An Examination of Some Issues Related to Benefit Measurement and the Benefit Cost Ratio

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1 Introduction

There has been a renewed interest in economic evaluation of transport projects in recent times. Updated guidelines and practice notes have been published in the UK (DFT 2007) and New Zealand (Land Transport NZ 2006). In Australia, a first edition of the Australian Transport Council's "National Guidelines for Transport System Management, in Australia" in 2004 established a significant new benchmark. A second edition of the ATC National Guidelines has recently been published (ATC 2006), further strengthening the basis for rigorous and consistent appraisal of transport initiatives in Australia.

One of the tools for appraisal of initiatives is economic evaluation. This involves the use of numerous technical elements, many of which are complex and sometimes confusing. This paper addresses two of them.

The first issue is that the method for calculating the benefits of an initiative can be articulated in a number of different ways. The ATC National Guidelines includes two such approaches; a social welfare approach and a gainers and losers approach. The paper expands these into five ways of describing the benefits of an initiative, and demonstrates that they all result in the same benefit. The consequence is a need for analysts to select the method that is appropriate for their application and to be clear and systematic in their use of it.

The second is the general use in Australia of the benefit-cost ratio as the premier, and generally sole, indicator of the result of an economic evaluation of an initiative. As it is a ratio, the definition of changes associated with an initiative as a "cost" or a "benefit" will alter the benefit-cost ratio even though the underlying features of the initiative and its counterfactual base case are unchanged. This issue is examined and practical ways forward identified.

2 Alternative representations and calculations of project impacts

As a general approach to the calculation of the benefits of an initiative, the ATC National Guidelines (2006, Vol 3, p 64) adopts the social welfare approach. It indicates that the benefits of an initiative should be calculated as follows:

- for existing traffic, the difference between total social generalised costs for the Base and Project Cases; and
- for diverted and generated traffic, the difference between the increase in willingness-to-pay (WTP) and social generalised costs for the Project Case.

This description will be familiar to many people, but there are also other ways to envisage the estimation of benefits. The Guidelines acknowledge this in two ways. Firstly, in Volume 5 (pages 52-64), consideration is given to both this and an alternative approach, i.e.:

- the "social welfare approach", in which the net benefit is equal to the increase in WTP (defined in generalised cost terms) less increase in social generalised costs (i.e. the general approach described above), and
- the "gainers and losers approach", in which the net benefit is equal to the net gains to consumers plus net gains to producers plus, if appropriate, net gains to governments plus net gains to third parties.

The remainder of this section examines these two approaches in further detail. It describes five methods for the measurement of project impacts, and demonstrates with formulae and a simple numerical example that they are alternative representations of the impacts and all arrive at the same estimate of net benefits. In doing so, it uses two key representations of costs:

- Perceived costs, which are the costs that travellers recognise and on which they base their travel decisions. Perceived costs are sometimes also described as behavioural costs because they affect travel decisions. They can be expressed in "generalised cost" terms to combine the mix of quantitative and qualitative factors that people take into account when making travel decisions. These factors include the value of travel time (which is influenced by travel conditions, e.g. see ATC National Guidelines Volume 4 Appendix A for the influence of various attributes of travel by public transport). It is usual for them to also include cash payments made in the course of a trip (e.g. public transport fares and road tolls). They also include vehicle operating costs perceived by motorists when making travel decisions, recognising that it is generally accepted that private motorists substantially under-perceive the actual cost they incur.
- Resource cost, which is the underlying value of all resources used for travel. It includes financial costs net of taxes and subsidies (because the latter two items are transfer payments that do not represent any use of resources) and costs that may not have a market value such as most travel time and environmental impacts. Resource costs are sometimes also described as social costs (as in the ATC National Guidelines) to indicate their broader perspective.

The current examination commences with the literature on the estimation of user benefits in transport projects that goes back over three decades. Two essential references are Neuberger (1971) and McIntosh and Quarmby (1972), both of which emerged from a body of work at the time that examined the measurement of benefits in transport networks. The former outlined three methods for calculating benefits when evaluating transport and land use plans. McIntosh and Quarmby, whose paper was first published in 1970, provide a simpler and more general form for estimating user-related benefits, and is therefore used as the starting point for the current examination. They indicated user benefits to comprise:

A. increase in user surplus: $0.5 * (T_1 + T_2) * (PC_1 – PC_2)$ plus

B. increase in (perceived) costs to users: $(T_2 * PC_2) - (T_1 * PC_1)$ less

C. increase in resource costs: $(T_2 * RC_2) - (T_1 * RC_1)$

where (see also Figure 1):

T = number of trips;

PC = perceived generalised cost per trip;

RC = resource cost per trip; and

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

and where, more precisely, T, PC and RC should be with respect to each trip from zone i to zone j by mode k during time period t.

