

A new approach to evaluating on-road public transport priority projects: balancing the demand for limited road-space

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Abstract Despite widespread growth in on-road public transport priority schemes, road management authorities have few tools to evaluate the impacts of these schemes on all road users. This paper describes a methodology developed in Melbourne, Australia to assist the road management authority, VicRoads, evaluate trade-offs in the use of its limited road-space for new bus and tram priority projects. The approach employs traffic micro-simulation modelling to assess road-space reallocation impacts, travel behaviour modelling to assess changes in travel patterns and a social cost benefit framework to evaluate impacts. The evaluation considers a comprehensive range of impacts including the environmental benefits of improved public transport services. Impacts on public transport reliability improvements are also considered. Although improved bus and tram reliability is a major rationale for traffic priority its use in previous evaluations is rare. The paper critiques previous approaches, describes the proposed method and explores some of the results found in its application. A major finding is that despite a more comprehensive approach to measuring the benefits of bus and tram priority, road-space reallocation is difficult to economically justify in road networks where public transport usage is low and car usage high. Strategies involving the balanced deployment of bus and tram priority measures where the allocation of time and space to PT minimises negative traffic impacts is shown to improve the overall management of road-space. A discussion of the approach is also provided including suggestions for further methodology development.

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Abbreviations

DETR	The Department of Environment Transport and the Regions
IVT	in-vehicle travel time
NPV	net present value
PT	public transport
TGC	total generalised cost
VPH	vehicles per hour
WT	wait time

1 Introduction

Road-space management involves balancing often conflicting pressures for limited space and time. The reallocation of road-space (and time) to give priority to bus and tram services is one of many of these pressures. In cities where public transport (PT) use is high, the case for priority is relatively easy to justify. However deciding the extent of priority to give is not so simple. In cities where PT use is low but where road traffic levels are high, economic justification for PT priority is less clear. Although promoters of PT priority highlight wider environmental, efficiency and reliability improvements, road-space managers are often faced with the realities of a finite resource, high car usage and low PT use.

Road management authorities have a difficult trade-off to make between competing demands. They must understand the complex space/time vehicle and passenger flow implications of changing the road environment whilst also valuing the transport and wider environmental impacts of these changes.

This paper describes a methodology developed in Melbourne, Australia to assist the road management authority VicRoads make these difficult trade-offs (Currie et al. 2004a). A critique of previous approaches is presented and the new methodology detailed. Some example results are described and research findings outlined. A discussion of the approach in its current form is also presented and areas for further improvement identified.

2 A critique of previous approaches

2.1 Limited evaluation criteria

Table 1 presents a summary of the evaluation criteria included in key research papers in this area. Most research has focussed on travel time impacts for road and PT users often to the exclusion of all other types of impacts. Vuchic (1981) considered the relative person carrying abilities of bus vs car traffic per lane as a basis to justify exclusive use of a traffic lane by bus. No travel time or resource implications were considered. Radwan and Benevelli (1983) recognised that building bus priority schemes costs money and that an evaluation should also consider the financial

Table 1 Assessment of public transport priority research

	Research Reference						
	Vuchic 1981	Black et al. 1992	Jepson and Ferreira 1999	Radwan and Benevelli 1983	Oldfield et al. 1977	Delgoffe 1973	UK Dept. of Environ. Transport & Regions 1997
<i>Evaluation criteria</i>							
Relative People carriage per lane	✓	-	-	-	-	-	-
Travel Time Impact	×	✓	✓	✓	✓	✓	✓
<i>Resource Impact</i>							
Fuel Costs	×	×	×	✓	✓	✓	✓
Capital Costs	×	×	×	✓	×	×	✓
Maintenance Costs	×	×	×	✓	×	×	✓
Transit Fleet and Crew Costs	×	×	×	×	×	×	✓
Construction Impacts	×	×	×	×	×	×	✓
Accident Cost Impacts	×	×	×	×	×	×	✓
Environmental Impacts	×	×	×	×	×	×	✓ (a)
PT Reliability Impacts	×	×	×	×	×	×	✓
Patronage Growth	×	×	×	×	×	×	✓
<i>Modelling approach</i>							
Traffic flow modelling	✓	-	-	-	-	-	-
No Direct Consideration of Traffic Impacts	-	-	-	-	-	-	✓
No Specific Model Adopted	-	-	-	-	✓	✓	-
Standard Static Analytical or Mathematical Model	-	✓	-	-	-	-	-
Dynamic Traffic Simulation Modelling Used	-	-	✓	✓	-	-	-
Travel Behaviour Modelling							
Speed Flow Capacity Analysis	×	✓	✓	✓	✓	✓	✓
Traffic Route Diversion Considered	×	×	×	×	✓	✓	✓
Mode Shift Considered	×	×	×	×	✓	✓	✓
Trip Generation Considered	×	×	×	×	×	×	✓
Disappearing Traffic Considered	×	×	×	×	×	×	✓

