Evaluating the congestion reduction impacts of public transport – a comparative assessment

Md Aftabuzzaman, Graham Currie and Majid Sarvi

Institute of Transport Studies, Monash University

1 Introduction

Traffic congestion can be a major barrier to economic growth (Douglas, 1993). Increasing demand for travel will compound the problem if appropriate solutions are not actively sought. Efficient public transport (PT) can be one of the potential solutions to the problem of urban road traffic congestion (Pucher *et al*., 2007; Mogridge, 1984 cited in Hyman and Mayhew, 2002; Vuchic, 1999).

Public transport plays an important role for mobility in urban areas, particularly, in the central business districts (CBD) of major cities and in other concentrated employment centres (Black, 1995; Downs, 1992; Cervero, 1988; Pushkarev and Zupan, 1977). Public transport systems can carry a significant amount of trips during congested hours improving overall transportation capacity and can release excess demand on congested road networks. The congestion reduction impacts of public transport improvements depends on the scale of their impacts on mode of travel and the subsequent decongestion impacts on road travel.

This paper presents a comparative assessment of international research valuing the congestion relief impacts of PT. It explores previous research valuing congestion relief impacts and examines secondary evidence demonstrating changes in mode split associated with changes in public transport. The research establishes a framework for estimating the monetary value of the congestion reduction impacts of public transport. To illustrate findings a theoretical model is presented where congestion impact evidence is applied to understand congestion relief impacts.

Section 2 of this paper outlines the methodological approaches adopted in previous research concerning PT and congestion relief impacts. Section 3 summarises valuations of PT congestion relief benefits from Australasian, European and North American research. Section 4 synthesises the research from section 2 and 3 to establish valuations of congestion relief impacts on a common currency and single year basis. Section 5 reviews mode shift evidence associated with car travel and public transport changes. Section 6 presents a theoretical model where research findings are illustrated by estimating congestion relief impacts for a hypothetical city model.

The paper concludes with a summary of key findings and suggestions for further research.

2 A review of benefit assessment methodologies

A range of studies have examined the economic benefits of public transport congestion relief impacts. This section reviews previous research related to the economic evaluation of congestion relief associated with public transport.

A literature review of quantitative approaches for measuring and valuing public transport benefits and disbenefits was undertaken by Cambridge Systematics and Apogee Research (1996). The review identified that three main tools are central to the assessment of public transport benefits and disbenefits:

- travel demand models
- transport cost analysis techniques
- transport sketch planning and impact spreadsheets.

A report by ECONorthwest and PBQD (2002) provided practical methods in the framework of cost-benefit analysis for estimating the benefits and costs of a typical public transport project. The report noted that a public transport improvement affects the user costs of alternative modes due to the interconnected nature of the typical urban transport network. The report suggests that under congested conditions, even small changes in vehicle volumes can have significant effects on the performance of the roadway. Travel time and vehicle operating costs are affected and can be estimated as follows:

- changes in travel time can be calculated from volume-delay relationships which are embedded in the traffic assignment element of transport planning models. These can be monetised by using a standard value of time (as a percentage of standard average wage rate).

- vehicle operating cost can be estimated from the information provided by motoring organisations (e.g. the American Automobile Association etc.) who perform research calculating the cost of operating automobiles of various types.

Research on the economic implications of congestion was conducted by Weisbrod *et al*. (2001). Estimation of the economic cost savings for road users (the traditional user impacts) associated with urban roadway congestion reduction can be determined from the difference of use time and vehicle operating costs in base and project cases. Their methodology for estimating user time and expense costs can be described in the following steps:

1. **Trip Data:** It is first necessary to obtain zone-to-zone trips matrices to show the number of trips corresponding to each origin-destination pair of traffic analysis zones.

2. **Travel Time and Distance Data:** Transport planning models typically include zone-to-zone matrices of travel distances and mean travel times. These travel time and distance data together with trip data can be used to calculate vehicles hours of travel and vehicle miles of travel.

3. **Unit Travel Costs:** The components of unit travel costs (costs of driver time and vehicle operating expenses) are obtained from standard sources. Unit cost factors are multiplied by the travel time, distance, and trip data to calculate aggregate user time and expenses.

The Australian Transport Council (2006) present national guidelines for urban transport project evaluation. Their method for estimating decongestion benefits is essentially the same as that as is the New Zealand approach (LTNZ, 2005).

Beimborn *et al*. (1993), in reviewing the principles and issues for public transport benefit measurement, provided a framework for benefit analysis and described measurement techniques. Their study proposed that traffic congestion relief benefits for auto users in terms of travel time savings can be estimated through an enhanced consumer surplus technique. The enhanced consumer surplus can be estimated by using appropriate travel forecasting models in which the trip distribution and model split steps are based upon roadway disutilities that are appropriate for the amount of traffic congestion. The technique measures the decrease in disutility of travel in units of time (i.e. the increase of consumer surplus) for an alternative public transport system as compared to a base system. Again travel time savings are converted to monetary units by multiplying by the value of time.

An estimation of the congestion reduction effects of public transportation was made in a study of 85 cities (Schrank and Lomax, 2005). The report determined the delay benefits by assuming the question "what if all transit riders were in the general traffic flow instead of on public transport?" The additional shifted traffic would clearly increase congestion on road networks. The number of additional roadway traffic was calculated by dividing the number of existing PT users by car occupancy factor. In the 85 North American urban areas studied, there were approximately 43 billion passenger-miles of travel on public transport systems in 2003. Ridership ranged from 17 million in the small urban areas to about 2.7 billion in the very large areas. Overall, if riders did not use public transport systems they were estimated to cause an additional roadway delay of approximately 1.1 billion hours (a 29 percent increase in delay) and an additional congestion cost of $18 billion (US$, 2005) (Table 1).

