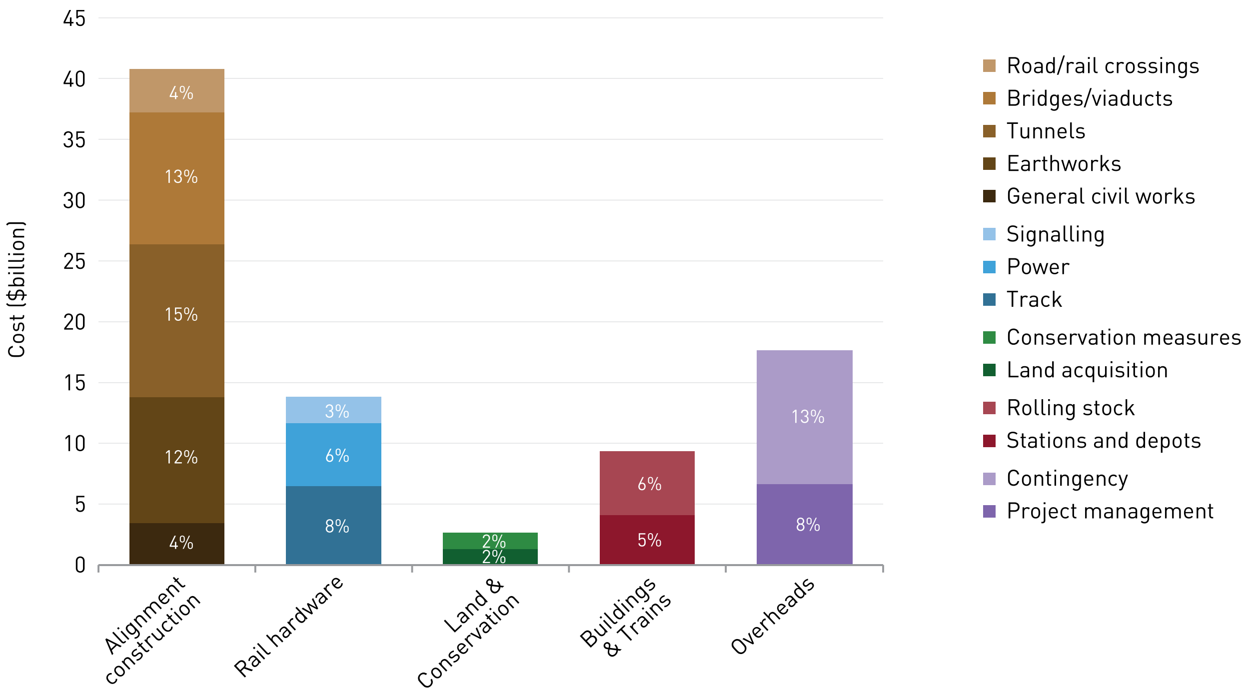


TABLE 27 **Summary of HSR system cost elements**

	Length km	Alignment $M	$M/km	Stations $M	Indicative cost $M	Management and contingency $M	Total $M
Southern Cross-Tullamarine	27.5	1,940	73	570	2,510	665	**3,175**
Tullamarine-Seymour	75.7	1,640	22	70	1,710	453	**2,163**
Seymour-Shepparton	77.8	1,405	18	70	1,475	391	**1,865**
Shepparton-Albury	141.3	3,020	21	70	3,090	819	**3,909**
Albury-Wagga Wagga	121.7	2,252	18	100	2,352	623	**2,975**
Wagga Wagga-Gunning	188.6	6,487	34	—	6,487	1,719	**8,206**
Canberra-Goulburn	124.8	2,990	24	170	3,160	837	**3,997**
Goulburn-Moss Vale	69.6	1,836	26	70	1,906	505	**2,411**
Moss Vale-Glenfield	85.6	2,292	27	70	2,362	626	**2,988**
Glenfield-Sydney Central	29.7	3,229	109	1,000	4,229	1,121	**5,349**
Sydney Central-Hornsby	29.8	3,229	108	70	3,299	874	**4,174**
Hornsby-Central Coast	44.3	2,722	61	70	2,792	740	**3,532**
Central Coast-Newcastle	85.3	1,650	25	70	1,720	456	**2,176**
Newcastle-Taree	142.1	4,285	30	70	4,355	1,154	**5,509**
Taree-Port Macquarie	58.5	2,066	35	70	2,136	566	**2,702**
Port Macquarie-Coffs Harbour	138.7	4,155	30	70	4,225	1,120	**5,344**
Coffs Harbour-Grafton	73.9	2,583	35	70	2,653	703	**3,356**
Grafton-Lismore	100.0	2,308	23	70	2,378	630	**3,008**
Lismore-Gold Coast	109.1	4,395	40	70	4,465	1,183	**5,648**
Gold Coast-Brisbane	74.8	3,581	48	500	4,081	1,081	**5,162**
Full alignment	**1,799**	**58,064**	**32**	**3,320**	**61,384**	**16,267**	**77,650**
Rolling stock					5,220	1,383	**6,603**
Full HSR system					**66,604**	**17,650**	**84,253**

FIGURE 81 **Breakdown of capital cost estimate for Melbourne-Brisbane HSR system**



