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The influence of Melbourne-Sydney intercity high-speed rail on spatial accessibility: an analysis of current proposals

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Abstract: This paper explores the influence of high-speed rail development on spatial accessibility in southeastern Australia. The aim is to understand how current proposals for intercity high-speed rail would distribute accessibility improvements across regions between Sydney and Melbourne. Special attention is given to spatial effects in Hume, an administrative region in northeast Victoria, where improvements to social infrastructure and services are linked to the growth of existing regional cities.

The analysis draws on methods developed in Gutiérrez et al. (1996), Gutiérrez (2001) and López et al. (2008) to explore the influence of transport infrastructure investments on spatial equity and regional cohesion. Two scenarios for intercity high-speed rail are analysed to understand which scenario is more likely to support the strategic planning goals of Hume: a government-led proposal prepared by AECOM et al. (2013) and a market-led proposal by Consolidated Land and Rail Australia (2016).

The results suggest that the government-led proposal is more likely to promote the strategic planning goals of Hume because it treats existing regional cities between Sydney and Melbourne as gateways to the network. The market-led proposal, in contrast, targets accessibility improvements towards sparsely populated regions in southern New South Wales as part of an ambitious plan to rebalance population growth. This could have negative consequences for existing communities in Hume if growth is diverted away from regional cities.

Keywords: high-speed rail Australia; regional cohesion; spatial accessibility; transport connectivity.

A spatial equity approach to high-speed rail planning

Recent debates about high-speed rail in Australia have related the concept of 'transport connectivity' to a range of social, economic and environmental benefits. Connectivity improvements enabled by high-speed rail can, it has been argued, rebalance Australia's polarized settlement structure by promoting regional development, urban decentralization and, potentially, the construction of new cities. These ideas were advanced through a recent House of Representatives inquiry into transport connectivity and regional development (see Parliament of Australia 2016, xxvi) and now inform federal government policy (see Australian Government 2018).

However, international experts (Ginés de 2008, Preston 2017, Albalate and Bel 2012) and authors of several studies into the feasibility of high-speed rail in Australia (Arup and TMG 2001, AECOM et al. 2013) take a more cautious view of the relationship between transport connectivity and regional development. High-speed rail has been showed to support the development of non-metropolitan regions in Asia and Europe, but the nature and extent of development benefits are dependent on contextual social and economic factors and government policy settings (Chen and Hall 2011, Chen and Vickerman 2017). Experts are also divided on the extent to which high-speed rail can increase economic activity in non-metropolitan regions. While there is evidence to suggest that high-speed rail has encouraged intermediate-sized cities and some regional cities with stations to grow (Bellet et al. 2012, Bellet 2016, Bellet and Santos Ganges 2016), network-wide development benefits tend to concentrate in densely populated metropolitan regions (see Spiekermann and Wegener 2008, Vickerman 2017). Therefore, ambitious claims about the development potential of high-speed rail should be tempered by a clear understanding of its distributional effects.

High-speed rail can improve connectivity between regions, affording opportunities for urban and regional development, but it can also "disarticulate" the space between network nodes and contribute to reduced levels of social and economic cohesion (Levinson 2012, 290). This "selective capacity" to modify accessibility at large planning scales (Ureña et al. 2009, 266) can produce "tunnel effects" when intermediate regions are bypassed (Gutiérrez et al. 1996) and polarize spatial development towards better connected regions (see Mazzeo 2012). These phenomena occur in parallel through a process that Hall (2009) describes as the "peripheralization of the periphery" where the development potential of underperforming or poorly connected regions is reduced as central regions grow. These planning challenges are well rehearsed in policy debates in Europe (European Commission 2001, Hall and Pain 2006, Garmendia et al. 2012) but rarely register in the Australian context.

To foreground these challenges, Monzón et al. (2013, 28) propose a "spatial equity approach" to high-speed rail planning that "addresses both the possible benefits and their spatial distribution." This approach aims to complement findings from detailed studies into the social and economic impacts of high-speed rail by showing how accessibility improvements are distributed across metropolitan and non-metropolitan regions. Transport investments promote spatial equity, the authors argue, when accessibility improvements are distributed more evenly across regions. In a parallel study by Ortega et al. (2012, 130), a 'regional cohesion' framework is used to explore how accessibility improvements introduced by high-speed rail are distributed across different planning scales. The authors use multiscale analysis to show how high-speed rail tends to promote social and economic cohesion at the corridor level and reduce cohesion at the regional and local levels.

According to López et al. (2008, 277), these studies use "changes in the spatial distribution of accessibility as a proxy to assess [the] regional cohesion effects of transport infrastructure investment." These methods do not stand in for detailed social and economic analysis of the development impacts of transport investments but are instead used to broaden understanding of the way that benefits (and costs) are distributed in space. Concepts of spatial equity and regional cohesion are used by these authors to relate changes in accessibility to ideas about 'balanced spatial development'—a planning framework that aims to balance competitive pressures across regions by targeting strategic locations for growth (Faludi 2000). Under the rubric of balanced spatial development, equity improves not because all cities and regions grow equally but because access to locations where economic activity, social infrastructure and services are concentrated is optimised. According to Chen and Hall (2013), one way that high-speed rail can promote balanced spatial development is by targeting accessibility improvements strategically, towards cities and regions that are designated by policy makers for growth.

Aim and questions

This paper explores the influence of high-speed rail development on spatial accessibility in southeastern Australia. The aim is to understand how current proposals for intercity high-speed rail would distribute accessibility improvements across regions between Sydney and Melbourne. Special attention is given to spatial effects in Hume, an administrative region in northeast Victoria, where improvements to social infrastructure and services are linked to the growth of existing regional cities. The analysis is part of a Ph.D. thesis investigating the governance of high-speed rail planning in Hume.

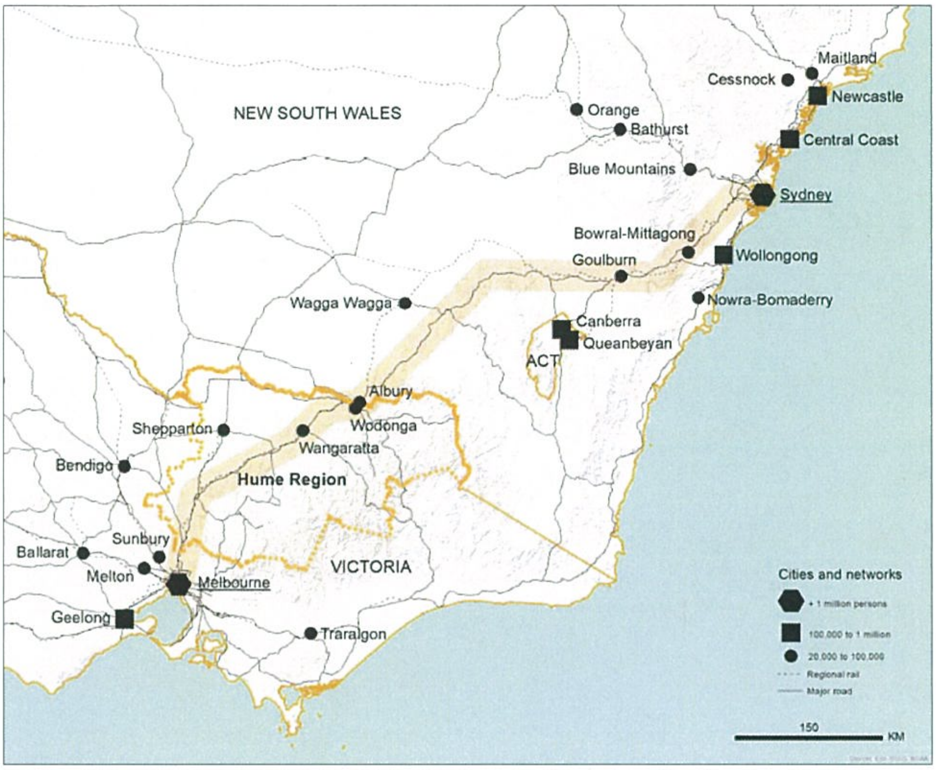
Figure 1 describes the relationship of the Hume region to the Hume corridor—a major intercity transport artery connecting Sydney and Melbourne. In Hume, the goal of balanced spatial development is articulated through a set of planning strategies that connect population growth in three regional cities to economic development and region-wide improvements to social infrastructure and services. Planning strategies detailed in the Hume Strategy for Sustainable Communities (2010) and the Hume Regional Growth Plan (2014) frame Albury-Wodonga and Shepparton as "major growth locations" and Wangaratta as a "moderate to high growth location." State and local government policy-makers contend that a polycentric framework for spatial development will improve social and economic outcomes in surrounding townships and rural communities and help to mitigate the negative environmental impacts of growth.