Key: ✓ = Included, × = Not Included, - = Not Relevant
 Note: (a) Environmental impacts considered but not part of the quantitative evaluation

implications of investment. They also examined fuel cost implications, a feature of other approaches (e.g. Oldfield et al. 1977).

Most research papers omit consideration of the full range of potential resource implications of bus priority. Priority can result in reductions to bus and tram running times which will reduce bus fleet and crew resource requirements. Patronage growth resulting from travel time and reliability improvements have also been reported (e.g. Balcombe et al. 2004, p. 159). However these benefits are rarely considered in the evaluation approaches used in the literature.

Oldfield et al. (1977) noted that no consideration was given to impacts on bus service reliability in their approach, although this was considered to be a benefit of bus priority schemes. DETR (1997) expands on this theme; “Improved reliability is often seen as a major benefit of bus priority measures, and an invaluable factor in the attempt to persuade more people to switch from their cars”. However reliability is rarely included in evaluation approaches in this area.

The most comprehensive approach is that taken by the DETR (1997) in its guidelines for traffic management for buses. While these guidelines are certainly comprehensive they do not expand in detail about how measurement of these criteria may be undertaken.

2.2 Simplistic traffic flow modelling

Traffic flow modelling was either not considered or was undertaken using analytical or algebraic modelling in earlier studies (Table 1). DETR (1997) mention the use of both analytical and dynamic traffic simulation models but don't recommend any particular system. Rather they point out the high costs associated with modelling and recommend modelling for only higher cost schemes.

Jepson and Ferreira (1999) use a semi-dynamic traffic flow model (SIDRA and TRANSYT) to assess the impacts of treatments such as active traffic light priority. A dynamic traffic flow simulation model was also used by Radwan and Benevelli (1983). They used NETSIM to compare the costs and benefits of bus traffic signal preemption systems on traffic flow.

The traffic flow impacts of priority schemes clearly lend themselves to dynamic simulation modelling approaches. There is considerable variability in traffic flow in space and time and trying to represent these in a complex traffic system is difficult using an analytical or stochastic approach.

2.3 Limited travel behaviour modelling

Almost all research approaches considered the speed flow impacts of changes in road capacity as the main form of travel behaviour to be represented (Table 1). Wider travel behaviour impacts are rarely considered. Traffic diversion as a result of reduced road capacity was considered in some models. Mode shift to PT or bus trip generation resulting from benefits to PT are only mentioned by DETR (1997). However even this reference does not describe how these behaviours may be modelled.

Disappearing traffic is a global term used to describe situations where traffic volumes often reduce when road capacity is restricted (Cairns et al. 2002). The resulting lower traffic volumes can negate potential traffic congestion impacts of reduced road capacity. The effect is caused by a mix of mode shift, trip diversion, trip re-timing, trip re-distribution and trip suppression. The absence of the

representation of ‘disappearing traffic’ in the PT priority evaluation is not surprising given the relatively recent nature of research developments in this area (and any associated modelling of these).

Overall we conclude that the research approaches to date have been limited. Improvements were a central focus for methodology development.

3 Methodology

In outline the methodology involves the use of dynamic traffic micro-simulation model to represent vehicle flow impacts. Vehicle flow impacts of priority schemes are then input to a travel behaviour model. Results are fed into an economic evaluation framework including a wide range of evaluation criteria.