Table 1 – Increase in delay if public transport service were eliminated - 85 areas

			Delay reduction due to public transport		
Population Group	*Annual average travel (millions of pax-miles)*	*Annual delay (millions of hours)*	*Delay reduction (millions of hours)*	*Proportion of base delay*	*Savings (US$ million)*
Very Large (*n*=13)	2,718	2,526	919	36%	15,289
Large (*n*=26)	233	875	148	17%	2,485
Medium (*n*=30)	58	288	27	9%	444
Small (*n*=16)	17	34	2	4%	25
Total (*n*=85)	**43,403**	**3,723**	**1,096**	**29%**	**18,243**

Source: Schrank and Lomax (2005)

Nelson *et al*. (2006) estimated both the total system benefit to PT users and congestion impact to motorists of PT in Washington DC. The study used a regional travel demand model and calculated the aggregate welfare change by reducing public transport supply to zero. The decline in traveller welfare minus the savings in operating costs was interpreted as a measure of benefits of the existing system. The study tested three scenarios: eliminating bus and rail separately, and eliminating both modes together. Shutting down both modes simultaneously produced an estimate of motorists' congestion reduction benefits of $736 million (US$, 2000) annually.

In summary two principal measurement approaches are adopted, those based on transport models and those from other indirect approaches. These are summarised in Table 2.

Table 2 – Summary of economic estimation methods for roadway congestion reduction impacts of public transport

Estimation method	*Description*
Transport system model	**Transport system models** are used to simulate and forecast the effects of transport facilities and services on trip generation, mode split, trip routing, travel times and travel costs. The output from the model (the travel time savings in time units) is multiplied by a value of time to quantify the benefits in monetary terms.
Indirect measurement technique	**Indirect measurement techniques** measure the effects of existing transport facilities and service through analysis of historical data/ user impacts through surveys of travellers, nearby business or both as well as through secondary data.

As an example of the indirect measuring technique,

- Increase in road traffic congestion from the cessation of public transport = Number of passengers diverted to car ÷ Car occupancy rate × Average motor vehicle trip distance × Estimated road decongestion benefit

- Benefits to private motorists remaining after an improved public transport system = Estimated quantity of road traffic removed from the road system × Estimated changes in travel speed × Value of travel time for car occupants.

3 Congestion relief valuation – A summary of evidence

This section reviews international evidence where public transport decongestion benefits were valued to better understand the range and types of impacts studied.

3.1 Australasian evidence

Congestion relief associated with the provision of Sydney CityRail services was quantified by investigating the cost and benefits associated with the hypothetical cessation of CityRail services (Karpouzis *et al*., 2007). The study used a second best alternative mode approach. This assumed that journeys would divert from rail to road (about 53% to car, about 42% to bus) and walking (about 5%). A traffic congestion relief benefit of 30.5 cents (Aus$, 2007) per car kilometre and 104.0 cents (Aus$, 2007) per bus kilometre was derived. The study estimated the total cost of additional congestion at $740.5 million p.a. (Aus$, 2007) if CityRail services were removed.

A preliminary study was conducted by Thornton (2001) for the scoping study of a very high speed train in Eastern Australia. This used a road decongestion value of 28 cents per vehicle-kilometre (Aus$, 2001) diverted to rail in metropolitan areas.

The Department of Infrastructure, Victoria, 2005 (cited in ATC, 2006) suggests a generalised unit decongestion value of 17 to 90 cents ($Aus, 2004) per vehicle-kilometre (vkm) of reduced car travel. The value covers both time and vehicle operating cost changes.

Estimates of decongestion benefits (the reduced congestion costs experienced by remaining road users due to removal of a marginal vehicle) were made by Land Transport NZ (LTNZ, 2005). The average congestion cost saving was Auckland NZ$1.190 / vkm and Wellington $0.911/ vehicle-kilometre. This is adjusted for induced traffic effects.

3.2 European evidence

A procedure for assessing the road decongestion benefits arising from the reduction in car traffic was developed by the UK Department of Transport (2007). This study valued the decongestion benefit as the savings of travel time and other externalities due to the removal of a vehicle kilometre of car travel from a road. The marginal external costs for cars were considered as the decongestion benefits. Decongestion benefits were estimated for “A” (or major) Roads as 53.4 pence (UK£, 2007) per km (including travel time and vehicle operating costs) and 98.4 pence (UK£, 2007) per vehicle-kilometre (including travel time penalty, vehicle operating costs and other externalities such as accidents, noise, infrastructure damage, local air quality and greenhouse gases).

According to Sansom *et al*. (2001), the congestion benefits of ‘major-rail based urban public transport’ per car-kilometre removed from the road network range from 12.7 to 50.8 pence per PCU-km (in 1998 prices; PCU = passenger car unit).

Newbery (1990) estimated congestion costs for Britain by using values from the marginal congestion cost associated with traffic speed-flow relationships. Marginal congestion cost estimates ranged from 0.26 p/PCU-km for motorways to 36.37 pence per PCU-km (UK£, 1990) for urban central peak roads.

Lobé (2002) estimated the congested costs of Brussels by using STRATEC demand models. The model estimated a marginal congestion cost (i.e. the benefits of removing a marginal vehicle from the traffic stream) of 0.09 € per PCU-km.

3.3 North American evidence

Research estimating congestion reduction benefits from reduced vehicle traffic by Litman (2003, 2006) reviewed several measurement methods and proposed an “easier approach”. The approach is to assign a monetary value to reduced vehicle travel, typically estimated at 10-30 cents ($US, 1996) per urban peak vehicle-mile, for calculating congestion reduction benefits. Skolnik and Schreiner (1998*)* used the midpoint of Litman’s value (20 cents) for congestion benefit calculation of public transport.

Marginal costs of roadway use studied by FHWA (2000) reflect the changes in total costs associated with an additional increment of travel. The study estimated the congestion costs associated with an additional mile of travel on an urban interstate highway for passenger vehicles as 7.7 cents (i.e. 4.8 cents per kilometre) (US$, 2000).