Two scenarios for high-speed rail are assessed in relation to these goals. Scenario 1 (S1) is a government-led proposal prepared for the Commonwealth by AECOM et al. (2013) and Scenario 2 (S2) is a market-led proposal by Consolidated Land and Rail Australia (CLARA 2016). Existing conditions of accessibility along the Hume corridor are described by a base case, Scenario 0 (S0).

S1 proposes to maximise patronage demand by prioritizing integration with existing urban and infrastructure networks. Consequently, S1 pursues high levels of connectivity with metropolitan areas and intermediate cities where central station locations are proposed, and moderate levels of connectivity with non-metropolitan areas where "regional through stations" are proposed to be located between 10km and 20km from established urban areas (AECOM et al. 2013, 249). This station location strategy aims to balance proximity to existing population centres and designated growth areas with access to surrounding townships (AECOM et al. 2013, 143).

S2 proposes to ameliorate growth pressures in Sydney and Melbourne by using high-speed rail to support the development of eight new inland cities on greenfield sites (CLARA 2016). Land value capture from property development is intended to fund the construction of high-speed rail at no direct cost to governments (Koslay 2017). S2 pursues high levels of connectivity in metropolitan areas but low levels of connectivity in non-metropolitan areas because the value capture framework depends heavily on the conversion of agricultural land to higher-value urban uses (Manning 2016). Although S2 is in the very early stages of development, enough is known about the spatial and mobility characteristics of the scheme to undertake a corridor-level analysis.

Figure 1. Study area



Data sources: ABS states and urban centres and localities, ESRI terrain data and PSMA road and railway data.

Spatial analysis is used to identify cities and regions along the Hume corridor that are targeted by S1 and S2 for accessibility improvements. Regional cohesion provides an overlay to the analysis that enables the possible implications of each scenario for spatial development to be explored. Discussion of the results focuses on the following three questions.

1. Is one scenario more likely to promote the strategic planning goals of Hume more than the other? If yes, why?
2. How has the network structure (corridor alignment and station locations) and operational speeds of both scenarios influenced the results?
3. What are the potential planning implications for Hume?

Methods

A four-step process was used in the spatial analysis. Initial steps involved (1) acquiring base data and (2) building an impedance (travel time) model of the southeastern seaboard of Australia in GIS that describes S0. Impedance models for S1 and S2 were built after a short verification phase that compared travel time results for S0 to results from Google Maps. Results for all scenarios were then (3) imported into an accessibility model where equations for three accessibility indicators were applied and the results exported. The final step (4) involved mapping these results in GIS. Travel time maps were also produced with contours (isochrones) at 15-minute and 60-minute intervals interpolated using GIS.

In step 1, a set of origin and destination points were needed to calculate travel times for each scenario. Table 1 details the census and spatial data used in this part of the analysis. Because spatial data for S1 and S2 were not available from official sources, corridor alignments, station locations and operational speeds were approximated using information from planning studies, media reports and interview notes.

Table 1. Data sources and data types used in the analysis

Data source	Data type
Australian Bureau of Statistics (ABS)	– Digital boundaries for State Suburbs (SSCs) and Urban Centres and Localities (UCLs) 2016 – Digital boundaries for States (STEs) 2016 – 2016 Census population counts (usual resident population)
Earth Science Research Institute (ESRI)	– Terrain base map
Public Sector Mapping Agency (PSMA)	– Roadways 2012 – Railways 2016* – Railway stations*
Regional Development Australia (RDA)	– Digital boundary for the Hume Regional Development Australia Committee

Note: * indicates data acquired under licence from AURIN

In step 2, parameters of the impedance model for S0 were set using methods in Pérez et al. (2011) that assign nominal speeds to different elements in a transport network. The categories assigned to major roads in Australia are national/state highways, arterial roads, sub-arterial roads and collector roads. Speeds for these road categories were set at 95 km/h, 85 km/h, 75 km/h and 55 km/h, respectively. Air travel and travel by local roads was not incorporated into the impedance model for S0, nor did this model incorporate public transport networks because, in most cases, rail and bus services in Australia do not compete with private cars based on travel time. These omissions reveal a key limitation of the analysis—it does not capture factors like cost, purpose of travel, frequency and reliability of service and convenience and comfort that influence travel behaviour.

The verification process found that results for S0 were lower (i.e. faster) than results from Google Maps. Figure 2 describes the percent difference in travel time between S0 and Google Maps for 200 randomly selected origin-destination pairs. The pattern of variations observed in the results is deemed sufficiently accurate for the purposes of this investigation because the trendline for travel distances between 200 km and 800 km—the range at which high-speed rail effectively competes against other transport modes (Givoni 2006)—is ±10%.

Figure 2. Percent difference between the impedance model and Google Maps

Notes: Travel mode for S0 is by private car. Congestion levels in Google Maps API set as 'usual' traffic.

Nominal speeds for S1 and S2 were set based on travel times for regional services (i.e. stopping all stations) proposed by the respective proponents. The speed of S1 was set at 270 km/h based on travel times described in AECOM et al. (2013, 8) and the speed of S2 was set at 320 km/h based on travel times between Melbourne and Shepparton stated by federal members of parliament (Thomson 2018) and local councillors (Akerman 2016) with knowledge of the proposal. Spur lines to Albury-Wodonga and Wagga Wagga in S2 were set at nominal speed of 160 km/h (the author could not find information in the public domain about this aspect of the proposal). Finally, a generic penalty of 12.5 minutes was applied to transfers between high-speed rail and road modes.

Step 3 applied three accessibility indicators developed in Gutiérrez et al. (1996), Gutiérrez (2001) and López et al. (2008) to explore the influence of transport infrastructure investments on spatial equity and regional cohesion in Europe. These indicators were developed to explore the "different effects of transport infrastructure investments" (López et al. 2008, 281).

Each indicator is governed by an equation that is designed to foreground a different spatial effect of improved accessibility. Because population is a prominent factor in each of the equations, it is important to note that population growth projections are not incorporated into this analysis. This may bias the results towards S1 because the anticipated population rebalancing effects of S2 are not considered.

The Location indicator foregrounds changes to the settlement structure introduced by high-speed rail. As a weighted-average distance indicator, it factors the number of major destinations within a given area, the population of these destinations and the average time that it takes to travel to each destination from all origin points (López et al. 2008, 286). Location (Lo) is calculated using an equation derived from López et al. (2008, 282).

$$Lo_a = \frac{\sum_{b=1}^{n} I_{ab} \cdot P_b}{\sum_{b=1}^{n} P_b} \tag{1}$$

where Lo_a indicates the accessibility of origin *a*; I_{ab} is the impedance in travel time (minutes) from origin *a* to destination *b*; and P_b is the population of destination *b* (a major economic centre above a certain population level).