Figure 1 shows an outline of the evaluation framework and criteria used in assessing the impacts of improved re-allocation of road space for PT priority. The micro-simulation produces travel time and reliability information for all road users which are input to the evaluation. Travel time and reliability outputs are then used in the assessment of PT operating resource impacts and to the modelling of patronage impacts. The criteria included in the economic evaluation are all indicated as dot points in Fig. 1. The approach to their measurement is now described.

3.1 Travel time impacts

Travel time impacts are measured for both PT and auto travellers based on the in-vehicle travel times output from the micro-simulation model. The Paramics (Quandstone 2000) micro-simulation system is used to generate these impacts.

3.2 Reliability impacts

Reliability impacts are measured in two ways:

- Impacts on in-vehicle travel (IVT) time for auto and PT users
- Impacts on unexpected wait time (WT) at stops for PT users

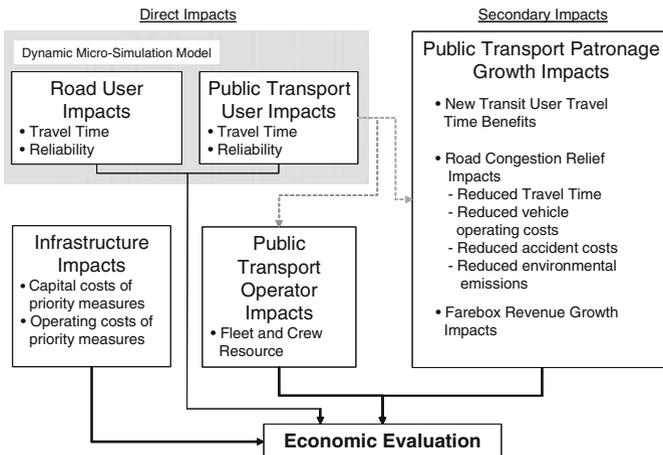


Fig. 1 Evaluation Framework and Criteria

In both cases it is the late aspect of unreliable service, which is measured as part of the evaluation. This is the element valued more highly in previous research (Abkowitz 1981). Early arrivals are also omitted in the evaluation because a standard bus operator response would be to retime schedules or to extend waiting time at timing points to avoid early running.

For IVT time the average amount of late arrival time experienced on the road network is measured as the 50th percentile of the distribution of arrivals above the mean. Based on a normal distribution of arrival times this equates to 0.68 of one standard deviation.

A similar approach is used for WT reliability. The average amount of late running is assumed to be 0.68 of the standard deviation of transit vehicle arrival times. A range of evidence suggested that WT delays should be weighted to reflect passenger perceptions of unexpected delays (Ryan 1996; Kjoerstad and Renolen 1996 and Janssen 1994 quoted by Transfund 2000). Based on this evidence a perceived WT delay at transit stops is valued at a factor of 5.0 of the measured delay. No IVT reliability perceptual weighting is applied due to lack of good secondary information to support any weighting.

3.3 Transit operator impacts

Operator impacts are measured in terms of changes in fleet and crew resources. A simple fleet resource estimation formulae is used:

$$\text{VehicleFleet} = \frac{\text{RoundTripTime}}{\text{Headway}} \quad (1)$$

Round trip time includes adjustments for the impacts of average speeds as a result of the modelled transit priority measures. The result is an estimate of operating vehicle (and crew) impacts of priority measures. Fractions of vehicles are accepted since these may be used to make savings over the whole network. Unit costs are applied to value any changes in operating resources. For bus a value of \$Aust 51,906 p.a. per vehicle applies, based on costing of local services (Department of Infrastructure 2002).

3.4 Infrastructure impacts

The capital and operating costs of any new transit priority infrastructure are estimated and included in the assessment.

3.5 Secondary or PT market growth impacts

A simple weighted total generalized cost (TGC) model is used to forecast any changes in demand for PT and how this may impact on road congestion and farebox revenues. The model takes the form:

$$\text{ChangeDemand}_{\text{PT}} = \text{ChangeTGC}_{\text{PT}} \times \text{TGCElasticity}_{\text{PT}} \quad (2)$$