As indicated in Table 1, component A in the McIntosh and Quarmby representation of benefits is commonly known as the change in consumer surplus. Component B reflects the value of the additional travel to users as indicated by their willingness to pay for the additional travel that they undertake, though it needs to be offset against the actual change in the resource cost of travel indicated by component C. Components A and B reflect the value of travel to people, and thus must be measured on the basis of the values they perceive.

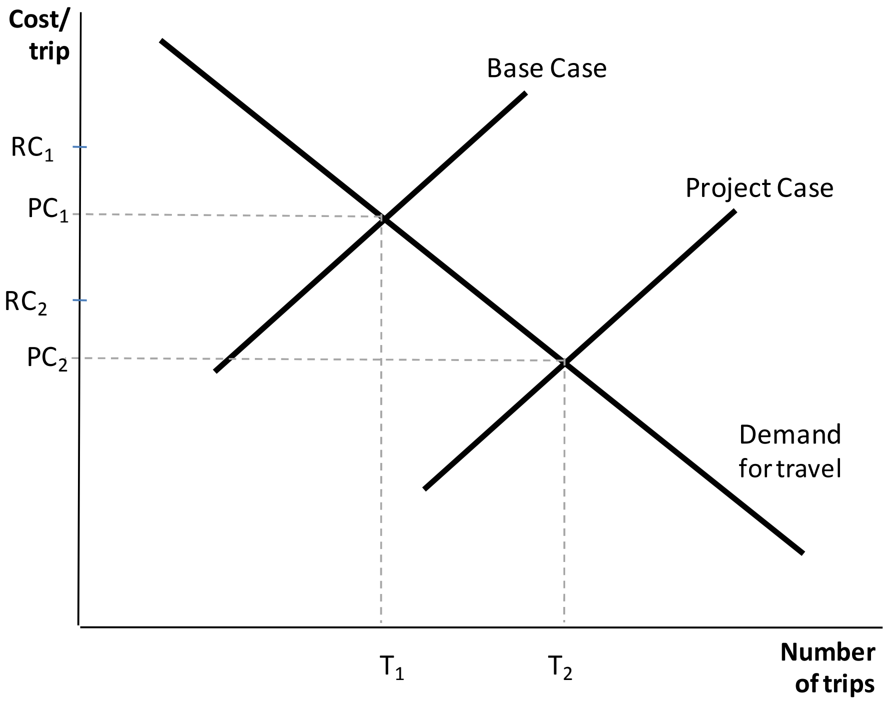


Figure 1 Quantity and cost of travel in the Base Case and Project Case

Subsequent rows in Table 1 relate to the measurement of the benefits. Notably, another representation of benefits emerges from the second substantive row in the table, in which benefits are equal to the change in consumer surplus plus a resource correction, where the latter takes account of changes in resource costs that are not perceived by travellers.

Table 1 Features of McIntosh and Quarmby's presentation of user-related benefits

	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 (i.e. resource) cost of travel
Common term	Change in consumer surplus	Net effect is often called a 'resource correction', i.e. 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 (e.g. 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

Source: Bray (2005)

Approaches in the ATC National Guidelines can be added to these representations of benefits. Volume 4 describes an approach for the estimation of benefits for public transport initiatives that is based on a disaggregation of the perceived and resources costs indicated in McIntosh and Quarmby's representation of benefits described above. Volume 3 of the Guidelines describes the social welfare approach (i.e. the increase in WTP less the increase in social generalised costs), while Volume 5 describes the winners and losers approach.

