Improving economic evaluation of urban transport projects in Australia

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1 Introduction

This paper was prompted by observation of the use of data from computerised integrated travel demand models in the evaluation of urban transport projects. Two principal issues emerge. The first relates to matrices used in travel demand models. It may be expected that many policy options and project proposals initiated by governments seek to alter travel demand, either the mode, time or location of travel or, more fundamentally, land use. Others may affect demand, irrespective of government intentions. Current levels of congestion suggest a likely difficulty in accommodating future unconstrained travel demand on an existing (or even ‘do minimum’) Base Case. Use of a fixed trip matrix for modelling travel demand in future years to provide information for economic evaluations is inappropriate in these circumstances because it does not fully reflect the potential effects of projects and policies on travel demand. In general, use of fixed trip matrices is likely to result in over-estimation of project benefits, though this is not certain, nor is the potential extent of over-estimation.

The second key issue is the measurement of traveller benefits. The literature on this subject goes back over three decades. It makes clear the limited extent to which link based information from travel demand models can be used as input to economic evaluation. Rather, evaluations of projects that result in a change in the travel demand matrix relative to the Base Case need to draw on both origin-destination based information and link based data. Some key guidelines for evaluation practice in Australia do not provide information on this correct practice.

Finally, this paper raises several other issues related to the evaluation of urban transport projects, in particular the unit of account used in valuing benefits, disaggregation of benefits, quality of valuation data, definition of the Base Case, and sensitivity testing.

The objective of this paper is not to set out recommendations for future practice, though an implication that emerges is that use of variable trip matrices should be the default methodology for demand forecasting of major urban transport projects and fixed trip matrices should be used only when inelastic demand is a realistic condition Nor does it present new data or methodologies. Rather, it notes some key historic literature that remains pertinent to current transport planning and evaluation practice.

2 Use of fixed and variable trip matrices

A fundamental theme of most urban transport strategies for Australian capital cities is travel demand management, with a desire for increased use of public transport and reduced car use. It may therefore be expected that many policy options and project proposals initiated by governments seek to alter travel demand, either the mode or time of travel or, more fundamentally, land use (ie the location of activities, and therefore travel). Others may affect demand, irrespective of government intentions, whilst some may simply seek to accommodate travel demand.

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There will generally be no need to use an integrated network model where the effect of a project on travel demand is small or localised. However, network-based travel demand models are needed to identify the impacts of larger and/or more complex project and policy initiatives. That is, by definition, the need to use a demand travel model implies that significant travel change is expected.

Economic evaluations compare a Project Case with a Base Case. Current levels of congestion suggest a likely difficulty in accommodating future unconstrained travel demand on an existing (or even 'do minimum') Base Case. This requires that some future travel in the Base Case change location, shift to another time or be suppressed, and thus increases the likelihood that a future trip matrix for the Base Case and Project Case will differ.

It appears that demand modelling of urban transport proposals for Australian cities is generally based on the number of trips generated and attracted for each zone being the same for the time period being modelled for the Base Case and the Project Case (ie a fixed trip matrix). Practice usually allows for alternative travel modes within this general constraint of fixed origins and destinations. Some effects of this situation are:

- Mode choice impacts may be partially taken into account, but not to the full extent if the project or policy is also likely to influence the location or time of travel.

- People can be expected to change the location of some of their trips in response to an improvement in accessibility that results from a proposed project, and potentially all of their trips if they make more fundamental changes such as moving to another place. Holding origins and destinations fixed does not permit people to optimise their use of the changed transport situation. This will lead to under-estimation of user benefits (eg see Section 3.3 for an example).

- The effect of capacity constraints in the Base Case is not taken into account. This will generally result in over-estimation of project benefits due to excessive travel demand in the Base Case relative to the available network capacity (or excessively high travel costs if all demand is accommodated on a constrained network).

- An increase in transport supply resulting from a project may allow some people who changed the time of their travel due to capacity constraints in the Base Case to instead journey at their preferred time with the project. These people gain a benefit from the change. However, if they shifted to the peak they will increase travel time for continuing peak users, though people who continue to travel in the off-peak time period gain some benefit from reduced traffic congestion. With congestion in the Base Case and an absence of marginal social cost pricing for travel, a fixed trip matrix approach is likely to over-estimate user benefits by failing to take account of the external costs of temporal changes in travel. Modelling a wider period about the peak that assumes temporal diversion occurs within the period cannot take account of costs and benefits that result from the changes in the time of travel.

- A project that improves accessibility can be expected to result in some generated travel relative to the Base Case. Ignoring generated travel will, in the absence of prices set equal to marginal social cost, result in over-estimation of user benefits, as in the previous example. (Bray and Sayeg (2002) illustrates the effect of generated road traffic on project benefits in the case of vacated road capacity resulting from diversion of car drivers to Bangkok's elevated rail line being filled to varying degrees with generated traffic.)

While transport agencies in Australia may sometimes use trip matrices that vary between the Base Case and the Project Case, economic evaluation methodologies for projects presented in guidelines are usually appropriate only for situations where the trip matrix for any given model year is the same for the Base Case and the Project Case (eg RTA 2004 and Main Roads 1999). While the potential for variable trip matrices is noted in these references (and also Austroads 2004a), the implications for evaluation methodology is not clearly addressed.

