Assessing Land Use and Urban Form Impacts of Changes in Relative Accessibility

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Praveen Thakur

Associate Director

SGS Economics & Planning Pty Ltd

Suite 4 / 1327 Hay Street

WEST PERTH WA 6005

Ph: +61 8 9254 9962

Fax: +61 8 9254 9965

Email: Pthakur@sgsep.com.au

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Abstract

It is a long held tenet of economic geography that land use, including population and jobs, will adjust over time in response to changes in relative accessibility. Moving operations to areas of superior accessibility reduces transaction costs in dealing with suppliers and distributors, as well as improving access to much needed workforce skills. These same dynamics apply to households. They adjust location to maximise opportunities for employment, education, recreation and other services. This paper statistically assesses and quantifies the relationship between accessibility and locational decisions of firms (jobs) and households (population) in Melbourne. The regression analysis confirmed that relative accessibility is a significant factor in a suburb's ability to attract and retain jobs and households.

The three final transport options proposed by the East West Link Needs Assessment study in Melbourne are then used as case studies to demonstrate the varying land use impacts of apparently similar transport projects. The paper concludes that such analysis should be routine in accessing the efficacy of the proposed transport options in contributing towards broader societal goals and objectives.

Introduction

Traditional location theory argues that firms will establish their businesses in most accessible locations. Much of the underpinnings of this research trace back to Krugman (1979, 1995) who used transport costs and accessibility estimates of differentiated inputs to explain wide differences in regional productivity. In essence, this and related research argue that firms produce slightly differentiated products and face potential economies of scale as a result of major improvements in accessibility. Therefore, changes in accessibility will change the scale of market demand and the unit costs of production, through improved access to specialised skills (Fujita, 1989, Krugman, 1995, Ciccone and Hall, 1996).

Banister and Berechman (2001) argued that most of the benefits that accrue from such accessibility improvements are localised. That is, "changes in accessibility resulting from transport infrastructure investment causes a redistribution of employment" (p212-213). In this sense, firms will, over time, adjust their locations to take advantage of improved accessibility within an economic region. Moving operations to areas of superior accessibility reduces transactions costs in dealing with suppliers and distributors, as well as improving access to much needed workforce skills.

These same dynamics apply to households. They will adjust location to maximise opportunities for employment, education, recreation and other services. However, these choices will be made within a more constrained canvas, reflecting family ties and historic neighbourhood affiliations. Many household moves are made 'within corridor' rather than 'across town'. However, when moves are made within this context, accessibility is a key consideration.

This view of transport investments altering growth patterns in a metropolis is not new and has been widely held by urban geographers and planners. Newman and Kenworthy (1999) for example have argued for using public transport accessibility improvements as a key instrument to promoting increased densities.

Land use and transportation are therefore inter-dependent (Giuliano, 2004); any change in one will impact on the other and vice versa. Nevertheless, most transport evaluation studies tend to ignore this inter-dependency, only analysing the demand for transport given a set of land use projections. The impact of transport infrastructure projects on land use is almost always ignored, or acknowledged but not necessarily quantified.

This paper statistically assesses and quantifies the relationship between accessibility and locational decisions of firms (jobs) and households (population) (i.e. land use) in Melbourne. The three final transport options proposed by the East West Link Needs Assessment study in Melbourne are then used as case studies to demonstrate the varying land use impacts of apparently similar transport projects.

Accessibility and its Impact on Land Use

Defining and Estimating Accessibility

There are various ways in which accessibility can be defined and measured. Accessibility in its simplest form may refer to the ease of access to a set of transport infrastructure, or simply, travel times from origin to other destinations. This paper uses a similar definition to that proposed by Geurs and Wee (2004), and is defined as "the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)" (p128).

Consequently, accessibility of a Statistical Local Area (SLA) was estimated as the sum of the weighted average of the inverse of travel times from origin SLA to all destination SLAs. Travel times were weighted with total destination trips from across all other SLAs to the destination SLA.

Total destination trips were used as a proxy for that SLA's 'attractiveness' / 'importance' in the economic geography of metropolitan Melbourne. The inverse function allows for the distance decay with destination SLAs that are within reasonable travel time and have a high number of destination trips being weighted more heavily than destinations that are further out but may also attract similar number of trips.