Operating costs and payback

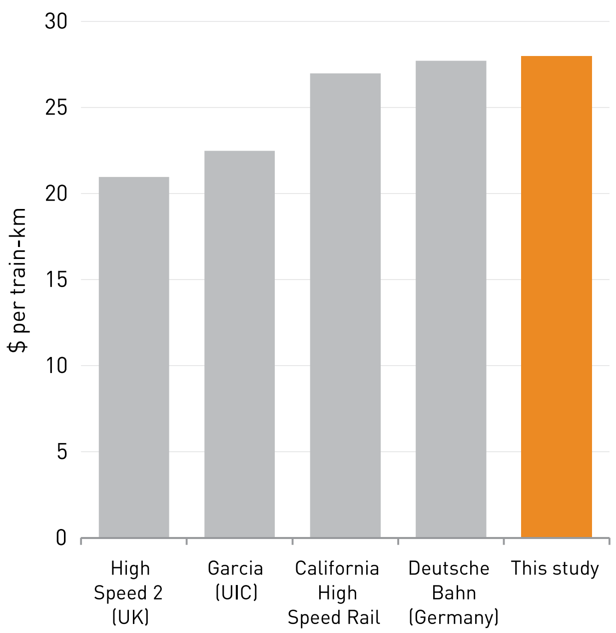
An analysis of the operating costs and revenues of the HSR network has identified that there is a significant positive operating profit once operational. By 2030, the operating profit (revenue minus operating costs) would reach $4.6 billion per year, and increase with future patronage growth. In undiscounted terms, this would result in the HSR network capital cost being recovered after 19 years of operation. At a 4% real discount rate, the financial net present value reaches zero after 40 years of operation.

Operating Costs

The operating costs have been based on a review of data from HSR internationally. Variable operating costs are shown in Figure 82. The component data and accounting methodologies differ between the different sources[55,56,57,58], but all fall within the range of $20-28 per train-kilometre travelled, with an average of $24.5/train-kilometre. These do not include infrastructure and track maintenance, which is accounted separately.

Operating cost items include:
- Train drivers, attendants and other operational staff
- Ticketing and station services
- Rolling stock maintenance
- Energy costs
- Insurance
- Administration and management
- Infrastructure and track maintenance

FIGURE 82 Variable operating costs per train-km, 2012[55-58] (excludes infrastructure and track maintenance)

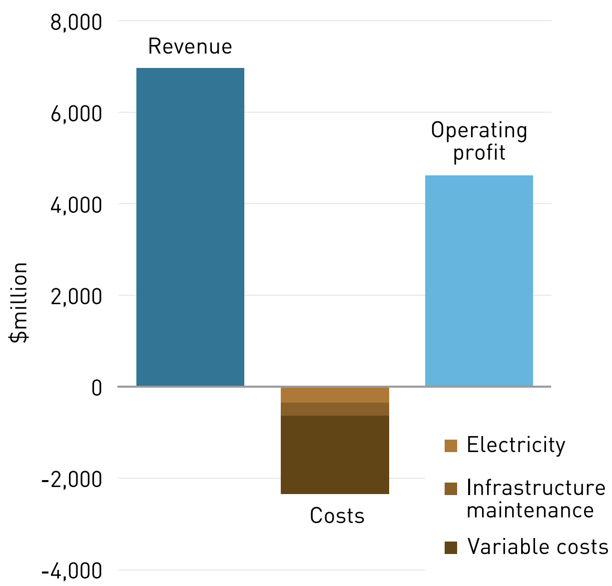


Some of these items such as track maintenance are relatively steady annual costs. Others are strongly dependent on the network activity, such as train staff and the electricity required by the train fleet (traction energy). In this study, a value of $28 per train-kilometre has been used to estimate the annual variable operating costs, applied to the annual operating statistics from the Regional Travel Model. The majority of this is staffing and variable maintenance costs. It is inclusive of traction electricity charges—based on an electricity price of 12 cents per kWh, traction electricity costs will contribute $4.07 per train-kilometre to the total. These values are in real 2012 dollars, and projections for future years take into account expected increases in labour and electricity prices (in real dollar terms).

Maintenance of track infrastructure is calculated in addition to the variable costs outlined above, as it is relatively independent of network traffic. The use of concrete slab track means that the ongoing maintenance costs of this infrastructure are less than that of traditional ballasted track. An annual cost of $150,000 per track kilometre has been applied.

For 2030, the total operating cost comes to $2,341 million in 2030. Of this, traction electricity is $351 million (15%) and infrastructure maintenance is $280 million (12%).

FIGURE 83 Operating cash flows estimated for HSR operation in 2030



Some operational business models would also include costs relating to the capital cost of the HSR track infrastructure. It may be direct debt service repayments if the operating entity is also responsible for the capital costs, or access charges if the network is operated by a separate entity on behalf of the infrastructure owner. This analysis does not account for these arrangements; the relationship of the operating profit to the capital cost of infrastructure is presented for a clear picture of financial flows. The operating profit represents the total surplus cash flow available for capital infrastructure repayments, irrespective of any particular financial arrangements.

It should be noted here that rolling stock has been considered as a capital cost item, as opposed to a lease arrangement realised as an annual operational cost.

Revenue

As detailed in Section 3, combined fare revenues from commuter, business and other travellers have been estimated to be $6,960 million in 2030. This is based on the fare structure developed which is an average price. In practice, fares tend to fluctuate with discount offers in order to smooth out demand variability associated with seasonal travel and peak activity as well as other factors. It is likely that a range of HSR fares lower and higher than the average fares estimated would be offered to passengers. Due to the volume of passengers estimated to use the HSR network, fare prices strongly influence the profitability of the operation.