The Potential indicator foregrounds "the potential of opportunities for interaction" enabled by high-speed rail (López et al. 2008, 283). As a gravity-based indicator, it shows how economic activity agglomerates around cities that are networked into dense clusters. According to Gutiérrez (2001, 232), it factors the nearness of an origin point to the total volume of economic activity within a study area. Potential (Po) is calculated using an equation derived from López et al. (2008, 283)

$$Po_a = \sum_{b=1}^{n} \frac{P_b}{I_{ab}^{\alpha}} \tag{2}$$

where Po_a indicates the potential for economic activity at location *a*; and α is a gravity parameter usually set at 1. All other values are known (above).

The Daily Accessibility indicator estimates the combined population of urban centres that can be reached within a predefined threshold of travel time (López et al. 2008, 284). An extended, one-way travel threshold of between 3 and 4 hours (180 and 240 minutes) is used to show the geography of trips made for non-economic purposes. Daily Accessibility (DA) is calculated using an equation derived from López et al. (2008, 283).

$$DA_a = \sum_{b=1}^{n} P_b \cdot \delta_{ab} \tag{3}$$

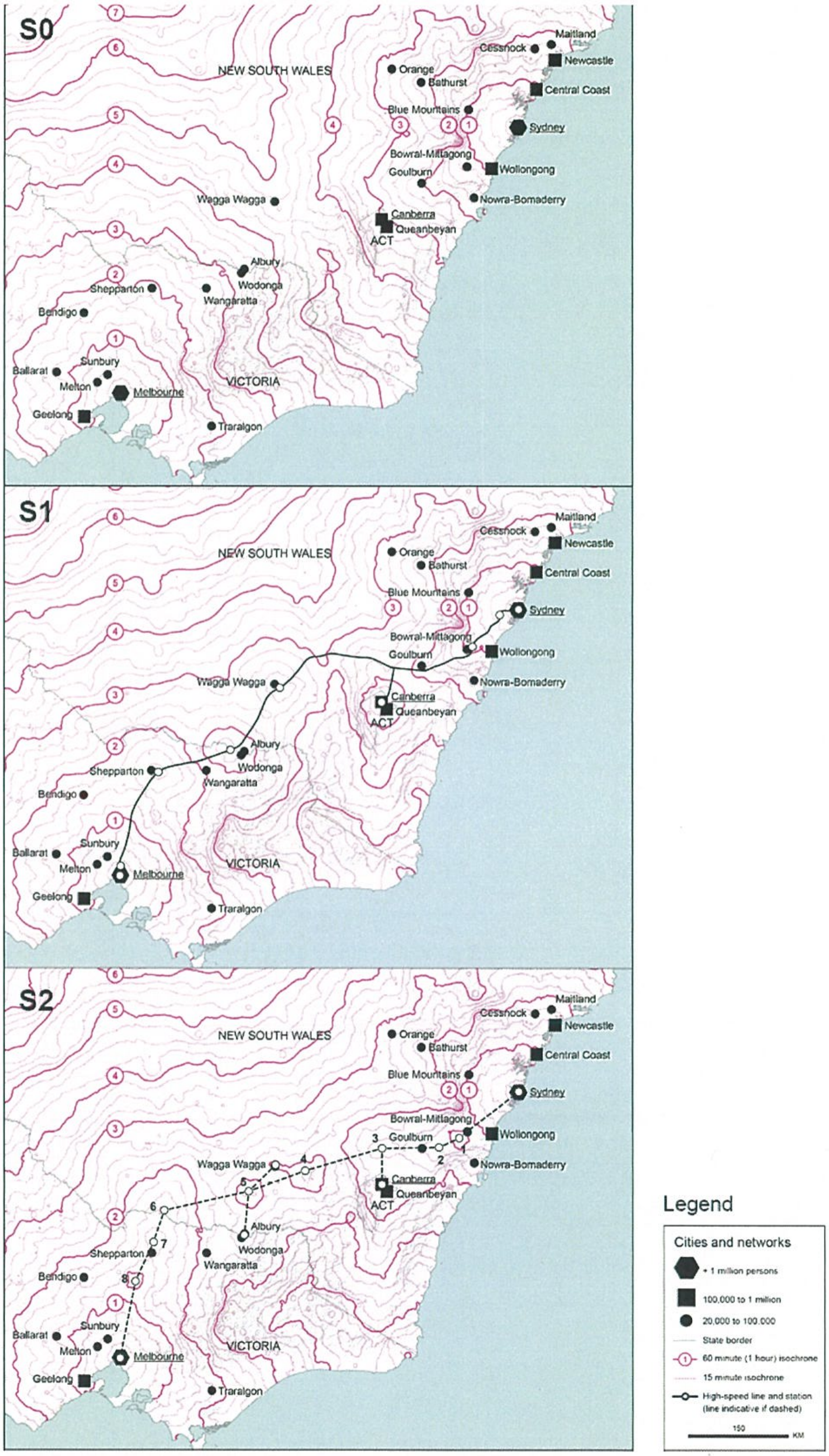
where DA_a indicates the Daily Accessibility of location *a* from destination *b*; δ_{ab} is the travel threshold set at 3.5 hours (210 minutes) for this analysis (based on a two-way trip that starts at 8 am and finishes at 6 pm, leaving 3 hours for the conduct of business). All other values are known (above).

In the final step 4, results from the accessibility model were imported into GIS and maps representing each indicator and each scenario produced. Contour maps depicting travel times were also produced.

Results from the spatial analysis

Results from the travel time analysis are discussed first, followed by the Location, Potential and Daily Accessibility indicator results. Observations about the influence of each scenario on spatial accessibility are synthesized in the final section where the possible implications for Hume are discussed. It is important to note that results from the impedance models of S0, S1 and S2 are approximations of city-to-city travel times. Also, results from the Location, Potential and Daily Accessibility indicators for individual cities are relative, and must be read in relation to the results for other cities.

Figure 3. Travel time to Sydney or Melbourne for S0, S1 and S2



Notes: Isochrones indicate travel time to Sydney or Melbourne CBD, whichever is closer. Access to high-speed rail is by car. Station numbers in S2 indicate the proposed location of new cities on greenfield sites. Travel time results are approximate only. Refer to the table (right) for detailed results in selected regional cities.

Figure 3 shows travel time results from the impedance models of S0, S1 and S2. The results for S0 show existing conditions of access to Sydney and Melbourne from surrounding cities and regions. Sydney and Melbourne were chosen as destinations for this stage of the analysis because their population size will strongly influence the results from each accessibility indicator.

The prevalence of high-quality road infrastructure around Sydney and Melbourne means that isochrones extend from these cities in regularly-spaced concentric rings. Irregularities in isochrones originating from Sydney show the constraints imposed on transport network development by physical geography.

Table 2 describes travel times to Sydney and Melbourne from selected cities along the Hume corridor. Wagga Wagga, located midway between Sydney and Melbourne, is approximately 284 minutes' travel time to both Sydney and Melbourne. Other regional cities that are of interest to this study are Shepparton, Wangaratta and Albury-Wodonga. Travel times to Melbourne from these cities are approximately 112, 148 and 194 minutes, respectively.

Travel time results for S1 show how high-speed rail would transform the transportation geography of Australia's southeastern seaboard. Isochrones are restructured around the national capital Canberra and regional cities in the proposed network including Albury-Wodonga, Shepparton and Wagga Wagga. Isochrones extend out from the sites of proposed high-speed rail stations at regular intervals, indicating that accessibility enhancements would be evenly distributed at the regional and sub-regional levels.

