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A Comparison of the Impact of Different Urban Strategies on Travel and the Environment in Adelaide and Melbourne

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Abstract:

Cities vary in size. The mix of urban and transport strategies, aimed at maximising the quality of the urban environment in different sized cities, may also vary. This paper investigates traffic and environmental changes consequent on different transport strategies in two cities with approximate populations of 1 million (Adelaide) and 3.3 million (Melbourne) to determine potential differences. CityPlan is used to compare the cities. CityPlan is a land use-transport-environmental interaction model which has been verified and validated using data describing both Adelaide and Melbourne. In this study, different transport policies are set up to assess their transport and environmental impacts over a study period of 20 years. Comparisons are made between a base scenario, developed in the verification and validation study and representing actual events, and a number of development scenarios. The comparison is based on a range of indicators, including modal split, travel, fuel consumption and traffic emissions.

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Introduction

With the continuously increasing usage of motor vehicles in cities, the impact of externalities such as traffic congestions, noise and pollution are increasing and the urban population is becoming more sensitive to their presence. Australia is particularly sensitive since it has one of the highest per capita rates of motor vehicle use in the world (Newman and Kenworthy 1989). The ultimate challenge for urban transport planners is to set up transport strategies to enhance transport efficiency, reduce the rate of growth in car travel, encourage the use of the public transport systems and hence reduce externalities. However, the travel patterns and environmental impacts in cities of different sizes may be influenced differently by transport strategies. The ISGLUTI (International Study Group on Land-Use and Transport Interaction) study (Webster and Paulley 1990) has shown that study area size, which determines the number of opportunities for those changing location, seems to be critical and seems to have an important influence on the relative strength of the travel modal shifts when the cost of travel is changed (Mackett 1989). This paper uses the CityPlan model (Gu 1996a) to investigate travel and environment changes in two major Australian cities: Adelaide and Melbourne. This study takes the results of the CityPlan verification and validation study (Gu and Young 1997) as a base scenario, since this represents the actual changes that took place over a given period. Five transport strategy scenarios are used in the comparison to determine the potential transport and environmental impacts for the two cities. The five transport pricing strategies are:

- free public transport,
- reduce public transport fares by 50%,
- road pricing of 20 cents per kilometre,
- increase car travel cost by 50%, and
- double car travel cost

Comparisons of the results of the different scenarios are presented and discussed.

The CityPlan model

CityPlan is a land use–transport–environmental interaction model which has been verified and validated on data describing Adelaide and Melbourne (Gu and Young 1997). CityPlan has been applied as an educational tools at Monash University, the Australian Defence Force Academy (ADFA), University of New South Wales, Engineering Education Australia Pty Ltd and other institutions. CityPlan has also been applied as an analysis tool to assess the greenhouse emissions and other local air pollutants under different development scenarios for the South Eastern Growth Area of Melbourne (Young and Schyschow 1994), and to investigate fuel consumption responses to different urban land use and transport patterns in Melbourne (Ma and Young 1996). The dynamic structure of the CityPlan model is shown in Figure 1.

The user can set a simulation period of up to 50 years. Base year transport networks, zonal land use data and other set-up parameters for the study area can be defined by the