Alternative revenue streams including advertising, commercial rental incomes at stations and track access fees for other operators among others have not been counted in this analysis. These alternatives may further increase the operating profit of the HSR network.

Capital cost and timeline

As outlined above, the total construction cost estimate is $84.3 billion. This includes alignment infrastructure, rolling stock, engineering and construction management, and contingencies.

This has been allocated over a 10-year design and construction period, beginning in 2015. The first two years is dedicated to design and planning activities, accounting for 4% of the construction budget. This would then ramp up for an eight-year construction period, with extra spending in the final three years on rolling stock purchase. Operations would begin on the full Melbourne-Brisbane HSR network by 2025. A three-year ramp-up period has been factored in between the commencement of full services and reaching full expected patronage levels, as full user uptake would not be immediate.

An additional $12.6 billion (15% of the capital cost) has been allocated for asset renewal, carried out over a 10 year period, 30 years after operations begin. This would mainly cover the renewal of infrastructure such as track, power, signalling and stations.

Future HSR operations

The key values of revenue and operating costs have been based on the output of the Regional Travel Model. This has been run over a number of years from 2020 to 2030 to allow projection of the underlying trends. The Model takes into account a number of factors which will affect future travel demand and patronage on different modes of transport, including:

- Population growth by region (ABS)
- GDP growth
- Per-capita travel growth
- Changes in operational costs such as fuel and electricity

The prevailing trends have then been extended beyond 2030 along the same annual growth trajectory of approximately 1.2% per annum. This is slightly higher than projected population growth, reflecting an increase in per-capita travel over the period.

Results

The operating costs, revenue, and net operating profit for the year 2030 are shown in Figure 83. The operating profit of $4.6 billion (real undiscounted 2012 dollars) is approximately 66% of total fare revenue. The operating cost model has been used to project costs, revenue and the cumulative net balance of these from the perspective of an entity that both builds and operates the HSR network. The cumulative balance reflects the annual net position where the initial capital expenditure (shown as negative) is offset by positive net profits once the network is operational.

The results of this analysis in real undiscounted 2012 dollars are shown in Figure 84. The results discounted at 4% (real) from the initial construction commencement year of 2015 are shown in Figure 85, with the cumulative net present value (NPV). In undiscounted terms, the cumulative net balance turns positive after 18 years of operation from 2025. In discounted terms, the net present value turns positive in 2065, after 40 years of operation. This means that the capital cost of construction is paid off, and future operating profits after this date are generating positive returns overall.

Note that this analysis has not taken into account detailed financial considerations such as tax, depreciation, or interest on loans. This would depend on the financial and governance arrangements of the building and operating entity. By showing the full costs and revenues available to the entire project, this analysis demonstrates that independent of how the HSR construction and operation is set up, there is sufficient operating profit to pay off the capital cost of the network.

FIGURE 84 **Annual costs, revenue and cumulative balance for HSR network (real undiscounted 2012 dollars)**