Thus five different articulations of benefits are identified, the first four of which are variations on the social welfare approach and the last is the winners and losers approach:

- Method 1, which is McIntosh and Quarmby's articulation of benefits being equal to the increase in consumer surplus plus the increase in costs perceived by users less the increase in resource costs.
- Method 2, which retains the estimate of change in consumer surplus indicated by McIntosh and Quarmby but combines the second and third term to create a "resource correction". The resource correction is needed because travellers will generally not perceive the resource cost of their travel because of the influence of taxes, subsidies and misjudgement. If such misperception was not present, the increase in consumer surplus (i.e. component A of McIntosh and Quarmby's estimate of benefits) would fully represent the benefits of a project. This method is described in LTNZ (2006).
- Method 3, which is commonly used for valuing the benefits of public transport initiatives. It begins again with component A of McIntosh and Quarmby (i.e. the change in consumer surplus for existing and generated public transport users), but presents the resource correction in a different manner by disaggregating perceived and resource costs. With regard to the former, it notes that perceived costs for travel by public transport includes fares paid by public transport users as well as other perceived costs such as travel time. However, the provision of subsidies for public transport, the presence of taxes and the nature of fare setting means that fares will only by coincidence equal the resource cost of providing public transport. The gap between the perceived and resource cost of public transport could be presented as the resource correction. However, it is useful to explicitly show the change in the resource cost of providing public transport in an evaluation, i.e. by disaggregating the resource cost of travel into the resource cost of providing public transport and other resource costs associated with the trip by public transport. If this is done, it is necessary to add the change in fare revenue attributable to an initiative as a benefit so that the net resource correction is accurately represented. This revenue should be based on the perceived cost of fares, which will include taxes. Another way of explaining the addition of fare revenue as a benefit is that it is a correction to allow for the inclusion of fares in the calculation of the change in consumer surplus given that fares are not a resource cost but rather are a financial transfer. Yet another means of explanation is that the fare revenue represents a transport provider's benefit, i.e. a change in producer surplus. Method 3 is the method indicated for evaluating public transport initiatives in the ATC National Guidelines (Volume 4).
- Method 4, which is the social welfare approach to estimating benefits presented in the ATC National Guidelines (Volumes 3 and 5), which comprises the increase in WTP less the increase in social generalised costs, where the former is equal to the sum of components A and B in McIntosh and Quarmby's description of benefits and the change in social generalised cost is equal to the component C.
- Method 5, which is the winners and losers approach to estimating benefits described in the ATC National Guidelines (Volume 5) in which benefits are equal to the sum of consumer and producer surplus.

Volume 5 of the ATC National Guidelines (Section 2.6.3) presents a diagrammatic reconciliation of the first, fourth and fifth methods. This paper extends this reconciliation to cover all five of these methods using formulae. The formula that indicates the benefit for each of the methods is described in Table 2, with equations (1), (3), (5), (7) and (8) respectively estimating the benefits for Methods 1, 2, 3, 4 and 5. The transformation of the formula for Approach 1 to that for each of the other five methods demonstrates that the methods are simply alternative representations of the same underlying impacts of an initiative.

