PUTTING THE ECONOMICS BACK INTO EVALUATION: SOME INSIGHTS INTO THE EVALUATION OF URBAN ROAD PROJECTS

I Ker
Manager,
Metropolitan Policy
Department of Transport
Nedlands
Western Australia

ABSTRACT

Urban road projects can have substantial impacts on travel in addition to rerouting of existing trips. Economic evaluation of such projects often fails to recognise the complexity of those impacts, despite the theoretical basis for doing so being well-established.

A practical methodology to bridge the gap between economic theory and current practice is described and applied to a major urban road project. Estimated benefits were around half the level with the simple resource cost differential model, with further variations of 10-15% each from additional refinements.

The paper also identifies problems relating to traffic growth forecasting and user perception of costs, which should be addressed.

> *The traffic models appropriate for analysing major schemes must reflect the changes in travel behaviour that will occur. The changes could include traffic generation and redistribution, changes in the choice of travel mode, and reassignment as well as changes in the times at which journeys are made. A significant implication for the assessment process is that the economic evaluation will be carried out with variable trip matrices. (Standing Advisory Committee on Trunk Road Assessment, 1986.)*

INTRODUCTION

Urban road networks are complex entities and major road projects can have substantial impacts on travel throughout the network. Traffic models have recognised this for a long time, but the economic evaluation of road projects may be at a much more simplistic level, despite the basis in theory being well-established. Estimates of benefit levels are likely to be erroneous, not necessarily because of deficiencies in the travel and traffic models but because outcomes are wrongly assessed or relevant outcomes are not included.

This paper outlines the economic theory for, and current practice of, economic evaluation of urban road projects and attempts to develop a methodology to bridge the gap between them.

BACKGROUND TO ROAD PROJECT EVALUATION

Consumers respond to changes in price by altering patterns of demand. This occurs both for changes in the price of any specific commodity and for changes in the price(s) of other commodity(ies); the demand impacts will be exhibited by the product the price of which has changed and by other products.

Micro-economic literature is replete with the relevant technical terms: own-price elasticity, cross-elasticity, income effect and substitution effect. Even casual observation of daily behaviour shows the validity of these concepts.

Why, then, is there little reference to demand elasticity in the application of economics to road project evaluation? Why are demand forecasts often presented apparently with no consideration of the concept of elasticity?

Part of the answer lies in the magnitude of the impacts, which may be relatively small. Demand elasticities, other things being equal, will tend to be greater:

1. For own-price elasticity,

   - where expenditure on the item is a higher proportion of disposable income;

   - in the case of luxuries (optional purchases) rather than necessities.

2. For cross-elasticity, in the case of close substitutes and, in the opposite direction, close complements.

If changes in price (or "generalised cost", in the case of transport) will have no significant impact on demand, it is reasonable to adopt simple methods for evaluation, predicated on demand being the same in both the base and project cases. If that assumption is not reasonable, such simple methodologies can lead to substantial errors.

In road project evaluation, the methods adopted appear to reflect the following view of demand elasticities:

1. There is a high degree of substitutability between alternative routes within a developed network, such that improvements to one route (reduction in user generalised cost) will bring about a significant redistribution of traffic between routes which serve the same trips. This is reflected in the effort put into the development of traffic assignment models.

2. There is a very much smaller degree of substitutability between trips (ie alternative origin-destination pairs) and between modes. This is the 'territory' of the strategic travel demand model.

3. There is no generation of additional trips with a reduction in user cost. This is usually described in terms of all trips being "committed".

'he importance of these implicit assumptions lies in lifferences in the economic evaluation methodology ppropriate in various cases. If a project has no impact on rip-making behaviour, other than on the route by which a rip is made, the gross benefit from any trip can be assumed o be unaffected. Hence, benefits from the project can be easured solely in terms of the change in the resource cost f trips.

Once substitution of origins, destinations or modes is allowed, however, it is no longer appropriate to adopt so simplistic an approach, since the gross benefit to the user may be very different from that of the original trip. Generation of new trips creates a totally new area of benefit, some of which has to be offset by the benefit foregone from any activity no longer undertaken.

All too often, however, the potential significance of the impacts on user benefits is overlooked. This may have to do with engineers' preferences for precisely quantifiable measures, such as resource costs, over what may be seen as rather nebulous concepts such as consumer surplus. Economists, on the other hand are more likely to accept the dictum that "there is more to be said for rough estimates of the precise concept than precise estimates of economically irrelevant concepts" (Mishan, 1971a).