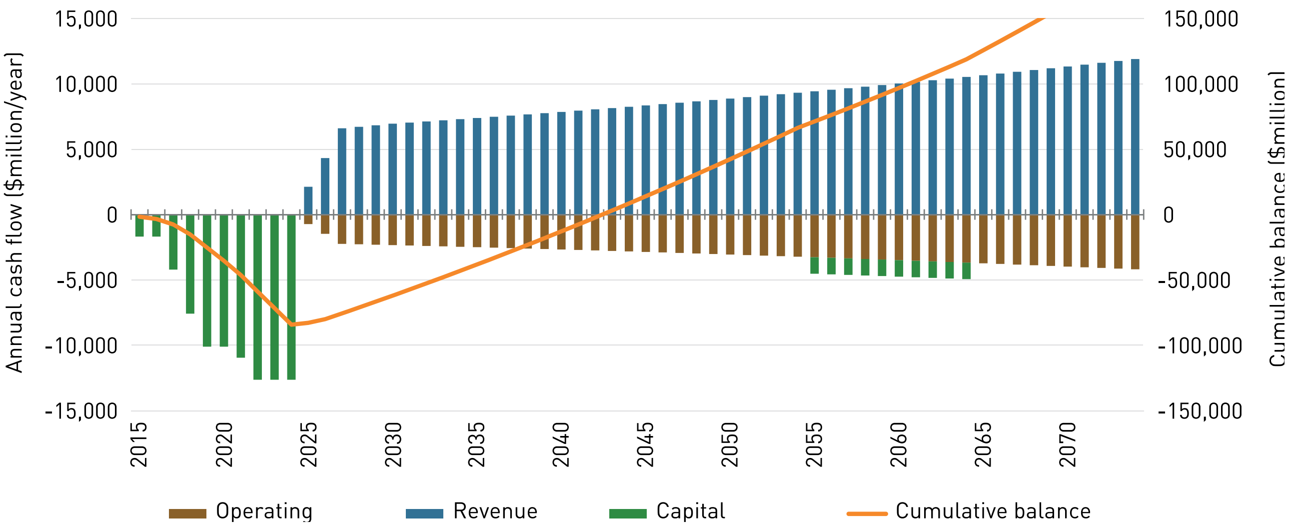
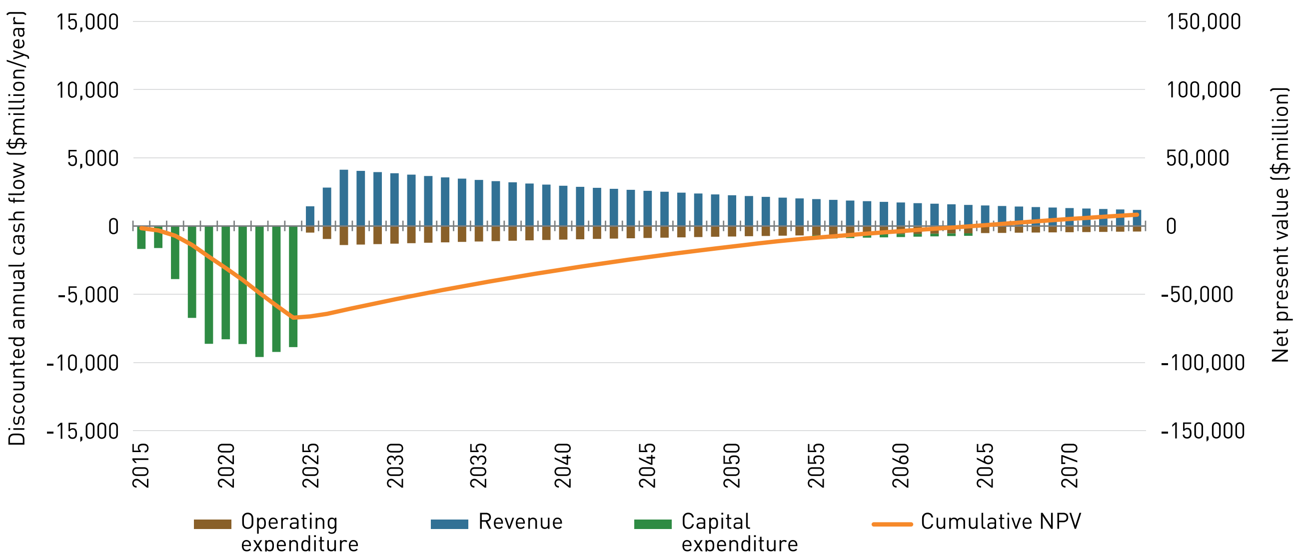


FIGURE 85 **Annual costs, revenue and net present value for HSR network (real 4% discounted 2012 dollars)**



Capacity and timeline

This study has identified significant demand for HSR in Australia now and in the future. While the capital cost is significant, this investigation has found that the revenue generated by its patronage is sufficient to recover this investment. HSR could also bring many more benefits to the Australian community that go beyond financial quantification such as enabling closer connections between regional Australia and major cities. The last question remaining is: how soon could Melbourne-Brisbane HSR become a reality?

HSR for Australia's eastern coast has been discussed and studied for several decades. This discussion could continue indefinitely. It is worth bearing in mind that it would be possible to physically construct the entire 1,798km HSR alignment within just one decade.

A staged delivery may prove more manageable, perhaps initiating the Melbourne-Sydney section first, followed a few years later by the Sydney-Brisbane section. This study proposes a timeline to complete the full network as soon as possible. This timeline allows for continued negotiation between various government jurisdictions to reach agreement by 2015. Two years are allocated for finalising funding and planning agreements as well as detailed design work, before an eight year construction period from 2017-2024.

There are precedents for major Australian projects progressing through detailed planning to commencement in 2-3 years; comparable international HSR projects have been built in eight years or less; and Australia's construction industry has the capacity to carry out the required activity over this time period.

The proposed HSR network will traverse three states and one territory, and will likely require significant input from the Australian government. Reaching agreements between State, Territory and Federal governments as well as other community and industry stakeholders will be complex, but is not unprecedented for infrastructure projects and other initiatives recognised as being in the national interest.

When given priority, legislative arrangements for national projects featuring shared jurisdiction and funding have been achieved in as little as two years. A number of projects feature tendering of some works such as planning, preparation and environmental impact statements allowing them to begin while project details and/or legislation are yet to be finalised.

A few recent examples are the National Broadband Network (NBN), Victoria's Regional Rail Link and New South Wales' North West Rail Link. These projects were all preceded by years of discussion and studies, but moved quickly to implementation once governments decided to proceed.

The National Broadband Network, one of Australia's largest ever national infrastructure projects, was announced as a formal Commonwealth government initiative in April 2009[59]. With approval in an earlier round of tendering, construction commenced in Tasmania in early 2010[60], with construction beginning in a number of mainland jurisdictions in late 2011 after contracts were awarded[61].

Following studies at a state government level, Victoria's Regional Rail Link project was submitted to Infrastructure Australia in December 2008[62]. Infrastructure Australia announced funding in May 2009[63] and by August 2010 the state government had established an authority to oversee construction[64], allowing work to commence in July 2011[65]. This $5 billion project involves constructing a new dedicated regional train line through the western suburbs of Melbourne including a number of new and upgraded stations.

In late 2011, the recently elected New South Wales state government their first priority was building the North West Rail Link in Sydney[66]. Following planning studies and tendering, construction work is due to start in 2014 with state government funding[67]. The North West Rail Link is an $8.3 billion project that involves 15 kilometres of tunnelling and the construction of up to eight new rail stations.