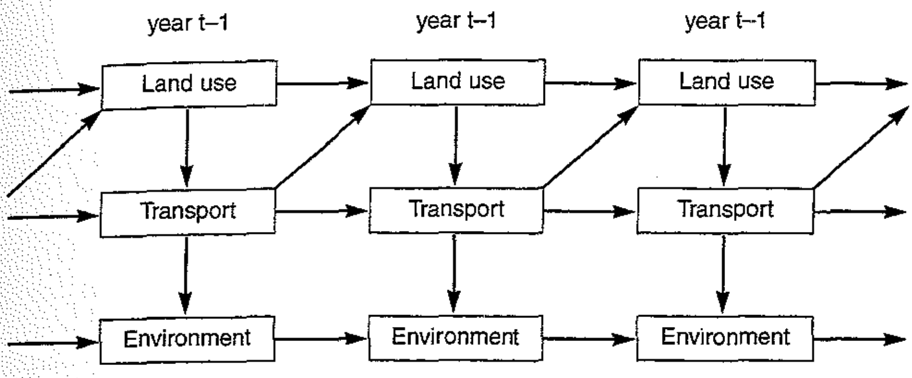


Figure 1 The dynamic structure of CityPlan

user. However, total net changes in population migration, new housing and jobs, and vehicle fleet composition by fuel type are exogenously forecast based on available sources such as census data from the Australian Bureau of Statistics. CityPlan starts from the land use model which estimates the location of activities in the different zones based on zonal accessibility and attractiveness within the study area These in turn are input into a transport demand model which estimates trip distribution, link traffic flow and interzonal generalised travel costs on private (capacity-constrained) and public transport networks. After the travel pattern is determined, the environmental impacts of the transport system are assessed Estimates of air traffic emission levels, vehicle fuel consumption and roadside traffic noise levels are provided based on link congestion level. The determined travel pattern will in turn impact location decisions in the future. CityPlan updates location activities, transport patterns and environmental impacts every year A detailed model description is provided by Gu (1996b).

The study areas and transport scenarios

Adelaide and Melbourne were chosen as study areas because they provided an indication of the impact of urban changes on travel and the environment in two cities of considerably different size The CityPlan model was verified and validated using data from these two cities. The base year of the data was 1971 and the study period in the verification and validation study (Gu and Young 1997) for both cities was 1971–1991. This paper takes the results of the verification and validation study as a base scenario. This base scenario represents the 20 years of change that has taken place in the two cities

The characteristics of the two study areas are shown in Table 1. The major spatial difference between the study areas is the size of the city. Adelaide covers 2043 km^2 while Melbourne covers an area of 5,923 km^2. Further, Melbourne is about three times as large as Adelaide in population, housing and employment. Over the study period (1971–1991), both cities experienced considerable structural change in their economy with a consequent increase in unemployment from approximately 1.5% to 12%. Average household size, on the other hand, decreased from approximately 3.3 to 2.7 people per household for Adelaide and from 3.4 to 2.9 people per household for Melbourne.

Table 1 The characteristics of the two cities

	Adelaide		Melbourne	
	1971	1991	1971	1991
Number of zones	30	30	56	56
Total area (km^2)	2043	—	5923	—
Population (000s)	843	1024	2504	3008
Houses (000s)	265	404	786	1144
Employment (000s)	346	442	1075	1318
Unemployment rate (%)	1.83	12.95	1.58	12.03
Average household size	3.343	2.697	3.41	2.880

Figures 2 and 3 show the base year zoning systems for Adelaide and Melbourne, respectively. The local government areas (LGAs) within Adelaide and Melbourne statistical divisions were used for the zoning systems. This provides a good basis for accessing detailed land use and transport information available from the Australian Bureau of Statistics. The number of spatial zones used in Adelaide was 30, while 56 were used in Melbourne.