Table 2 Five representations of benefits for a public transport initiative

•Method 1 - McIntosh and Quarmby			
(a) Increase in consumer surplus, plus	*(b) increase in perceived user cost, less*	*(c) increase in resource costs*	
$0.5\ (T_1 + T_2)\ (PC_1 – PC_2) +$	$(T_2\ PC_2 - T_1\ PC_1) -$	$(T_2\ RC_2 - T_1\ RC_1)$	(1)
which transforms to			
$0.5\ (T_1 + T_2)\ (PC_1 – PC_2) +$	$T_2\ PC_2 - T_1\ PC_1 - T_2\ RC_2 + T_1\ RC_1$		(2)
and thence to			
Method 2 – Consumer surplus with resource correction			
(a) Increase in consumer surplus, plus	*(b) Resource correction*		
$0.5\ (T_1 + T_2)\ (PC_1 – PC_2) +$	$T_2\ (PC_2 - RC_2) - T_1\ (PC_1 - RC_1)$		(3)
which can be disaggregated into			
$0.5\ (T_1 + T_2)\ (PC_1 – PC_2) +$	$T_2\ (F_2 + OPC_2) - T_2\ (PTRC_2 + ORC_2) –$ $T_1\ (F_1 + OPC_1) + T_1\ (PTRC_1 + ORC_1)$		(4)
and thence transformed to			
Method 3 - Consumer surplus approach with allowance for fares (e.g. for public transport – where the fare is part of the cost of travel perceived by passengers)			
(a) Increase in consumer surplus, plus	*(b) Change in other resource costs, plus*	*(c) Change in fare revenue*	
$0.5\ (T_1 + T_2)\ (PC_1 – PC_2) +$	$(T_1\ PTRC_1 – T_2\ PTRC_2) +$ $[T_1\ (ORC_1 - OPC_1) - T_2\ (ORC_2 - OPC_2)]$	$T_2\ F_2 – T_1\ F_1$	(5)
with equation (1) also transforming to			
$0.5\ (T_1\ PC_1 - T_1\ PC_2 + T_2\ PC_1 – T_2\ PC_2) + T_2\ PC_2 - T_1\ PC_1 - T_2\ RC_2 + T_1\ RC_1$			(6)
and thence to both Method 4 and Method 5			
Method 4 - ATC National Guidelines Social Welfare approach			
(a) Increase in willingness-to-pa, plus	*(b) Social cost in the Base Case, less*	*(c) Social cost in the Project Case*	
$0.5\ (T_2 – T_1)\ (PC_1 + PC_2)$	$T_1\ RC_1$	$T_2\ RC_2$	(7)
Method 5 - ATC National Guidelines Winners and Losers approach			
(a) Consumer surplus (perceived plus unperceived), plus	*(b) Producers surplus (increased revenue less increase in costs)*		
$0.5\ (T_1 + T_2)\ (PC_1 – PC_2) +$ $[T_1\ (ORC_1 - OPC_1) - T_2\ (ORC_2 - OPC_2)]$	$(T_2\ F_2 – T_1\ F_1) – (T_2\ PTRC_2 - T_1\ PTRC_1)$		(8)

where

T = number of trips from zone i to zone j by mode k during time period t

PC = perceived generalised cost per trip from zone i to zone j by mode k during time period t, which in turn comprises

- F = fare for public transport, plus
- OPC = other perceived travel costs (e.g. perceived cost of travel time)

RC = resource cost per trip from zone i to zone j by mode k during time period t, which in turn comprises

- PTRC = public transport resource cost (i.e. the resource cost of providing public transport services), plus
- ORC = other resource costs associated with public transport travel (e.g. personal travel time)

Subscript 1 represents the Base Case and subscript 2 the Project Case.

That all five methods derive the same answer is illustrated using indicative quantitative information for a project to improve public transport. Table 3 presents illustrative data for the Base Case and Project Case for a hypothetical initiative. It shows an initiative that results in the average perceived cost of travel falling (from 13 units in the Base Case to 10 units with the initiative) and the number of public transport trips rising as a result (from 100 trips in the Base Case to 110 trips with the initiative). In the simple representation here, it is assumed that no users are attracted from car, i.e. the additional public transport trips are generated travel. The example includes a breakdown of each of perceived and resource costs into two components, with the resource cost of travel time indicated to be 90 percent of the perceived value to illustrate how such a difference is taken into account.

Table 3 Indicative example of alterative means for estimating the impacts of a public transport project

	Number of public transport trips	Unit resource cost of a public transport trip (cost/trip)			Unit perceived cost of using public transport (cost/trip)		
		Public transport supply cost	User cost (i.e. travel time)	Total	Fare	Travel time	total
Base Case	100	12.0	9.0	21.0	3.0	10.0	13.0
Project Case	110	11.0	5.4	16.4	4.0	6.0	10.0

Benefits calculated under each of the five metods previously described are:

- Method 1 - McIntosh and Quarmby
  - change in consumer surplus[1] 0.5*(100+110)*(13-10)=315; plus
  - change in perceived user costs (110*10)-(100*13)=-200; less
  - change in resource costs (110*21)-(100*16.4)=-296;
  - giving a total benefit of <u>411</u>
- Method 2 – consumer surplus with resource correction
  - change in consumer surplus 315; plus
  - resource correction 100*(21-13)-110*(16.4-10)=96;
  - giving a total benefit of <u>411</u>
- Method 3 – ATC National Guidelines (Volume 4, Urban Public Transport)
  - change in consumer surplus 315; plus
  - other resource changes, comprising
    - incremental supply cost (100*12)-(110*11)=-10; plus
    - unperceived user benefit 110*(6-5.4)-100*(10-9)=-34;
    - giving other resource changes of -44; plus
  - incremental fare (110*4)-(100*3)=140;
  - giving a total benefit of <u>411</u>

[1] A positive value from each calculation represents a benefit, i.e. in this case a rise in consumer surplus of 315 units.