Australia is not alone in the general use of fixed trip matrices. While not seeking to provide a comprehensive review of international practice, some features of UK practice are noted. The standard practice for cost benefit analysis introduced in the United Kingdom in 1980 determined a limited set of circumstances where it was considered that variable trip matrices should be used (DOT 1980). In recent years, the Department for Transport has enhanced its appraisal methodology, including introduction in 2001 of new evaluation software that allows multi-modal evaluation with variable trip matrices. The new model is called Transport User Benefit Appraisal (TUBA) – see DfT 2004a for an overview of the model. Nevertheless, limited guidance is provided on use of variable trip matrices, other than with regard to indicating their use for multi-modal projects.

The Scottish Transport Appraisal Guidance (Scottish Executive 2003:B17) provides more, though still methodologically ambiguous, direction. It indicates that “generally a variable trip matrix assessment is appropriate for this type of scheme [see below], however, a fixed trip matrix assessment should be undertaken for comparison purposes”, where the schemes for which a variable trip matrix should be used is defined by:

- “Are the existing roads in the study area operating close to capacity, or are they expected to do so within the design life of the scheme? In these circumstances, congestion is likely to lead to suppression of traffic effects, and schemes may result in the release of some of the suppressed traffic.

- Is the potential change in overall traffic flows high with respect to changes in travel times or costs? This is likely to be the case where there are good alternatives available for the movements affected by the proposed scheme, e.g. other routes or public transport alternatives.

- Will the implementation of the proposed scheme cause large changes in travel costs, road capacity or both? These conditions are likely to occur where the scheme or improvement bypasses extended lengths of low standard or congested network, or where new road links or public transport systems cause major changes in accessibility (e.g. estuarial crossings, LRT network).”

The Standing Advisory Committee on Trunk Road Assessment has been less ambiguous, recommending that “variable matrix economic evaluations are undertaken for schemes as the cornerstone of the economic appraisal in every case, except where it can be shown that the trip matrix will not vary as a result of the scheme being appraised” (SACTRA 1994:15.24).

DOT (1980s) suggested that “In most cases the variable trip evaluation of benefits is unlikely to yield more than about 10 percent extra benefits over the fixed trip evaluation, although this will be scheme specific.” Williams and Moore (1990) used a simplified, uni-modal equilibrium model to examine the effect of fixed and variable trip matrices on benefits. They found circumstances in which use of fixed trip matrices could result in either severe over or under estimation of benefits. In particular, they noted that “substantial over-estimation will tend to be associated with congested conditions and moderate (to large) traveller response. Predicably, such conditions will be found in or near urban areas.”

A generalisation of the analysis by Williams and Moore found that “Both the equilibrium demand forecasts and the benefits measures have been shown to be sensitive to a range of parameters and in particular the elasticity of demand. We have demonstrated that application of inelastic, or ‘fixed demand’, methods which are commonly applied in highway appraisal might result in significant overestimation both of road traffic and the benefits of policies if there is even a small propensity to respond to cost changes." (Williams and Yamashita 1992:281).

With regard to peak shifting, Henderson (1992) notes that "ignoring peak shifting in cost-benefit analysis leads to an overestimate of benefits and excessive capacity investment."

It is concluded that use of a fixed trip matrix approach for many urban transport projects in Australia is inconsistent with government objectives for urban transport, with future circumstances likely to exist in Base Cases, and with the likely impacts of the types of projects and policies that require use of a travel demand model. In these circumstances, a fixed trip matrix will not provide data that accurately indicates the benefits of projects. Finally, the direction and degree of the inaccuracy will not be uniform, and will depend on current travel conditions and the extent and nature of generated and diverted travel demand, but the general likelihood is that it leads to overestimation of benefits.

3 Deriving user benefits

3.1 Historic literature

The literature on the estimation of user benefits goes back over three decades. Two essential references are Neuberger (1971) and McIntosh and Quarmby (1972). McIntosh and Quarmby provide the general case for estimating user-related benefits, which comprise:

A. increase in user surplus: $0.5 * \Sigma_{ijkt} ({}_{kt}T^1_{ij} + {}_{kt}T^2_{ij}) * ({}_{kt}PC^1_{ij} - {}_{kt}PC^2_{ij})$ <u>plus</u>

B. increase in perceived user costs: $\Sigma_{ijkt} [({}_{kt}T^2_{ij} * {}_{kt}PC^2_{ij}) - ({}_{kt}T^1_{ij} * {}_{kt}PC^1_{ij})]$ <u>less</u>

C. increase in resource costs: $\Sigma_{ijkt} [({}_{kt}T^2_{ij} * {}_{kt}RC^2_{ij}) - ({}_{kt}T^1_{ij} * {}_{kt}RC^1_{ij})]$

where:

${}_{kt}T_{ij}$ = number of trips from zone i to zone j by mode k during time period t;

${}_{kt}PC_{ij}$ = perceived generalised (ie behavioural) cost per trip from zone i to zone j by mode k during time period t;

${}_{kt}RC_{ij}$ = resource cost (ie excluding taxes that are transfer payments) per trip from zone i to zone j by mode k during time period t; and

superscript 1 represents the Base Case and superscript 2 the Project Case.