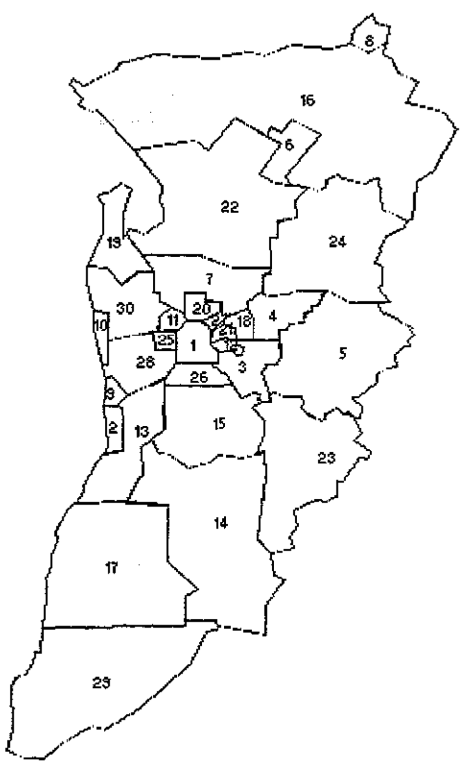
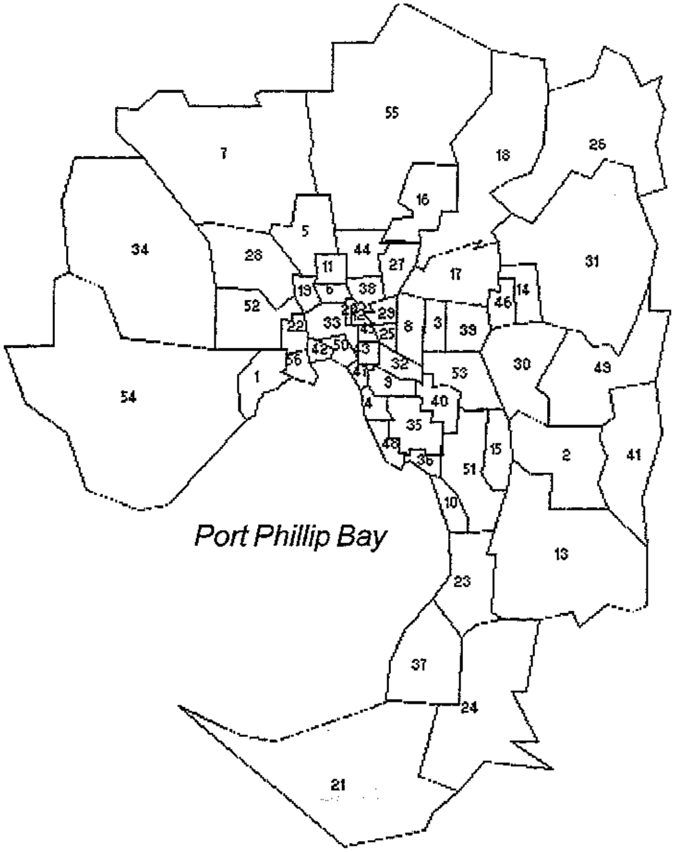


Figure 2 Zoning system for Adelaide



1 Altona
2 Berwick
3 Box Hill
4 Brighton
5 Broadmeadows
6 Brunswick
7 Bulla
8 Camberwell
9 Caulfield
10 Chelsea
11 Coburg
12 Collingwood
13 Cranbourne
14 Croydon
15 Dandenong
16 Diamond Valley
17 Doncaster/Templestowe
18 Eltham
19 Essendon
20 Fitzroy
21 Flinders
22 Footscray
23 Frankston
24 Hastings
25 Hawthorn
26 Healesville
27 Heidelberg
28 Keilor
29 Kew
30 Knox
31 Lilydale
32 Malvern
33 Melbourne
34 Melton
35 Moorabbin
36 Mordialloc
37 Mornington
38 Northcote
39 Nunawading
40 Oakleigh
41 Pakenham
42 Port Melbourne
43 Prahran
44 Preston
45 Richmond
46 Ringwood
47 St Kilda
48 Sandringham
49 Sherbrooke
50 South Melbourne
51 Springvale
52 Sunshine
53 Waverley
54 Werribee
55 Whittlesea
56 Williamstown

Figure 3 Zoning system for Melbourne

Table 2 briefly describes the computer representation of the two cities used in the study. The transport network used in Adelaide was more detailed with a greater number of nodes and links. This was primarily the result of the need for greater detail in the Adelaide study for verification of the CityPlan model.