- Method 4 - ATC National Guidelines (Volume 5, Social Welfare Approach)
  - total social cost in the base case (100*21)=2,100; less
  - total social cost in the project case, comprising:
    - existing traffic (100*16.4)=1,640; plus
    - generated traffic (110-100)*16.4=164;
    - giving a total social cost of 1,804; plus
  - the change in the willingness-to-pay for travel 0.5*(110-100)*(13+10)=115;
  - giving a total benefit of <u>411</u>
- Method 5 - ATC National Guidelines (Volume 5, Winners and Losers Approach)
  - consumer surplus, comprising:
    - perceived surplus 315; plus
    - unperceived surplus 110*(6-5.4)–100(10-9)=-34;
    - giving total consumer surplus of 281; plus
  - producer surplus, comprising:
    - increase in revenue (110*4–100*3)=140; less
    - increase in costs (110*11-100*12)=10
    - giving total producer surplus of 130; and
  - giving a total benefit of <u>411</u>

Completion of an economic evaluation requires that impacts such as those described above be compared with the costs that would be incurred to achieve them. Such costs might be for introduction of a busway, major bus lane or some other improvement. Other impacts such as environmental and social consequences not directly associated with individual trips (and hence included in the resource costs considered above) also need to be included in the evaluation.

The same general formulation for estimating benefits can be applied to other cases where user charges are perceived and the cost of the services or infrastructure to which they pertain are separately included in the evaluation (e.g. for a road project where tolls would be used in the place of fares), and extrapolated to incorporate benefits where car users divert to public transport. The key issue is that the analyst must be internally consistent and use only one of the five methods, with the knowledge that they are simply different representations of the same overall benefit.

The appropriate method to use in an evaluation will largely depend on the complexity of the initiative. Where travel behaviour is unaffected by an initiative (i.e. there is no change in the mode or time of travel or the origin and destination of each trip), benefits can be derived on the basis of the change in aggregated resource travel costs for all users resulting from the initiative. The benefits can be derived on a link basis because they are related solely to the quantity and conditions of travel on each link in the network under consideration, i.e. they are independent of the contiguous route taken through the network.

However, where there is a change in travel behaviour (e.g. a change in route, mode, time or quantity of travel), it is necessary to estimate the change in consumer surplus on the basis of the change in perceived travel costs for each trip (Bray 2005). Doing this is somewhat simplified where a computerised travel demand model is used because the model presents the number and average cost of trips between each origin and destination zone in the model.

Use of a computerised travel demand model has one other important consequence – the modelling of travellers' behaviour is undertaken on the basis of perceived travel costs. This means that changes in consumer surplus can be derived on an origin-destination basis using calculations internal to the normal operation of the model.

Computerised travel demand models cannot be easily used to estimate the resource cost of travel on an origin-destination basis. It is impractical to do so in the case of public transport travel because the cost of providing public transport is not related to each passenger trip, but rather to the cost of providing the public transport service that is used by both the trip under consideration and a number of other person trips that converge to use the service for some part of each person's journey between their respective origins and destinations. In any event, for the reasons previously described, changed in resource costs can more easily be derived using aggregated link-based information.

The effect of these conditions is that Method 4 is not appropriate for evaluations that draw on data from computerised travel demand models, and one of the other methods must be used. Similarly, where a computerised travel demand model is used and user charges are part of the perceived cost of travel, Method 3 must be used.

3 The benefit cost ratio

3.1 The role of the benefit cost ratio

The second focus of this paper is the benefit cost ratio (BCR), an indicator of the economic merit of an initiative used in benefit cost analysis (BCA).

Net present value (NPV) is generally held in economic texts and general guides to BCA (e.g. Department of Finance and Administration 2006) to be the most appropriate economic merit decision criterion. NPV is the present value of the benefits of an initiative less the present value of its costs, where benefits and costs are both determined for the situation 'with' the initiative (the 'project' case) compared to the situation 'without' the initiative (the 'base' case). NPV is a measure of the net benefit of a project, and all projects with NPV > 0 are worth implementing in economic terms.

However, NPV is of less value where a budget constraint exists. In this case, the BCR is the most commonly used BCA indicator. BCR is calculated by dividing the present value of benefits (the numerator, or top line) by the present value of costs (the denominator, the bottom line).It is used to rank initiatives in priority order to aid economically efficient resource allocation decisions. BCR has widespread and intuitive acceptance in Australia and New Zealand, and is often the sole indicator used.