4 Synthesis of congestion relief values

Table 3 summarises the evidence presented above. Results have been standardised to comparable terms by adjusting for currency (to Australian Dollars) and year of estimate (using Australian CPI indices). Standardised value show a considerable range. Congestion impacts per reduced car km range between 4.4 and 151.4 cents with an average of 46.2 cents. The highest valuations are associated with “A” roads in Greater London and also for “heavy congestion” in the Melbourne, Australia context. In both these cases travel time and vehicle operating cost impacts have been considered. The lower valuations of congestion relief impacts are associated with Christchurch, UK motorways and non-major roads of small urban areas, and USA urban interstate highways. One possible explanation for low congestion relief benefit values for small urban areas is that they witness relatively low volume of traffic in comparison to their big counterparts and hence, the unit congestion relief benefits are less. UK motorways and USA urban interstate highways having relatively big capacity compared to roads in urban cental areas witness less congestion and therefore unit congestion relief benefits are small.

Figure 1 illustrates the average decongestion value assuming a linear relationship with public transport supply (measured here as the number vehicle-kilometres removed). The figure is the linear interpolation of the average decongestion value (42.6 cents) of Table 3.

Table 3 – Summary of decongestion benefit rates (values per km of reduced auto travel)

City / Country		*Original value per auto vehicle-km*	*Original year*	*Standardised value in Australian cents (2008 rate)**	*Source*	*Comments*
Melbourne	Heavy congestion	A90.0¢		100.8		Includes both travel time (TT) and vehicle operating costs (VOC) benefits
	Moderate congestion	A64.0¢		71.7		
	Light congestion	A17.0¢	2004	19.0	ATC (2006)	
Sydney		A30.5¢	2007	31.4	Karpouzis *et al*. (2007)	Includes both TT and VOC benefits
Sydney and other metropolitan areas		A28.0¢	2001	33.9	Thornton (2001)	Includes both TT and VOC benefits
Auckland		NZ59.5¢		62.2		
Wellington		NZ45.6¢		47.6		
Christchurch		NZ 4.21¢	2002	4.4	LTNZ (2005)	Includes TT benefit only
Urban conurbations	Motorways	UK 5.7p		16.2		
	A roads	UK 53.4p		151.4		
	Other roads	UK 26.2p		74.3		
Other urban areas	A roads	UK 22.2p		62.9		
	Other roads	UK 5.6p	2002	15.9	Department for Transport (2002)	Includes both TT and VOC benefits
Brussels		0.09€	2002	17.6	Pascale (2002)	Includes TT benefit only
USA		US 4.8¢	2000	8.0	FHWA (2000)	Includes TT benefit only
USA		US 12.4¢	1996	21.8	Litman (2003, 2006)	Includes both TT and VOC benefits (average urban peak)
Average				46.2		

* *The values of other currencies were converted to Australian cents by using the average of last 5 years' exchange rate of Reserve Bank of Australia (2008) and all values were converted to 2008 terms using consumer price index of Australian Bureau of Statistics (2008).*

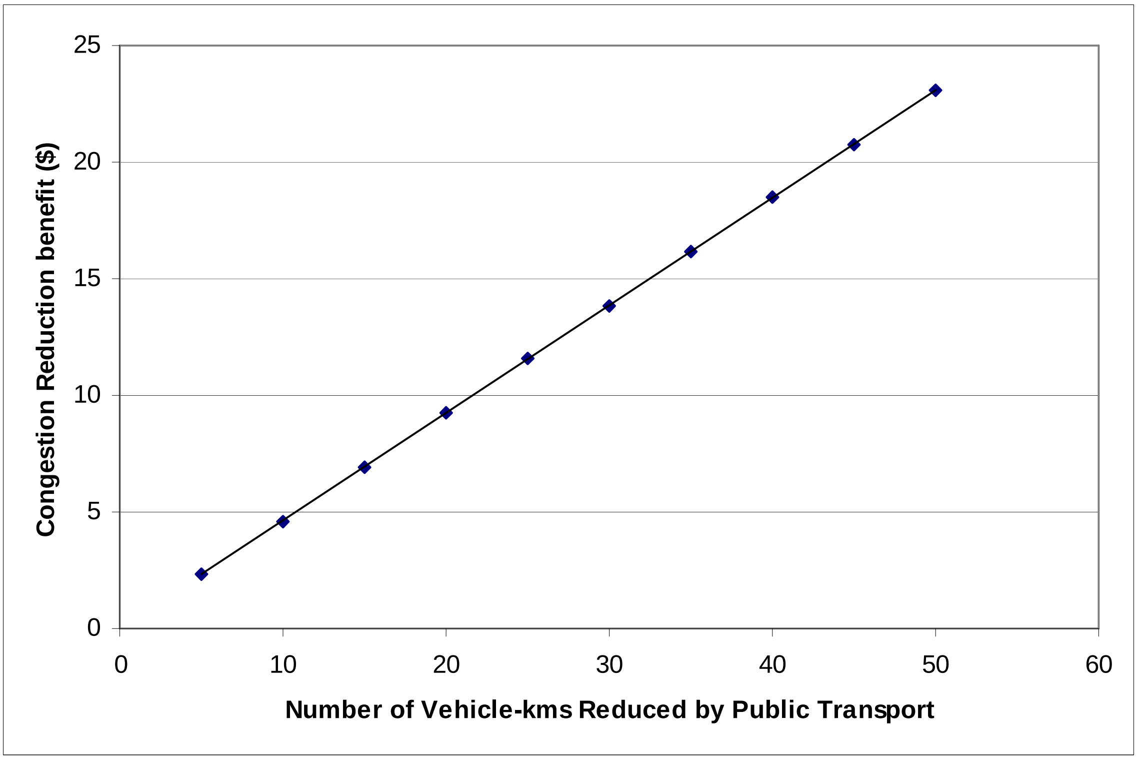

Figure 1 – Congestion reduction benefit resulting from reduction of vehicle kilometres travelled due to public transport

5 Travel mode shift evidence

This section examines revealed and stated evidence where travel behaviour acted to change urban traffic congestion in relation to public transport. Its aim is to establish evidence which might better inform the assessment of congestion relief impacts.