Recent HSR projects overseas have demonstrated that construction of these large projects can be very rapid. The bar has been set high by these international efforts and the Australian construction industry can draw on these experiences to achieve comparable productivity.

Some recent international examples are:

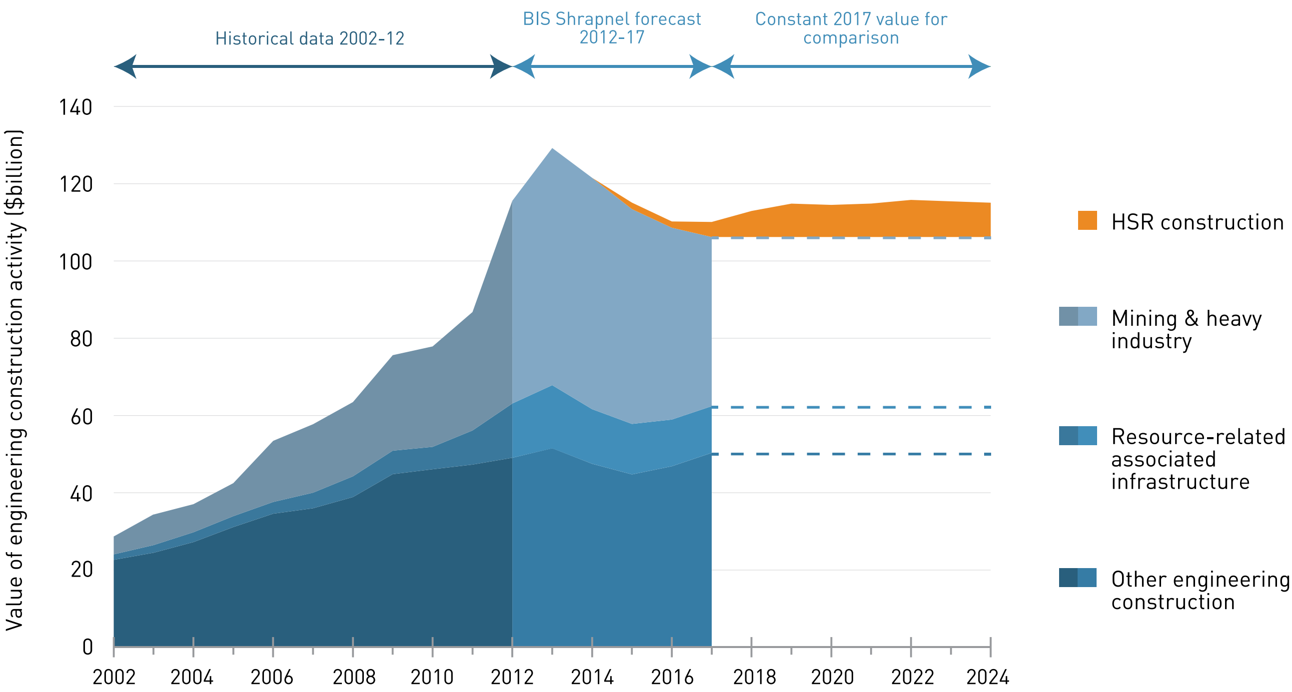
- Spain's program of extending HSR across the country, in eight years from 2005 to 2013 bringing over 2,550 km of new HSR line into service, on seven new individual lines connecting a total of 31 cities and towns[68].
- Taiwan's HSR line, which began construction in March 2000[69] and opened in January 2007[70], in just under seven years. This example is notable as while the entire length is only 345 km, approximately 300 km of this is in tunnels and on bridges or viaducts[71], a significant construction challenge. The proposed HSR network for Australia would require 180 km of elevated structures and tunnels.
- The 1,318 km Jinghu railway from Beijing to Shanghai was constructed in three years from April 2008[72] to opening in June 2011[73]. Whilst this experience would not be expected to be directly transferable from China to Australia, it does highlight how rapid the potential upper bound for construction rates could be.

The last ten years have seen impressive growth in construction activity in Australia. Construction employs over a million people in Australia, 9% of the workforce[74]. Engineering construction (as defined by the Australian Bureau of Statistics) covers all construction activity outside of buildings (residential and non-residential). The total value of engineering construction completed annually in Australia has increased by over 400% from 2002 - 2012, in real dollar terms (Figure 86).

Much of the overall growth has been due to demand from the resources industry, though non-resource engineering construction has more than doubled over the same time period. This does indicate the potential for rapid industry growth to meet demand. However, declining activity in the resources industry is expected to lead to an overall significant drop in construction activity over the next decade, according to industry analysts BIS Shrapnel[75]. From an expected peak of $130 billion per annum in 2013, engineering construction could drop by over $20 billion per annum by 2017. As shown in Figure 86, constructing the HSR network over eight years from 2017-2024 would require a maximum of $10 billion per annum of work completed. Of course not all construction industry resources are immediately transferable to railway construction, though much of the required activity is skills in earthmoving and infrastructure not specific to rail (see Figure 81). For comparison, railway-specific engineering construction increased by almost 600% over the last decade, from $1.5 billion per annum in 2002 to $8.9 billion per annum in 2012[76]. Both the demonstrated capability for growth and the looming outstripping of supply over demand indicate that the proposed construction of the $84 billion HSR line over eight years (after two years of planning) is within the capability of Australia's construction industry.

