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Commuting to work by private vehicle in Melbourne: Trends and policy implications

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Abstract

This paper presents empirical analysis of factors influencing work-related travel in and around Melbourne. The analysis used census data in conjunction with data and information from several sources to carry out this analysis. Whilst a variety of factors determine the use of private vehicle in work-related-travel, the paper identifies factors that are specifically important in work-related travel in and around Melbourne in 2006 and their relative significance as drivers of private vehicle use. For this purpose a functional relationship is established between the percentage of workers in a SLA commuting to employment centres by private vehicle and various determinants such as accessibility to public transport and commuting distances between population centres and employment hubs — particularly the Melbourne CBD. The paper identifies important aspects that could add value when developing policies aimed at reducing private vehicle usage for work-related travel — including focused public infrastructure investment and urban planning in areas that could best enhance the use of sustainable travel modes when commuting to work.

1. Introduction

Largely due to such factors as the affordability during post-war period, the freedom and flexibility of travel, compared to public transport modes (Forster, 2004), the reliance on private vehicle — especially the car — as a mode of travel has grown in cities of virtually all developed countries and at the expense of a once thriving system of public transport. This growing reliance on private vehicle travel on a daily basis has posed major socio-economic, environmental and land-use challenges in Australia and in other similar countries — particularly the growing demand for transport infrastructure, high external costs (pollution, road crash deaths and injuries, congestion in cities) and the threat of social exclusion of disadvantaged community groups. Reversing this trend in favour of public transport has now become an important planning goal of many Australian cities. This is stipulated as a key focus of Melbourne's strategic plan — '*Melbourne 2030'.*

Drawing information from a number of past studies and ABS census data on journey-to-work since 1976, Moriarty and Mees (2005) noted that in Melbourne, the modal share of public transport for all purposes of commuting has fallen dramatically from its peak in the mid-1940s. Although ABS journey-to-work data from 2006 census show a slight pause of this long term downward trend, it is not immediately clear whether it is the beginning of the much anticipated reversal in the private vehicle usage pattern. The aim of this paper is to reality check this observation by carrying out a spatial analysis of modal choice and commuting patterns with a view to elicit inferences that could be meaningfully pursued towards achieving Melbourne's public transport usage target of '*20 per cent of all motorised trips across metropolitan Melbourne by 2020'* (DPC 2001).

The analysis in the paper focuses on the Melbourne working zone (BITRE 2009). This is the area that encompasses the Melbourne Statistical Division and the 12 contiguous Statistical Local Areas (SLAs). Confining the analysis to the working zone is justifiable given that the ABS data available for the analysis has been gathered from those commuting to work — where work-related-travel comprises a major part of all passenger kilometres travelled in a year.

The next section of the paper outlines spatial trends and patterns in work-related-commuting by private and public transport. For this purpose, the authors consider only one factor or variable at a time (uni-variate analysis). Next it uses a multi-variable construct to (a) identify the most appropriate subset out of an array of determinants that explains commuter decisions to use private vehicle in work related commuting and (b) determine the relative contribution of each determinant in the decisions to use private vehicle over public transport. The last section provides policy implications ensuing from the analysis.

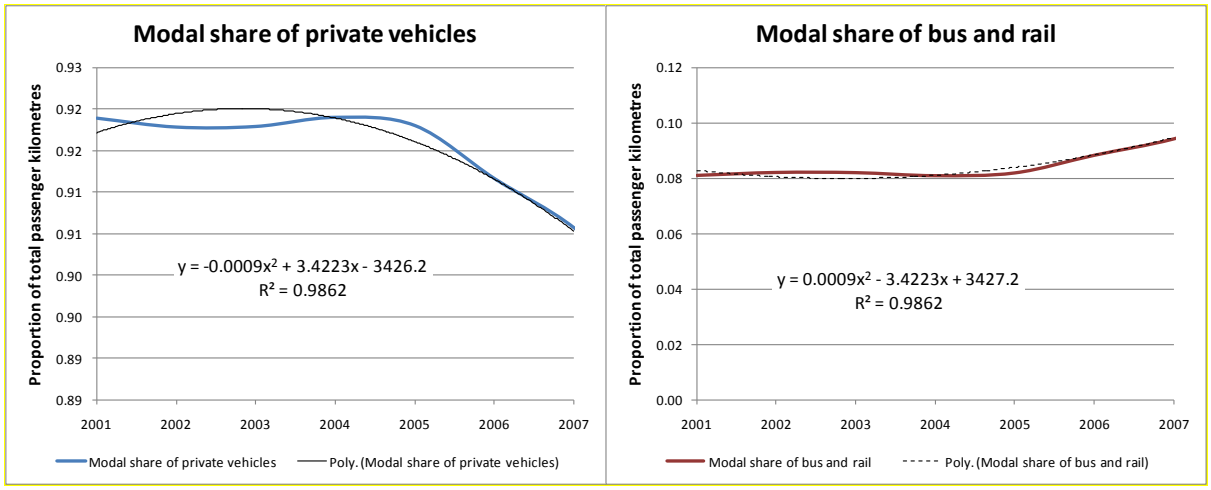
2. Existing trends in commuting to work

Adopting a uni-variate approach, this section outlines the time and spatial trends in the modal share between public and private transport in travel-to-work in Melbourne. Spatial trends are explored by grouping the relevant Melbourne Working Zone population into several regions and sub-regions. The analysis in this and in the remaining sections primarily used ABS Census data on working population profile and the basic community profile for 2001 and 2006 supplemented by data obtained from the Victorian department of transport and data from data bases maintained by the Bureau of Infrastructure, Transport and Regional Economics (BITRE).

2.1 Time trends in commuting to work

Figure 1 shows the change in modal shares for work-related travel across metropolitan Melbourne. It captures the period since the announcement in 2001 of a 20 per cent target by 2020 in the use of sustainable transport modes for all purposes of travel in Melbourne. The two panels of this figure show a promising upward trend in the usage of public transport and a corresponding drop in the private vehicle use. As evident from the polynomial trend lines fitted to the data, the rates of change in these opposing trends are statistically significant.