It is not proposed to discuss why consumer surplus should be incorporated in evaluations (for which, see Mishan (1971b, chs 7 and 8)). It is worth noting, however, that even "resources" only have value because of a "willingness to pay" in the market place. Consumer surplus is simply a willingness to pay which is not skimmed off by the market; it is nonetheless real for not being captured by the market. Similar arguments are central to the valuation of accident reduction consequences (Wigan, 1989; Ker, 1980).

EVALUATION ECONOMICS

The economic theory basis for evaluation of road projects with network effects is set out in McIntosh & Quarmby (1970). The problems associated with inappropriate specification of evaluation methodology are discussed by Neuburger (1971). Whilst there have been some refinements in principle since then (Jara-Diaz and Farah, 1988), the Neuburger paper is still the authoritative work.

The components of benefit estimation are:

1. Change in consumer surplus.

2. Change in the surplus transferred to other parts of the community (through taxation and other transfer payments).

Figure 1 illustrates the simple case of a change in price (where b is the generalised behavioural cost of travel). This also shows (n) the part of generalised cost which does not represent consumption of resources (and is transferred to the rest of the community by means of taxes), the total of which (nq) must be added as a 'non-resource correction' to the consumer surplus to provide a complete measure of benefits.

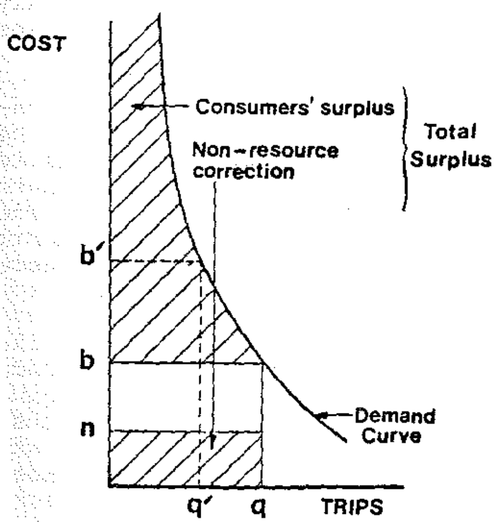
Figure 2 illustrates the more usual case of comparing two projects which have different supply (cost) functions. In this case, both b (the generalised behavioural cost of travel) and n (the non-resource cost component) are different in the two cases (one of which may be the 'do-nothing case). User benefits (of project 2 compared with project 1) are the sum of:

- (q1 + q2) * (b1 - b2)/2, which is the change in consumer surplus; and

- n2q2 - n1q1, which is the non-resource cost correction.

Given that n = b - r (where r is the unit resource cost), the benefit calculation can be reformulated as:

(q1 + q2)(b1 - b2)/2 + (q2b2 - q1b1) - (q2r2 -q1r1). [1]



IGURE 1 DEMAND CURVE AND SURPLUS

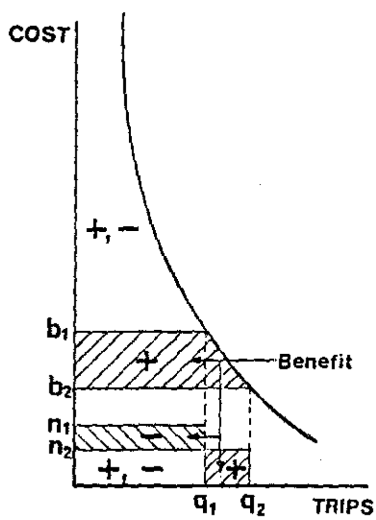


FIGURE 2 COMPARISON OF ALTERNATIVES

ource (Figs 1 and 2): McIntosh and Quarmby (1970)

This formulation is simple to calculate and contains three readily understandable measures. It may be read as:

a) increase in consumer surplus,
PLUS
b) increase in perceived costs to users,
MINUS
c) increase in resource costs.

Items (a) and (b) represent the gross increase in value received by travellers, as measured by behavioural costs. Item (c) represents the real cost of achieving that increase in value. In the limiting case, where there is no change in travel behaviour, other than route choice, the formula resolves down to the change in resource cost.