S1 would reduce travel time from Albury-Wodonga to Melbourne by 47% to approximately 103 minutes and would bring Shepparton into the commuter-shed of Melbourne, reducing travel time by 37% to approximately 71 minutes. The most dramatic change is observed at Wagga Wagga where travel times to both Sydney and Melbourne drop by 56% to approximately 126 minutes.

S2 produces greater travel time savings for non-metropolitan regions along the proposed corridor because the proposed operational speed is 50 km/h faster than S1. A corridor of strong connectivity now extends into the sparsely populated areas of southern New South Wales (NSW). Relative to S1, a greater proportion of regions along the proposed corridor would be within 2-hours travel time to both Sydney and Melbourne.

For the regional cities of Shepparton and Wagga Wagga, however, S2 does not afford any significant advantage in terms of travel time savings over S1 because stations on the main line are located at a greater distance from their city centres. Furthermore, travel time savings from Albury-Wodonga to Melbourne are 20 minutes less for S2 than for S1.

S2 tends to produce inferior travel time savings for regional cities along the Hume corridor relative to S1 because connectivity to Sydney and Melbourne is rerouted through cities that are proposed to be constructed on greenfield sites. In doing so, it is possible that S2 would impact the hierarchy of regional settlements between Sydney and Melbourne.

Table 2. Difference in travel time to Sydney or Melbourne for S1 and S2 relative to S0

Origin – Destination	S0 (min.)	S1 (min.)	Δ S0-S1	S2 (min)	Δ S0-S2
To Sydney from –					
Canberra	177	89	-50%	80	-55%
Wagga Wagga	284	126	-56%	116	-59%
CLARA City 5	238	–	–	99	-58%
To Melbourne from –					
CLARA City 8	83	–	–	53	-36%
Shepparton	112	71	-37%	70	-38%
CLARA City 7	122	–	–	61	-50%
Wangaratta	148	120	-19%	132	-11%
Albury-Wodonga	194	103	-47%	123	-37%

Notes: The destination points for Sydney and Melbourne are the central CBD. The origin points for regional cities are the central urban area. Access to high-speed rail is by car. Travel time results are approximate only.

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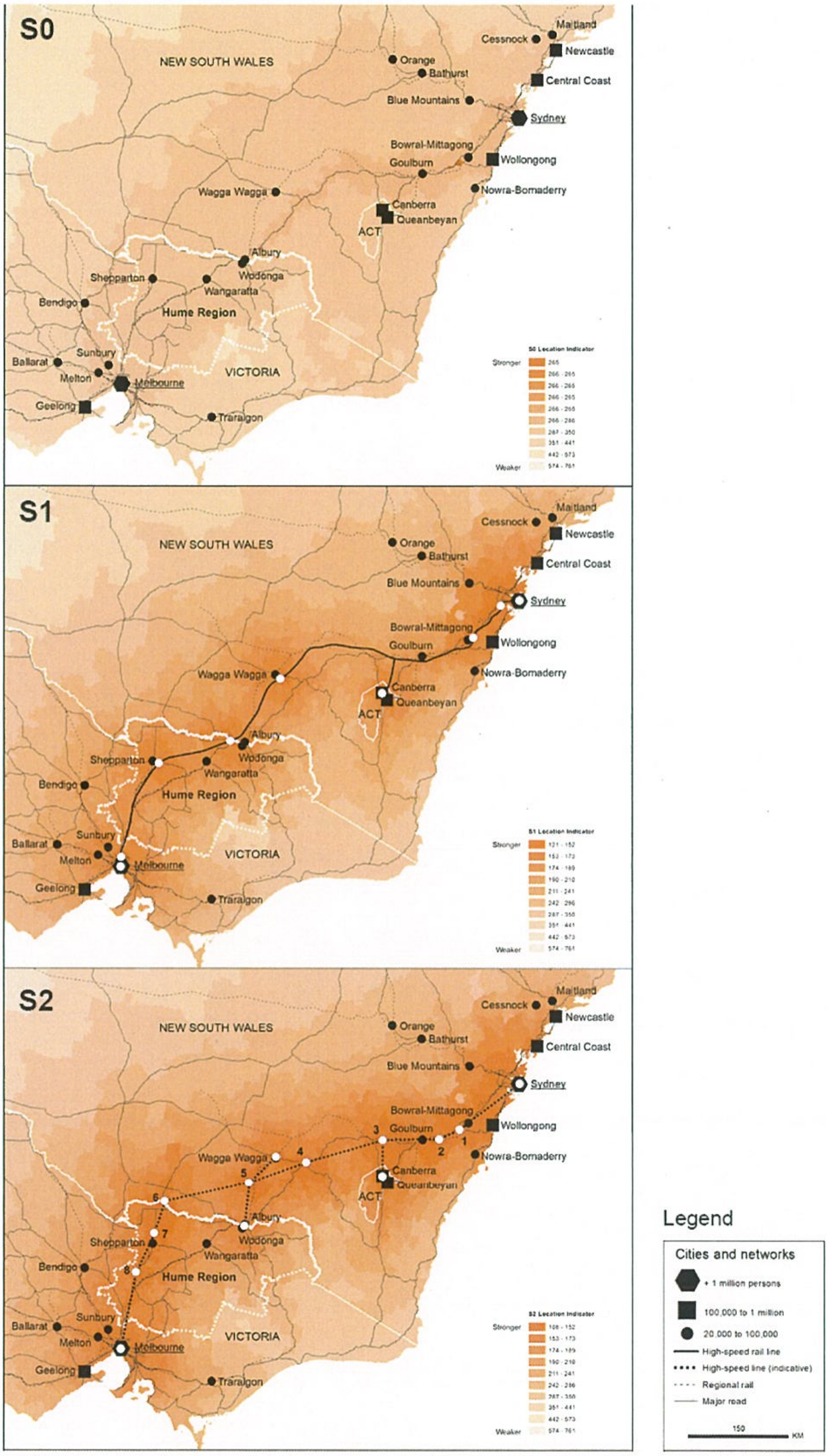
Figure 4. Location indicator results (Lo) for S0, S1 and S2



Notes: These maps are intended to facilitate a visual assessment of the results. Refer to the table (right) for detailed results in selected cities. Station numbers in S2 indicate the proposed location of new cities on greenfield sites.

Figure 4 shows Location indicator results for S0, S1 and S2. The results for S0 show how accessibility concentrates around large metropolitan areas and along the major transport corridors connecting them. Levels of accessibility are stronger around Sydney due to its greater population size relative to Melbourne, and its proximity to the intermediate-sized cities of Canberra, Central Coast, Newcastle, Queanbeyan and Wollongong.

Levels of accessibility in S0 are also relatively strong along the Hume corridor because it provides access to Sydney and surrounding intermediate-sized cities from Victoria. The nearness of Sydney to the geographic centre of analysis may also contribute to the relatively high concentrations of accessibility observed (i.e. Sydney is proximate to more points of origin in the analysis than Melbourne).

These results suggest that high-quality road infrastructure and low-quality passenger rail in non-metropolitan regions promotes a more homogenous distribution of accessibility. The Location indicator results for S1 show how high-quality passenger rail infrastructure would concentrate accessibility around nodes within the transport network.

The distributive effects of high-speed rail development become clear when the Location indicator results for S1 are compared to results for S0. Accessibility is restructured around nodes in the high-speed rail network. Albury-Wodonga, Canberra, Shepparton and Wagga Wagga are defined as centres of their respective regions and the extent of Sydney and Melbourne's mega-metropolitan regions becomes more clearly defined.