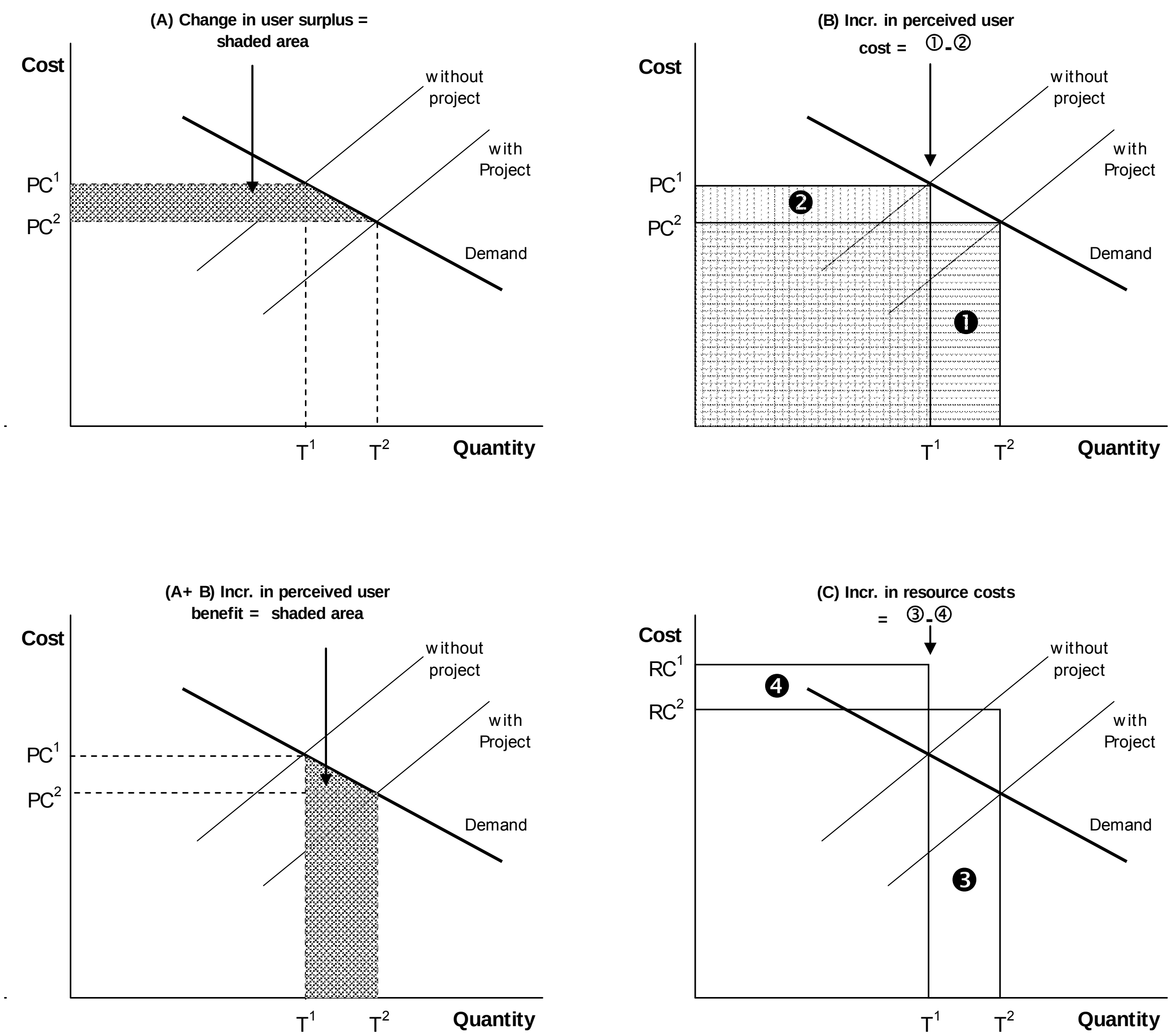
As indicated in Table 1, component A is commonly known as the change in consumer surplus, and the net effect of components B and C as the resource correction. Component B reflects the increased willingness of users to pay (WTP) for the additional travel that they undertake, though it needs to be offset against the actual change in travel cost indicated by component C. This articulation of benefits differs from that presented in recent national evaluation guidelines in which the combination of components A and B are described as the "increase in WTP" and component C is the change in "total social cost" (ATC 2004: Vol 2, pp 49-50). While the terminology differs, both the ATC and McIntosh and Quarmby articulations result in the same benefit.

Subsequent rows in Table 1 relate to the measurement of the benefits, and are discussed later in this paper. The three components that make up the net user-related benefit are shown diagrammatically in Figure 1.

Table 1 Features of components of user-related benefit

	Component (as per McIntosh and Quarmby 1972)		
	A (change in user surplus)	**B (change in user costs)**	**C (change in resource cost)**
Nature of benefit	Change in the value of travel in excess of its perceived cost	Benefit as indicated by demonstrated willingness to pay for additional travel	Change in the real (ie resource) cost of travel
Common term	Change in consumer surplus	Net effect is often called a 'resource correction', ie an allowance for resource costs not perceived by travellers	
Based on	Perceived costs, which are in turn related to market prices		Resource costs
Derived using	Number of trips and perceived cost for each origin-destination pair		Sum of costs (eg VOCs) for each link in the network
Situation with a variable trip matrix	Takes account of both changes in the number of trips and perceived trip cost for each origin-destination pair		Change in resource costs estimated from link data
Situation with fixed trip matrix	Value of components A and B offset each other with a fixed trip matrix		User benefit is equal to the change in resource costs

Figure 1 User-related benefits



Part of the difference between resource and behavioural costs is indirect taxation, which finds its way into project benefits via its inclusion in perceived costs. However, taxation is a transfer payment, and there will be a compensating effect elsewhere in the economy. Accordingly, there is a need to take account of this effect of indirect taxation only to the extent that taxation rates in the transport sector differ from those applying elsewhere in the economy. This may occur, for example, as a result of GST exemptions and fuel excise. While no reported analysis is evident, the difference may be sufficiently small that the effect can be ignored.