Figure 1: Historical trends in public and private transport share, Melbourne, 1977 to 2008



Source: Based on information published in BITRE (2008).

Referring to '*Melbourne 2030'* goal of reversing the past trends in modal share to achieve a public transport usage target of 20 per cent of all motorised trips across metropolitan Melbourne by 2020, Moran (2006:p9) noted that "such a reversal of previous trends is unprecedented in any country in the world". He added that "even icon cities such as Portland, which have implemented tough anti-parking restraints and spent a fortune on light rail, have seen transit patronage grow by less than a percentage point" (Moran, 2006:p9). Nevertheless, if the downward trend in private vehicle usage and the upward trend in public transport usage that were observed in and around 2004 continue for all purposes of travel, a reversal in the trend would perhaps not be an unrealistic target — at least in the medium term.

Figure 1 also compares the total passenger kilometres travelled by bus and rail and that by private vehicle — car, light commercial vehicle, truck and motorcycle and their growth trends. If modal share is expressed as a percentage of the passenger kilometres travelled by a particular mode relative to the total kilometres travelled by all modes, then, the modal share of public transport (i.e. bus and rail) for Melbourne would average around 9 percent of the total passenger kilometres travelled in the 6 year period ending 2007 (Note: in the Melbourne 2030 strategy, modal share is expressed as a percentage of the total 'motorised trips'). BITRE modelling shows that in the 4 years between 2006 and 2009, the modal share of public transport in Melbourne would have grown to about 10 per cent (BITRE 2008). This amounted to an average annual growth of 12 per cent in the four year period. The corresponding figure for private vehicle use is -0.6 per cent. If travel by all public transport modes is considered — that is including travel by tram — which is not considered in Figure 1, the share of public transport in these 4 years would average well over 10 per cent of all motorised travel (right side panel of Figure 1).

As noted before, *Melbourne 2030* has planned to achieve a public transport usage target of 20 per cent of all motorised travel within a 25 year time frame which began in 1995. It envisages that by 2020, (a) the car use would decline from 74 per cent of all trips to 60 per cent; (b) public transport would increase from 7 per cent of all trips to roughly about 15 per cent; and (c) walking and cycling would increase from 19 per cent to 25 per cent. In this context it is worth noting the observation made by Mees, Sorupia and Stone (2007). They argued that with regard to public transport usage, Melbourne stands out as the worst performer, 'with the largest increase in car driving, and the largest declines in car-pooling' (Mees, Sorupia and Stone 2007:p14). This, they attributed to:

- Growth in more lane-kilometres of urban freeway and tollway than any other Australian city;
- Failure to construct significant extensions to its suburban heavy rail system over this period; and
- Remarkably poor public transport management that has worked against coordinated operations of the different modes (ibid).

2.2 Spatial trends in commuting to work

This section examines the individual effects of a number of important spatial aspects affecting the public-private modal split in work-related commuting with a view to model their combined effect in the next section.

2.2.1 Journey to work by employed residents

The modal share for 2006 is shown in Table 1. As shown there, car serves as the dominant mode of workplace access to a large majority of workers in the Melbourne working Zone.

The number of persons using public transport to commute to work remains at 13.2 per cent and it is only a 0.3 percentage point increase compared to the corresponding figure for 2001. Similar mode share patterns are not uncommon in virtually all other Australian capital cities.

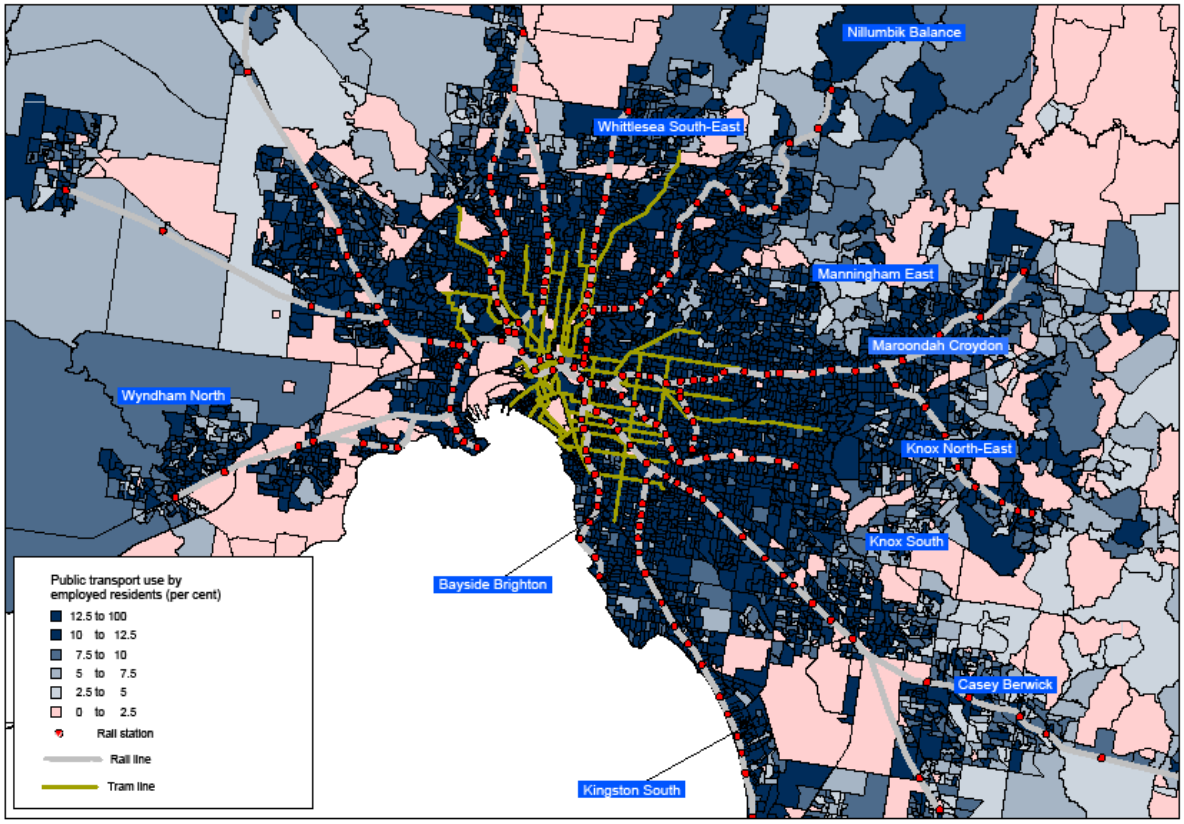
Table 1: Journey to work by employed residents by mode of transport, Melbourne, 2006