Mathematically, the accessibility measure for a SLA can therefore be expressed as follows:

$$A_i = \sum_{j=1}^{n} \frac{1}{tt} \times D_j \qquad (1)$$

where:

A_i is the measure of the accessibility of SLA *i* to all other SLAs or opportunities in the metropolitan area;

tt is the travel time from SLA *i* to destination SLA *j*; and

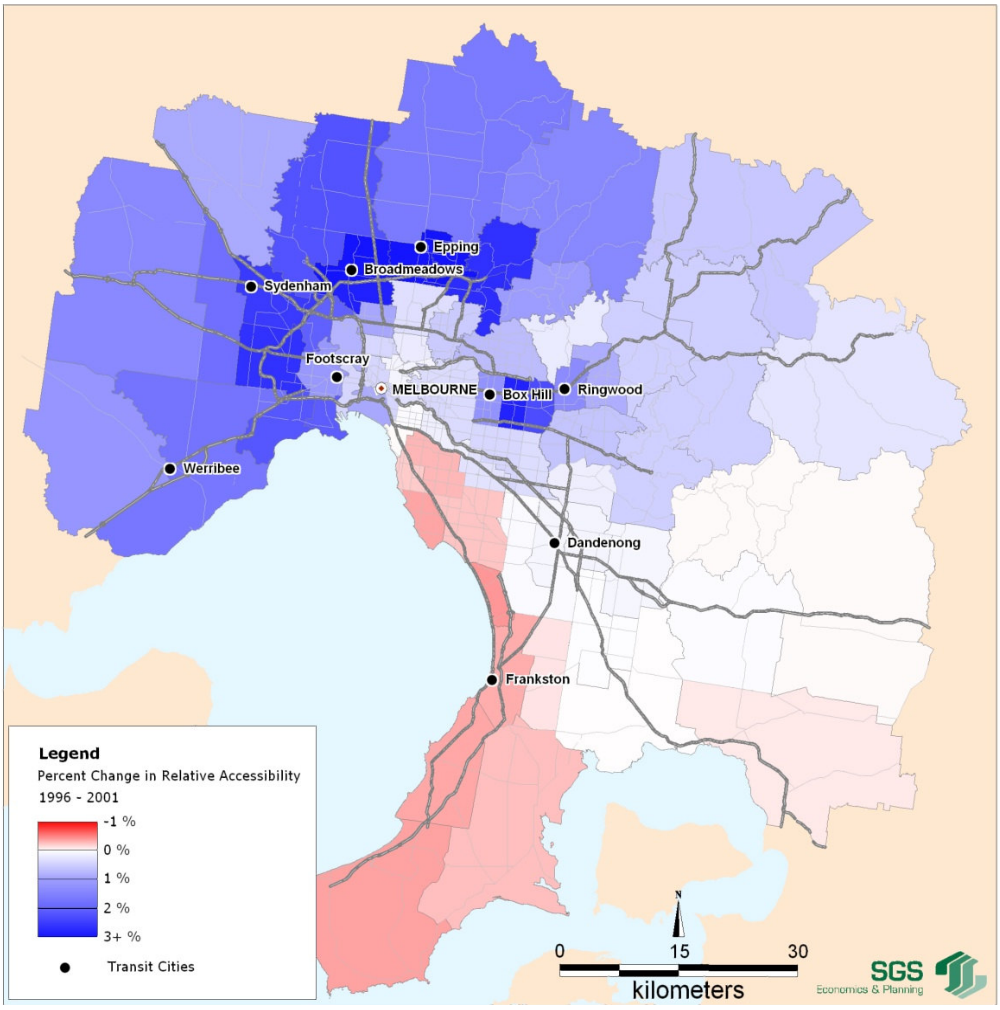
D_j is the total destination trips from all origin SLAs to destination SLA *j*

The above estimate provides a useful measure of the 'absolute' accessibility of the SLA. However, it does not on its own provide sufficient information to firms and households when making location decisions. What matters is whether a candidate SLA is more or less accessible relative to other locales/ SLAs in a metropolitan area. In other words, it is the relative accessibility that is more pertinent in evaluating the land use impacts of changes in accessibility.

Consequently, a relative accessibility index was derived for each SLA in Melbourne for 1996, 2001 and 2006. The SLA with the highest absolute accessibility index (namely Melbourne (C) – Inner) was given a rating of 1, and all other SLAs were given a rating based on how well they compared relative to the SLA with rating one, rating one being absolute centrality and rating zero being absolute remoteness.