In summary, if Australia chose to prioritise the implementation of High Speed Rail, a ten-year timeline, while ambitious, would be possible.

FIGURE 86 **Engineering construction activity in Australia, historical (2002-12) and forecast (2012-17) data from BIS Shrapnel[75]. Proposed annual construction required for HSR network shown from 2015-2024 (first two years of expenditure allocated mostly to planning & design).**



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Surfing at local break Bar Reef, Newcastle PHOTO: KIMBO

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Appendices

Appendices

Appendix A: **Travel demand**

This features details of all travel scenarios modelled including geographic passenger distribution, mode share results and travel emissions. Passenger activity at Sydney Kingsford Smith Airport is presented for all scenarios. Further detail is provided on HSR passenger load estimates, station activity and user group profiles.

This appendix can be found online at http://media.bze.org.au/hsr/hsr_appendix_A.pdf

Appendix B: **Regional Travel Model**

This provides details of reference travel information, passenger distributions and future projections. Explanation of mode choice analysis is provided as well as specifications of the transport mode network models.

This appendix can be found online at http://media.bze.org.au/hsr/hsr_appendix_B.pdf

Appendix C: **Network Operation**

This features details of service performance and the operating schedule of the HSR network. A full network timetable is provided as well as the corresponding train utilisation schedule. Simulation results are included for each service.

This appendix can be found online at http://media.bze.org.au/hsr/hsr_appendix_C.pdf

Appendix D: **Alignment Design**

This explains the methodology and parameters used to design the HSR alignment. This refers to balancing the geometric requirements for HSR with impacts on people and the natural environment. This appendix also contains details of emissions created from construction of the HSR network.

This appendix can be found online at http://media.bze.org.au/hsr/hsr_appendix_D.pdf

Appendix E: **Cost and Financial Analysis**

This gives the costing data used to estimate the capital and operating costs of the HSR network, and the financial analysis of annual costs and revenues into the future.

This appendix can be found online at http://media.bze.org.au/hsr/hsr_appendix_E.pdf

Your High Speed Rail Timetable

Zero Carbon Australia **High Speed Rail**

Brisbane → Sydney → Melbourne

	MS	MS	AU	MS	MC	SC	AU	MS	CAN	AU	MS	SC	AU	SB	MC	CAN	AU	MS	SC	AU	SB	CAN	AU	MS	MC	SC	AU	SB	CAN	AU	
	AM																														
Brisbane (Roma Street)																	5:00				5:13		6:00				6:30	6:13		6:55	7:00
Gold Coast (Nerang)																	5:24				5:37		6:24				6:54	6:37		7:19	7:24
Lismore																	—				5:59		—				—	6:59		—	—
Grafton																	—				6:25		—				—	7:25		—	—
Coffs Harbour																	—				6:41		—				—	7:41		—	—
Port Macquarie														6:12			—				7:08		—				—	8:08		—	—
Taree														6:27			—				7:26		—				—	8:26		—	—
Newcastle Parkway														6:57			7:24				7:56		8:24				8:54	8:56		9:19	9:24
Central Coast Parkway														7:10			—				8:10		—				—	9:10		—	—
Hornsby														7:24			7:48				8:24		8:48				9:18	9:24		9:43	9:48
Sydney (Central)														7:33			7:57				8:33		8:57				9:27	9:33		9:52	9:57
Sydney (Central)			5:00	5:05		5:20	6:00	6:05	6:38	7:00	7:05	7:20	7:30			7:38	8:00	8:05	8:20	8:30		8:38	9:00	9:05		9:20			9:38		10:00
Glenfield			5:14	5:19		5:34	6:14	6:19	6:52	7:14	7:19	7:34	7:44			7:52	8:14	8:19	8:34	8:44		8:52	9:14	9:19		9:34			9:52		10:14
Moss Vale			—	5:34		5:49	—	6:34	—	—	7:34	7:49	—			—	—	8:34	8:49	—		—	—	9:34		9:49			—		—
Goulburn			—	5:50		6:05	—	6:50	—	—	7:50	8:05	—			—	—	8:50	9:05	—		—	—	9:50		10:05			—		—
Canberra			—	—	6:19	6:23	—	—	7:34	—	—	8:23	—		8:19	8:34	—	—	9:23	—		9:34	—	—	10:19	10:23			10:34		—
Wagga Wagga			—	6:35	7:05		—	7:35		—	8:35		—		9:05		—	9:35		—			—	10:35	11:05						—
Albury	6:01		6:43	7:01	7:31		7:43	8:01		8:43	9:01		9:13		9:31		9:43	10:01		10:13			10:43	11:01	11:31						11:43
Shepparton	6:33		—	7:33	8:03		—	8:33		—	9:33		—		10:03		—	10:33		—			—	11:33	12:03						—
Seymour	6:51	7:20	—	7:51	8:20		—	8:51		—	9:51		—		10:20		—	10:51		—			—	11:51	12:20						—
Melbourne Airport	7:11	7:40	7:45	8:11	8:41		8:45	9:11		9:45	10:11		10:15		10:41		10:45	11:11		11:15			11:45	12:11	12:41						12:45
Melbourne (Southern Cross)	7:21	7:50	7:55	8:21	8:51		8:55	9:21		9:55	10:21		10:25		10:51		10:55	11:21		11:25			11:55	12:21	12:51						12:55