Transport mode	Employed residents (number)	Employed residents (per cent)
Car	1 152 845	75.1
Private vehicle (excludes cars)	24 330	1.6
Public transport	202 695	13.2
Bicycle	19 104	1.2
Walk only	53 218	3.5
Other	16 847	1.1
Worked from home	66 548	4.3
Total going to work	1 535 587	100.0
Mode unstated	33 282	
Did not go to work	184 919	
Total	1 753 788	

Source: BITRE analysis of ABS 2006 Census DataPacks: Basic community profile release 2 (Cat. 2069.0.30.001)

Much of the reasons for the observed dominance of car for work related travel shown in Table 1 could be attributed to the inadequacy of public transport services in areas where they are needed — thus limiting people's access to jobs and other activities unless they own a car or drive.

Figure 2: Percentage of employed persons commuting by public transport, Melbourne, 2006



Source: BITRE analysis of ABS 2006 Census DataPacks: basic community profile release 2 (Cat. 2069.0.30.001) and data from the Department of Transport, Victoria

Figure 2 shows the spread of Melbourne's rail and tram networks — the two main public transport networks in the Melbourne working zone and the distribution of employed persons adjacent to those networks. As shown, the higher the accessibility to public transport — as in the Inner region — the higher the number of persons who travel to work by public transport. As the State Government of Victoria (DOI 2006) notes, "more than 90 per cent of households in Melbourne are now within 400m of a public transport service" (DOI 2006:p17). The Victorian Government's ongoing program of investment in local buses (see DOI 2006) recognises the important role played by accessibility and frequency of service of public transport and aims to sustain this level of access as the city grows, by improving hours of operation and frequency of services, and by targeting services where they are most needed.

2.2.2 Journey to work by region

The number of population centres served by public transport differs across the four regions within the Melbourne Working Zone. For example, the Inner region is well served by public transport and the opportunities for employment there, especially within shorter commuting distances are high. Consequently, the use of cars and other private vehicles in SLAs in the Inner region is much lower than that in the other regions (Table 2).

Table 2 also shows that the number of car and private vehicle users have progressively increased as the distance between the CBD and the outer regions widened. The extent of coverage by various public transport networks as well as the number of transit stops also diminished as the distance between the CBD and the outer regions widened. The available data suggests that outermost regions such as the Peri-urban area lack any form of public transport coverage. As shown in Figure 2, most SLAs in the Outer regions are not covered by the rail network. These SLAs are served by only a thinly spread bus network. Nevertheless, the SLAs in the Inner region are served by densely spread tram, train and bus networks — thus enabling a relatively higher percentage of Inner region commuters to use public transport than their counterparts in the Middle and Outer regions and sub-regions.

Table 2: Employed residents by mode of transport and sector, Melbourne working zone, 2006

Region/sub-region	Car	Private vehicle (excludes cars)	Public transport	Bicycle	Walked	Other mode	Worked from home
			Mode share (per cent)				
Inner	50.2	1.0	38.2	2.7	5.5	0.3	2.1
Middle	83.3	1.2	5.9	1.0	3.0	0.4	5.3
Middle East	82.8	1.0	6.3	0.8	2.9	0.4	5.8
Middle North	82.4	1.3	6.0	1.4	3.7	0.4	4.9
Middle South	81.9	1.1	6.1	1.0	3.2	0.4	6.3
Middle West	86.4	1.5	4.9	0.8	2.5	0.4	3.5
Outer	87.1	1.7	2.7	0.5	2.3	0.4	5.4
Outer Eastern	85.7	1.6	2.9	0.6	2.4	0.3	6.4
Outer Northern	89.2	1.7	2.6	0.4	1.7	0.4	4.0
Outer Southern	86.5	1.7	2.6	0.5	2.5	0.5	5.7
Outer Western	88.4	1.8	2.3	0.6	2.0	0.4	4.4
Peri-urban	77.2	2.0	1.0	0.5	5.9	0.5	12.9
Melbourne Working Zone	74.9	1.3	14.0	1.3	3.6	0.4	4.6

Source: BITRE analysis of ABS 2006 Census DataPacks: basic community profile release 2 (Cat. 2069.0.30.001)

2.2.3 Change from 2001 to 2006

Table 3 compares the change in modal share for work trips between 2001 and 2006 using the ABS Census data for the working population. As evident from the Census data for these two years, the primary mode of travel for employed persons in all regions and sub-regions of the Melbourne working zone was the car. In both years, the modal share of car averaged around 75 per cent. Although the modal share of car for those travelling to work dropped by 1.4 percentage points between 2001 and 2006, it was mostly due to the drop in car usage share in the Inner and the Middle regions. This decline in car usage can be attributed largely to the overall increases in public transport use, cycling and travel by other modes of transport in the Melbourne working zone.