5.1 Removing public transport

This section considers cases where public transport systems have been removed.

Exel and Rietveld (2001) reviewed 13 studies of PT strikes to determine nature and size of travel impacts. Their study showed that most travellers switch to the car either as driver or passenger (Table 4). Other travellers switch to alternative modes and some trips are cancelled. Mode shift to car driving was 5% to 50% (average 28.6%), mode shift to car lift was 21% to 60% (average 29.6%), shift to other modes was 23% to 60% (average 39.8%) and trip suppression (stop travelling) was between 5% and 15% (average 10.3%).

Table 4 – Effects of public transport strikes

Strike	*Year*	*Spatial scale*	*PT modes*	*Trips switched to car*		*Trips switched to other alternatives*	*Trips cancelled*
				Driver	*Pax*		
New York	1966	Urban	All	50%	17%	23%	10%
Los Angeles	1974	Regional	Bus	50%	25%	—	—
Leeds	1978	Urban	All	5%	60%	35%	15%
The Hague	1981	Urban	All	10%	25%	50%	5%
Ile-de-France	1995	Regional	All	28%	21%	51%	11%
Average				**28.6%**	**29.6%**	**39.8%**	**10.3%**

Source: Exel and Rietveld (2001)

In a study examining the choices which public transport riders might make HLB Decision Economics (2003) conducted a survey in Wisconsin, USA. Each individual was asked to indicate how their travel would differ if they did not have access to public transport. The study shows that about 50% public transport users would make trips via an alternative transport mode. Of these, car or taxi would be the likely mode for about sixty percent. Table 5, Table 6 and Table 7 summarise the important elements of the study. The likely mode shift to car driving varied from 7% to 11% (average 9.8%), mode shift to car/taxi riding as passengers varied from 13% to 19% (average 17.6%), using walking, cycling and other modes varied from 12% to 18% (average 16.7%).

Table 5 – Choices if public transport withdrawn- commuters

Not able to work	18.5%
Look for another job (closer to home)	22.2%
Adjust work hours	4.9%
Work at home	3.4%
Use another means of transport	48.0%
Other	3.0%

Source: HLB Decision Economics (2003)

Table 6 – Alternative transport modes for those individuals who responded they would make the same trip via an alternative mode (for work purpose riders)

Drive a personal vehicle	22.2%
Ride with family or friends	27.9%
Use a taxi-cab or other share ride	12.1%
Ride a bicycle	15.0%
Walk	19.9%
Other	2.8%

Source: HLB Decision Economics (2003)

Table 7 – Alternative transport modes for those individuals who responded they would make the same trip via an alternative mode (for riders of various journey purposes)

Journey purpose	*Use other means of transport*	*Driving car*	*Sharing car/taxi*	*Walking, cycling and other*
Work	48.0%	10.7%	19.2%	18.1%
Education	48.0%	10.7%	19.2%	18.1%
Healthcare	47.5%	10.5%	19.0%	18.0%
Shopping and recreation	32.7%	7.3%	13.1%	12.3%
Average		9.8%	17.6%	16.7%

Source: HLB Decision Economics (2003)

These studies demonstrate a range of variation in mode change behaviour if public transport is no longer supplied. Mode shift for car drivers ranged from 5% to 50% (average 20.2%) and mode shift for car passengers ranged from 13% to 60% (average 24.3%) (Table 8).

Table 8 – Summary of mode shift for car drivers and passengers

Source	*Mode shift (car drivers)*		*Mode shift (car passenger)*	
	Range	*Average*	*Range*	*Average*
Exel and Rietveld (2001)	5%-50%	28.6%	21%-60%	29.6%
HLB Decision Economics (2003)	7%-11%	9.8%	13%-19%	17.6%
Average[1]		20.2%		24.3%

1- Average of values appearing in Table 4 and Table 7

Litman (2006) noted specific subsets of passengers who might decide to get a lift by car:

- one group rideshares (additional passengers in a vehicle making a trip anyway)
- the other group chauffeurs (additional auto travel specifically to carry a passenger).

Litman suggested that motorists can spend a significant amount of time chauffeuring children to school and sports activities, family members to jobs, and elderly relatives on errands. Such trips can be particularly inefficient if they require drivers to make an empty return trip. Hence while ex-public transport users who drive a car clearly have a direct impact on congestion, those getting lifts may also impact congestion if chauffeuring acts to also increase car travel.

Overall this analysis suggests that removing public transport can result in increased traffic congestion of about a shift of 20.2% (Table 8) of public transport to car driving. However the work of Litman also suggests that ex-public transport users might also generate extra car travel in the form of chauffeuring trips. There is little data available on how many ex-PT users in this context might be involved in chauffeuring trips. For the purpose of our modelling analysis we assumed half of all trips transferring to a lift in a car might involve chauffeuring. Hence on average based on the results in Table 8 an estimate of 32.4% (20.2% car drivers + half of 24.3% car passengers as chauffeuring travellers) PT users might on average act to increase auto travel if public transport were removed. But the interpretation should be used cautiously as the proposed value is an average of a wide range of values from different cities of the world and the methodologies for obtaining these values are different. In addition, public transport strikes manifest short-term effects. In the long-term, the estimated percentage might be higher because people will adjust their travel behaviour to cope with the changed situation (such as trip re-timing, trip redistribution, changes of O-D pattern and travel behaviour).

5.2 Improving public transport

This section considers evidence of mode shift associated with improvements in public transport.

Anlezark *et al*. (1994) examined mode shift outcomes resulting from the introduction of new Transit Link (express bus services) in Adelaide Australia. They also compiled evidence from other new public transport initiatives (Table 9). They report that about 20% of users are new to public transport and of these the highest proportion are formerly car drivers. Mode shift from car drivers was from 8% to 23% (average 14.1%), mode shift from car passengers was from 1% to 12% (average 5.7%), trip generation was from 8% to 12% (average 9.8%) and diversion from existing public transport was between 64% and 78% (average 68.5%).