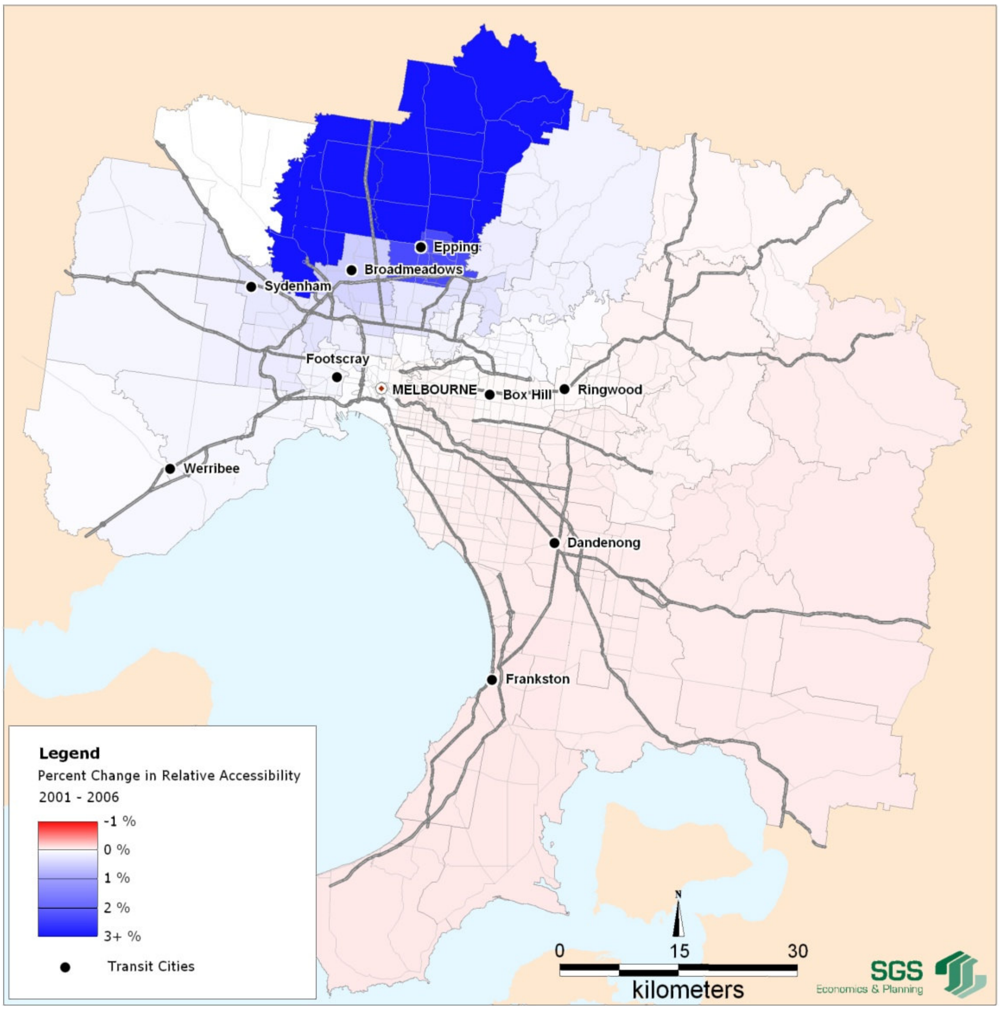
The estimated change in relative accessibility between 1996 to 2001 and 2001 to 2006 are shown in Figure 1 and 2 below. This shows that the relative accessibility of North East, North West and Western suburbs improved significantly over the five years to 2001. This can be attributed to the completion of the Western Ring Road and the CityLink.

Figure 1 Percent Change in Relative Accessibility, 1996 – 2001



Similarly, the relative accessibility of North East suburbs improved significantly between 2001 and 2006, principally due to the completion of the Hume bypass.

Figure 2 Percent Change in Relative Accessibility, 2001 – 2006



Assessing Accessibility's Impact on Land Use

An iterative approach was adopted to identify any potential relationship between changes in relative accessibility and changes in land use. In the first instance, changes in households as obtained from Australian Bureau of Statistics (ABS) Census over the inter-censal period of 1996–2001 and 2001–2006 were mapped and overlaid with changes in relative accessibility over the corresponding period. Similarly, changes in employment by major industry division as per the Australian and New Zealand Standard Industrial Classification, 1993 (ANZSIC) for each SLA as obtained from ABS Census, Journey to Work/ Place of Work (JTW) over the 1996-2001 and 2001-2006 were mapped and overlaid with changes in relative accessibility.

This preliminary mapping exercise confirmed the potential correlation between changes in relative accessibility and changes in distribution of households and employment. Regression equation were then specified and estimated to confirm and quantify any statistically significant relationship.

Regression Specification

There are various factors that can impact a SLA's ability to capture and retain a share of metropolitan employment growth. These include overall economic growth in the region, local population as it directly determines the level of population servicing jobs, availability of appropriately zoned land, economic development policies and strategies etc.