Table 3: Change in mode of transport used by employed people to travel to a place of work in the Melbourne working zone, 2001 to 2006

Region/sub-region	Car	Private vehicle (excludes cars)	Public transport	Bicycle	Walked only	Other mode	Worked from home
			(Percentage point change in mode share)				
Inner	-6.2	0.1	2.5	1.0	1.9	0.5	0.1
Middle	-1.0	-0.1	0.5	0.2	0.5	-0.0	-0.0
Middle East	-0.8	-0.1	0.8	0.2	0.4	0.0	-0.5
Middle North	-1.1	-0.2	-0.3	0.3	0.6	-0.1	0.6
Middle South	-2.1	-0.2	0.5	0.1	0.6	0.1	0.9
Middle West	-0.1	-0.1	0.3	0.1	0.3	-0.1	-0.5
Outer	1.0	-0.2	0.0	0.0	-0.1	-0.1	-0.7
Outer Eastern	0.5	-0.2	0.0	0.1	0.2	-0.1	-0.6
Outer Northern	0.8	-0.1	-0.1	0.1	-0.0	0.1	-0.8
Outer Southern	1.2	-0.2	0.0	-0.0	-0.2	-0.1	-0.6
Outer Western	1.5	-0.3	0.1	-0.0	-0.5	-0.1	-0.6
Peri-Urban	3.4	-0.6	-0.2	0.0	-0.1	-0.1	-2.4
Melbourne WZ	-1.4	-0.1	0.3	0.3	0.7	0.1	-0.11

Source: BITRE analysis of ABS 2006 Census DataPacks: Working population profile release 2 (Cat. 2069.0.30.006) and ABS 2001 Census data requested from the ABS

2.2.4 Distribution of jobs and mode of commuting to work

The aim of this section is to examine (a) how the number of jobs to the number of residents — or the self-sufficiency ratio in an area and (b) the proximity of such areas to train, tram and bus routes influence the modal choice of residents. To illustrate this relationship, the authors compared the jobs to resident ratio and the modal shares (percentage) of public transport and transport by private vehicles in Central Activities Districts (CADs) in various sub-regions of the Melbourne Working Zone and the areas immediately surrounding those.

CADs perform a critical capital city role and are considered to be dominant retail, commercial, cultural, administrative and civic centres. A notable objective of this planning concept is to provide “significant CBD-type jobs and commercial services” (DPCD 2008:p11) — thereby curb urban sprawl and the associated negative social, economic, and environmental impacts. Therefore similar to the CBD, these centres also have the potential to alter the scope of travel (e.g. vehicle kilometres travelled, duration of travel by a vehicle, travel frequency) and the mode choice (walking, cycling, using public transport or a private

vehicle) thereby making a notable difference in the modal split of travel-related commuting compared to their respective surrounding areas. Analysis undertaken by BITRE suggests that a similar function is performed by Principal Activity Centres and various other forms of activity centres that have emerged under the auspices of the *Melbourne 2030* plan. The locations of the CADs studied in this paper are shown in the Melbourne Working Zone map in Figure 3. This map shows that virtually all CADs are located closer to Melbourne's dominant mass transit routes. BITRE's spatial analysis of CADs using travel zone data shows that virtually all CADs are accessible using a single public transport mode. This result is of policy relevance and is supported by DPCD findings. DPCD (2007:p34) noted that "Journey to Work statistics reveal that even people who travel a few kilometres to work will favour using a car if their home or workplace is not close to a train or tram route, or if they have to board more than one public transport vehicle to get to work".

Figure 3: The Central Activities Districts and the transport networks serving those

Source: Based on DPCD (2010)

Table 4 shows a comparison of the jobs to resident ratios and the share of public and private transport usage in the seven CADs in the Melbourne Working Zone and the surrounding areas. As shown in Table 4, CADs have more jobs to residents — or a higher self-sufficiency ratio than in the remaining areas of the sub-regions where CADs are located. This result, coupled with the close proximity of CADs to mass transit routes appear to have

facilitated a higher patronage of public transport in CADs and discouraged private vehicle use.

Table 4: Modal share and self-containment in the Central Activities Districts and the surrounding areas in 2006

Central Activities District and the surrounding area	Jobs to residents ratio (self sufficiency)	Public transport (percentage use)	Private vehicle transport (percentage use)
Inner (excluding Melbourne CAD)	*0.3*	*27.7*	*44.9*
Melbourne CAD	3.8	25.8	21.7
***Middle East* (excluding Box-Hill)**	*0.4*	*19.7*	*72.4*
Box Hill	1.3	26.3	63.1
***Outer Northern* (excluding Broadmeadows)**	*0.1*	*11.3*	*83.2*
Broadmeadows	1.7	15.6	78.5
***Middle West* (excluding Footscray)**	*0.1*	*19.3*	*75.3*
Footscray	1.3	45.6	46.7
***Outer Eastern* (excluding Ringwood)**	*0.3*	*10.7*	*82.0*
Ringwood	4.0	24.2	73.0
***Outer Southern* (excluding Frankston/Dandenong)**	*0.2*	*8.5*	*83.2*
Frankston	3.7	16.7	51.6
Dandenong	1.6	19.9	73.2

Source: BITRE derived data from ABS 2006 Census DataPacks: Place of enumeration profile, Release 2 (Cat. 2069.0.30.004).

Note Method of travel to work data was collected in 2006 based on the method of travel to work used on the day of the census (ABS 2006d: page108).

The self-sufficiency ratio is the ratio of people who work in the sector to the number of employed people who live in the sector.

2.2.5 Accessibility to frequently serviced transit stops

According to literature, a lack of access to transport could markedly impede workplace participation, educational activities as well as securing a variety of other services required for the general wellbeing (Hurni 2006). Currie (2009) noted that a lack of transport access in the urban fringe could be a major limitation for young residents seeking employment opportunities. He also noted that the links between social disadvantage and transport are particularly significant in urban Australia. Some of the initiatives underlying Melbourne 2030 attempt to address this issue by managing growth and preserving liveability by "locating more intense housing developments in and around activity centres, along tram routes and the orbital bus routes on the Principal Public Transport Network, in areas close to train stations and on large redevelopment sites" (DPCD 2008:p12).

Table 5 shows the percentage of employed residents falling within 0.5, 1 and 2 kilometre boundaries of a frequently serviced tram or a train stop in the Melbourne Working Zone. For the purpose of analysis in this paper, the authors consider that any train, tram, or bus stop that is serviced at least once every 15 minutes from 7:30 AM to 10:00 AM on a week day is a frequently serviced public transport stop. As shown there, over 98 per cent of employed residents in the Inner sector have the ability to gain access to a frequently serviced public transport mode within 500 metres from a transport stop. A well-serviced inter-linked network of trams and train routes and the high-density housing in the Inner sector explain why such a high percentage of employed residents gain access to public transport within a short boundary of 500 metres. The inter-linkages of the transport network and the residential

densities in the Middle and Outer sectors are not as high as in the Inner sector. Therefore, only about 65 and 18 per cent of employed residents fall within a 500 metre boundary from a transport stop in the Middle and Outer sectors respectively.