	MS	SB	CAN	AU	AU	MS	MC	SC	SB	CAN	AU	AU	MS	SB	CAN	MS	AU	MS	SC	MC	AU	SB	CAN	AU	MS	SB	CAN	MS
	AM																											
Brisbane (Roma Street)		7:13		7:55	8:00				8:13		8:30	9:00		9:13			10:00				10:30	10:13		11:00		11:13		
Gold Coast (Nerang)		7:37		8:19	8:24				8:37		8:54	9:24		9:37			10:24				10:54	10:37		11:24		11:37		
Lismore		7:59		—	—				8:59		—	—		9:59			—				—	10:59		—		11:59		
Grafton		8:25		—	—				9:25		—	—		10:25			—				—	11:25		—		12:25		
Coffs Harbour		8:41		—	—				9:41		—	—		10:41			—				—	11:41		—		12:41		
Port Macquarie		9:08		—	—				10:08		—	—		11:08			—				—	12:08		—		13:08		
Taree		9:26		—	—				10:26		—	—		11:26			—				—	12:26		—		13:26		
Newcastle Parkway		9:56		10:19	10:24				10:56		10:54	11:24		11:56			12:24				12:54	12:56		13:24		13:56		
Central Coast Parkway		10:10		—	—				11:10		—	—		12:10			—				—	13:10		—		14:10		
Hornsby		10:24		10:43	10:48				11:24		11:18	11:48		12:24			12:48				13:18	13:24		13:48		14:24		
Sydney (Central)		10:33		10:52	10:57				11:33		11:27	11:57		12:33			12:57				13:27	13:33		13:57		14:33		
Sydney (Central)	10:05		10:38		11:00	11:05		11:20		11:38		12:00	12:05		12:38		13:00	13:05	13:20				13:38	14:00	14:05		14:38	
Glenfield	10:19		10:52		11:14	11:19		11:34		11:52		12:14	12:19		12:52		13:14	13:19	13:34				13:52	14:14	14:19		14:52	
Moss Vale	10:34		—		—	11:34		11:49		—		—	12:34		—		—	13:34	13:49				—	—	14:34		—	
Goulburn	10:50		—		—	11:50		12:05		—		—	12:50		—		—	13:50	14:05				—	—	14:50		—	
Canberra	—		11:34		—	—	12:19	12:23		12:34		—	—		13:34		—	—	14:23	14:19			14:34	—	—		15:34	
Wagga Wagga	11:35				—	12:35	13:05					—	13:35				—	14:35		15:05				—	15:35			
Albury	12:01				12:43	13:01	13:31					13:43	14:01				14:43	15:01		15:31				15:43	16:01			
Shepparton	12:33				—	13:33	14:03					—	14:33				—	15:33		16:03				—	16:33			
Seymour	12:51				—	13:51	14:20					—	14:51			15:20	—	15:51		16:20				—	16:51			17:20
Melbourne Airport	13:11				13:45	14:11	14:41					14:45	15:11			15:40	15:45	16:11		16:41				16:45	17:11			17:40
Melbourne (Southern Cross)	13:21				13:55	14:21	14:51					14:55	15:21			15:50	15:55	16:21		16:51				16:55	17:21			17:50

	AU	MS	SC	AU	AU	MC	SB	CAN	AU	MS	AU	SB	CAN	AU	MS	SC	AU	AU	MC	SB	CAN	AU	AU	MS	AU	SB	CAN	AU	AU	MS	MC
	PM																														
Brisbane (Roma Street)	12:00			12:30			12:13		13:00			13:13		14:00			14:30			14:13		14:55	15:00			15:13		15:55	16:00		
Gold Coast (Nerang)	12:24			12:54			12:37		13:24			13:37		14:24			14:54			14:37		15:19	15:24			15:37		16:19	16:24		
Lismore	—			—			12:59		—			13:59		—			—			14:59		—	—			15:59		—	—		
Grafton	—			—			13:25		—			14:25		—			—			15:25		—	—			16:25		—	—		
Coffs Harbour	—			—			13:41		—			14:41		—			—			15:41		—	—			16:41		—	—		
Port Macquarie	—			—			14:08		—			15:08		—			—			16:08		—	—			17:08		—	—		
Taree	—			—			14:26		—			15:26		—			—			16:26		—	—			17:26		—	—		
Newcastle Parkway	14:24			14:54			14:56		15:24			15:56		16:24			16:54			16:56		17:19	17:24			17:56		18:19	18:24		
Central Coast Parkway	—			—			15:10		—			16:10		—			—			17:10		—	—			18:10		—	—		
Hornsby	14:48			15:18			15:24		15:48			16:24		16:48			17:18			17:24		17:43	17:48			18:24		18:43	18:48		
Sydney (Central)	14:57			15:27			15:33		15:57			16:33		16:57			17:27			17:33		17:52	17:57			18:33		18:52	18:57		
Sydney (Central)	15:00	15:05	15:20		15:30			15:38	16:00	16:05	16:30		16:38	17:00	17:05	17:20		17:30			17:38		18:00	18:05	18:30		18:38		19:00	19:05	
Glenfield	15:14	15:19	15:34		15:44			15:52	16:14	16:19	16:44		16:52	17:14	17:19	17:34		17:44			17:52		18:14	18:19	18:44		18:52		19:14	19:19	
Moss Vale	—	15:34	15:49		—			—	—	16:34	—		—	—	17:34	17:49		—			—		—	18:34	—		—		—	19:34	
Goulburn	—	15:50	16:05		—			—	—	16:50	—		—	—	17:50	18:05		—			—		—	18:50	—		—		—	19:50	
Canberra	—	—	16:23		—	16:19		16:34	—	—	—		17:34	—	—	18:23		—	18:19		18:34		—	—	—		19:34		—	—	20:19
Wagga Wagga	—	16:35			—	17:05			—	17:35	—			—	18:35			—	19:05				—	19:35	—				—	20:35	21:05
Albury	16:43	17:01			17:13	17:31			17:43	18:01	18:13			18:43	19:01			19:13	19:31				19:43	20:01	20:13				20:43	21:01	21:31
Shepparton	—	17:33			—	18:03			—	18:33	—			—	19:33			—	20:03				—	20:33	—				—	21:33	22:03
Seymour	—	17:51			—	18:20			—	18:51	—			—	19:51			—	20:20				—	20:51	—				—	21:51	22:20
Melbourne Airport	17:45	18:11			18:15	18:41			18:45	19:11	19:15			19:45	20:11			20:15	20:41				20:45	21:11	21:15				21:45	22:11	22:41
Melbourne (Southern Cross)	17:55	18:21			18:25	18:51			18:55	19:21	19:25			19:55	20:21			20:25	20:51				20:55	21:21	21:25				21:55	22:21	22:51