Taking these varying factors into account, a theoretical model for employment by industry at the SLA level can be formulated as follows. Employment in an industry *a* in *i*th SLA at time *t* (y^a_{it}) is explained by various SLA specific variables (w_{it}); the relative accessibility of each SLA (x_{it}); number of households ($\boldsymbol{h}_{it}$) and unobservable random disturbances (e_{it}). Hence,

$$y^a_{it} = \beta_o + \alpha_{\mathbf{h}} w_{it} + \beta_k x_{it} + \beta_{\mathbf{h}} \boldsymbol{h}_{it} + e_{it} \qquad (2)$$

where:

w is an *h*-element vector of policy variables of SLA *i* at time *t* and encapsulates factors such as availability of appropriately zoned land and economic development strategies;

x is a *k*-element vector of relative accessibility for SLA *i* at time *t* to all other destinations in an economic region;

h is the household in SLA *i* at time *t*;

β_o is a constant term that takes into account various exogenous variables such as state wide economic trends, industry specific business cycles, investor confidence, State and Federal government policies; and

e_{it} is a zero mean, fixed variance, serially uncorrelated, disturbance term.

Equation 2 above assumes that all data is readily available. However, this is not necessarily the case. Policies applied in various SLAs are difficult to obtain in the form that can be readily quantified and used in a regression analysis. In addition, there are a large number of exogenous variables that can affect employment growth at a suburban or SLA level. Besides, due to large number of statistical boundary changes in Melbourne between 1991 and 1996, only 1996, 2001 and 2006 data could be used. Limitations associated with the number of data points for each SLA means that not all the variables that may affect employment can be included. Hence, subsuming *w* into the constant term gives the new constant term (β_o'), which takes into account the exogenous variables as well as the policy variables. Equation (2) thus becomes:

$$y_{it}^{a} = \beta_o' + \beta_k x_{it} + \beta_h \boldsymbol{h}_{it} + e_{it} \qquad (3)$$

Similarly household in *i*th SLA at time *t* (h_{it}) can be explained by:

$$\boldsymbol{h}_{it} = \beta_o + \beta_k x_{it} + \beta_m y_{it} + e_{it} \qquad (4)$$

where:

x is a *k*-element vector of relative accessibility for SLA *i* at time *t*;

y is the total employment opportunities in SLA *i* at time *t*;

β_o is a constant term; and

e_{it} is a zero mean, fixed variance, serially uncorrelated, disturbance term.

Equations 3 and 4 are the basic reduced form regression equations that can be statistically estimated.

Regression Analysis

Using the ABS JTW data on employment, ABS Census data on households, and estimated relative accessibility by SLA for 1996, 2001 and 2006; the above noted equation 3 and 4 were estimated using E-views 5.0 software.

Since there are two dimensions to the data – the cross-section (i.e. SLAs) and time series (1996, 2001 and 2006) – a panel data regression using SLA specific fixed effects and one-step weighting matrix generalised least squares was used. By using fixed effects and allowing the constant to vary across the SLAs, one can take into account the 'individuality' of each SLA.

The cross-section, time series nature of the data means that there is bound to be a degree of heteroscedasticty and autocorrelation. One-step weighting matrix generalised least squares is the most feasible and reliable estimator when the residuals are both cross-section heteroscedastic and contemporaneously correlated.

The use of fixed effects and allowance of each SLA to have a separate constant term means that there are 75 constants for each equation. To allow for conciseness of the paper these estimates have not been reported, summary results are reported in Table 1 below, with detailed results available upon request.

The coefficients indicate the magnitude of the effect that each of the independent variables have on the dependent variable. The t-statistics indicate whether the coefficients estimated are statistically significant. The p-value provides the probability of rejecting the null hypothesis that the estimated coefficients are statistically in-significant.

Signs of all the coefficients for each of the regression equations are as expected. The examination of the t-statistics and p-value suggests that all the independent variables bar one in each of the estimated equations are statistically significant at 95% level of confidence.

The exception applies to regression equation for employment distribution of Wholesale Trade, with coefficient for households being statistically in-significant at 95% level of confidence.

All the regression equations have high r-squared values, indicating a high level of fit for the model. The analysis confirms, that other things equal, variation in the distribution of employment in each industry can be explained by variations in relative accessibility and households. Similarly, variation in distribution of households can be explained by the variations in relative accessibility and total employment.

As noted earlier, the relative accessibility is an index, the value of which ranges from 0 (extreme isolation, a theoretical concept) to 1 (absolute centrality). The regression coefficients therefore provide an indication of the impact that the relative accessibility will have on employment if that SLA's relative accessibility improved from extreme isolation to absolute centrality. Similarly, improvement of a theoretical SLA's relative accessibility from 0 (extreme isolation) to 1 (absolute centrality) would lead to that SLA losing approximately 134 agriculture jobs, but gaining 657 mining jobs, 11,122 manufacturing jobs etc. Coefficients for other industries and households can be interpreted similarly.