Table 5: Percentages of employed residents in each sector falling within 0.5, 1 and 2 km of a regularly serviced rail or tram stop, 2006

Region/sub-region	Proportion of Melbourne's employed residents within 0.5km (per cent)	Proportion of Melbourne's employed residents within1km (per cent)	Proportion of Melbourne's employed residents within 2km (per cent)
Inner	98.2	100.0	100.0
Middle	64.7	90.5	91.9
Middle East	58.7	85.8	86.9
Middle North	63.7	93.5	97.3
Middle South	74.7	94.0	93.9
Middle West	66.2	91.8	92.5
Outer	18.3	39.9	40.2
Outer Eastern	14.7	42.3	41.3
Outer Northern	23.8	39.8	47.7
Outer Southern	20.9	50.9	49.6
Outer Western	13.5	15.3	9.4
Peri—Urban	0.0	0.0	0.0
Melbourne total	71.3	88.3	89.1

Source: BITRE analysis of ABS Census of Population and Housing 2006 usual residence data at CCD scale and Victorian Department of Transport provided stops and services data for 2006.

2.2.6 Impact of commuting distance on mode choice

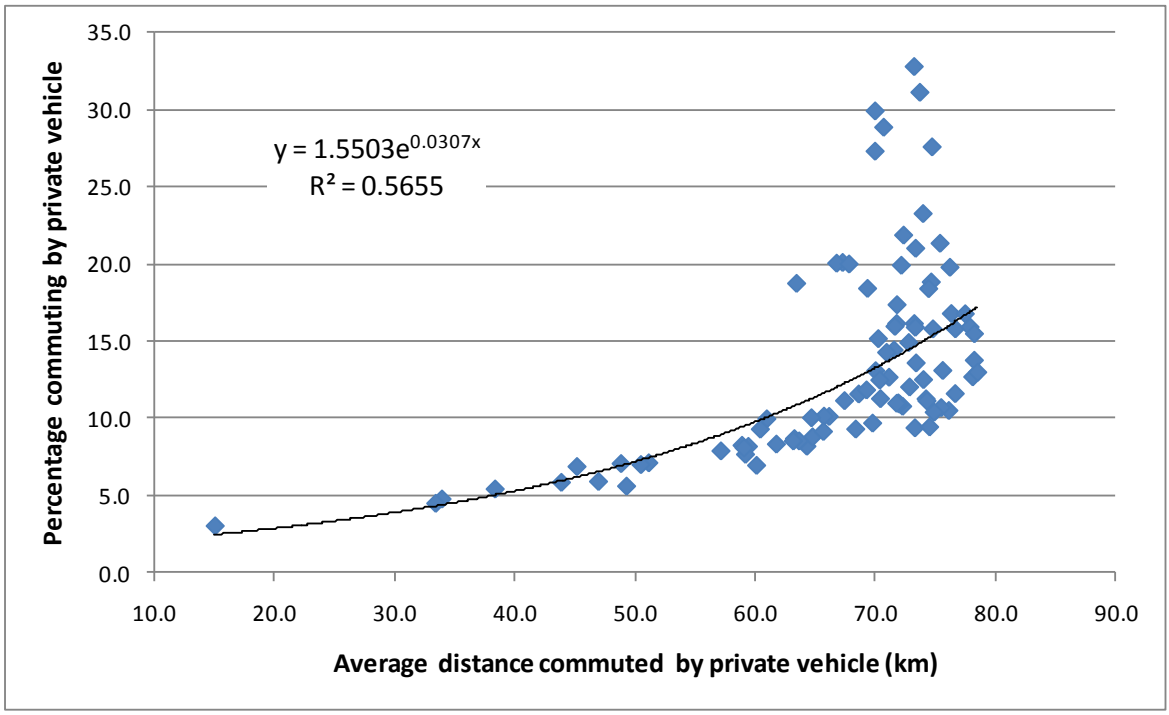
A recent Victorian Parliamentary Committee noted that the residents in many of the outer suburbs often travel lengthy distances to work by car because (a) those areas do not have efficient, affordable and reliable public transport systems and (b) the number of local employment opportunities are limited. Multi-centre development and containment of employment to designated activity centres is seen as one of the plausible solutions to reduce private vehicle usage. Melbourne 2030 strategy envisages that the kilometres travelled by all modes of transport — especially the car can be effectively reduced through the development of activity centres. The aim of this section is to use the available data to explore if any relationship exists in commuting to work by private vehicle and the travel distances between population and employment centres.

One main difficulty in using travel distances in modal choice models is the difficulty in obtaining a reasonably accurate measure of commuting distances between population and employment centres. Based on the preliminary work done by BITRE on a range of different methods, this paper utilises the method of estimating the average distances using commuting flows between SLAs. These estimates however are less accurate than those estimated based on spatially disaggregated data such as data on destination zones — but suffices the purpose intended in this paper.

The travel distance between each population centre (origin) and employment centre (destination) in a SLA was calculated using MapInfo as the straight line distance between the population-weighted centroid of the origin SLA (calculated using 2006 data for Census Collection Districts) and the job-weighted centroid of the destination SLA (calculated using 2006 data for destination zones). People who work at home are assigned a distance of zero, while people who work elsewhere in their home SLA are assigned the straight-line distance between the population-weighted centroid and the job-weighted centroid of the home SLA.

Table 6 shows the average commuting distances and the percentage of travel in each region by private vehicle in the Melbourne working zone. Preliminary statistical tests using SLA level data showed that percentage commuting by private vehicle use increases with the increase in the travel distance (Figure 4).