It is important to note that there are two distinct measures of cost in the estimation of benefits. One is the cost perceived by users, on the basis of which they make decisions about whether or not to travel, and which are, therefore, related to the benefits they derive from that travel. The second is the real resource cost of travel. NEITHER is the full market cost of that travel, unless users perceive all costs of travel, which is known not to be the case for urban private car travel. Full market cost is only relevant in the calculation of a taxation correction (see below).

In practice, a single value of time is adopted for non-business travel for evaluation purposes, rather than the true behavioural value, on the grounds that public investment should not be biased towards those who, because of higher incomes, put a higher value on their time. The concept of behavioural cost is, hence, different in economic evaluation from that used in demand prediction, where individual values should be used.

This formula assumes a linear demand function, which will almost always over-estimate the user benefits (Neuburger, 1971), since demand curves are usually convex to the origin. Whilst it is possible to develop more accurate estimates, given a knowledge of the demand function (Jara-Diaz and Farah, 1988), any error will be relatively small for most project evaluations.

User Perception of Costs

There has been debate, over many years, about the level of cost-recovery from road users (Ogden, 1988). Because of higher relative cost-recovery levels from car users, compared with heavy commercial vehicles, it has been concluded that current road evaluation procedures favour projects with larger heavy vehicle traffic components (Ker, 1988).

Another factor, however, is the extent of user perception of costs. Two, sometimes conflicting, processes may be at work:

* Market prices for materials consumed in vehicle operation exceed their resource costs, because of taxation.

* Users may not perceive all costs in making decisions about travel.

In general terms, if the perceived cost is lower than the resource cost, travel demand will be higher than optimal and project benefits will be over-stated. This is exacerbated for urban projects by:

* The greater importance of external costs

* The higher demand elasticity for car travel resulting from the greater availability of alternatives, most notably public transport.

The perceived cost of urban private car travel is significantly less than the real resource cost (DGT, 1982, P19). The perceived cost may consist of fuel cost and all or part of any parking charge (McIntosh and Quarmby, 1970, Annexe C). The cost of time is also perceived by users.

Leaving aside parking costs, the estimated relationships of perceived costs to resource costs for various road user groups are shown in Table 1. These values do not include externalities in the resource costs and, therefore, overstate the perception of full economic costs.

Whilst the elasticity of demand for car travel in general is low, because of actual or perceived constraints (Socialdata 1987) and lack of suitable alternatives, the impact of under-perception of costs by private car users may be significant where road and public transport are highly-competitive. The most important instance of this would be in the case of roads providing access to the central city, where conventional economic evaluation will show a consistent bias in favour of roads and against public transport. This bias is in addition to that which is usually recognised on the basis of externalities only.

TABLE 1. PERCEIVED COST: RESOURCE COST RATIOS FOR URBAN TRAVEL[(a)]

	March 1985	June 1988
Private Car	0.58	0.56
Business Car	0.89 to 1.03[(b)]	0.88 to 1.05[(b)]
Light Commercial	1.07	1.10
Heavy Commercial	1.10	1.12
Weighted Mean	0.91	0.92

(a) Cost includes value of time

(b) Depending upon assumptions on perception of non-fuel operating costs. High value used for weighted mean.

Taxation Correction

The McIntosh and Quarmby formulation includes a non-resource correction, which is based on the fact that some part of the cost perceived by users does not reflect consumption of resources, but is additional surplus transferred usually to the community as a whole through taxation.

A further correction is required if the total user expenditure on transport is changed, since expenditure formerly (or subsequently) in other sectors of the economy would also contain a component of non-resource cost. In the absence of specific determination of expenditure impacts on specific goods and services, McIntosh and Quarmby argue for the use of the average rate of indirect taxation in the non-transport sectors to derive this further adjustment. The basic formula is then modified by the term $(-\Delta T . \Phi_n / \Phi_t)$,

where ΔT is the change in total tax paid on transport
Φ_n is the non-transport indirect tax "rate"
Φ_t is the transport-specific tax "rate"

Where the costs perceived by the user differ from the total market costs, the taxation component should be based on the difference between perceived costs and resource costs (which may be negative). The non-resource transfer related to other costs occurs when they are paid/perceived and are related to separate, non-trip-related benefits.

The value of Φ_t is the market cost: resource cost ratio. The value of Φ_n may be approximated by the ratio of indirect tax revenue from non-transport consumption (non-fuel excise duties, sales taxes, import duties and taxes on gambling) to total final consumption expenditure on non-transport items. If we assume that there is no substitution between transport consumption expenditure and capital expenditure, the value of Φ_n for Australia is around 0.067.