Table 2 Base year transport network descriptions for Adelaide and Melbourne

Network	Adelaide		Melbourne	
	Road Transport	Public Transport	Road Transport	Public Transport
Zone centroids	30	30	56	56
Nodes (intersections/stops)	461	341	258	214
Roads/routes	117	63	71	41
Links (one-way)	1856	852	762	500
Network length (km)	813	628	1932	982

The study of the two cities focused primarily on transport pricing mechanisms. This aspect was chosen in order to determine the sensitivity of the cities to the introduction of lower cost short introduction period pricing mechanisms, rather than high cost long introduction period infrastructure and land use changes. Other studies have focused on infrastructure change and the reader is referred to Ma and Young (1996), and Young and Schyschow (1994). More specifically, five transport scenarios were set for comparison with the base scenario in this study. These are:

- free public transport,
- reduce public transport fares by 50%,
- road pricing of 20 cents per kilometre,
- increase car travel cost by 50%, and
- double car travel cost.

Each scenario was implemented in each study area by changing the relevant model inputs. All other parameters remained the same as those used in the base scenario. The model was run and the model outputs from the base and test scenarios over 20-year study period wre collected. Comparison of the changes in the cities are based on the results of a wide range of indicators produced by CityPlan. These include:

Private transport indicator
- total daily vehicle trips,
- daily vehicle kilometres travelled (VKT),
- daily vehicle hours travelled,

- average travel speed (km/h), and
- average trip length (km).

Public transport indicator
- total daily passenger trips,
- daily passenger kilometres travelled, and
- daily passenger hours travelled

Daily traffic emissions
- carbon dioxide (CO_2),
- carbon monoxides (CO),
- hydrocarbons (HC),
- nitrogen oxides (NO_x), and
- lead (Pb)

Daily fuel consumption
- leaded petrol (LP),
- unleaded petrol (ULP),
- diesel, and
- liquid petroleum gas (LPG).

Changes in the base scenario (1971–1991)

Table 3 shows the base scenario comparison of travel pattern, traffic emissions and fuel consumption for Adelaide and Melbourne.

The base scenario shows that during the study period 1971–1991, both public and private travel increased. However, there was a shift in the proportion of travel from public transport to private transport. Total daily vehicle trips for private transport increased 129% in Adelaide and 142% in Melbourne, while total daily passenger trips for public transport only increased marginally (approximately 6%) over the 20-year period. Total fuel consumption increased 68.7% for Adelaide and 56.9% for Melbourne. Total CO_2 emissions increased 65.7% and 55.9% for Adelaide and Melbourne, respectively. Lead emission decreased 13% and 58% for Adelaide and Melbourne, respectively, due to increased use of ULP after 1986.

Results of different scenarios

This section presents the results of the application of the five different scenarios to each study area. The comparisons are based on the range of indicators that measure change in travel, fuel consumption and traffic emissions indicated in Table 3. Comparison results are presented as the percentage deviations of different scenarios from the base scenario in the final year (1991) of the study period.

Table 3 Base scenario comparison of travel pattern, gaseous emissions and fuel consumption between Adelaide and Melbourne in 1971 and 1991

	Adelaide		Melbourne	
	1971	1991	1971	1991
Private transport indicator				
Total daily vehicle trips (10^6)	0.922	2.109	2.544	6.154
Daily VKT (10^6)	11.782	21.986	36.056	73.004
Daily vehicle hours travelled (10^3)	227.6	588.2	742.183	1804.33
Average travel speed (km/h)	51.8	37.4	48.2	40.5
Average trip length (km)	12.8	12.9	14.2	11.9
Public transport indicator				
Total daily passenger trips (10^6)	0.148	0.158	0.666	0.712
Daily passenger kilometres travelled (10^6)	1.266	1.151	7.481	7.592
Daily passenger hours travelled (10^3)	43.7	48.1	193.9	223.8
Daily fuel consumption				
LP (10^3 litres)	1787.8	1890.3	5748.6	4834.0
ULP (10^3 litres)	—	770.1	—	2588.8
Diesel (10^3 litres)	359.5	755.8	594.6	2022.0
LPG (10^3 litres)	—	207.3	—	506.9
Total daily fuel consumption (10^3 litres)	2147.3	3623.5	6343.2	9951.7
Daily traffic emissions				
CO_2 (10^6 kg)	5.732	9.502	16.774	26.143
CO (10^3 kg)	454.1	506.7	1491.8	1709.3
HC (10^3 kg)	72.2	74.0	209.2	245.3
No_x (10^3 kg)	32.1	62.1	93.2	204.4
Pb (kg)	918.0	798.0	2241.0	942.0

Travel pattern

Table 4 shows the percentage deviations of the study parameters for the different scenarios in relation to the base scenario in the final year of the study period. It can be seen that in all scenarios, there is a positive shift from car to public transport. The percentage change in car use is smaller than that in public transport because of the considerably larger use of private transport.