Figure 4: Relationship between distance commuted and the percentage commuting by private vehicle, 2006



Source: BITRE

Table 6: Average commuting distances and the percentage commuting by car

Region	Percentage of total workers commuting to work by car and other private vehicle	Average commuting distance to a workplace in this region (km)
Inner	42.0	5.6
Middle	64.7	9.5
Middle East	64.8	9.7
Middle North	61.1	8.7
Middle South	64.6	9.5
Middle West	68.2	9.9
Outer	74.6	14.4
Outer Eastern	73.3	12.7
Outer Northern	75.0	13.3
Outer Southern	75.1	15.1
Outer Western	75.3	17.6
Peri Urban	70.7	21.9
Melbourne Working Zone	67.1	11.6

Note: The average commuting distances have been adjusted by deducting the person-kilometres travelled within the home SLA.

Source: BITRE estimates

2.2.7 Effects of employment self containment on mode choice

Employment self-containment refers to the proportion of local employed workforce that works within the same area. Table 7 shows that except the Inner region, all regions and sub-regions with lower self-containment have the tendency to attract workers to that region or sub region. Accordingly, commuting by private vehicle could be expected to increase if the workers from the outer regions lack adequate access to public transport or lack cross-town connectivity of public transport routes.

Table 7: Self-containment and proportion commuting from outer regions, Melbourne working zone, 2006

Region/sub-region	Workers	Employed residents	Work in home region or sub-region	Self-containment rate (per cent)	Proportion who commute to the home region or sub-region (per cent)
Inner	443841	135430	100491	74	77
Middle	613024	734465	298973	41	51
Middle East	230061	248164	107575	43	53
Middle North	105490	153638	50030	33	53
Middle South	142640	171393	72586	42	49
Middle West	134833	161270	68782	43	49
Outer	488164	631675	332084	53	32
Outer Eastern	129020	172173	92265	54	28
Outer Northern	108333	130249	55890	43	48
Outer Southern	202542	250394	156907	63	23
Outer Western	48269	78859	27022	34	44
Peri-urban area	41424	55652	33234	60	20
Melbourne Working Zone	1,586,453	1,557,222	764,782	49	52

Note: The place of work total is substantially less than the number of employed residents, due to non-response and no fixed work address.

Source: BITRE analysis of ABS Census of Population and Housing 2006 unpublished data.

2.2.8 Effect of infrastructure on mode choice

The spatial analysis in the previous section using ABS 2006 Census data shows that in general, the modal share of public transport for work-related travel in Melbourne working zone was 13.2 per cent in 2006. The Census, data also shows that an average of two out of three residents (67 per cent) in Melbourne's outer suburbs travelled to work on census day — either as a sole driver or accompanied by passengers. Although the Census does not provide any insight as to why Melbourne's outer suburbs have an above-average reliance on driving to work or a below-average use of public transport, public submissions to the Outer Suburban/Interface Services and Development Committee suggests that the 'observed usage pattern is influenced by:

- the limited or non-existent '*cross-town*' connectivity of Greater Melbourne's established train network;
- limited car-parking at outer suburban train stations, to encourage a '*park and ride mentality*'; and
- a higher than average concentration of residents listing '*technicians and trades*' as their occupation and thus generally relying on driving to their workplaces with tools, plant and equipment aboard, rather than using public transport' (for details see Parliament of Victoria, 2008:p273).

Melbourne University's Australasian Centre for the Governance and Management of Urban Transport (GAMUT) reports: "More cars are driven to work each day in Melbourne than in Sydney, despite Sydney's much bigger workforce. The share of workers who drive is now higher in Melbourne than in Sydney, Brisbane, Hobart and even Canberra. This appears to be a result of Melbourne having constructed more urban freeways and tollways over the last 30 years than any other capital" (as cited in Parliament of Victoria, 2008).

2.2.9 Socio-economic factors

Currie and Senbergs (2007) noted that as high as 23 per cent households in outer Melbourne area had little or no walk access to local activities and their ability to access public transport was limited. They also noted that these residents are running two or more cars despite their low weekly income. Recent research by Currie and Delbosc (2009) reveal that 'those on low incomes living in fringe areas without cars make access-oriented home location and transport decisions which may contrast with the choices of those with high car ownership. These observations do not provide conclusive evidence of either a positive or a negative causal relationship between lower socio-economic status of individuals and their lower use of public transport.

The Index of Relative Socio-economic Disadvantage (IRSD) which is estimated by ABS under the Socio-economic Index for Areas (SEIFA) was used for measuring the extent of socio-economic disadvantage experienced by employed residents — both within and outside the buffer areas of frequently serviced transport stops. The results suggest that a majority of the residents in SLAs outside frequently serviced transport stops are socio-economically more disadvantaged (ISRD closer to 10) than their counterparts in rest of the Working Zone. Table 8 shows the top five SLAs with the highest IRSD. There, except for four SLAs in the Middle sector, a majority of the SLAs with very high ISRDs are located in the Outer sector. The SLAs shown in the table are marked in Figure 2.

Table 8: Socio-economic disadvantage and access to public transport, 2006

Rank out of all SLAs	SLAs outside 0.5 km transit stop	SEIFA IRSD (decile)	SLAs outside 1.0 km transit stop	SEIFA IRSD (decile)	SLAs outside 2.0 km transit stop	SEIFA IRSD (decile)
1	Knox South	9	Whittlesea South-East	10	Nillumbik Balance	10
2	Maroondah Croydon	10	Kingston South	9	Banyule North	9
3	Wyndham North	5	Casey Berwick	9	Maroondah Croydon	9
4	Knox North-East	6	Knox South	8	Bayside Brighton	8
5	Whittlesea South-West	4	Banyule North	10	Manningham East	10

Source: BITRE analysis of ABS Census of Population and Housing 2006 usual residence data at CCD scale; and Victorian Department of Transport stops and services data for 2006.

The results of BITRE analysis presented in this section together with the evidence presented by Currie and Senbergs (2007a) and Senbergs and Currie (2007) perhaps indicate a situation of 'high car ownership on low incomes' (HCOOLI) — especially in the Middle and Outer sectors of Melbourne. Such situations perhaps could lead to social exclusion. Unless firm evidence exists to the contrary, such situations should be addressed through infrastructure investment and traffic demand management policies that are geared towards enhancing adequate, frequent and secure access to public transport as well as suitable employment and other relevant policies. This issue is further investigated later in this paper.