This correction can be applied directly to the McIntosh and Quarmby formula in the following form:

$$\text{Benefit} = (q_1+q_2)(b_1-b_2)/2 + (n_2q_2-n_1q_1) - \Delta T.\Phi_n/\Phi_t$$

$$= (q_1+q_2)(b_1 - b_2)/2 + [q_2b_2-q_1b_1-(q_2r_2-q_1r_1)] - \Phi_n (q_2m_2 - q_1 m_1) \quad [2]$$

where m_1, m_2 are the market costs of travel.

PROJECT IMPACTS ON TRAVEL BEHAVIOUR

Any transport project has an impact on the amount of transport consumed. There are four types of impact:

a) **Trip generation** - additional trips made as a result of the lower cost of travel:

b) **Modal substitution** - change of mode, as a result of the relative lowering of travel costs on one mode;

c) **Trip substitution** - changes in origin-destination patterns, as a result of the selective lowering of travel cost on some parts of the network; and

d) **Route substitution** - changes in route for existing trips, as a result of the selective lowering of travel costs on some parts of the network.

Current evaluation methodology does not estimate trip generation. The trips most affected by urban projects are peak-period trips, which are argued to be largely non-discretionary; hence, any trip generation would be small.

Similarly, modal-substitution is not always estimated. Interfacing of the DOT strategic transport models with MRD traffic assignment models, which is currently being pursued as part of the Road Reserves Review in Perth, will assist the estimation of such effects (RRR, 1988).

Excluding trip-generation and modal-substitution, any change in the amount of vehicle travel is the net impact of trip substitution and route substitution. The question then is of whether the full McIntosh and Quarmby (1970) methodology is appropriate in this context or, since the number of trips is constant, it resolves down to the measuring benefits by the change in the resource cost of transport. Should generated travel, through trip substitution, be treated, for economic evaluation, analogously to generated trips?

Trip Substitution

The economic evaluation of generated trips is based on their ranging from trips which were only just not made at the previous travel cost (ie the net benefit to the potential traveller would have been slightly less than zero) to those which would only just be made at the new travel cost (ie the net benefit of the new trip to the traveller would be only slightly greater than zero).

In the case of trip-substitution, an existing trip is not made, with the consequent loss of gross benefits and saving of all costs, and an alternative trip is made, with accrual of benefits and the incurring of costs. We can say nothing about gross levels of benefits or costs, since the new trip may actually cost more than the existing (but less than it previously would have) to obtain a higher gross benefit. However, the net benefit of the alternative trip must be greater than that of the existing trip, by an amount which lies within the range from slightly above zero to slightly less than the reduction in perceived cost for the alternative trip.

It is wrong simply to assess the change in resource costs as the measure of benefit for substituted trips because trips are substituted to achieve an increase in net benefit to the consumer. This benefit must be based on the cost of trips as perceived by the consumer.

The resource cost measure would favour projects which reduced the cost of existing trips relative to projects which expanded the range of options available to tripmakers. A project which simply shortened existing trips would show a greater 'benefit' than an identical project which resulted in some people substituting a more distant destination because of the wider range of choice now available to them at what they consider to be an acceptable cost. Whilst this may be desirable for other reasons (eg energy conservation), the appropriate response is not to fudge the evaluation methodology but to put an appropriate shadow price on the resource in question (eg fuel).

The confusion over methodology arises partly from the use of a presentation which shows trips as an homogenous measure of quantity, when all trips are not equal and, therefore, cannot simply be added together. The conventional diagram represents a conceptual aggregation of demand functions, rather than a unique, mathematical aggregation.

A major problem in relating traffic models to economic theory is that the former deal with **vehicle travel** (traffic volumes), whereas the latter is based on **trips** (and **person trips**, at that).

The dichotomy between vehicles and persons is usually resolved by the use of vehicle occupancy factors and related adjustments to travel costs. The dichotomy between travel and trips is less readily resolved, since the user benefits are intimately related to trips or, more correctly, the activity the trip makes possible. Each origin-destination (O-D) pair must be treated as a separate "commodity", with its own supply and demand functions. These functions cannot be aggregated in the same way as individuals' demand functions for a specific commodity. Consumer surplus changes for each O-D pair must be estimated and then those changes summed.