PT = PT, TGC = Total Generalised Cost, TGCElasticity = 1.0 Peak and 1.5 Off Peak

The total generalised cost (TGC) of PT travel is calculated using the following formulae:

$$\begin{aligned} \text{TGC} = & ((\text{Walktime} * \text{Walk}_{\text{wt}}) + (\text{Waittime} * \text{Wait}_{\text{wt}})) \\ & + (\text{UXWaittime} * \text{UXWait}_{\text{wt}}) + (\text{IVT} * \text{IVT}_{\text{wt}}) + (\text{UXIVT} * \text{UXIVT}_{\text{WT}})) \\ & * \text{VOT} + \text{Fare} \end{aligned}$$

Walktime = Time in minutes walking to and from the transit service, Walk_{wt} = Weighting of walk time to and from transit stops, Waittime = Time waiting for bus to arrive at the bus stop if it is on scheduled time, Wait_{wt} = Weighting of wait time at transit stops, UXWaittime = Time waiting for a bus delayed due to unreliable running, UXWait_{wt} = Weighting of unexpected wait time at transit stops due to unreliability, IVT = Expected time travelling in the transit vehicle, IVT_{wt} = Weighting of in vehicle travel time in transit vehicles, UXIVT = The time spent in the vehicle when the bus is delayed due to unreliability, UXIVT_{wt} = Weighting of unexpected IVT (valued at 1.0—see text), VOT = Value of Travel Time, Fare = Average Fare per Trip Table 2 shows the parameter values and assumptions used in formula (3).

The TGC model forecasts PT demand impacts resulting from transit priority initiatives using formulae (2) and (3). These are used to identify a range of benefits as follows:

- Transit User Benefits—Using the change in TGC (formula 3) from the base to the option or project situation.
- New Transit User Travel Time Benefits—The economic ‘rule of a half’ is applied to estimate the scale of benefits to apply to new transit users. In effect the average benefit from existing transit users is halved and applied to any growth in demand in the transit system.

Table 2 Public transport demand model parameters

Parameter	Value	Source/Basis
<i>Perceptual parameter weightings</i>		
Walk Time Weight	2.0	Based on a meta study of values from numerous studies (Transfund New Zealand 2000). Values shown are the average of values derived from secondary research.
Wait Time Weight	2.0	
Unexpected Wait Time Weight	5.0	
In Vehicle Travel Time Weight	1.0	
<i>Parameter values</i>		
Walk Time	10 min	5 min access and egress to stops
Wait Time	0.5 Headway	Based on service headway inputs
Unexpected Wait Time	0.68 SD	50th percentile of standard deviation of modelled running time (see text)
In Vehicle Time (Base)	19.4 min	Based on typical average travel behaviour in Melbourne. Option travel times are varied based on micro-simulation modelling.
Value of Time	\$8.69/Hour	Based on standard values
Fare	\$0.84	Based on bus boardings and estimated bus revenue for 2002

- Farebox Revenue Growth—estimated by multiplying transit patronage by the average fare.

In addition, forecasts of PT patronage growth are used to estimate a range of road congestion relief benefits. These benefits include reductions in travel time as a result of fewer cars using the road because the drivers are using PT. It also includes reduced levels of accidents, vehicle operating costs and also environmental emissions from reductions in car usage. The following formulae is used in this assessment:

$$\text{RCRB} = (\text{Growth}_T * \text{Share}_{\text{CD}}) * \text{Av. TravelDist} * \text{UnitKmBenefit} \quad (4)$$

RCRB = Road Congestion Relief Benefit, Growth_T = Forecast growth in Transit (from Formula 3), Share_{cd} = Share of new transit users who previously drove a car, Av.TravelDist = Average travel distance in kms (from secondary evidence), Unit-KMBenefit = per car vehicle km benefit representing the benefits of reductions in road congestion, road accidents costs, vehicle operating costs and the value of reduced environmental noise and pollutant emission resulting from less car usage

The unit km benefit of road congestion relief is an important input to the evaluation and is derived from experimental research of road traffic relief impacts in Melbourne (Ogden and Stanley 2001 in Department of Infrastructure 2003). Table 3 shows the unit values applied for this assessment of secondary impacts.

3.6 Trip diversion impacts

Any reductions in road space as a result of bus or tram priority measures are likely to result in at least some traffic diverting to alternative roads. Diversion will lessen the traffic impacts of any road capacity reduction. Three separate impacts occur:

- Diverting traffic will potentially have a longer journey (or disbenefit)
- Diverting traffic provides some relief to remaining traffic
- Traffic on alternate routes will have longer travel times as a result of diverting traffic increasing congestion on the alternate route.