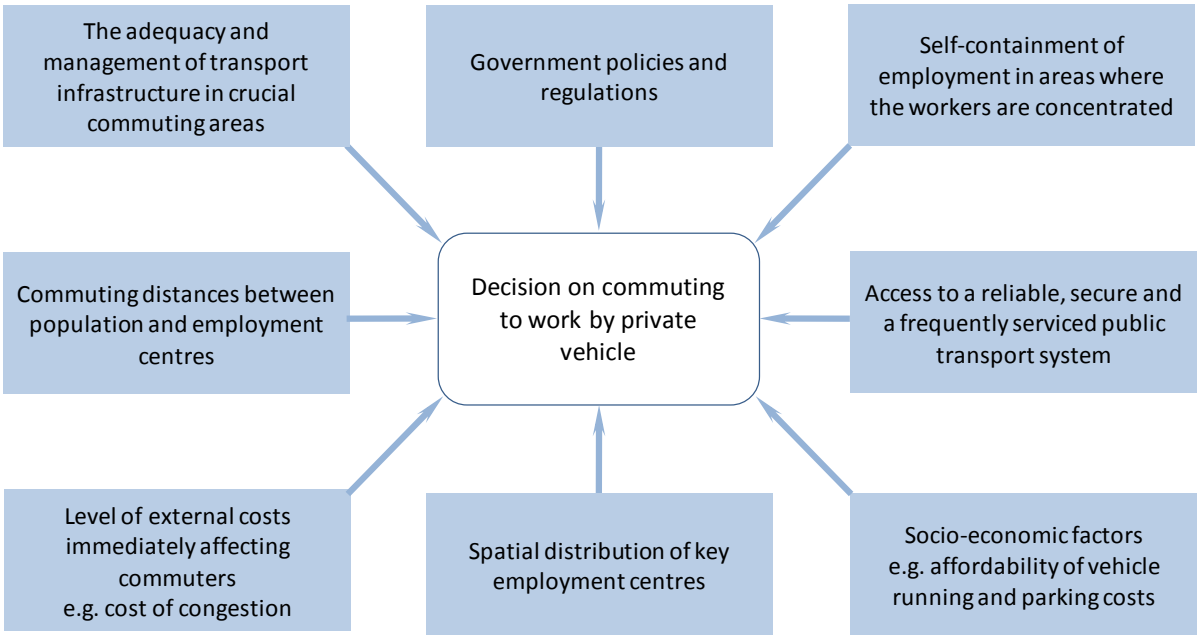
2.2.10 Externalities and modal choice

The ABS Census data is the main source of data underlying the analysis presented in this paper does not have information to carryout analysis of the influence of externalities on modal choice. Nevertheless external costs are important determinants of modal choice — especially if government policies are to be geared to recover these costs from commuters. Such policies would be effective only if reliable access to alternative and cost effective transport modes are available. The Victorian Council of Social Service (2004:p7) noted that "congestion taxes or increased fuel costs in Melbourne would particularly disadvantage low-income residents, doubly penalising people for being excluded from the public transport net". Low-income residents in urban fringe suburbs with poor transport services would "have little or no choice but to rely on cars to get around (Victorian Council of Social Service, 2004:p7). Due to the lack of (a) data and (b) its immediate relevance in the Australian context, this aspect will not be discussed any further in this paper.

3. Use of private vehicle in commuting to work

The aim of this section is to construct a modal choice model by combining the different decision variables discussed in the previous section to identify the variables relevant in the context of work-related commuting in the Melbourne Working Zone and to gauge their relative contribution to mode choice decisions.

Figure 5: Factors influencing the decision on commuting to work by private vehicle



Expressing the percentage of workers in a SLA who are commuting to work by private vehicle (car—as a driver and passenger, motor bicycle and truck) in 2006, modal choice model can be expressed conceptually as:

$PCOM = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_{8,})$.

Due to unavailability of data, not all the variables discussed in Sections 2.3.1 to 2.3.10 and summarised in Figure 5 (see also the above equation) have been directly included in the empirical model. Table 9 explains each of the variables in the equation and how the empirical model captured the influence of different variables — both directly and indirectly and variables that are not included.

Table 9: Variable in the conceptual model and those included in the empirical model

Variable	Description of the variable	How variables are captured in empirical analysis
X_1	*Adequacy and management of transport infrastructure in crucial areas*	The adequacy and management of transport infrastructure markedly influence spatial differences in decisions to use private vehicle in work-related commuting. In the Inner region, there is a well dispersed and frequently serviced public transport network that significantly favours commuters to opt for public transport at the expense of private vehicle use. Due to heavy traffic volumes, long waiting times, parking difficulties, the Inner region is unappealing to the private vehicle user — compared to less congested Middle and Outer regions. These spatial characteristics are captured in the empirical model using a binary dummy variable with the Inner region assigned a value of 1 to distinguish it from other regions which are assigned 0. Because of the mass-transit advantage in the Inner region, this variable is expected to have a *negative influence* on private vehicle commuting.
X_2	*Commuting distance between population and employment centres*	The empirical model captures the effect of this variable by including the straight line distances between the population-weighted centroids of origin and destination SLAs. Because of sparse distribution of frequently serviced mass transit networks in Outer regions and the longer commuting distances characterising those regions (see Table 6) this variable is expected to bear a *positive influence* on private vehicle commuting.
X_3	*Level of external costs immediately affecting commuters*	Traffic congestion and longer waiting times are the dominant external costs that directly affect commuters. The effect of this variable indirectly influences the spatial characteristics that distinguish the Inner region from the rest (i.e. variable X_1). Therefore a separate variable has not been included.
X_4	*Spatial distribution of key employment centres*	The effects of this variable are adequately contained in X_3. Therefore a separate variable has not been included in the empirical model.
X_5	*Socio-economic factors affecting work-related commuting decisions*	Socio-economic disadvantages have influence the ability to own and operate a vehicle. Therefore this variable is expected to have a *negative influence* on private vehicle use. The effect of this was captured using the SLA-specific Index of Socio-economic Disadvantage estimated by ABS.
X_6	*Public transport accessibility and service frequency*	For empirical analysis, this variable was constructed using stops and services data from the Victorian department of Transport. It identifies mass transit stops in SLAs that offer services at least at 15-minute intervals during the morning peak hours and the accessibility to those by walking a maximum distance of 2 kilometres. It is expected that SLAs with frequently serviced and easily accessible mass transit stops would impart a *negative influence* on private vehicle commuting.
X_7	*The level of self-sufficiency of work in the region where employees live*	Employment self containment is discussed in Section 2.3.7. Two variable have been used in the empirical model to capture the effects of employment self containment in SLAs. SLAs that offer ample employment opportunities spur a larger inflow of commuters from outer areas than those who commute out for employment in outer SLAs. This effect was captured using the variable called 'Net inflow' and as public transport services are considerably better in and around employment centres, it is expected that the variable would bear a *negative influence* on private vehicle commuting, The second variable refers to a situation requiring travel outside population centres due to poor employment opportunities relative to the size of population there. Such travel usually occurs from SLAs in regions outside the Inner region — especially from the Outer and Peri-urban regions. As travel from outer regions involve relatively longer travel distances and invariably require private vehicle use for reasons noted earlier, the variable used to capture this effect called 'Working outside home SLA' is expected to have a *positive influence* on private vehicle use.
X_8	*Government policies and regulations impacting commuting by private vehicle*	This variable was excluded from empirical modelling.