Table 1 Regression Estimates, Employment by Industry and Households

	Dependent Variable Agriculture, Forestry and Fishing		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	-133.88	-2.95	0.00
Households	0.00	-2.16	0.03
R-Squared	0.86		
Adjusted R-Squared	0.86		
Number of Observations	225		

	Dependent Variable Mining		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	657.41	7.82	0.00
Households	-0.01	22.63	0.00
R-Squared	0.79		
Adjusted R-Squared	0.79		
Number of Observations	225		

	Dependent Variable Manufacturing		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	11,121.74	167.67	0.00
Households	0.10	45.43	0.00
R-Squared	0.97		
Adjusted R-Squared	0.97		
Number of Observations	225		

	Dependent Variable Electricity, Gas and Water Supply		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	987.99	30.41	0.00
Households	-0.01	-29.91	0.00
R-Squared	0.89		
Adjusted R-Squared	0.88		
Number of Observations	225		

	Dependent Variable Construction		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	2,192.35	18.18	0.00
Households	0.02	9.19	0.00
R-Squared	0.97		
Adjusted R-Squared	0.97		
Number of Observations	225		

	Dependent Variable Wholesale Trade		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	6,579.01	17.04	0.00
Households	-0.01	-1.22	0.22
R-Squared	0.79		
Adjusted R-Squared	0.79		
Number of Observations	225		

	Dependent Variable Retail Trade		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	9,570.86	24.59	0.00
Households	0.06	82.75	0.00
R-Squared	0.96		
Adjusted R-Squared	0.96		
Number of Observations	225		

	Dependent Variable Accommodation, Cafes and Restaurants		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	14,116.84	8.22	0.00
Households	0.10	109.59	0.00
R-Squared	0.90		
Adjusted R-Squared	0.90		
Number of Observations	225		

	Dependent Variable Transport and Storage		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	4,509.12	9.91	0.00
Households	0.03	276.61	0.00
R-Squared	0.90		
Adjusted R-Squared	0.90		
Number of Observations	225		

	Dependent Variable Communication Services		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	-4,610.18	-7.11	0.00
Households	0.03	37.52	0.00
R-Squared	0.80		
Adjusted R-Squared	0.80		
Number of Observations	225		

	Dependent Variable Finance and Insurance		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	22,349.96	19.01	0.00
Households	0.22	21.41	0.00
R-Squared	0.78		
Adjusted R-Squared	0.77		
Number of Observations	225		

	Dependent Variable Property and Business Services		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	27,477.65	22.84	0.00
Households	0.21	14.83	0.00
R-Squared	0.91		
Adjusted R-Squared	0.91		
Number of Observations	225		

	Dependent Variable Government Administration and Defence		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	10,940.97	9.02	0.00
Households	-0.11	-7.18	0.00
R-Squared	0.77		
Adjusted R-Squared	0.77		
Number of Observations	225		

	Dependent Variable Education		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	26,265.01	15.95	0.00
Households	0.09	36.29	0.00
R-Squared	0.90		
Adjusted R-Squared	0.90		
Number of Observations	225		

	Dependent Variable Health and Community Services		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	11,112.41	56.79	0.00
Households	0.03	18.81	0.00
R-Squared	0.94		
Adjusted R-Squared	0.94		
Number of Observations	225		

	Dependent Variable Cultural and Recreational Services		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	4,729.79	27.13	0.00
Households	0.03	32.98	0.00
R-Squared	0.76		
Adjusted R-Squared	0.76		
Number of Observations	225		

	Dependent Variable Personal and Other Services		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	4,590.72	2.78	0.01
Households	0.02	8.49	0.00
R-Squared	1.00		
Adjusted R-Squared	1.00		
Number of Observations	225		

	Dependent Variable Households (Total Occupied Dwellings)		
Independent Variable	**Coefficient**	**T-Statistics**	**P-value**
Relative Accessibility	217,772.20	14.80	0.00
Total Employment	0.23	29.52	0.00
R-Squared	0.90		
Adjusted R-Squared	0.90		
Number of Observations	225		

Land Use Impacts of East West Link Options

In 2006, the Victorian Government asked Sir Rod Eddington to undertake a comprehensive study into improving east-west transport connections across Melbourne. The East West Link Needs Assessment (EWLNA) study, as it later became to be known, resolved 3 private transport options for further detailed evaluation. These included:

- Option A – providing a direct 'freeway to freeway' connection between the Eastern Freeway and the Westgate Bridge;
- Option B – connecting the Eastern Freeway more directly to the west via Sunshine Road; and
- Option C – involving a range of capacity upgrades and road management initiatives utilising largely, existing infrastructure.

All of these options were to be accompanied by 3 major public transport investments (i.e. "Option D") as follows:

- A rail tunnel stretching from the 'Caulfield/ Domain area' to the Melbourne University / Parkville district – commonly referred to as CBD rail tunnel;
- A bus based rapid transit facility operating along the Eastern Freeway; and
- A Tarneit passenger rail link.