The approach to this issue assumes that impacts (b) and (c) are relatively minor and to some extent counteract each other. Hence they are ignored. The value of factor a. cannot be zero otherwise no one would divert, they would remain on the existing roadway. However it cannot be higher than the value of disbenefits faced by other traffic using the road where transit priority initiatives have been implemented.

Table 3 Unit values applied to estimate congestion relief benefits

Externality Impacts	Situation	Value (Cents Aust./ reduced road vehicle km)
Congestion Relief Benefits including:	Peak Heavy Congested Area	90
• road travel time benefits	Peak Moderate Congested Area	60
• reduced vehicle operating costs	Peak Other/Off Peak	16
• reduced road accident benefits		
Environmental Relief Benefits	All	2.4

Source: Ogden and Stanley (2001) in Department of Infrastructure (2003)

If it were higher no traffic diversion would occur. The ‘rule of a half’ is therefore adopted by assuming disbenefits to diverting traffic are half of those applying to traffic, which does not divert.

3.7 The economic evaluation

The economic evaluation trades-off project costs and benefits valued in monetary terms over a 30 year project horizon using a discount rate of 6%. Capital and recurrent expenditures are included in a discount cash flow analysis. The base case refers to an existing situation either without PT priority or with existing designs of PT priority. Costs and benefits included are:

Resource Impacts	Infrastructure costs of the priority scheme Implications of priority on PT fleet and operating costs
PT User Impacts	Travel time and reliability impacts Includes existing and new PT users
Private Vehicle Impacts	Travel time and reliability impacts
Fare Box Revenue Change	Included as a ‘producer surplus’ in the evaluation
Externality Impacts	Impacts of reductions in road users on travel times, vehicle operating costs, accident costs and environmental emissions

4 Example results

Two main types of modelling were undertaken; *Case Studies*; real world road network examples, and *Test Groups*; hypothetical single road configuration models. Two Case Studies were undertaken and 8 sets of Test Group configurations used (Currie et al. 2004a). In total 3,287 separate evaluations were documented. It is impractical to report all these results in this paper. Rather some example tests are described and an overview of the results presented. Wider reporting of the studies findings are presented in Currie et al. (2004a–c, 2005).

Figure 2 shows an example set of results for Test Group modelling of a full-length kerbside bus lane introduced into a 2 by 2 lane mixed traffic road environment. The results show the key evaluation outputs for a series of bus service headways and traffic volumes or vehicles per hour (vph) combinations. In each case there are project costs with values below the x -axis and project benefits, with values above the x -axis. The net value of the combined series of evaluation parameters is shown in black. If its value is above the line it is a benefit. If below the line it is a net disbenefit (or a poor project with costs greater than benefits).

Figure 2 illustrates the complex series of factors affecting the performance of introducing the bus lane. The following are the main characteristics of project performance:

- In general the performance of the bus lane involves a trade-off between the benefits to bus users, from having faster and more reliable operation against the disbenefits to road users from having to run in a single as opposed to 2 lanes.
- Road user disbenefits, from having to operate in a single lane, increase with traffic volume. At traffic volumes above 1,000 vph, road user disbenefits dominate the evaluation and create substantial net negative overall project performance.