Traffic models do not generally estimate trip costs. Since most models work on the basis of incremental loading of trips onto the network, it would be a major computing task to apply link costs, which are only determined at the end of the assignment, to all trips.

Although we do not have information on the numbers or perceived cost of substituted **trips**, we can use **travel** information to calculate the consumer-surplus benefits. If we divide the cost axis by the length of trip (to give cost per kilometre) and multiply the trip axis by the same factor (to give vehicle travel), the calculations involving the two are unaffected. (All terms in the McIntosh and Quarmby function are products of quantity and a measure of cost.)

Route substitution simply represents a change in the resources required for, and the perceived cost of, a known set of trips which produce a fixed level of benefits. The extent of route substitution, however, may be substantial, with adverse impacts on the validity of the method discussed immediately above. However, travel and traffic models do provide a means for estimating the travel distance impact of route substitution separately.

A single, base-case, trip table combined with two traffic assignments ((a) to the base-case network, and (b) to the 'with project' network) provides, by subtraction, an estimate of the impact of route substitution on travel distance and travel cost. The difference between (b) and the assignment of the "with-project" trip table is due to trip substitution.

EVALUATION IN PRACTICE

It is not uncommon for road projects to be evaluated on the basis of there being no change in the level or composition of demand resulting from them. In the case of urban projects, this is reflected in the use of a single trip table (origin-destination) for both the base and project cases. For both urban and rural projects, it is often reflected in the use of a single growth rate for traffic.

Single Trip Table

The use of a single trip table in the base and project cases is inconsistent with observed behaviour, although it is often justified by reference to the ability of models to replicate observed traffic volumes. Since the models do not allow generation of additional trips or, in the case of a single trip table, substitution of trip destinations, it is argued that there is no significant trip generation or trip substitution.

There are two problems with this argument:

1. The models have a wide range of error, even at screenline level, and more so for individual road links, which is critical for evaluation of road projects.

2. Traffic volume gives no information on trip origins and destinations. It is quite possible to calibrate a traffic model to give acceptable traffic volume estimates using a trip table which contains errors.

However, if the same model is used to generate trip tables with and without a new link in the road network, different patterns of trips will emerge. This means that the difference in resource cost is not a reliable measure of project benefits. The new trips will differ in length from the original trips, and may, therefore, have a higher cost than existing trips, even with the new project. Recent application to a major urban road project has highlighted the extent to which evaluation errors may arise in practice.

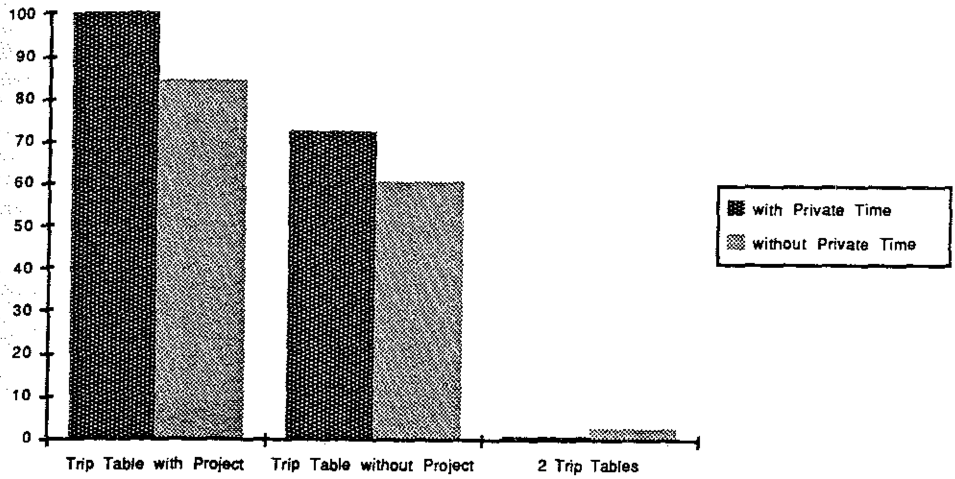


FIGURE 3 RELATIVE VALUES OF RESOURCE COST SAVINGS (DISCOUNTED 30 YEARS @ 7%)

The project was one option for a major inner urban bridge and road link. Since the specification of the project has been subject to many changes, results are presented in index value terms rather than dollars. Even the lowest index values (in Figure 4) still represent user benefits well in excess of project costs. Results in Figure 3 are solely to illustrate the instability of the resource cost value.