3.1.2 Results and discussion

Table 10 shows results for the finally chosen regression model to explain the type of commuter response to private vehicle as a means of commuting to work in the Melbourne Working Zone data. This model was chosen following several diagnostic tests of the estimated model. These tests in particular included running stepwise regressions by removing one variable at a time to determine which of the variables contributed most explanatory power. This process showed that the removal of any one variable at a time could not reduce the explanatory power by more than 7.5 percent or defy *a-priori* expectations about signs of the coefficients.

The model explained slightly over 85 per cent (adjusted R^2 is 0. 8510) of the variability in demand for private vehicle as a means of commuting to work. All the explanatory variables of the model were significant at least at 5 per cent level of probability. The signs of the regression coefficients accorded with *a-priori* expectations about those variables. An analysis of the residuals of the regression model suggests that there is scope for extracting further information contained in the data by including variables formed by appropriate interactions between independent variables and/or suitably transforming the variables to non-linear forms for fitting of non-linear regression models to the data. In this paper the authors used a single binary dummy variable to account for spatial effects on commuting decisions. This approach seems inadequate. Any future research requiring modelling of spatial effects on decisions of people should of necessity adopt other empirical techniques such as geographically weighted regressions.

Table 10: Results of the regression on combined effects of factors affecting private vehicle use

Independent variables	Coefficients	t Statistic
Intercept	41.9352	8.9557
Index of Relative Socio-economic Disadvantage (Decile)	-2.3603	-3.3768
SLAs with frequent transport at least within 2 kilometres	-6.3652	-5.0333
Log (Average commuting distance between population and employment centres)	31.3246	6.5345
Percentage that work and live in the SLA (self- sufficiency rate)	-0.0970	-2.3500
Conditions favouring public transport patronage in the Melbourne CAD	-14.0518	-6.2307
Net inflow of work-related travel to a SLA	-0.0001	-4.7990

Source: BITRE estimates.

4. Conclusions and policy implications

The results of the analysis in this paper support the findings of various State government bodies of Victoria and that of independent researchers (see for example, DPCD 2008; Moriarty and Mees 2005; Casey 2008). They have argued for marked increases in public transport patronage in Melbourne — particularly through such measures as:

- Implementing policies aimed at promoting the development of activity centres (e.g. Central Activities Districts) to contain employment and reduce the need for work-related private vehicle travel as envisaged in *Melbourne 2030.*
- Responsive public infrastructure investment — where government policies are designed to promote public transport usage by strategically focusing infrastructure investment to rectify notable gaps in the public transport network.

The results in the paper clearly suggest that greater self-containment of employment in SLAs of the Outer region would reduce car reliance. Development of activity centres that are currently progressing in the Melbourne Working Zone aim to improve self-containment but as

the 2006 data analysed in this paper suggests the target levels of employment self-containment have not been achieved thereby requiring a significant number of workers to commute outside their home SLAs to places of work. Such a trend could markedly reduce the rate of progression of public transport patronage — thus causing difficulties in achieving the *Melbourne 2030* public transport usage target of 20 per cent of all motorised travel by 2020.

Analysis in the paper also shows a strong tendency for commuters in areas of the Melbourne Working Zone that currently lack cross-town connectivity of the rail network and the Outer and Peri-urban regions to opt for private vehicle usage when commuting to work. Perhaps this is due to the combined effect of unavailability of adequate public transport facilities and services as well as lower self-containment of employment in those outer regions. These appear to be target areas for public transport infrastructure investment: (a) as highlighted by interested groups (see for example Mees 2007; Casey 2008); as well as (b) evident from Victorian Government action to provide public transport through the high frequency Orbital 'Smart Bus' routes that are announced in *Linking Melbourne: Metropolitan Transport Plan* (DOI 2004) and being rolled out under *The Victorian Transport Plan* (DOI 2008).

The analysis in the paper showed that socio-economic disadvantage has a significant negative influence on the use of private vehicle. As noted earlier, Currie and Senbergs (2007) noted evidence to the contrary. The analysis in the paper also showed that most socio-economically disadvantaged commuters are in the population centres that are located in the Outer and Peri-urban regions. Therefore as to whether the negative influence on private vehicle use due to socio-economic disadvantage, coupled with the lack of public transport in these areas could result in social exclusion of affected communities in such areas cannot be proven conclusively. As noted in Parliament of Victoria (2008:p271) based on Currie and Senbergs (2007), *"much research has illustrated that low income households trade off lower housing costs for higher transport costs by deciding to locate on the urban fringe of Australian cities. In this context high car ownership could be seen as a rational decision rather than an imposition"* leading to social exclusion.

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