Another indicator sometimes used when funding is constrained is to divide NPV by the present value of the net cost of the initiative. This indicates the effectiveness of the expenditure on the initiative compared with the base case. If the only constraint is limited capital, the denominator can be limited to the present value of the capital cost; otherwise it should be the sum of both capital and ongoing costs. The net present value per unit of investment (NPVI) is described in several Australian economic appraisal guidelines (RTA 1999:2-11, and Main Roads 1999:13).

Another indicator of the merit of an initiative is the economic internal rate of return (EIRR). This is the discount rate at which the NPV of a project is zero. It is possible to get multiple solutions if the flow of net benefits through the evaluation period is highly irregular, but this is generally a rare occurrence. It is also not possible to calculate an EIRR (and the BCR also) where net benefits occur in every year of an evaluation as might occur, albeit rarely, where a small investment or a low cost policy initiative result in net benefits within the first year. International agencies such as the World Bank and the Asian Development Bank use EIRR and NPV as their principal indicators of the economic merit of an initiative and distinctly avoid use of the BCR (ADB 1997 and World Bank 1998).

3.2 An issue in BCR calculation

At a generic level, BCR is simply a ratio of benefits to costs, with a BCR>1.0 indicating an initiative to have economic merit. However, when calculating the BCR, a complication arises in deciding whether certain impacts should be classified as benefits or costs. The selection of one classification over another varies the relative sizes of the top line and bottom line of the BCR, and hence the size of the BCR. This is the principal limitation of the BCR and one of the reasons it is not used more widely in international practice.

Some items are generally unambiguously held to be a cost (e.g. the capital cost of infrastructure) or a benefit (e.g. the value of travel time savings and changes in externality costs). However, others such as changes in recurrent operating costs are less clear. As a result, some inconsistency occurs in appraisals of transport initiatives in Australia, for example:

- The usual practice for road projects has been for capital and maintenance costs to be in the denominator, with all consequences for travellers, the transport industry and others in the community to be recorded as “benefits” (which could be positive or negative) in the numerator (e.g. Main Roads 1999, Austroads 2004, LTNZ 2006 and DfT 2007).
- In the case of a public transport investment initiative, changes in public transport operating costs are generally recorded as a cost (in contrast with a road investment initiative in which they would be recorded as a benefit), with remaining impacts considered to be benefits.

In contrast, the ATC National Guidelines indicate that only capital costs should be recorded on the bottom line, with all other changes included on the top line (ATC Vol 3:76).

At its simplest, two possible options are to consider operating costs as either a consequence of capital expenditure on an initiative (i.e. be on the top line) or an inherent part of the cost of securing the initiative (i.e. be in the bottom line). These two situations can be represented via the following two BCR definitions:

$$BCR1 = \frac{(PVB - PVOC)}{PVIC} \tag{1}$$

$$BCR2 = \frac{PVB}{(PVIC + PVOC)} = \frac{PVB}{PVC} \tag{2}$$

where $$PVC = PVIC + PVOC \tag{3}$$

PVB = present value of benefits

$PVOC$ = present value of operating costs

$PVIC$ = present value of investment costs

PVC = present value of costs

and all benefits and costs are determined on an incremental basis for the project case relative to the base case.

When PVOC equals zero, BCR1 and BCR2 are equivalent, making the issue of which BCR measure to use irrelevant for a project that consists solely of investment, or capital, costs, and no impact on operational costs. However, as PVOC deviates from a zero value, BCR1 and BCR2 do differ from each other. The next section briefly explores numerically the scale of the difference between BCR1 and BCR2.

3.3 Numerical comparison

The extent of the difference between BCR1 and BCR2 can be gleaned from the following expressions that represent the relationship between the two BCR measures (see appendix for derivations):

$$BCR2 = BCR1(1 - fPVOC) + fPVOC \tag{7}$$

or alternatively:

$$BCR1 = BCR2(1 + z) - z \tag{8}$$

where $f = \dfrac{PVOC}{PVC}$ (9)

denotes PVOC expressed as a fraction of PVC

and $z = \dfrac{f}{1-f}$ (10)

Tables 4 and 5, and Figure 2, illustrate the relationship (for positive values of *f*).