These results suggest that S1 would reinforce patterns of urban investment in regions serviced by high-speed rail stations because accessibility improvements target existing population centres. The same may not be true, however, for regions disconnected from the high-speed rail network.

Table 3 uses results from the Location indicator to show the settlement structures that would be promoted by S1 and S2. Levels of accessibility in Ballarat and Bendigo, major population centres in regional Victoria, appear to drop below Albury-Wodonga and Shepparton, which have smaller population sizes. A slight 'tunnel effect' is also observed in the area between Albury-Wodonga and Shepparton where Wangaratta is located.

The distribution of accessibility enhancements in S2 differs markedly from S1. In S1, the greater distances between high-speed rail stations promote clustering around network nodes. The higher operational speed of S2, combined with the nearness of proposed high-speed rail stations, produces a contiguous corridor of heightened accessibly between Sydney and Melbourne. Patterns of accessibility also appear to be more strongly polarized towards regions along the proposed corridor.

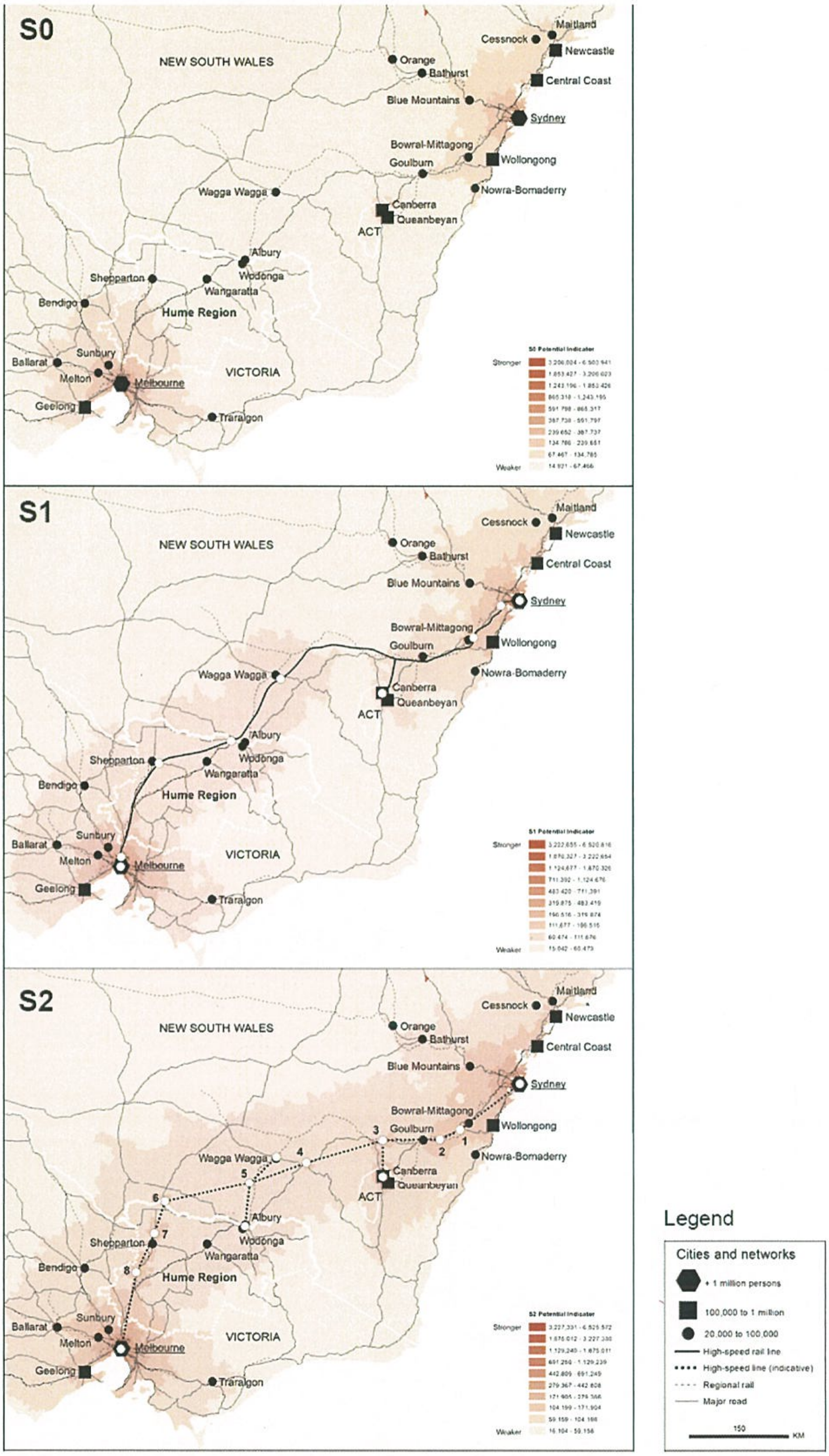
The results also suggest that new cities constructed as part of S2 would have a locational advantage over surrounding regional cities. When ranked in order of results, CLARA City 5 would enjoy a strong locational advantage over Albury-Wodonga and Wagga Wagga, and CLARA City 7 and CLARA City 8 would have a slight locational advantage over Shepparton.

Table 3. City rank by State by Location indicator (Lo) results for S1 and S0

State	Rank	S1 Lo	S1 City Rank	S2 Lo	S2 City Rank
NSW and ACT	1	122	Sydney	108	Sydney
	2	144	Canberra	128	Canberra
	3	149	Wagga Wagga	129	CLARA City 5
	4	–	–	144	Wagga Wagga
Victoria	1	142	Melbourne	125	Melbourne
	2	152	Shepparton	129	CLARA City 7
	3	156	Albury-Wodonga	135	CLARA City 8
	4	175	Wangaratta	137	Shepparton
	5	202	Bendigo	152	Albury-Wodonga
	6	204	Ballarat	179	Wangaratta
	7	–	–	184	Bendigo
	8	–	–	189	Ballarat

Notes: The results for each city are relative only, and must be read in relation to the results for other cities. Lower numerical values indicate a stronger locational advantage whereas higher numerical values indicate a weaker locational advantage.

Figure 5. Potential indicator results (Po) for S0, S1 and S2



Notes: These maps are intended to facilitate a visual assessment of the results. Refer to the table (right) for detailed results in selected cities. Station numbers in S2 indicate the proposed location of new cities on greenfield sites.

Figure 5 shows Potential indicator results for S0, S1 and S2. The results for S0 show how economic potential is currently polarized towards Sydney and Melbourne. An area of heightened potential extends in a concentric ring from the centre of both cities to encompass peripheral regions.

Levels of potential for S0 outline two mega-metropolitan regions where accessibility agglomerates around a dense urban core: a Sydney mega-metropolitan region encompassing Blue Mountains, Central Coast, Newcastle and Wollongong and a Melbourne mega-metropolitan region encompassing Ballarat, Geelong, Melton and Sunbury. Beyond Sydney and Melbourne and intermediate-sized cities like Newcastle, Canberra and Geelong, where moderate-to-high levels of potential are observed, an area of low-to-moderate potential extends to encompass regional cities along the Hume corridor.

Potential indicator results for S1 illustrate how high-speed rail could increase opportunities for economic interaction beyond the growth boundaries of Sydney and Melbourne. Table 4 shows the difference in results for each scenario compared to the base case S0. The results suggest that S1 could increase the economic potential of regional cities in Victoria and southern NSW. Levels of Potential increase along the 'midland arc' connecting Geelong, Ballarat, Bendigo and Shepparton, and then extend along the Hume corridor to encompass Albury-Wodonga and Wagga Wagga. This corridor stops north of Canberra where the large distance between station nodes produces a gap.