	SC	AU	SB	CAN	AU	AU	MS	SB	CAN	AU	AU	MS	MC	SC	SB	AU	AU	MS	SB	AU	MS	SC	SB	SB	SB
	PM																								
Brisbane (Roma Street)		16:30	16:13		16:55	17:00		17:13		17:55	18:00				18:13	18:30	19:00		19:13	20:00			20:13	21:13	22:13
Gold Coast (Nerang)		16:54	16:37		17:19	17:24		17:37		18:19	18:24				18:37	18:54	19:24		19:37	20:24			20:37	21:37	22:37
Lismore		—	16:59		—	—		17:59		—	—				18:59	—	—		19:59	—			20:59	21:59	22:59
Grafton		—	17:25		—	—		18:25		—	—				19:25	—	—		20:25	—			21:25	22:25	23:25
Coffs Harbour		—	17:41		—	—		18:41		—	—				19:41	—	—		20:41	—			21:41	22:41	23:41
Port Macquarie		—	18:08		—	—		19:08		—	—				20:08	—	—		21:08	—			22:08	23:08	0:08
Taree		—	18:26		—	—		19:26		—	—				20:26	—	—		21:26	—			22:26	23:26	
Newcastle Parkway		18:54	18:56		19:19	19:24		19:56		20:19	20:24				20:56	20:54	21:24		21:56	22:24			22:56	23:56	
Central Coast Parkway		—	19:10		—	—		20:10		—	—				21:10	—	—		22:10	—			23:10	0:10	
Hornsby		19:18	19:24		19:43	19:48		20:24		20:43	20:48				21:24	21:18	21:48		22:24	22:48			23:24	0:24	
Sydney (Central)		19:27	19:33		19:52	19:57		20:33		20:52	20:57				21:33	21:27	21:57		22:33	22:57			23:33	0:33	
Sydney (Central)	19:20			19:38		20:00	20:05		20:38			21:05		21:20				22:05			23:05	23:20			
Glenfield	19:34			19:52		20:14	20:19		20:52			21:19		21:34				22:19			23:19	23:34			
Moss Vale	19:49			—		—	20:34		—			21:34		21:49				22:34			23:34	23:49			
Goulburn	20:05			—		—	20:50		—			21:50		22:05				22:50			23:50	0:05			
Canberra	20:23			20:34		—	—		21:34			—	22:19	22:23				—			—	0:23			
Wagga Wagga						—	21:35					22:35	23:05					23:35			0:35				
Albury						21:43	22:01					23:01	23:31					0:01			1:00				
Shepparton						—	22:33					23:33	0:03					0:33							
Seymour						—	22:51					23:51	0:20					0:51							
Melbourne Airport						22:45	23:11					0:11	0:41					1:11							
Melbourne (Southern Cross)						22:55	23:21					0:21	0:51					1:21							

Services

AU
Australia Express

MS
Melbourne ↔ Sydney
stopping

MC
Melbourne ↔ Canberra
stopping

SC
Sydney ↔ Canberra
stopping

CAN
Sydney ↔ Canberra
express

SB
Sydney ↔ Brisbane
stopping

NOTE: Central Coast and Newcastle shuttle services not shown, and times shown can differ from travel times determined later by simulations

High Speed Rail in Australia can:

- Connect Melbourne-Sydney-Brisbane with stations at six major cities and twelve regional towns on route
- Enable passengers to travel between Melbourne and Sydney and between Brisbane and Sydney in less than three hours
- Have trains departing major cities every ten minutes at peak times
- Provide a station within 50km for 60% of Australians population
- Be powered by 100% renewable energy enabling zero emissions travel
- Repay capital investments and generate long term profits
- Provide lower fares and more convenience than air travel
- Be operational in ten years

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