These options are expected to variously impact on the accessibility contours of metropolitan Melbourne. Changes in relative accessibility under each of the EWLNA proposed options, compared to the base case scenario, were estimated using the projected travel time matrices. The estimated changes are shown in Figure 3, 4 and 5 below.

Figure 3 Percent Change in Relative Accessibility, Base Case to Option A+D

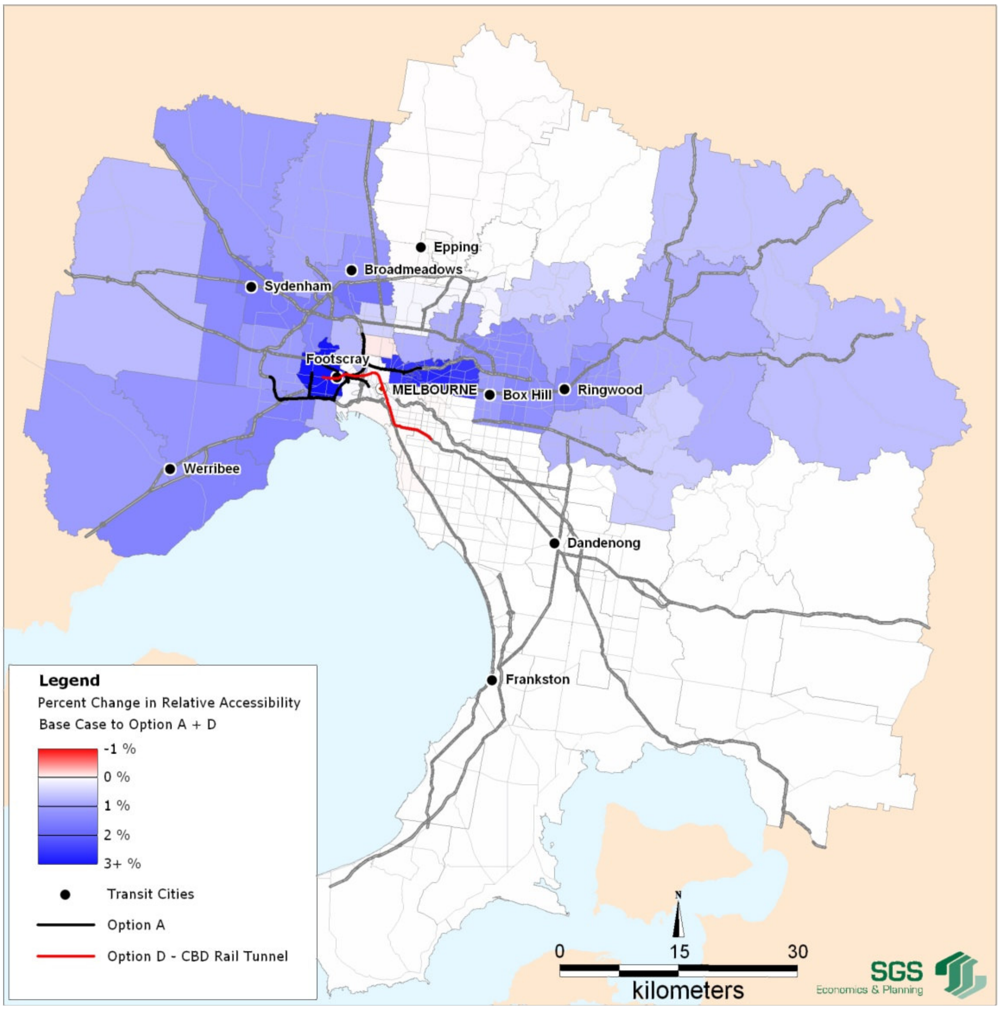


Figure 4 Percent Change in Relative Accessibility, Base Case to Option B+D

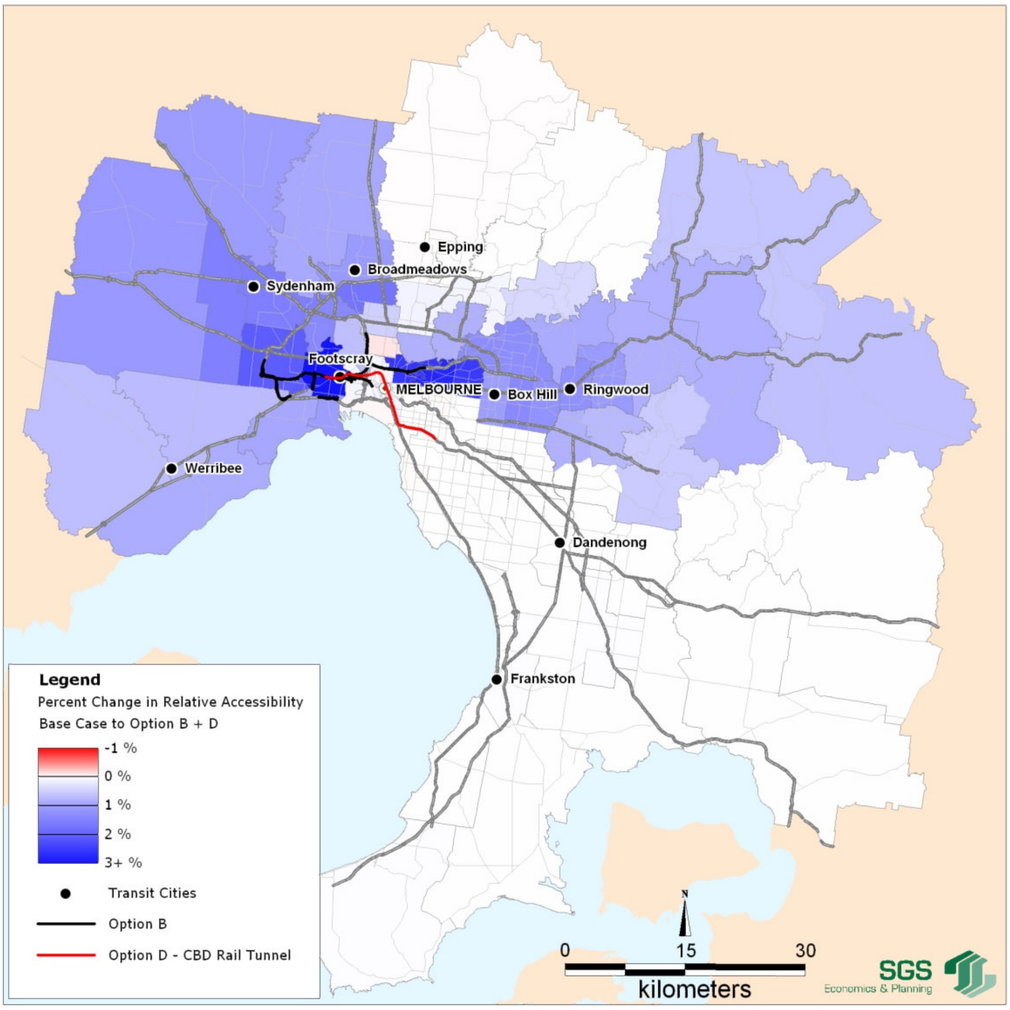
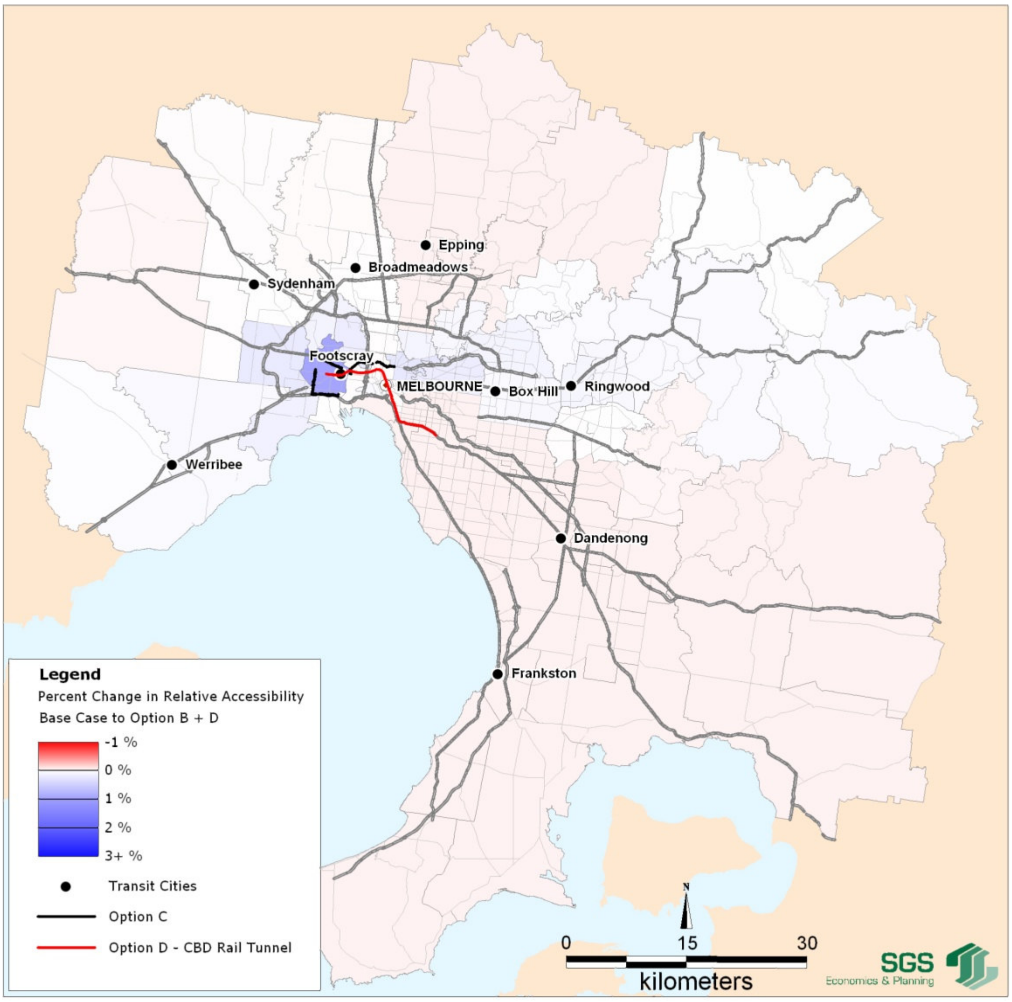