However, levels of Potential do not increase dramatically overall. Increases in the economic potential of metropolitan regions are small as a proportion of current levels. Increases in regional cities along the Hume corridor are proportionately high, but these cities are starting from a relatively low base.

The pattern of results observed suggest that S2 would produce a continuous corridor of heightened economic potential between Sydney and Melbourne. The results also suggest that S2 would produce a greater increase in levels of potential across the study area than S1.

The relatively strong results for new cities constructed as part of S2 suggest that it has the capacity to recast settlement patterns over the longer term. In Hume, for example, it is possible that CLARA City 7 and CLARA City 8 could compete economically with Albury-Wodonga and Shepparton because they recorded similar levels in the results. The strong results for Ballarat and Bendigo relative to other regional cities suggest that they would retain their prominent position within the settlement hierarchy.

These results suggest that S2 could disrupt existing patterns of investment in Hume by concentrating economic potential in the west of the region and in southern NSW. The economic potential of Albury-Wodonga and Wangaratta, bypassed by the main high-speed rail line, are reduced relative to the cities that are proposed to be constructed as part of S2. Whether new cities would be successful in attracting population is a question for another study.

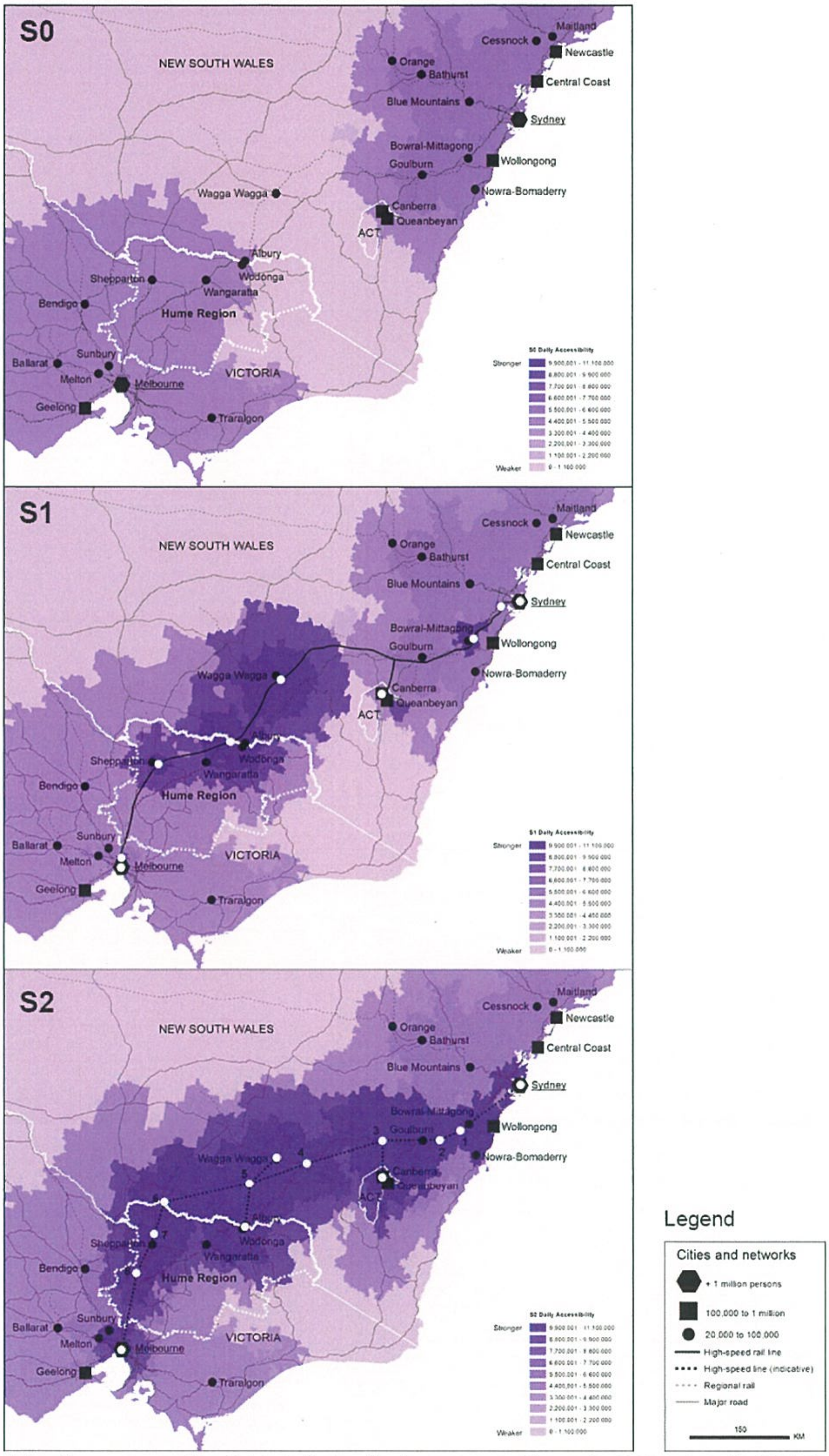
Finally, the results suggest that any regional development benefits from high-speed rail would flow disproportionately to NSW because most of the network is situated there. Conversely, S1 would be likely to produce a more equitable distribution of benefits both within and between states because the corridor enters Victoria at Albury-Wodonga and deviates towards Shepparton en route to Melbourne.

Table 4. Difference in Potential indicator (Po) results for S1 and S2 relative to S0

State / City	S0 Po	S1 Po	Δ S1-S0	S2 Po	Δ S2-S0
NSW and ACT					
Sydney CBD	1,971,398	1,988,482	1%	1,993,010	1%
Canberra Civic	884,399	927,581	5%	938,767	6%
Wagga Wagga	60,736	104,275	72%	107,859	78%
CLARA City 5	42,435	–	–	101,750	140%
Victoria					
Melbourne CBD	2,568,166	2,586,001	1%	2,590,626	1%
CLARA City 8	72,725	–	–	126,568	74%
Ballarat	328,635	340,324	4%	342,556	4%
Bendigo	281,820	293,800	4%	297,131	5%
Shepparton	84,391	127,423	51%	133,240	58%
CLARA City 7	58,863	–	–	122,495	108%
Wangaratta	67,831	91,570	35%	88,185	30%
Albury-Wodonga	73,455	113,233	54%	111,556	52%

Notes: Cities are organized by State and by distance from Sydney or Melbourne. The results for each city are relative only, and must be read in relation to the results for other cities.

Figure 6. Daily Accessibility (DA) results for S0, S1 and S2



Notes: These maps are intended to facilitate a visual assessment of the results. Refer to the table (right) for detailed results in selected cities. Station numbers in S2 indicate the proposed location of new cities on greenfield sites.

Figure 6 shows Daily Accessibility results for S0, S1 and S2. Due to the polarized structure of Australia's settlement system, results for S0 are strongly influenced by proximity to Sydney and Melbourne.

The benefits of city clustering are observed in eastern NSW where access to Sydney and intermediate-sized cities like Canberra, Central Coast, Newcastle and Wollongong produces strong results. Sydney's greater population size and proximity to several intermediate-sized cities also means that Daily Accessibility levels in NSW exceed levels in Victoria.

In Victoria, stronger levels of Daily Accessibility are recorded around central areas of the state where regional cities are clustered. Spill over from Melbourne into southern NSW is also observed, indicating an increased likelihood of trips from regions in southern NSW to Melbourne for non-economic purposes.

Daily Accessibility results for S1 suggest that high-speed rail would dramatically transform the geography of trips taken for non-economic purposes. In contrast to the patterns observed in S0, strong levels of Daily Accessibility are now observed in non-metropolitan regions.