It is notable that this general case provided by McIntosh and Quarmby (1972) applies both where demand is fixed and variable. Neuberger (1971) describes a "Method 1" for the specific case in which the trip matrix is fixed and a "Method 2" where this is not the case. Under Method 1, the benefit will equal the change in resource costs, ie component C of the formula above – this occurs because the change in user benefits is equal to the change in perceived user costs but opposite in sign. Neuberger provides useful discussion of ways in which user benefits may be miscalculated.

Neuberger (1971) also presents a Method 3 that avoids the implicit assumption in his Method 2 (and also that of McIntosh and Quarmby) that the demand curve is a straight line between the levels of travel demand being considered. His Method 3 is also necessary for the evaluation of land use plans. The issue of evaluating land use plans is addressed in more detail in Neuberger and Wilcox (1976) and, for example in more recent times, Bates (2003).

3.2 The implications of variable trip matrices for benefit estimation

Changes in perceived travel costs from the Base Case to the Project Case, and consequences of the changes for travel demand, must be determined on an origin-destination basis. That is, the benefit to travellers for any given time, and mode (ie T^2_{ij} - T^1_{ij}) is a function of travel conditions between the Base Case and the Project Case for each ij zone pair. It is therefore not a function of any particular link (or set of links that can be uniquely identified from aggregate link information).

By contrast, resource costs (eg resource vehicle operating costs - VOCs) are independent of the origin and destination of a trip. They are a function of the length and travel conditions on each link over which vehicles travel. It is therefore possible to estimate the change in resource costs by summing costs for each link in the Base Case and in the Project Case and to thus obtain the net benefit.

If the trip matrix is the same in the Base Case and Project Case in every respect, user-related benefits will be equal to the difference in the resource cost of travel between the two cases. It is in this case only that link based data alone can be used to determine user benefits. This outcome occurs because any perceived user benefit will be offset by a decrease in user costs (ie component A exactly offsets component B), leaving reduced resource costs (component C) as the sole benefit. This is Neuberger's Method 1. In explaining the situation, Neuberger (1971:54) notes that it "arises from the fact that demand is unaffected by cost changes. Thus it should not matter how users perceive costs, since they do nothing about it."

If it is accepted that use of the same trip matrix for the Base Case and the Project Case for a given time period and mode for a particular model year is inappropriate for many urban transport projects, link data cannot be the sole basis for user benefits. Rather, perceived user benefits need to be estimated for each origin-destination pair. Implementation of this approach would represent a substantial change in current Australian practice.

3.3 An example

Figure 1 shows the situation with three zones and a single link (or weighted average of multiple links) between each zone. A set of cases examines the potential effect of various demand responses to an improvement in the link between zones A and B. A final example illustrates the effect of a network wide change. It can be seen that:

- Project Case 1a shows that, with a fixed trip matrix, the benefit is simply the change in resource costs between the Base Case and the Project Case.

- Project Case 1b shows a situation in which the total number of trips remains unchanged but the distribution of them between zones changes (in Project Case 1b 30 trips made each way between zones A and C in the Base Case are made instead between Zones A and B in the Project Case to take advantage of the improved link between the latter pair of zones. It shows that user benefits increase as people change their travel pattern to take advantage of the improved link (from 7,975 units in with a fixed trip matrix in Project Case 1a to 8,422 units with a somewhat variable trip matrix in Project Case 1b).

- Project Case 1c tests the effect of no shift in travel between Zones A and C, but allows for trip generation in response to the improved link between Zones A and B. It is notable that the user benefit of 7,237 units is less than for Project Case 1a (ie the generated trips result in a net disbenefit).

- Project Case 1d shows a more fully variable trip matrix by combining both of the two previous cases, ie the improved link between Zones A and B both results in a land use change (ie a change in the distribution of trips) and in the generation of additional travel. The user benefit in this case is 7,683 units, which is less than would have been the case if the project has been modelled with a fixed trip matrix (ie Project Case 1a).

- Even with a uniform change in the cost of travel across the network (Project Case 2), there is a need to derive benefits on a trip basis.

As the extent of the error is not uniform or proportional, it is not possible to use a simple approach using aggregate network data and make a correction to obtain the right answer. Factors such as the elasticity of demand and the scale and location of the project's impact affect the extent of the error.

More detailed analysis indicates that an error still occurs if aggregated perceived benefits are used, eg the number of trips in the Base Case multiplied by the average unit perceived benefit, plus generated trips multiplied by half the unit perceived benefit, plus account for changes in resource costs. The data shown can be used to illustrate other incorrect methods for estimating benefits, eg change in the total perceived cost of travel with or without a resource correction.

Hence, it should be evident that any diversion and generation of travel demand that might occur in response to a project or policy needs to be taken into account if user benefits are to be reasonably estimated, and where either or both of these effects occur, user benefits must be derived on an origin-destination basis to be accurately calculated.