Table 9 – Comparison of mode change behaviour after the introduction of new public transport services.

	Source of Demand				
	Mode Shift				
New Service	*Car driver*	*Car pax*	*Generation*	*Diversion from PT*	*Redistribution*
Adelaide-Express Bus	8.4%	4.4%	8%	78%	1%
Adelaide-Obahn Busway	13.3%	5.7%	9%	67%	0%
Brisbase Cityxpress	11.6%	11.6%	12%	65%	0%
Perth Northern Railway	23.0%	1.1%	10%	64%	1%
Average	**14.1%**	**5.7%**	**9.8%**	**68.5%**	

Source: Anlezark et al. (1994)

A review of performance of Bus Rapid Transit (BRT) in Australasia by Currie (2006) reveals that introduction of BRT played a significant role in changing travel behaviour (Table 10). The percentage of BRT passengers who were previously driving is high in Adelaide (40%). Mode shift from car drivers was from 5% to 16% (average 11.9%).

Table 10 – Travel market data for Australasian BRT systems

	Immediate Travel Impacts		
	Direct corridor ridership growth	*% new pax who previously drove*	*% who previously drove as a total of all riders*
Adelaide Busway	24%	40%	16%
Sydney Transitway	56% (47% new journeys)	9%	5%
Brisbane SE Busway	56% (17% new journeys)	26%	15%
Average			**11.9%**

Source: Currie (2005)

A number of studies have sought to understand mode shift impacts from fare reduction and service increase policies in the USA (Bates, 1974; Weary *et al*., 1974 cited in McCollom and Pratt, 2004). These studies show diversion from auto ranging from 64% of new riders in Atlanta to 80% of new riders in Los Angeles. The full range of previous modes of travel is shown in Table 11. Mode shift for car drivers was from 42% to 59% (average 50.5%), mode shift for car passengers was from 21% to 22% (average 21.5%)

Table 11 – Prior mode for new public transport riders- fare reduction and service improvement

Location	*Prior Mode*					*Source (cited in McCollom and Pratt, 2004)*
	Driver	*Passenger*	*Walk*	*Other*	*Trip Not Made*	
Atlanta	42%	22%	4%	10%	22%	Bates (1974)
Los Angeles	59%	21%		10%	10%	Weary, Kenan and Eoff (1974)
Average	50.5%	21.5%				

Source: McCollom and Pratt (2004)

Overall, mode shift for car drivers ranged from 5% to 59% (average 21.4%) and mode shift for car passengers ranged from 1% to 22% (average 11.0%) (Table 12). Passengers who change mode from car driving to transit act to reduce traffic congestion. Considering the view of Litman (2006) that chauffeuring trips act to increase car travel it can be assumed that travel shifting from a car lift trip to transit would also reduce car travel. The data suggests that 26.9% (21.4% car drivers + half of 11.0% car passengers as chauffeuring travellers) of travellers on new public transport services might have acted to reduce road travel (Table 12). This is lower than the impact suggested for removing public transport (32.4%, see section 5.1). Withdrawal of PT means users have no choice but to make a change in behaviour. Improvements leave an element of user choice in deciding travel options and will largely depend in scale on the size of improvements being made.

Table 12 – Summary of mode shift for car drivers and passengers

Source	*Mode shift (car drivers)*		*Mode shift (car passenger)*	
	Range	*Average*	*Range*	*Average*
Anlezark *et al*. (1994)	8%-23%	14.1%	1%-12%	5.7%
Currie (2005)	5%-15%	11.9%	—[3]	—[3]
McCollom and Pratt (2004)	42%-59%	50.5%	21%-22%	21.5%
Average[2]		21.4%		11.0%

2- Average of values appeared in Table 9, Table 10 and Table 11
3- Data unavailable

Figure 2 illustrates the relationship between mode shift to/from auto trips and the removal or improvement for public transport assuming a linear relationship between them. The figure is the linear interpolation of 32.4% (mode shift to car traffic due to removal of public transport) and 26.9% (mode shift to public transport due to improvement of PT). As suggested removal of transit has a higher impact than improvements.