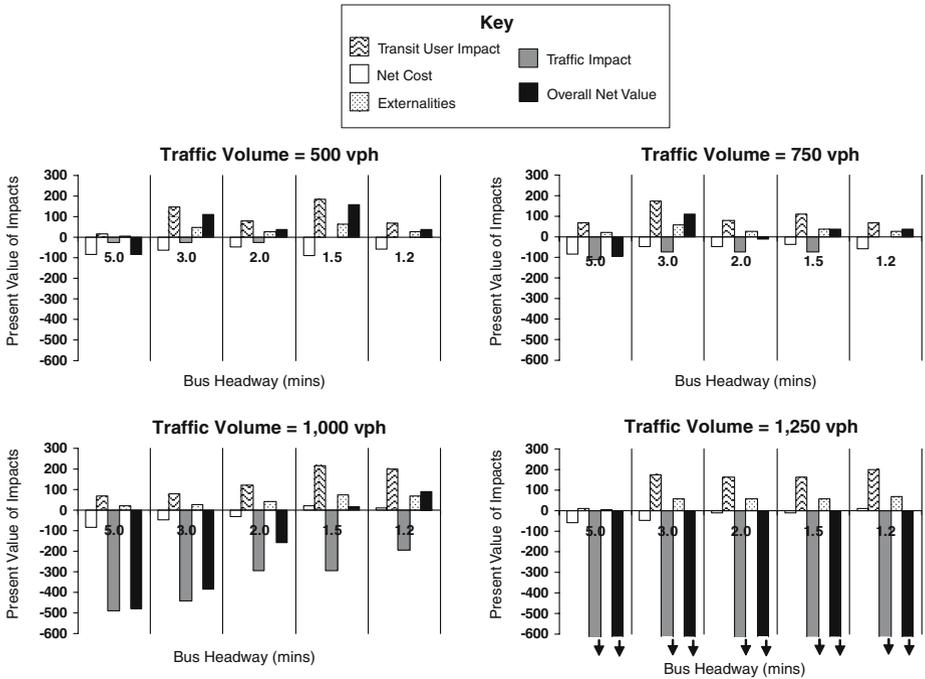


Fig. 2 Evaluation Results – Introduction of a kerbside Bus Lane at Various Bus Headways and Traffic Volumes. *Note:* NPV (\$000) based on 30 year evaluation period and a discount rate of 6%. Average bus occupancy is 30/vehicle. Scales deliberately set to illustrate results more clearly. This removes negative findings at 1,250 vph. *Source:* TG5 RIT6 V1.0

- In general bus user benefits are larger at higher volumes of bus movements. This is because there are more bus passengers to benefit from the lane.

However there are also several more subtle factors affecting performance in this example:

- Impacts on general traffic are less at higher bus frequencies. This is because the base case includes mixed bus and traffic operations without any priority. At high bus volumes traffic is delayed by mixed bus and traffic operations. Removing buses from the traffic stream in the option case involves a trade-off between less traffic interference from buses and the slowing of traffic due to reductions in lane capacity.
- At very high bus volumes (1.2 min headways) PT user benefits can be slightly less than at lower bus headways (1.5 min). This is because the 1.2 min headways result in some buses slowing each other down due to bus congestion in the kerbside lane.
- In general the infrastructure costs of the project are relatively small and negative (about -\$100 NPV) due to the costs of building and maintaining the bus lane. However at very high traffic volumes and with high frequencies of bus movements costs are influenced by savings in bus resources required to run the operation. This can result in small net savings in infrastructure and operating costs.

5 Summary of analytical findings

The following research findings provide insights into the fine balance which road management authorities must make in providing PT priority in the situations modelled.

5.1 Priority is difficult to justify at low mode share

In general a low proportion of the tests undertaken showed positive net economic gains as a result of introducing bus or tram priority schemes. However this does not necessarily mean that priority is a bad thing. Rather it is only appropriate in certain circumstances. However, the modelling parameters used were aimed at circumstances typical to conditions in Melbourne, Australia i.e. a city with low PT mode share (6% of all trips, Transport Research Centre 1996) and with very high car use (75% of all trips, Transport Research Centre 1996).

5.2 Circumstances for ‘Viable’ PT priority

Where a project resulted in net positive economic returns it was considered ‘viable’. In general ‘viable’ projects occurred where PT service frequencies (and patronage) were high and where traffic volumes were low:

- For inner suburban circumstances, short length bus and tram lanes were ‘viable’ at service headways less than 5 min and where traffic volumes per remaining lane were below 500 vph.
- In suburban circumstances, short tram and bus lanes were generally not considered worthwhile because delays to buses and trams entering and leaving short lanes negated the benefits of the priority design.
- In suburban circumstances, full length bus and tram lanes required PT headways below 3 min and traffic volumes below 750 vph.

A major finding was that priority designs should avoid circumstances where turning traffic volumes were significant in the traffic lanes used by PT. Building in a setback¹ into a priority lane acted to reduce traffic disbenefits in the evaluation but traded this off against delays to PT vehicles. Setback lengths could be optimised to trade-off these factors to optimise the evaluation.