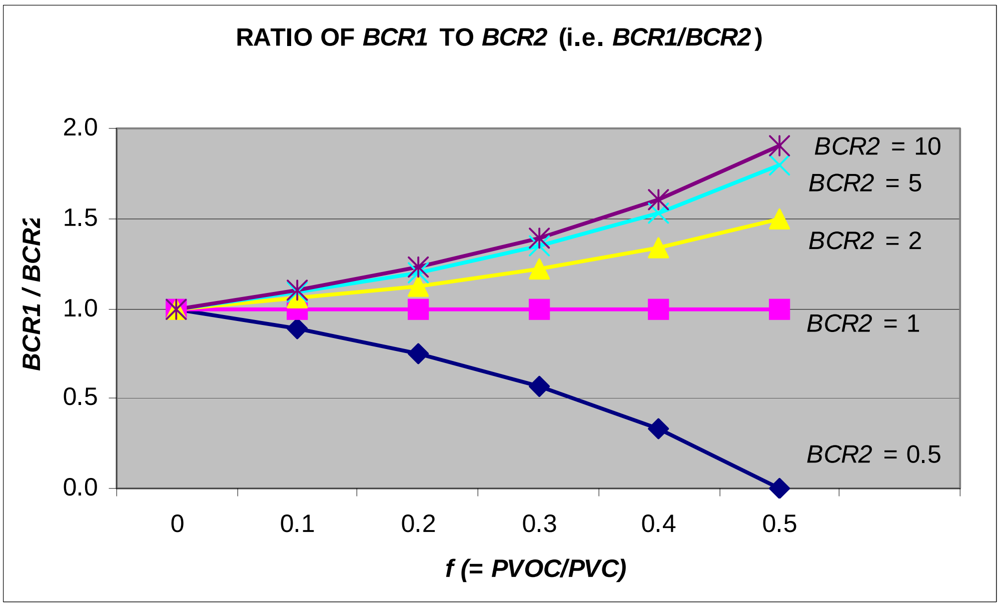
f	BCR1 =	BCR2 =
0	BCR2	BCR1
0.1	1.11 * BCR2 - 0.11	0.90 * BCR2 + 0.10
0.2	1.25 * BCR2 - 0.25	0.80 * BCR2 + 0.20
0.3	1.43 * BCR2 - 0.43	0.70 * BCR2 + 0.30
0.4	1.67 * BCR2 - 0.67	0.60 * BCR2 + 0.40
0.5	2.00 * BCR2 - 1.00	0.50 * BCR2 + 0.50

Table 4: Relationship between BCR1 and BCR2

Table 5: Results for given BCR2 values

		BCR1					BCR1/ BCR2				
f	BCR2 -->	0.5	1	2	5	10	0.5	1	2	5	10
0		0.5	1.0	2.0	5.0	10	1.0	1.0	1.0	1.0	1.0
0.1		0.4	1.0	2.1	5.4	11	0.9	1.0	1.1	1.1	1.1
0.2		0.4	1.0	2.3	6.0	12	0.8	1.0	1.1	1.2	1.2
0.3		0.3	1.0	2.4	6.7	14	0.6	1.0	1.2	1.3	1.4
0.4		0.2	1.0	2.7	7.7	16	0.3	1.0	1.3	1.5	1.6
0.5		0.0	1.0	3.0	9.0	19	0.0	1.0	1.5	1.8	1.9

Figure 2: Effect on BCR of the Scale of Recurrent Costs Relative to Capital Costs



A number of observations can be made from these results (with BCR2 used as the base for comparison):

- In all circumstances where one measure of BCR yields a result of 1.0, so does the other measure.
- When BCR2 is less than 1.0:
  - BCR1 will always be smaller than BCR2
  - the magnitude of this difference increases as *f* (the relative size of service operating costs) increases.
- When BCR2 is greater than 1.0:
  - BCR1 will always be greater than BCR2
  - the magnitude of this difference increases as *f* increases
  - for any given *f* value, the difference increases relatively more slowly as BCR2 progressively increases.

The results demonstrate that the two measures of BCR can yield significantly different results in some circumstances, something that users should be aware of. In particular, the analysis indicates the substantial effect that the treatment of recurrent costs can have on the BCR in cases where recurrent costs are a significant proportion of project cost, even though the initiative itself is unaltered.