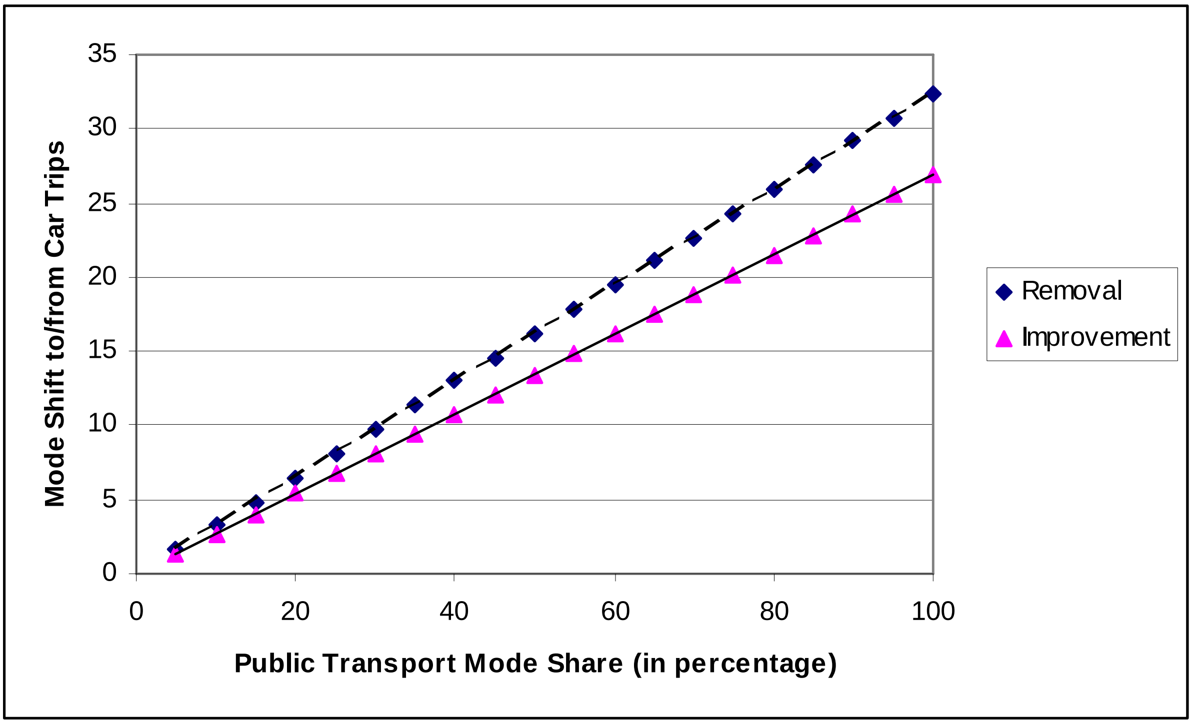

Figure 2 – Relationship between mode shift to/from car and public transport mode share

6 Application for a hypothetical city

This section models the congestion relief benefits of public transport for a hypothetical city by applying the evidence assembled in the previous sections. The aim is to present a simple illustration of the findings of the review by applying parameters to a hypothetical city. The performance of public transport to relieve traffic congestion depends on many city and transport variables such as population, trip rate, mode share, average trip distance, city size and density, land use, development patterns, topography, the roadway network and public transport system, existing levels of congestion, socio-economic status of users and non-users, overall travel patter and telecommuting, peak spreading and so on. Each of those variables can be viewed as a dimension of a hyper-cube. If the impacts of those variables are to be considered, it is necessary to specify values for numerous combinations of those variables. The six parameters for this model are selected to demonstrate a practical method with easily available data for most cities. A simple model is proposed of the following form:

$$DCB_{PT} = P \times TR \times PT \times D \times MS \times DB \quad \text{Equation (1)}$$

where:

- DCB_{PT} = Daily decongestion benefit of public transport in a city.
- P = population
- TR = average trip rate (trips per person per day)
- PT = public transport mode share
- D = average trip distance
- MS = percentage of mode shift (additional auto travel for removal of PT)
- DB = unit value of decongestion benefits

The above model considers one to one relationship between decongestion benefit and other variables. A better functional form (Formula 2) would have been proposed if proper elasticity values (α's) could have been added to Equation 1. Since appropriate elasticity values are unknown, considering them unity, Equation 2 takes the form of Equation 1.

$$DCB_{PT} = \alpha_0 \times P^{\alpha_1} \times TR^{\alpha_2} \times PT^{\alpha_3} \times D^{\alpha_4} \times MS^{\alpha_5} \times DB^{\alpha_6} \quad \text{Equation (2)}$$

Modelling with Equation 1 considers the cost impacts of removing public transport for the hypothetical city. Key parameters include:

- The mode shift impacts of removing public transport. In this case we have assumed the average of the evidence presented in section 5.1 i.e. an estimate of 32.4% of PT travel would end up using roads (including 20.2% car drivers + half of 24.3% car passengers as chauffeuring travellers).
- The unit value of congestion costs. In this case we have assumed 46.2c per additional vehicle km based on the average of the analysis in section 4.

The following assumptions are made about the demographic and transport characteristics for the hypothetical city.

- The population of the city is one million
- The average trip rate is 3.0 trips per person per day
- The public transport mode share is 10 percent
- The average trip distance is 10 km (it is assumed that trip distance remains unchanged when mode shift occurs between auto and public transport).

Using Equation 1 the congestion relief benefits of public transport are estimated as follows:

1,000,000 × 3.0 × 0.10 × 10 × 0.324 × \$0.462 = \$449,064

Figure 3 and Figure 4 illustrate how the outcome measures vary with population and PT mode share.

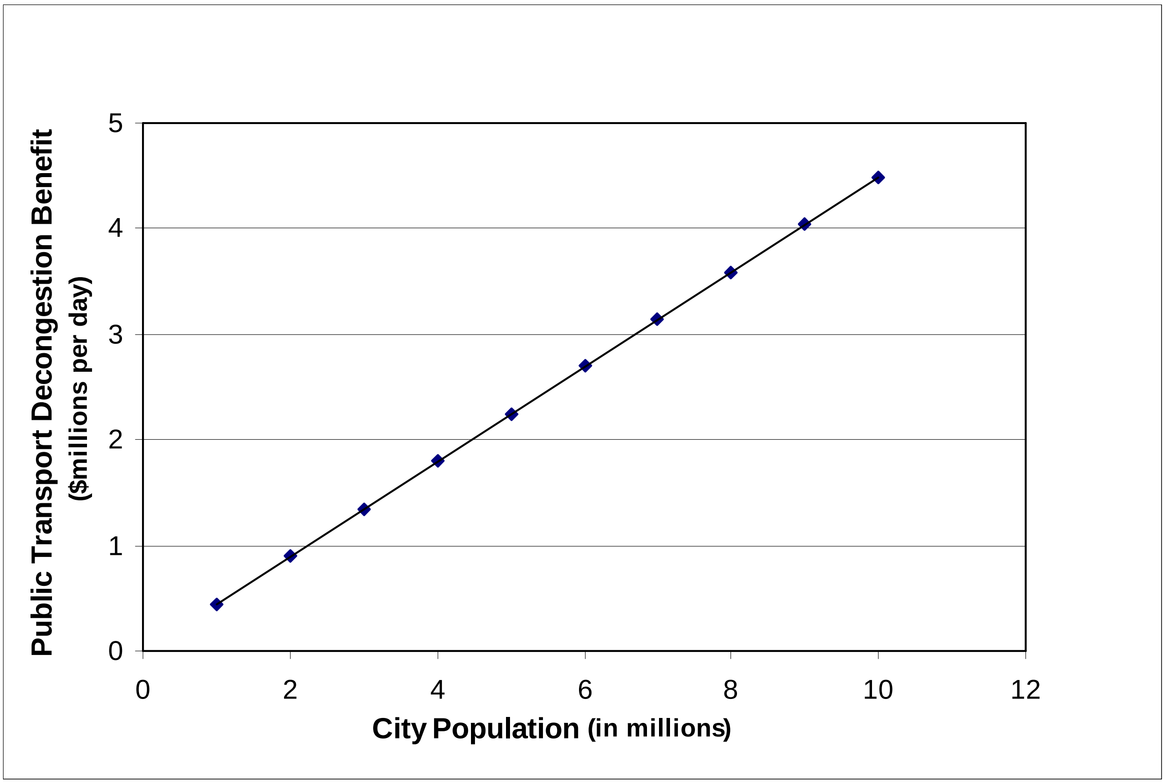

Figure 3 – The relationship between public transport congestion relief benefit and the city population size.