The analysis also showed strong support for the view that provision of a bus or tram lane is more likely to be ‘viable’ where PT is carrying the equivalent of a lanes worth of the person travel on the road (Vuchic 1981). Hence if PT carried a third of the travel on a three lane road, a PT lane is likely to be ‘viable’.

5.3 When PT priority makes PT worse

An important but seemingly counter-intuitive finding was that the introduction of some priority initiatives resulted in a poorer service outcome. These examples occurred in semi mixed traffic conditions where only parts of the road-space were given over to bus or tram use. In these occasions the traffic disruption caused by the

¹ A setback is a mixed traffic area at the front of a bus or tram lane at the traffic intersection to enable turning traffic to wait outside the traffic stream to make turns.

reduction in road-space caused merging queues at the entrance and exits of PT priority lanes. These queues acted to delay PT vehicles often negating the benefits of the priority lane. A similar example of this outcome occurred where time at intersections was skewed towards waiting PT vehicles and where traffic queues made access to this time more difficult for buses and trams.

5.4 Risk and the provision of PT priority

Results showed that priority initiatives often balanced a project with small net benefits in current road circumstances against negative impacts of a considerably greater scale if road traffic volumes were to increase in the future e.g. Fig. 2. The net benefit of a bus lane at 3 min headways is around \$100,000 NPV at 750 vph. This switches to an NPV of -\$400,000 at a traffic volume of 1,000 vph and to -\$2.2 M NPV at a traffic volume of 1,250 vph. The range of these results presents an element of risk which it is important for road authorities to be aware of in designing a priority initiative. Is it worth risking a benefit of \$100,000 for a potential disbenefit of \$2.2 M if traffic volumes increase?

Results consistently demonstrated that negative traffic impacts considerably dominate the evaluation where traffic volumes per remaining traffic lane (after lane priority is introduced) operate at volumes above 1,000 vph per lane. At these volumes traffic flows 'break down' and delays are considerable. We term this phenomenon the '1KL Threshold' i.e. that it is a useful general guideline to avoid introducing exclusive lane priority where traffic squeezed into remaining lanes operates at traffic volumes above 1,000 vph per lane.

Analysis also demonstrated that the performance of a priority project is very sensitive to the setting of design parameters of both the road and the priority project. Quite small changes in factors such as traffic light cycle times were demonstrated to result in a significant reversal of the performance of a priority scheme. This makes it difficult to generalise findings to use as guidelines in design. Risks are best mitigated by applying the modelling and evaluation tools used in the experiments.

5.5 Other findings

The results demonstrated the risks of trading off finite roadspace between road users when demands are high. This finding supports alternative approaches to managing roadspace. For example adopting travel demand management approaches such as car sharing, pricing or HOV lanes to reduce demand in association with PT priority schemes.

Findings also demonstrated that the inclusion of PT operator impacts in the evaluation was critical to overall project performance. An evaluation of tram priority initiatives (Currie et al. 2005) established that 52% of all project benefits come from savings in tram fleet resources as a result of faster street running.

6 Discussion

This section considers improvements to the methods described.

At a strategic level advocates for PT priority will question the scale of benefits and costs applied. The aim of methodology development was to be objective about

valuations of these elements. The value of times adopted to both PT and other road users is the same. However it is arguable that road traffic has a higher degree of business related travel. This could be a basis for increasing the value of time for road users and increasing the disbenefits of most PT priority projects. Sensitivity analysis was undertaken including a doubling of the scale of PT user benefits applied. While this causes a small increase in the range of viable priority projects the impact of such a substantial ‘bias’ was hardly noticeable overall. None of the research findings would be changed as a result.

Another potential criticism is that the concept of ‘disappearing traffic’ (Cairns et al. 2002) is missing from the modelling applied. This is only partly valid. The ‘disappearing traffic’ effect is caused by a mix of mode shift, trip diversion, trip re-timing, trip re-distribution and trip suppression. The approach explicitly models mode shift impacts, although these are only considered at a tactical/ short term level. The approach to mode shift modelling is certainly simplistic and could be improved through the use of multi-modal modelling including logit modelling of mode choice decisions. Trip diversion has been considered in the method but again in only the broadest manner. The analysis has also questioned whether trip diversion will really have positive impacts on the viability of priority projects. Certainly it can reduce traffic levels on roads being impacted by reduced road capacity as a result of PT priority. However, if roads used by diverting traffic are also congested, all this is doing is ‘spreading the pain’.