Figure 1 Estimating project benefits with fixed and variable trip matrices

Base Case

Trips

From zone \ To zone	A	B	C
A	300	600	700
B	600	400	800
C	700	800	500

Perceived cost of travel

From zone \ To zone	A	B	C
A	10	50	60
B	50	10	70
C	60	70	10

Note: red cells contain variables that can be altered

Aggregate outcomes (Base Case):	
Number of trips	5,400
Total perceived cost of travel	268,000
Average trip cost	49.63

O-D pair	Total perceived travel cost
A-A	3,000
A-B	30,000
A-C	42,000
B-A	30,000
B-B	4,000
B-C	56,000
C-A	42,000
C-B	56,000
C-C	5,000
Total	268,000

Project Case 1a (improve A-B route, no change in trips)

Trips (no change from Base Case)

From zone \ To zone	A	B	C
A	300	600	700
B	600	400	800
C	700	800	500

Perceived cost of travel (-10% change in A-B trip cost)

From zone \ To zone	A	B	C
A	10	45	60
B	45	10	70
C	60	70	10

Input data	
Change in perc. cost of A-B trip	-10%
Resource cost (% of perc. cost)	133%

Enter resource/perceived proportion, eg 125% (or use D for default value of 133%) ---> D

Aggregate (Project Case 1a):	
Number of trips	5,400
Total perceived cost of travel	262,000
Average perceived trip cost	48.52

	Correct estimate of net benefits	
McIntosh and Quarmby (component A) -->	Change in user benefits (ie incr. in consumer surplus)	6,000
McIntosh and Quarmby (component B) -->	Change in perceived user costs	-6,000
McIntosh and Quarmby (component C) -->	Change in resource cost	-7,975
	Total benefit	**7,975**

Derivation of perceived benefits

O-D pair	Perc. travel cost: Total perceiv-ed cost	Perc. travel cost: Differ-ence from BC	Change in con-sumer surplus
A-A	3,000	0	0
A-B	27,000	-3,000	3,000
A-C	42,000	0	0
B-A	27,000	-3,000	3,000
B-B	4,000	0	0
B-C	56,000	0	0
C-A	42,000	0	0
C-B	56,000	0	0
C-C	5,000	0	0
Total	262,000	-6,000	6,000

Notes: --> Meets Neuberger Method 1 conditions. M&Q equations A and B cancel out each other and are hence redundant, ie meets Neuberger comment that no need to know perceived costs in Method 1.

Project Case 1b (improve A-B route, same no. of network trips but different distribution)

Trips (no change in total trips, but redistribute trips to improved link)

From zone \ To zone	A	B	C
A	300	630	670
B	630	400	800
C	670	800	500

Perceived cost of travel (-10% change in A-B trip cost)

From zone \ To zone	A	B	C
A	10	45	60
B	45	10	70
C	60	70	10

Input data	
Change in perc. cost of A-B trip	-10%
Elasticity of demand with respec	-0.5
Resource cost (% of perc. cost)	133%

Aggregate (Project Case 1b):	
Number of trips	5,400
Total perceived cost of travel	261,100
Average perceived trip cost	48.35

Correct estimate of net benefits	
Change in user benefits (ie incr. in consumer surplus)	6,150
Change in perceived user costs	-6,900
Change in resource cost	-9,172
Total benefit	**8,422**

Derivation of perceived benefits

O-D pair	Perc. travel cost: Total perceiv-ed cost	Perc. travel cost: Differ-ence from BC	Change in con-sumer surplus
A-A	3,000	0	0
A-B	28,350	-1,650	3,075
A-C	40,200	-1,800	0
B-A	28,350	-1,650	3,075
B-B	4,000	0	0
B-C	56,000	0	0
C-A	40,200	-1,800	0
C-B	56,000	0	0
C-C	5,000	0	0
Total	261,100	-6,900	6,150

Benefit increases because more trips take advantage of improved A-B link.

Project Case 1c (improve A-B route, with additional trips on A-B from generation)

Trips (change A-B trips according to elasticity but leave other trips unchanged)

From zone \ To zone	A	B	C
A	300	630	700
B	630	400	800
C	700	800	500

Perceived cost of travel (-10% change in A-B trip cost)

From zone \ To zone	A	B	C
A	10	45	60
B	45	10	70
C	60	70	10

Input data	
Change in perc. cost of A-B trip	-10%
Elasticity of demand with respec	-0.5
Resource cost (% of perc. cost)	133%

Aggregate (Project Case 1c):	
Number of trips	5,460
Total perceived cost of travel	264,700
Average perceived trip cost	48.48

Correct estimate of net benefits	
Change in user benefits (ie incr. in consumer surplus)	6,150
Change in perceived user costs	-3,300
Change in resource cost	-4,387
Total benefit	**7,237**

Derivation of perceived benefits

O-D pair	Perc. travel cost: Total perceiv-ed cost	Perc. travel cost: Differ-ence from BC	Change in con-sumer surplus
A-A	3,000	0	0
A-B	28,350	-1,650	3,075
A-C	42,000	0	0
B-A	28,350	-1,650	3,075
B-B	4,000	0	0
B-C	56,000	0	0
C-A	42,000	0	0
C-B	56,000	0	0
C-C	5,000	0	0
Total	264,700	-3,300	6,150

Benefit decreases compared with previous case (option 1b) when resource cost is greater than perceived cost.