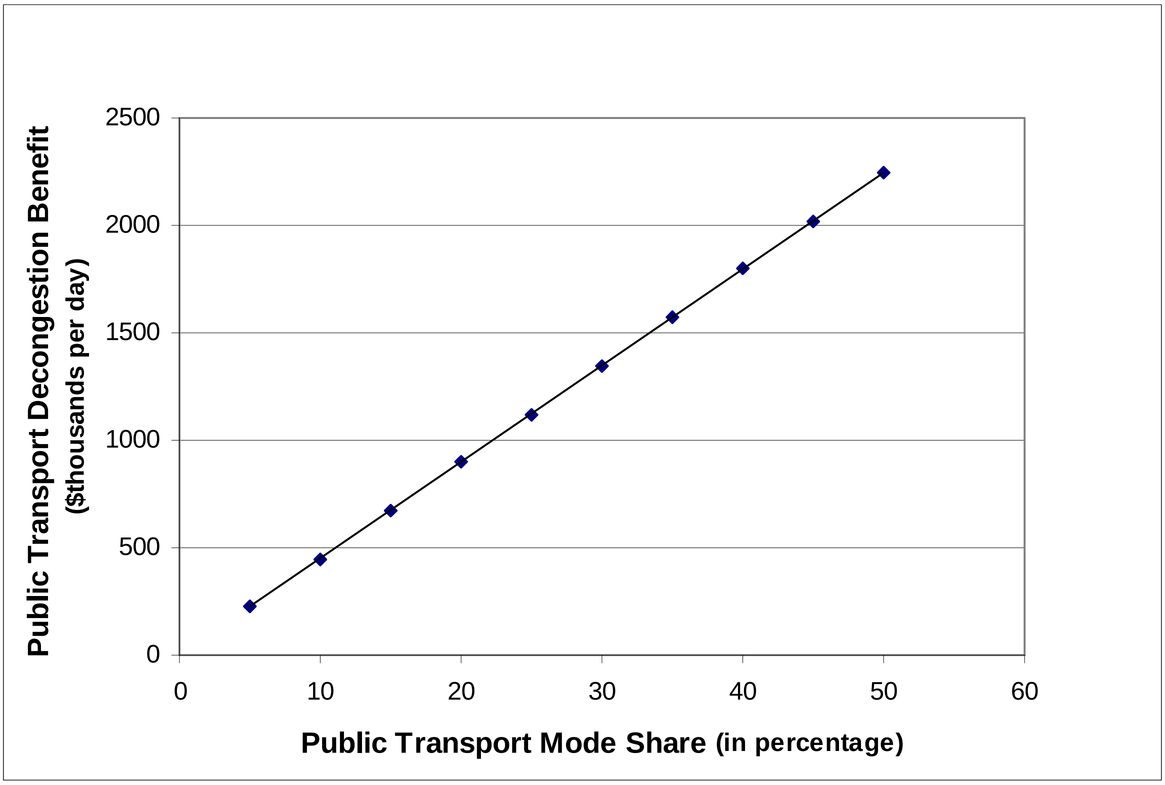

Figure 4 – The relationship between public transport congestion relief benefit and the public transport mode share.

7 Conclusion

The paper has presented a comparative assessment of international research valuing the congestion relief benefits of public transport. It has also explored previous research methodologies evaluating congestion relief impacts and examined secondary evidence demonstrating changes in mode split associated with changes in public transport.

Congestion relief impacts are valued at between 4.4 and 151.4 cents (Australian, 2008) per marginal vehicle km of travel with an average of 46.2 cents. Valuations are higher for circumstances with greater degrees of traffic congestion and also where both travel time and vehicle operating cost savings are considered.

Mode shift evidence suggests on average some 21% of PT trips might be attracted to PT from car drivers (or could be returned to car driving if PT were removed). On average around 11% of passengers getting lift have been encouraged onto PT (or might return to getting a lift if PT were removed).

A simple model is presented to value the congestion relief benefits of PT based on population, trip rate, distance travelled and mode share. Using the average congestion valuation and mode shift evidence this has been applied to a hypothetical city to demonstrate how congestion relief impacts might vary with city size and mode shift.

A range of areas for further analysis are suggested by the research:

- A linear relationship between the unit benefit of congestion reduction and the number of users has been assumed but in reality, the unit congestion unit is expected to vary at different level of number of users.
- A simple methodology has been demonstrated using the data of a hypothetical city, further application using actual data from a range of metropolitan areas is needed to understand a congestion relief value of public transport.
- The values shown in this paper for the effects of PT removal /improvement are short-term in nature and further research can be carried out to distinguish between the short-term and long-term effects.
- The paper does not consider the effects of land use change, existing levels of congestion, socio-economic status of users and non-users, overall travel patter and telecommuting, peak spreading and other related issues. The model in section 6 can be extended by including the effects of these variables.

Overall the analysis presents a simplified method to investigate the impact of public transport on traffic congestion. Further research is warranted to develop a comprehensive approach for understanding the congestion relief impacts of public transport.