The 'double car travel cost' scenario has the largest impact on travel, especially on VKT and total vehicle hours, with up to 53% and 58% reduction in vehicle hours travelled in Adelaide and Melbourne, respectively.

The 'free public transport' scenario also has a positive impact on private travel. In Melbourne, average car travel speed increases 12% and mean travel distance decreases 13% when public transport is free. This scenario reduces total car trips by 4.8% in Adelaide and 12.9% in Melbourne. Total VKT is reduced 7.9% and 24.5% in Adelaide and Melbourne, respectively.

Table 4 Comparison of private transport travel indicators (percentage deviations from the base scenario)

Scenario		Free public transport	Reduce public transport fares by 50%	Road pricing of 20 cents/km	Increase car travel cost by 50%	Double car travel cost
Total vehicle trips	A	–4.8	–1.9	–3.5	–3.8	–10.5
	M	–12.9	–4.9	–6.4	–6.8	–15.7
Total VKT	A	–7.9	–2.7	–17.4	–17.7	–37.0
	M	–24.5	–10.9	–31.3	–31.9	–54.9
Total vehicle hours	A	–7.2	2.45	–27.4	–27.9	–53.3
	M	–32.6	–14.0	–38.2	–38.9	–58.8
Mean speed	A	0.8	1.5	13.6	14.2	35.0
	M	11.9	3.5	11.1	11.4	9.4
Mean distance	A	–2.3	–0.8	–11.6	–11.6	–24.0
	M	–13.45	–6.7	–26.9	–26.9	–47.1
Total passenger trips	A	104.2	37.4	71.8	73.5	209.3
	M	163.3	58.7	88.3	90.5	211.4
Total passenger kms	A	222.9	69.7	111.8	115.2	465.9
	M	412.9	143.5	178.0	185.2	421.1
Total passenger hours	A	137.5	45.3	87.3	89.8	311.9
	M	302.5	106.7	148.2	153.9	349.2

Note: A = Adelaide, M = Melbourne.

The 'increase car travel cost by 50%' and the 'road pricing of 20 cents/km' scenarios have almost the same influence on both private and public transport: Adelaide is expected to achieve an increase of 14% in car travel speed and a reduction of 27% of mean travel times for private motorists.

The 'reduce public transport fares by 50%' scenario resulted in a little improvement in travel conditions, reflected by a small percentage increase in travel speed and reduction in mean travel distance in both cities.

It is interesting to note that the transport and environmental impacts on Melbourne are almost always larger than those in Adelaide. This indicates that larger cities have greater latitude to change and are hence more sensitive to pricing policies than smaller cities.

Vehicle fuel consumption

Table 5 presents a comparison of fuel consumption for different scenarios. The percentage change relates to the base scenario. Fuel consumption of all fuel types, except diesel in Adelaide, are reduced. 'Free public transport' causes a reduction of fuel consumption by 6.6% in Adelaide and 23.6% in Melbourne. The 'double car travel cost' scenario causes savings in fuel consumption of 26% in Adelaide and 45% in Melbourne.

It should be noted that during the study period 1971–1991, LPG was introduced for use in motor vehicles in 1979, and ULP was introduced after 1985.