Project Case 1d (improve A-B route, with additional trips on A-B from generation and diversion)

Trips (change A-B trips according to elasticity)

From zone \ To zone	A	B	C
A	300	660	670
B	660	400	800
C	670	800	500

Perceived cost of travel (-10% change in A-B trip cost)

From zone \ To zone	A	B	C
A	10	45	60
B	45	10	70
C	60	70	10

Input data	
Change in perc. cost of A-B trip	-10%
Elasticity of demand with respec	-0.5
Resource cost (% of perc. cost)	133%

Aggregate (Project Case 1d):	
Number of trips	5,460
Total perceived cost of travel	263,800
Average perceived trip cost	48.32

Correct estimate of net benefits	
Change in user benefits (ie incr. in consumer surplus)	6,300
Change in perceived user costs	-4,200
Change in resource cost	-5,583
Total benefit	**7,683**

Derivation of perceived benefits

O-D pair	Perc. travel cost: Total perceiv-ed cost	Perc. travel cost: Differ-ence from BC	Change in con-sumer surplus
A-A	3,000	0	0
A-B	29,700	-300	3,150
A-C	40,200	-1,800	0
B-A	29,700	-300	3,150
B-B	4,000	0	0
B-C	56,000	0	0
C-A	40,200	-1,800	0
C-B	56,000	0	0
C-C	5,000	0	0
Total	263,800	-4,200	6,300

Benefit increases compared with option 1c because of trip diversion. But benefit is less than for option 1b when resource cost of generated trips is more than the perceived cost.

Project Case 2 (with uniform increase in cost of travel, eg change in fuel tax)

Trips (change number of trips according to elasticity)

From zone \ To zone	A	B	C
A	292.5	585	682.5
B	585	390	780
C	682.5	780	487.5

Perceived cost of travel (5% increase in unit travel costs)

From zone \ To zone	A	B	C
A	10.5	52.5	63
B	52.5	10.5	73.5
C	63	73.5	10.5

Input data	
Change in cost of travel	5%
Elasticity of demand with respec	-0.5
Resource cost (% of perc. cost)	133%

Aggregate (Project Case 2):	
Number of trips	5,265
Total perceived cost of travel	274,365
Average perceived trip cost	52.11

Correct estimate of net benefits	
Change in user benefits (ie incr. in consumer surplus)	-13,233
Change in perceived user costs	6,365
Change in resource cost	8,461
Total benefit	**-15,328**

Derivation of perceived benefits

O-D pair	Perc. travel cost: Total perceiv-ed cost	Perc. travel cost: Differ-ence from BC	Change in con-sumer surplus
A-A	3,071	71	-148
A-B	30,713	713	-1,481
A-C	42,998	998	-2,074
B-A	30,713	713	-1,481
B-B	4,095	95	-198
B-C	57,330	1,330	-2,765
C-A	42,998	998	-2,074
C-B	57,330	1,330	-2,765
C-C	5,119	119	-247
Total	274,365	6,365	-13,233

An increase in travel costs results in a total benefit that is greater than the consumer surplus if resource costs are greter than perceived costs.

3.4 Implications for travel demand models

The previous discussion on the use of variable trip matrices and the associated calculation of user benefits places particular needs on transport models. These are discussed below.

Obtaining necessary evaluation data from models

Data needed from travel demand models to properly estimate user benefits comprises: (a) for the Base Case and the Project Case, the number of trips and average perceived cost of travel for each origin-destination pair; and (b) the resource cost of travel on each link in the network.

Given the large number of origin destination pairs in most models, it is preferable that the change in perceived user surplus and perceived user costs be estimated within the model. This should not be difficult because the necessary data on user costs for each origin-destination pair is used in the internal processing of the model and user surplus will be based on the combination of assigned demand and these user costs.

It is unlikely that the transport model will have the necessary data to estimate the resource cost of travel on each link in the network as the data is not needed for any other model functions. Data on link characteristics (ie physical features of the link and traffic using the link) therefore need to be transferred from the model into a spreadsheet or similar associated model and used in conjunction with unit resource costs to estimate the value of Component C as indicated by McIntosh and Quarmby.

A possible short-cut

Deriving benefits for each origin-destination pair can be onerous. Neuberger (1971) notes a practical short-cut for use with variable trip matrices that allows link based rather than origin-destination based data to be used. The method loads both the Base Case and Project Case trip matrices to each of the Base Case and Project Case networks (sometimes called “cross-loading”). The approach is also described in Transfund (2004). In this approach, the change in user surplus is derived as:

$$0.5 * [\Sigma_l (V^1_l * PC^1_l + V^2_l * PC^1_l) – \Sigma_m (V^1_m * PC^2_m + V^2_m * PC^2_m)]$$

where:

V = Traffic volume on a link

PC = Perceived cost of travel on a link

1 = Base Case network, and 2 = Project Case network

l = each link in the Base Case network, and m = each link in the Project Case network

Model equilibrium

Using demand and perceived travel cost for each origin-destination pair requires that demand for travel for each pair be matched to the related cost of travel. Two issues arise.

Travel demand models usually load demand in a number of steps (so that demand in a subsequent step will choose routes that take account of the presence of other traffic). Thus, the generalized cost of travel between each origin destination pair in one iteration of the model is used to assign demand for travel between the same pair to particular links in the next iteration. As a result, a single model run contains mismatched demand and travel costs. This should not be a problem if the iterations eventually converge.

The second issue is that the assignment process will result in final demand for each origin destination pair using multiple routes. Hence, there is a need to derive the average travel cost for travel between each ij pair taking account of the various routes used. Effective evaluation using variable trip matrices requires a model that can provide the origin-destination information needed for economic evaluation, and application of the model to ensure equilibrium is achieved.