Table 5 shows that the strongest increases in Daily Accessibility accrue to communities around Albury-Wodonga, Shepparton and Wagga Wagga because high-speed rail would promote strong access to both Sydney and Melbourne. Levels of Daily Accessibility in the centres of Sydney and Melbourne change dramatically, however levels in their middle and outer metropolitan areas change only marginally because high-speed rail services the metropolitan core. It is important to note that incorporating air travel into the impedance model would produce a very different set of results.

These findings could have implications for the planning of social infrastructure and services, some segments of the housing market (e.g. lifestyle properties and retirement living) and tourism development in regional areas—economic sectors where demand is influenced by the demographic characteristics of large geographic areas. Activity in these sectors could intensify in southern NSW and north-eastern Victoria after the introduction of high-speed rail.

The network structure and higher operational speed of S2 distributes patterns of Daily Accessibility very differently to S1. The results reinforce the idea that S2 could introduce a corridor of strong connectivity that would integrate southern NSW and northeast Victoria with Sydney and Melbourne. This raises an important question about the planning of S2: to what extent would the benefits of compact forms of urban development, clustered around high-speed rail stations, be undone by a dramatically expanded envelope of Daily Accessibility?

At present, state governments retain a relatively high level of control over the planning of urban development (Searle and Bunker 2010). Would the intensity and scope of Daily Accessibility enhancements introduced by S2 make it more difficult for governments to coordinate urban and infrastructure development in non-metropolitan regions? What models of urban decentralization would stem from S2, and what would be the social, economic and environmental consequences for communities in Hume?

Table 5. Difference in Daily Accessibility (DA) results for S1 and S2 relative to S0

State / City	S0 DA	S1 DA	Δ S1-S0	S2 DA	Δ S2-S0
NSW and ACT					
Sydney CBD	6,114,977	10,507,307	72%	10,614,714	74%
Canberra Civic	5,298,060	10,558,765	99%	10,907,135	106%
Wagga Wagga	669,563	10,483,673	1,466%	10,499,093	1,468%
CLARA City 5	629,322	–	–	10,871,926	1,628%
Victoria					
Melbourne CBD	5,049,799	9,873,129	96%	10,220,624	102%
CLARA City 8	4,987,600	–	–	10,182,079	104%
Ballarat	4,974,404	5,105,771	3%	5,105,771	3%
Bendigo	5,033,936	5,082,199	1%	5,514,337	10%
Shepparton	5,029,252	10,171,936	102%	10,182,079	103%
CLARA City 7	5,003,821	–	–	10,532,194	111%
Wangaratta	5,001,714	10,120,461	102%	10,105,402	102%
Albury-Wodonga	4,569,486	10,200,239	123%	10,481,413	129%

Note: Cities are organized by State and by distance from Sydney or Melbourne. The results for each city indicate the total population that can be accessed by a 3.5 hour, one-way trip.

The potential implications of high-speed rail development for Hume

The analysis suggests that S1 (the government-led proposal) would promote the strategic planning goals of Hume more than S2 (the market-led proposal) because accessibility improvements are targeted towards key existing regional cities.

A comparison of travel times and Location indicator results suggest that S1 would be more likely than S2 to reinforce the current hierarchy of settlements along the Hume corridor because it restructures accessibility around the existing regional cities of Albury-Wodonga, Shepparton and Wagga Wagga, framing them as gateways to the network. Isochrones also extend out from proposed station sites at regular intervals, showing that accessibility improvements would be more evenly distributed at the regional and sub-regional levels.

The analysis also identifies areas where S1 could introduce imbalances into the settlement structure by reducing, for example, the prominence of Ballarat and Bendigo in the settlement hierarchy. Location indicator results suggest that S1 could cause the locational advantage of these population centres to fall below Albury-Wodonga and Shepparton, which have smaller population sizes. However, Potential indicator results suggest that levels of economic activity would be maintained in Ballarat and Bendigo because of their strong connectivity to Melbourne and larger population size relative to other regional cities.

In contrast to S1, the results suggest that S2 has the potential to polarize spatial development away from existing regional cities. The travel time analysis shows that S2 would introduce a corridor of strong connectivity spanning southern NSW, where accessibility would be restructured around cities that are proposed to be constructed on greenfield sites. Isochrones extending from Sydney and Melbourne are stretched to the extent that the existing regional settlement system is rendered invisible—a literal "annihilation of space by time" (Harvey 2006, 379). Isochrones extending from nodes in the network are also more irregular in shape comparted to S1. This is possibly due to the location of some stations in areas that are geographically constrained (e.g. between Sydney and Canberra) and where transport networks are currently under developed (e.g. in southern NSW).

Consequently, the network structures and operational speeds of S1 and S2 are likely to produce very different spatial effects.

At the regional level, in Hume, S1 is likely to promote patterns of development that are more spatially balanced than S2. Although S1 would polarize spatial accessibility towards Shepparton and Albury-Wodonga, levels across the region are stronger than for S2 and more extensive in their coverage of surrounding subregions. The potential for tunnel effects to impact the spatial development of Wangaratta was also observed. A later iteration of the analysis could explore the potential for upgrades to the existing regional rail network to mitigate these impacts.

The Location indicator and Potential indicator results for S2 showed how the possible development benefits of high-speed rail would bypass Hume. The strong results for new cities constructed as part of S2 also suggest that it has the potential to recast settlement patterns over the longer term. In relation to Hume, it is possible that CLARA City 5 would compete economically with Albury-Wodonga because it recorded similar levels of economic potential. It is important to note that disparities in the results for new and existing cities would be exacerbated if the population size of the new cities was factored into the analysis. Conversely, the economic potential of Shepparton appeared to be boosted by CLARA City 7 and CLARA City 8. S2 could therefore reduce levels of regional cohesion in Hume if it diverts growth away from existing regional cities. Whether new inland cities would be successful in attracting population is a question for another study.

In conclusion, the analysis has highlighted the potential for S2 to introduce negative planning impacts in Hume, however, S1 is also not without its planning challenges.

The planning approach adopted in S1 would be likely to reinforce settlement patterns along the Hume corridor because stations are proposed to be located near existing regional cities. S2, on the other hand, could overhaul settlement patterns in the longer-term because accessibility is enhanced in regions where population centres do not currently exist. Because the alignment of S2 strays so far from the Hume corridor, connectivity to stations is constrained by both the underdevelopment of transport networks and an absence of existing population centres. This could reduce access to high-speed rail for surrounding communities and further concentrate development benefits.

However, targeting accessibility improvements towards greenfield sites is central to the land value capture framework adopted for S2. High-speed rail stations are located at a considerable distance from existing population centres to increase the potential for value 'uplift' (CLARA 2016) and reduce the likelihood of planning conflicts (interview notes). But results from the spatial analysis bring the overall effectiveness of this development strategy into question. Extensive spill over effects are observed in areas of northern Victoria and southern NSW. S2 also dramatically expands the envelope of Daily Accessibility compared to S1, and would be likely to increase development pressures in a greater number of regions.

Would these spatial effects cause the development potential of new cities to leak, leading to diffuse forms of urban decentralisation? If the new cities constructed as part of S2 are successful in attracting population growth, would this be to the benefit or detriment of existing regional cities along the Hume corridor? The answer to these questions will have significant planning implications for communities in Hume where planned improvements to social infrastructure and services are linked to the growth of existing regional cities.

S1 instead targets accessibility improvements towards existing regional cities. Consequently, in Hume, any urban and economic development attributable to high-speed rail is likely to be aligned with existing strategic plans. If one of the goals of high-speed rail development is to promote population growth in non-metropolitan regions, S1 arguably presents as the more pragmatic approach because it leverages the locational advantage and economic potential of existing population centres.