3.4 Implications for practice

At a simple very practical level, it is important that analysts be aware of the above issue. A very simple response is to ensure that in sensitivity testing both BCR1 and BCR2 be determined to see if significantly different values occur. ATC (2006) recommends that PVOC should be included in the top line (as per BCR1). This has the merit of being straightforward and allows the effectiveness of capital expenditure to be tested, which is especially useful given that governments usually face capital constraints.

At a more formal level, the issue becomes rather more complex. ATC (2006, Vol 5, pp. 85-88) discusses the issue in a much more comprehensive manner. It makes two points. First, for new road and rail initiatives, the issue will be of little significance due to the small size of infrastructure operating costs (e.g. road maintenance) and their occurrence well into the future. Second, where recurrent infrastructure operating costs are significant relative to capital costs (e.g. public transport initiatives), the situation is complicated by the fact that these costs for new capital initiatives compete for funds with capital initiatives out of future budgets. It effectively concludes that the use of BCR2 won't result in wrong resource allocation decisions provided the economically efficient approach of using a constant cut-off BCR in future years is adopted.

In the UK, the Department for Transport (2007) addresses this issue by defining BCR in terms of the present value of the cost public accounts. It defines the BCR as follows:

$$BCR = \frac{\text{NPV + PV of Cost to Public Accounts}}{\text{PV of Cost to Public Accounts}}$$

This reduces to BCR1 when the value of the PV of Cost of Public Accounts equals PVIC, and BCR2 when the value of PV of Cost of Public Accounts equals PVC (= PVIC+PVOC).

The issue of how to best calculate the BCR is clearly complex. The above discussion has attempted to very briefly highlight the issue and its potential importance. Whilst ATC (2006, Vol 5) provides a more detailed treatment of the issue, the authors of this paper believe further research is worthwhile to ensure decisions optimise government expenditure across all transport projects and gain the acceptance of jurisdictions. It is suggested that this research should focus on the extent to which the issue is likely to be a problem in practice, whether expenditure decisions are constrained by capital alone or both capital and recurrent expenditure, and the extent to which the approach described in the ATC National Guidelines ensures optimal resource allocation over time.

4 Conclusion

This paper has examined two issues in benefit cost analysis to provide insight and understanding. First, it noted five articulations for the measurement of project benefits, and demonstrated that they are simply alternative representations of the same underlying effects. Analysts can therefore adopt the method that is best suited to the circumstance of the initiative that they are evaluating, and ensuring that they do not use a mix the alternative methods. The choice of approach will be influenced by the complexity of the transport network under consideration, whether the trip matrix is fixed or variable between the Base Case and the Project Case, where there is a difference between the perceived and resource cost of travel, and where user charges such as road tolls and public transport fares are part of the perceived cost of travel.

The second issue is related to the benefit-cost ratio, the widely used benefit cost analysis indicator in Australia for ranking projects by economic merit when budgets are constrained. The paper highlighted the issue in calculating the BCR of whether recurrent costs should be treated on the top line (as a benefit / disbenefit) or the bottom line (as a cost). Both approaches occur in practice. The analysis showed how the treatment of recurrent costs can have a substantial effect on the BCR when recurrent costs are high relative to capital costs. Analysts should be aware of this. In general, analysts should follow the ATC National Guidelines to ensure consistent national practice. The authors believe further research into determination of the BCR is warranted.

Appendix: Derivation of BCR relationship equations (7) and (9) on page 9

This appendix provides the derivation of equations (7) and (9) on page 11 (representing the relationship between BCR measures BCR1 and BCR2).

Combining equations (1) and (3) in the main text yields:

$$PVB = BCR1(PVC - PVOC) + PVOC \tag{11}$$

Substituting (11) into (2) yields:

$$BCR2 = \frac{BCR1(PVC - PVOC) + PVOC}{PVC}$$

$$= BCR1\left(1 - \frac{PVOC}{PVC}\right) + \frac{PVOC}{PVC} \tag{12}$$

Substituting (9) into (12) yields:

$$BCR2 = BCR1(1 - fPVOC) + fPVOC$$

and rearranging $$BCR1 = \frac{BCR2}{(1-f)} - \frac{f}{(1-f)}$$

or alternatively $$BCR1 = BCR2(1+z) - z$$

$$\text{where } z = \frac{fPVOC}{1 - fPVOC}$$

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