Model time periods

Modelling for a given time period cannot ascribe any benefits or costs that result if trips change their travel schedule within the time period in response to the project or policy. It is therefore necessary to ensure that projects that may affect temporal choices are modelled so that these changes are taken into account.

4 Other Issues

Some other issues related to sound project evaluation are considered below. The list is not exhaustive, but raises some issues considered worthy of debate and clarification.

4.1 Perceived and resource costs

It is likely that perceived costs used in models and unit resource costs used for economic evaluations will be derived independently. As both are required to derive user benefits with a variable trip matrix, it is essential that they be based on prices at the same date.

4.2 Unit of account

The conventional unit of account that underlies transport evaluation in Australia is social costs valued at factor prices. However, implicit to demand modelling and associated project evaluation is the use of perceived costs. Perceived costs are related to market prices because people can be expected to base their decisions on the face value of prices they encounter. For example, they will perceive the market price of fuel, not its untaxed or some other value. Even travel time is derived relative to the value to some other thing that has a financial (ie market) value. Hence, there is merit in the underlying basis for valuation of benefits being willingness-to-pay based on market prices adjusted to reflect differences from resource values.

This is the approach that has been adopted by the UK Department for Transport, which describes it as the “willingness-to-pay calculus” (DfT 2003 and DfT 2004b). Its principal advantage is that it starts with market prices, which are arguably more intuitive than synthesised resource prices. More importantly, it allows the distribution of benefits between those affected by a project to be more clearly identified. The choice of the commencing unit of account does not affect the final result of an evaluation.

It also accords with derivation of benefits as described by McIntosh and Quarmby earlier, wherein components A and B are based on perceived prices, ie market-related prices.

4.3 Disaggregation of benefits

An underlying assumption of economic evaluation is that a unit value of resource has the same value irrespective of whether a person gains more or less of it, ie a reduction of say five minutes of travel time has the same value as a five minute increase in travel time. A second assumption is the potential compensation principle: that a potential welfare improvement is achieved if the beneficiaries of a project could compensate those who lose to the extent of their loss and still be better off, ie it is net benefits that matters. It is not necessary that this compensation be paid - that is a matter of equity rather than whether society is, as a whole, better off. If compensation is not paid, as is generally the case other than with respect to the purchase of land, a project will have distributional impacts.

It may be judged that politicians sense that neither of these assumptions is fully realistic – for it is usual for those who will be disadvantaged by a project to be more vociferous than those who will benefit. In other words, there is a need to understand distributional impacts.

The issue of weighting different components of costs and benefits to reflect distributional issues was debated in the early 1970s (eg Little and Mirrlees 1974), but has generally been found to be difficult to implement and thus not used in practice. Sugden and Williams (1978:131) note that “in most cases dealt with in cost-benefit analysis, the actual magnitude of income effects is likely to be small in relation to the margins of error present in all the information used by the analyst.” A practical approach is to separately identify those who gain and lose from a project, and the scale of their respective benefit and disbenefit, to aid a better understanding the likely concerns of the community and potential remedial measures if distributional issues are substantial. Some travel demand models allow benefits and disbenefits to be separately identified.

The UK Department for Transport notes difficulties in attributing benefits to groups of users where, for example, users change their mode of travel (DfT 2004c). It recommends a methodology developed by Sugden (1999) to attribute user benefits to particular modes of transport. This subject, amongst others, is also discussed in Bates (2003).

4.4 Quality of resource cost data

The quality of economic evaluations is dependent on reliable unit cost parameters (both perceived and resource values). The most recently released general guidance on unit resource costs for use in transport projects in Australia pertain to prices in June 2002 or about that time (Austroads 2004b). However, the presentation of the data does not allow users to update VOCs to take account of inflation other than by applying an average price change index. In addition, the approach does not make fully clear the variables assumed to influence VOCs, eg the road surface condition, terrain, congestion and vehicle deterioration, and is constrained by the limited number of road and vehicle categories and traffic conditions for which costs are derived.

The role of VOCs and other unit costs is to allow estimation of the value of user benefits over the duration of the evaluation period. The current approach implies that prices that existed in about June 2002 are representative of future prices and will be unchanged over time. However, for example, the substantial fluctuation in the resource cost of fuel that has occurred in the past suggests it would only be by chance that the cost at any point in time was an average for the past or, more importantly, was a reasonable estimate of its future value. The trend of improved fuel efficiency of vehicles and changes in vehicle size and technology suggests that a historic average fuel consumption will again only by chance represent future fuel consumption. This suggests a need for further consideration of appropriate values for such parameters. Expressing values to be used in evaluations in probabilistic terms would facilitate risk analysis (see Section 4.6).

In addition, a VOC model needs to include the range of link variables (ie road and traffic conditions) that affect VOCs and should be capable of being applied to each link (including intersections) in a transport model to accurately determine resource costs (ie Component C described by McIntosh and Quarmby). This is best done with an integrated model such as TRAMS (Austroads 2005) but can also be done externally by exporting data from the demand model into a separate evaluation model (Rust PPK et al 1996).

4.5 Definition of the Base Case

There is generally a focus on the Project Case in project evaluation studies. However, the result of an economic evaluation is the difference between the Base Case and Project Case, and hence is affected as much by definition of the Base Case as the proposed project.