Figure 5 Percent Change in Relative Accessibility, Base Case to Option C+D



Using the above reported regression coefficients along with the estimated change in relative accessibility under the various options; potential shifts in Melbourne's land use can be estimated. The outcomes of this analysis are reported in Table 2 and 3 below.

Table 2 Net Shifts in households due to changes in relative accessibility, Option A+D, B+D and C+D

	Option A+D versus Base Case	Option B+D versus Base Case	Option C+D versus Base Case
Additional household growth in established SLAs	-487	25	2,960

Additional household growth in fringe SLAs	487	-25	-2,960

Table 3 Net Shifts in total employment due to changes in relative accessibility, Option A+D, B+D and C+D

	Option A+D versus Base Case	Option B+D versus Base Case	Option C+D versus Base Case
Additional employment growth in established SLAs	-5,353	-4,093	1,170
Additional employment growth in fringe SLAs	5,353	4,093	-1,170

One of the key objectives of Melbourne 2030, the Victorian Government's planning strategy for Melbourne and the subsequent update, Melbourne @ 5 million is to redirect an increased share of Melbourne's future residential growth from the urban fringe to the established suburbs. Melbourne @ 5 million further notes the current low levels of job provisioning in the outer suburbs and aspires to increase the number of jobs in these communities.

The land use shifts sparked by changes in relative accessibility under each of the EWLNA proposed transport options can be evaluated against these stated objectives. The analysis shows that while option A+D is likely to increase the level of job provision in the fringe, it also contributes to urban sprawl, with increasing number of households locating in the fringe. Option C+D promotes household growth in established suburbs, but further exacerbates the already low levels of job provisioning in the fringe. On the other hand option B+D is largely urban form neutral; while improving the much needed employment in Melbourne's fringe areas.

This suggests that option B+D aligns well with the stated government objectives, while A+D and C+D are at odds with these objectives.

Concluding Remarks

It is a long held tenet of economic geography that firms will, over time, adjust their locations to take advantage of improved accessibility. Moving operations to areas of superior accessibility reduces transactions costs in dealing with suppliers and distributors, as well as improving access to much needed skilled labour force.

These same dynamics apply to households. They will adjust location to maximise opportunities for employment, education, recreation and other services. However, there is significant evidence in the literature that these choices will be made within a more constrained canvas, reflecting family ties and historic neighbourhood affiliations.

These theoretical predictions are amply borne out by recent experience in Australian cities, particularly with respect to the Western Ring Road, CityLink and Eastlink in Melbourne and Westlink (M7) in Sydney. This paper used regression analyses to statistically assess and quantify the relationship between relative accessibility and location decisions of firms (jobs) and households (population) in Melbourne. The regression analysis confirmed that variation in the distribution of employment and housing can be explained by variations in relative accessibility. Other things equal, improvement in the accessibility rating of a SLA relative to other SLAs in the metropolitan area will lead to significant urban adjustment whereby the SLA is able to permanently attract and retain relatively higher number of jobs and households, compared to the scenario where the accessibility rating remains unchanged.

Application of the estimated household and sector specific 'locational elasticities' to the projected changes in relative accessibility, under each of the three final options proposed by EWLNA study, demonstrated that similar transport projects can have varyingly different and significant impact on the economic landscape.

In conclusion, major transport projects not only have significant impact on the land use profile; projects with similar aims and objectives can also have substantially different land use and urban form outcomes. It is therefore imperative that analysis of the land use impacts of major transport projects are undertaken as a matter of routine and assessed against their efficacy in contributing towards the broader societal goals and objectives.

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