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References

AECOM, Grimshaw, KPMG, SKM, ACIL Tasman, Booz & Co., and Hyder. 2013. High Speed Rail Study: Phase 2 Report. edited by Department of Infrastructure and Transport. Canberra: Commonwealth Government of Australia.

Akerman, Tessa. 2016. "Shepparton community is 'all aboard the high-speed train concept'." *The Australian*, July 15.

Albalate, Daniel, and Germà Bel. 2012. *The Economics and Politics of High-speed Rail: Lessons From Experiences Abroad*. Lanham: Lexington Books.

Arup, and TMG. 2001. East Coast Very High Speed Train Scoping Study: Phase 1 Preliminary Study. edited by Department of Infrastructure and Regional Services. Canberra: Commonwealth Government of Australia.

Australian Government. 2018. Australian Government response to the House of Representatives Standing Committee on Infrastructure, Transport and Cities: Harnessing Value, Delivering Infrastructure. Canberra: Commonwealth Government of Australia.

Bellet, Carme, Pilar Alonso, and Alonso Gutiérrez. 2012. "The High-Speed Rail in Spanish Cities: Urban Integration and Local Strategies for Socio-economic Develoment." In *Territorial Implications of High Speed Rail: A Spanish Perspective*, edited by José Maria de Ureña, 163-196. Farnham, Surrey; Burlington, VT: Ashgate.

Bellet, Carme, and Luis Santos Ganges. 2016. "The High-speed Rail Project as an Urban Redevelopment Tool." *Belgeo* 3:1-18.

Bellet, Carmen. 2016. "Peripheral High-Speed Rail Stations in Spain." *The Open Transportation Journal* 10 (1).

Chen, Chia-Lin, and Peter Hall. 2011. "The Impacts of High-speed Trains on British Economic Geography: A study of the UK's InterCity 125/225 and its Effects." *Journal of Transport Geography* 19 (4):689-704. doi: http://dx.doi.org/10.1016/j.jtrangeo.2010.08.010.

Chen, Chia-Lin, and Peter Hall. 2013. "Using High Speed Two to Irrigate the Regions." *Built Environment* 39 (3):355-368.

Chen, Chia-Lin, and Roger Vickerman. 2017. "Can Transport Infrastructure Change Regions' Economic Fortunes? Some Evidence from Europe and China." *Regional Studies* 51 (1):144-160. doi: 10.1080/00343404.2016.1262017.

Consolidated Land and Rail Australia. 2016. "The CLARA Plan." Consolidated Land and Rail Australia, accessed Dec 31. www.clara.com.au.

European Commission. 2001. *Unity, Solidarity, Diversity for Europe, Its People and Its Territory: Second Report on Economic and Social Cohesion*: Office for official publications of the european communities.

Faludi, Andreas. 2000. "The European Spatial Development Perspective - What Next?" *European Planning Studies* 8 (2):237.

Garmendia, Maddi, Cecilia Ribalaygua, and José María Ureña. 2012. "High Speed Rail: Implication for Cities." *Cities* 29 (Supplement 2):S26-S31. doi: 10.1016/j.cities.2012.06.005.

Ginés de, Rus. 2008. The Economic Effects of High Speed Rail Investment. OECD Publishing / Éditions OCDE.

Gutiérrez, Javier. 2001. "Location, Economic Potential and Daily Accessibility: An Analysis of the Accessibility Impact of the High-speed Line Madrid–Barcelona–French Border." *Journal of Transport Geography* 9:229-242. doi: 10.1016/S0966-6923(01)00017-5.

Gutiérrez, Javier, Rafael González, and Gabriel Gómez. 1996. "The European high-speed train network: Predicted effects on accessibility patterns." *Journal of Transport Geography* 4 (4):227-238. doi: https://doi.org/10.1016/S0966-6923(96)00033-6.

Hall, Peter. 2009. "Magic Carpets and Seamless Webs: Opportunities and Constraints for High-speed Trains in Europe." *Built Environment* 35 (1):59-69.

Hall, Peter Geoffrey, and Kathy Pain, eds. 2006. *The Polycentric Metropolis: Learning from Mega-city Regions in Europe*. London; Sterling, VA: Earthscan.

Harvey, David. 2006. *The Limits to Capital*. London; New York: Verso.

Koslay, Mariam. 2017. "We're not trying to build a utopia: Nick Cleary talking about the CLARA Plan." *Goulburn Post*, June 15.

Levinson, David M. 2012. "Accessibility Impacts of High-speed Rail." *Journal of Transport Geography*:288-291.

López, Elena, Javier Gutiérrez, and Gabriel Gómez. 2008. "Measuring Regional Cohesion Effects of Large-scale Transport Infrastructure Investments: An Accessibility Approach." *European Planning Studies* 16 (2):277-301. doi: 10.1080/09654310701814629.

Manning, Paddy. 2016. "Green Fields and Blue Sky: Is Nick Cleary's ambitious CLARA project the answer to Australia's fast-rail question?" *The Monthly*, December.

Mazzeo, Giuseppe. 2012. "Impact of High Speed Trains on the Hierarchy of European Cities." *Jahrbuch fur Regionalwissenschaft* 32:159-173.

Monzón, Andrés, Emilio Ortega, and Elena López. 2013. "Efficiency and Spatial Equity Impacts of High-speed Rail Extensions in Urban Areas." *Cities* 30:18-30. doi: 10.1016/j.cities.2011.11.002.

Ortega, Emelio, Elena Lopez, and Andrés Monzon. 2012. "Territorial Cohesion Impacts of High-speed Rail at Different Planning Levels." *Journal of Transport Geography* 24:130-141.

Parliament of Australia. 2016. Harnessing Value, Delivering Infrastructure: Inquiry into the Role of Transport Connectivity on Stimulating Development and Economic Activity. edited by House of Representatives Standing Committee on Infrastructure Transport and Cities. Canberra: Commonwealth of Australia.

Pérez, Emilio Ortega, Santiago Mancebo Quintana, and Isabel Otero Pastor. 2011. "Road and Railway Accessibility Atlas of Spain." *Journal of Maps* 7 (1):31.

Preston, John. 2017. Direct and Indirect Effects of High-speed Rail. In *Evaluating High-speed Rail: Interdisciplinary Perspectives*, edited by Daniel Albalate and Germà Bel. Abingdon, Oxon; New York, NY: Routledge.

Searle, Glen H., and Raymond Bunker. 2010. "Metropolitan Strategic Planning: An Australian Paradigm?" *Planning Theory* 9 (3):163.

Spiekermann, Klaus, and Michael Wegener. 2008. "The Shrinking Continent: Accessibility, Competitiveness, and Cohesion." *European Spatial Research and Planning, Lincoln Institute of Land Policy, Cambridge, MA*:115-139.

Thomson, Hayden. 2018. "On fast track." *Shepparton News*, March 10.

Ureña, José María, Philippe Menerault, and Maddi Garmendia. 2009. "The High-speed Rail Challenge for Big Intermediate Cities: A National, Regional and Local Perspective." *Cities* 26:266-279. doi: 10.1016/j.cities.2009.07.001.

Vickerman, Roger. 2017. "Can High-speed Rail have a Transformative Effect on the Economy?" *Transport Policy*. doi: 10.1016/j.tranpol.2017.03.008.

Victorian Government, and Hume Regional Management Forum. 2010. The Hume Strategy for Sustainable Communities 2010-2020. edited by Department of Planning and Community Development and Hume Regional Management Forum. Melbourne: State Government of Victoria.

Victorian Government, and Hume Regional Management Forum. 2014. Hume Regional Growth Plan. edited by Department of Planning and Community Development and Hume Regional Management Forum. Melbourne: State Government of Victoria.