In the past, the Base Case might reasonably have been a “do nothing” or “do minimum” situation. However, with urban road networks already congested, such a Base Case will result in travel costs that go up exponentially as traffic rises towards and beyond capacity. A Base Case with excessively high and unrealistic travel costs may allow an evaluation to show almost any project to be worthwhile – which could convey a flawed impression. That is, an unrealistic Base Case will result in a misleading project evaluation.

Providing substantial additional capacity in the Base Case to accommodate rising future demand is undesirable because it means that the evaluation considers only the incremental cost of the project compared with the investment needed in the Base Case. It might be assumed that if the incremental investment is worthwhile, the initial tranche of expenditure was even more cost-effective, on the basis of a declining return from additional levels of expenditure. This is a substantial assumption that is better avoided.

A better alternative may be to accommodate future traffic growth in the Base Case to the extent that is realistic through changes in travel behaviour, and to assume that additional travel is suppressed. These constraints on travel behaviour would be released by the proposed project, at least to some extent. By definition, a change in quantity, time, location and mode of travel in the Project Case relative to the Base Case represent a variable trip matrix (and thus requires use of an origin-destination based approach to the estimation of user benefits).

4.6 Sensitivity testing

All values in an economic evaluation are estimates, if not conjecture. An evaluation result that is based on the best estimate of each input variable provides no guidance on the extent of uncertainty and hence the level of confidence in the result.

Sensitivity testing, which is a form of risk analysis, is generally applied only simply in public sector transport projects in Australia. Individual tests are generally made of the effect of variations in input parameters in the evaluation, though these have little meaning without an indication of the likelihood of their occurrence. The somewhat better methodology of applying a probability to each of the variations and determining a weighted result (as described in Austroads 1996) appears to be little used, and still represents a simple approach.

Recent guidelines (ATC 2004) describe four forms of risk analysis: the above two (ie alternative point estimates and a weighted average of various point estimates); an adjusted benefit-cost analysis (which factors the monetary value of individual components of cost or benefit according to their perceived importance); and use of a probability distribution for input values rather than point values. The first two approaches provide only a limited understanding to decision-makers of the confidence that should be given to evaluation results. The guidelines do not represent the adjusted benefit-cost analysis as a sensitivity test, but its effect is the same, ie to illustrate the impact on the evaluation results of an alternative set of judgements. However, the approach is not guided by a clear analytical approach, and is thus open to arbitrariness. It is not considered by the guidelines to be an essential form of analysis.

The methodology for undertaking the last of the approaches was detailed in Pouliquen (1970). Software to make the approach computationally practicable was introduced in the mid-1980s, and has been taken up by, for example, business schools and major companies. The methodology has also been noted in other reports in Australia (eg RTA 2004 and

Austroads 2002). Yet it appears to have been rarely used in public sector transport projects. Two reasons have generally been given to the author in the past for limited use of the technique. Firstly, it adds complexity to decision making – for example, a result that a project has a '95 percent probability of having a benefit cost ratio of more than 1' may be considered to be more difficult to interpret that one that simply states the project has a 'benefit cost ratio of 1.5.' Overcoming this difficulty seems to be a matter of experience, and should not be insurmountable. It can also be seen as a cost of providing sounder advice.

The second concern is determining probability distributions for input variables. However, work such as that presented by UMTA (1989), Flyvbjerg et al (2002, 2004, 2005), time series data on fuel prices, the range of estimates of the unit value of environmental externalities, and the considerable data held by transport agencies on cost estimates at various stages of project preparation and at construction, and on transport demand forecasts and outcomes, provide a considerable database on which authorities could develop appropriate distributions of parameter values.

Finally, the usefulness of risk analysis that is prepared as part of project appraisal will be considerably enhanced if it is used to identify actions that need to be taken during ongoing project preparation and implementation to ensure project objectives are achieved.

5 Conclusions

The discussion in this paper suggests that:

- Use of a fixed trip matrix for modelling urban travel demand is inconsistent with government objectives for transport, future conditions to be expected in the Base Case, and the likely impact of large and/or complex projects and policies. Hence, there is a general case to be made for use of variable trip matrices for any project or policy that needs to be subject to a computerised travel demand model to determine their likely impact.

- Link-based data from a demand model can be the sole basis for deriving user benefits only with a fixed trip matrix. In other cases, perceived user benefits need to be estimated for each origin-destination pair rather than based on link data.

- In these circumstances, a fixed trip matrix will not provide data that accurately indicates the likely benefits of projects and policies being tested. The direction and degree of the inaccuracy resulting from use of a fixed trip matrix is not uniform, and will depend on the extent and nature of the changes in travel demand.

- This suggests that if it is necessary to use a transport model to determine travel demand effects, it is likely that a variable trip matrix should be used and perceived user benefits derived on an origin-destination basis. This represents a substantial change in current Australian practice.

- The use of a variable trip matrix and the associated requirement for the calculation of user benefits on an origin-destination basis places particular requirements on transport modelling. It is necessary to ensure that the necessary data can be obtained from the models; that assignment iterations lead to consistency between perceived travel costs and travel assignment; consideration is given to sub-divisions of the day for which modelling is undertaken; and consideration is given to testing the reliability of the cross-loading short-cut that allows link-based data to be used to determine the reliability with which it can be used.

- Some other related matters for which practice could be improved include the unit of account used in valuing benefits, disaggregation of benefits, quality of unit resource cost data, definition of the Base Case and sensitivity testing.

These conclusions suggest a need for further deliberation and debate regarding the appropriate methodologies for the planning, modelling and evaluation of urban transport projects, and possible change to current practices.

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