The approach certainly lacks any consideration of trip re-timing, trip distribution or trip suppression. However the inclusion of these factors would be unlikely to significantly improve the case for PT priority in the tests undertaken because these behaviours have a small scale impact on road traffic demand with impacts felt only in the longer term. The more significant mode shift and trip diversion behaviours have been considered in the method.

While the approach improves the representation of PT vehicle and traffic interaction through micro-simulation, it is believed that this only partly represents the complex interactions occurring in the real world.

Traffic flow modelling would also be improved through the representation of ‘parking friction’ i.e. delays to road users caused by vehicles entering and leaving kerb side parking. This may be particularly important for tram operations in the median of two lane roads where the kerbside lane is taken up with parking. Illegal traffic behaviour and the impacts of drivers with imperfect knowledge are other behaviours which could validly be better represented in the method.

There was some debate during the development of the method regarding the validity of using small travel time impacts as a basis for the evaluation of large scale travel projects. Certainly some impacts involve small (a few seconds) changes in travel for a large volume of travelers. The method assumes this is valued the same as a large impact faced by a small volume of people. While these sets of impacts are clearly different, their representation in the method is considered valid for the purposes of overall project evaluation.

A major driver of the externality impacts is the unit values for reducing road vehicle use identified in Table 3. These values were based on secondary research including valuation of environmental impacts including greenhouse gas impacts. Some commentators could place a ‘priceless’ value on reductions in traffic levels where vehicle emissions are causing a deterioration to the planets ozone layer.

However, these views may become less valid as improvements in technology reduce vehicle emission levels into the future.

Finally a valid criticism is that the approach does not cover all impacts of PT priority schemes. Amongst the omitted impacts the most significant may be the social impacts associated with congested car use on inner urban streets. Severance caused by congested roads and congestion impacts on local amenity and quality of streets are valid concerns of inner urban communities. While the value of these concerns is mainly intangible, their inclusion in an assessment of impacts is a valid means of increasing the comprehensiveness of the approach.

7 Conclusions

This paper has presented a new approach for evaluating proposals for reallocating road space to introduce PT priority. Previous approaches have been reviewed and found lacking in the range of evaluation criteria adopted, the approaches used to represent vehicle traffic flow implications and in the range of travel behaviour patterns considered. The method uses a wider range of evaluation criteria including PT reliability impacts and the externality impacts resulting from mode shift to PT as a result of priority schemes. Traffic flow behaviour is represented using micro-simulation modelling to represent the dynamic nature of vehicle interactions in complex road space and traffic flow conditions. The method also represents mode shift and trip diversion impacts.

Application of the method has involved real world and theoretical experiments. In general priority schemes have proven difficult to justify in conditions representative of the low mode share and high car use conditions of Melbourne. ‘Viable’ priority schemes require high PT usage and low levels of traffic usage. A good rule of thumb for priority projects involving exclusive bus and tram lanes is that ‘viable’ projects have PT patronage which is the equivalent of a lanes share of all passenger travel on a road. The research demonstrated situations where priority projects could result in a deterioration of the quality of PT in certain circumstances. Priority schemes were also shown to be risky in many circumstances. A good rule of thumb is the ‘1KL threshold’ i.e. that exclusive lane priority should be avoided where traffic squeezed into remaining lanes operate at a traffic volume above 1,000 vph/ lane.

A range of criticisms and improvements to the method have been suggested. In general an objective evaluation for project benefits and costs has been sought and representation of the main elements of such phenomenon as ‘disappearing traffic’ has been partly represented. Several improvements to the method have been suggested.

Overall we suggest the approach provides an objective, transparent and defensible means of addressing the very difficult trade-offs which road management authorities must make in managing finite road-space with increasing travel demands. While aspects of the parameters and approach are open to criticism, the overall framework is reasonably robust and can be modified to reflect the views of different researchers.

The applications of this method have been in Melbourne, Australia; a low density city with low PT mode share and high car usage. We believe this method is appropriate in all cities since it clarifies the complex trade-offs resulting from reallocating road space and time in an objective, open and defensible manner.

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Biography

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