Acknowledgement

The authors would like to thank the reviewers of an earlier version of the paper for their useful comments and criticisms

References

Anlezark, A., Crouch, B. and Currie, G.V. (1994). *Trade-offs in the redesign of public transport networks, line haul, express and transit link service patterns*, 19th Australian Transportation Research Forum, pp. 261-279: Melbourne.

ABS (2008). *Consumer Price Index*, Cat. No. 6401.0. Australian Bureau of Statistics: Canberra. <http://www.abs.gov.au/AUSSTATS/abs@.nsf/mf/6401.0>.

ATC (2006). *National guidelines for transport system management in Australia: Urban transport*, Vol. 4, Australian Transport Council: Canberra.

Beimborn, E., Horowitz, A., Schuetz, J. and Zejun, G. (1993). *Measurement of transit benefits*, prepared by the Center for Urban Transportation Studies, University of Wisconsin-Milwaukee, for Federal Transit Administration: Washington, DC, USA.

Black, A. (1995). *Urban mass transportation planning*, McGraw Hill: New York.

Cambridge Systematics Inc. and Apogee Research Inc. (1996), *Measuring and valuing transit benefits and disbenefits*, TCRP Report 20, Transportation Research Board, Washington, DC, USA.

Cervero, R. (1998). *The transit metropolis: a global inquiry.* Island Press: Washington, DC, USA.

Currie, G. (2006). 'Bus rapid transit in Australasia: Performance, lessons learned and futures', *Journal of Public Transportation,* Special Edition: BRT, 9(3), pp. 1-22.

Department for Transport (2007). *Transport analysis guidance-Unit 3.9.5: MSA major schemes appraisal road decongestion benefits,* Department for Transport: London, UK.

Douglas, N. (1993). *Travel demand, economic growth and transport infrastructure in rapidly growing economics*, 18th Australasian Transport Research Forum, pp. 623-636.

Downs, A. (1992). *Stuck in traffic: coping with peak-hour traffic congestion*, The Brookings Institution: Washington, DC, USA.

ECONorthwest and PBQD (2002). *Estimating the benefits and costs of public transport projects: a guidebook for practitioners*, TCRP Report 78, Transportation Research Board, Washington, DC, USA.

Exel, N. J. A. V. and Rietveld, P. (2001). 'Public transport strikes and traveller behaviours', *Transport Policy*, 7(3), pp. 227-246.

FHWA (2000). *Addendum to the 1997 federal highway cost allocation study*, Final Report, Federal Highway Administration, Washington, DC, USA.

HLB Decision Economics Inc. (2003). *The socio-economic benefit of transit in Wisconsin*, Final Report No. 0092-03-07, Wisconsin Department of Transportation: WI, USA.

Hyman, G. and Mayhew, L. (2002). 'Optimizing the benefits of urban road user charging', *Transport Policy*, 9(3), pp. 189-207.

Karpouzis, G., Rahman, A., Tandy, K. and Taylor, C. (2007). *Value of CityRail to the community of New South Wales*, 30th Australasian Transport Research Forum, Melbourne, 25-27 September.

Litman, T. (2003). *Transportation cost and benefit analysis guidebook– congestion costs*, Victoria Transport Policy Institute: Victoria, BC, Canada.

Litman, T. (2006). *Rail transit in America: a comprehensive evaluation of benefits*, Victoria Transport Policy Institute: Victoria, BC, Canada.

LTNZ (2005). *Economic evaluation manual*, Vol. 2, Land Transport NZ, Wellington.

McCollom, B. E. and Pratt (2004). *Traveller response to transportation system changes: Chapter 12- transit pricing and fares*, TCRP Report 95, Transportation Research Board, Washington, DC, USA.

Nelson, P., Baglino, A., Harrington, W., Safirova, E., and Lipman, A. (2006). *Transit in Washington, DC: Current benefits and optimal level of provision*, Discussion Paper, RFF DP 06-21, Resource for the Future, Washington, DC, USA.

Newbery, D.M. (1990). 'Pricing and congestion: economic principles relevant to pricing roads', *Oxford Review of Economic Policy*, 6(2), pp. 22-38.

Lobé, P. (2002). *UNITE: Case Studies 7E – Brussels Urban Transport*, prepared by ITS, University of Leeds, for UNITE (UNIfication of accounts and marginal costs for Transport Efficiency) Working Funded by 5th RTD Program: Brussels.

Pucher, J., Peng, Z., Mittal, N., Zhu, Y. and Korattyswaroopam, N. (2007). 'Urban transport trends and policies in China and India: impacts of rapid economic growth', *Transport Reviews*, 27(4), pp. 379-410.

Pushkarev, B. and Zupan, J.M. (1977). *Public transportation and land use policy*, Indiana University Press: Bloomington.

RBA (2008). *Historical exchange rates.* Reserve Bank of Australia: Sydney. <http://www.rba.gov.au/Statistics/HistoricalExchangeRates/index.html>.

Sansom, T., Nash, C., Mackie, P., Shires, J. and Watkiss, P. (2001). *Surface transport costs and charges: Great Britain 1998*, prepared by Institute of Transport Studies, University of Leeds, for the UK Department of the Environment, Transport and the Regions (DETR): London, UK.

Schrank, D. and Lomax, T. (2005). *The 2005 Annual Urban Mobility Report*, Texas Transportation Institute, Texas A&M University: College Park, TX, USA.

Skolnik, J. and Schreiner, R. (1998). 'Benefits of transit in small urban areas: a case study', *Transportation Research Record*, 1623, pp. 47-56.

Thornton, P.B. (2001). *East coast high speed train scoping study, Phase 1- Preliminary study*, Final report, Prepared by ARUP and TMG International Pty Ltd, for Department of Infrastructure, Transport, Regional Development and Local Government: Canberra.

Vuchic, V. R. (1999). *Transportation for livable cities*, Rutgers Center for Urban Policy Research, New Brunswick: New Jersey, USA.

Weisbrod, G., Vary, D. and Treyz, G. (2001). *Economic Implications of congestion*, NCHRP Report 463, Transportation Research Board, Washington, DC, USA.