Table 5 Comparison of vehicle fuel consumption (percentage deviations from the base scenario)

Scenario		Free public transport	Reduce public transport fares by 50%	Road pricing of 20 cents/km	Increase car travel cost by 50%	Double car travel cost
LP	A	–6.6	–1.4	–10.6	–10.8	–26.4
	M	–23.6	–10.2	–24.1	–24.6	–45.0
ULP	A	–6.7	–1.7	–10.6	–10.9	–26.3
	M	–23.8	–10.2	–24.1	–24.6	–45.0
Diesel	A	–4.7	2.5	–9.8	–10.2	–26.7
	M	–23.5	–10.2	–24.1	–24.6	–44.5
LPG	A	–6.7	–1.7	–10.6	–10.9	–26.3
	M	–23.5	–10.2	–24.1	–24.6	–45.0
All fuel types	A	–6.6	–1.5	–10.6	–10.8	–26.4
	M	–23.6	–10.2	–24.1	–24.6	–45.0

Traffic emissions

A comparison of changes in traffic emissions is shown in Table 6. In all scenarios, traffic emissions from road traffic was reduced. The exception was HC in the 'reduce public transport fares by 50%' scenario in Adelaide.

The 'double car travel cost' scenario could reduce CO_2 as much as 26% and 45% for Adelaide and Melbourne, respectively. The impact of different transport strategies on traffic emissions are almost identical to the impact on fuel consumption. This is because the traffic emissions emissions are strongly related to fuel consumption levels.

Table 6 Comparison of traffic emissions (percentage deviations from the base scenario)

Scenario		Free public transport	Reduce public transport fares by 50%	Road pricing of 20 cents/km	Increase car travel cost by 50%	Double car travel cost
CO_2	A	–6.2	–0.5	–10.4	–10.7	–26.4
	M	–23.6	–10.2	–24.1	–24.6	–44.9
CO	A	–5.7	0.75	–10.9	–11.3	–27.9
	M	–24.0	–10.2	–23.8	–24.3	–43.8
HC	A	–5.7	0.62	–10.4	–10.7	–26.9
	M	–23.8	–10.2	–24.1	–24.6	–44.5
NO_x	A	–6.9	–2.4	–10.2	–10.4	–25.3
	M	–23.3	–10.2	–24.2	–24.8	–45.8
Lead	A	–6.5	–1.4	–10.5	–10.8	–26.3
	M	–23.6	–10.2	–24.1	–24.6	–45.0

Conclusions

This paper compares changes in travel, traffic emissions and fuel consumption in two Australian cities of two different sizes, consequent on different transport strategies. Five different transport scenarios were applied to the Adelaide and Melbourne study areas. These were:

- free public transport,
- reduce public transport fares by 50%,
- road pricing of 20 cents per kilometre,
- increase car travel cost by 50%, and
- double car travel cost.

Comparisons were made based on the percentage deviations of the impact of different scenarios from the actual change (base scenario) in the final year of the study period. Over these five scenarios, the 'double car travel cost' has the most significant impacts on travel, traffic emissions and fuel consumption. 'Road pricing of 20 cents per kilometre' and 'increase car travel cost by 50%' scenarios have almost the same impact. The 'free public transport' scenario has the second most significant impact

As would be expected, making public transport free or cheaper causes a shift from car to public transport. However, there is a much larger mode shift from car to public transport in Melbourne compared to Adelaide. The 'reduce public transport fares by 50%' has the least influence on travel and environment. This scenario only has marginal impact in Adelaide, while in Melbourne the reduction in fuel consumption and traffic emissions is significant. This may imply that transport strategies such as making public transport cheaper or free in larger cities is much more effective than in smaller cities, because people's perceived monetary savings by shifting from car to public transport in a larger city are more than that in a smaller city. The provision and quality of service of the public transport system may also affect the modal choice

All scenarios tested in this study showed positive effects on travel and the environment (less congestion, less emissions). However, the cost of implementation of these transport policies and the cost of urban transport externalities such as traffic congestions, noise and pollution needs to be analysed before any implementation of the transport policies.

City size and characteristics seem to have a strong influence on travel patterns and the environment when the cost of travel is changed. This confirms Mackett's (1989) conclusions as mentioned in the introduction to this paper. The comparison of two cities shows that transport policies are more sensitive in larger cities. The travel and environmental impacts of transport policies on the larger city, Melbourne, are two to four times stronger than that in the smaller city of Adelaide.

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