The present value of user resource cost savings, with development of base case and project case trip tables, was reduced virtually to zero. In addition, the estimated level of resource cost savings was greater with the base case trip table than with the project case trip table. Use of a single trip table is unstable, even in its own terms.

Two Trip Tables

The models can produce separate trip tables for the base and project cases, at a relatively small cost in computing and related effort. The full evaluation methodology can then be applied, to derive more accurate measures of benefits.

In this case, it was not possible to delve back into the current evaluation model, which would be necessary to derive all the values needed. However, the model outputs were adequate for manipulation to produce robust conclusions. Outputs from the model were the total user resource costs and the total vehicle kilometres of travel. Approximate traffic composition data were also available. Manipulation of the outputs was done using a spreadsheet.

The benefits were calculated on two bases:

1. Two trip tables (base and project cases) and two traffic assignments (one for each case).

2. Two trip tables (base and project cases) and three traffic assignments (two for the base case trip table, one each to the base and project networks; and one for the project case).

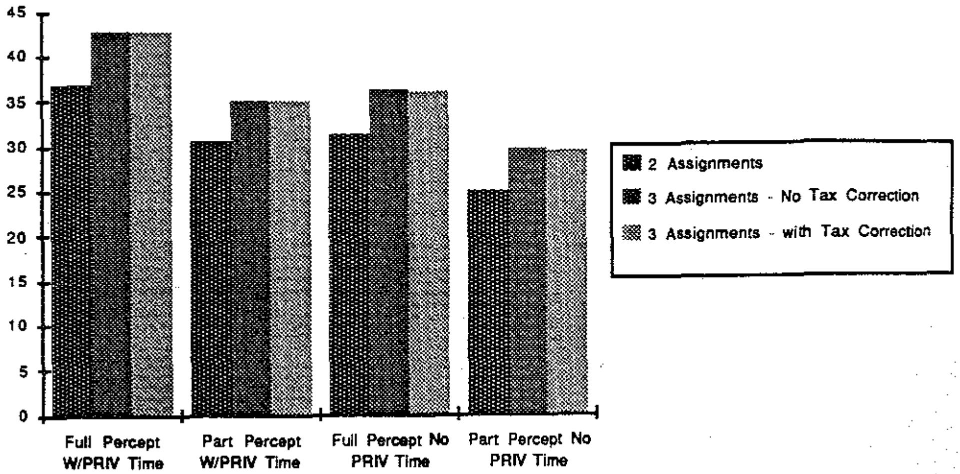


FIGURE 4 RELATIVE VALUES OF ECONOMIC BENEFITS WITH TWO TRIP TABLES (SINGLE TRIP TABLE WITH PRIVATE TIME = 100 (SEE FIGURE 3)

The difference between (1)and (2) provides a measure of the value of carrying out a third assignment. The estimated level of benefits increased by around 15% (Figure 4), which is almost as great as the effect of including a value for private time and is greater, therefore, than the potential improvement from further refinement of the value of time.

Application of the tax correction altered that higher level of benefits by an insignificant amount, but that was due to a change sign midway through the evaluation period. Further investigation of this would be useful.

Likewise, the differences from the values in Figure 3 are a measure of the additional accuracy from developing the second trip table (ie for the project case). Estimated benefits are as low as 35% of the levels estimated with the resource cost/single trip table method.

Traffic Growth and Congestion

Growth in travel is often defined by interpolation between, and extrapolation from, travel model outputs for two years. There is a very real danger, in this procedure, of ignoring the impact of increasing traffic volumes (congestion) on travel growth rates (ie the elasticity of demand).

This can manifest itself in two ways.

1. With a single trip table (and, hence a single growth rate), traffic on the network may be postulated to increase to a higher level than would actually occur. Given the typical performance of roads with increasing traffic, the base-case network is pushed to a relatively higher cost point than the project-case network. Benefits from the project are correspondingly over-estimated.

2. With two trip tables (and, hence, different growth rates for the base and project cases), the forecast level of service in the project case can deteriorate below that of the base case, if the project case growth rates are higher. The benefits from the project can, in consequence, turn negative in later years of the evaluation period.

In the case study reported in this paper:

* Nominal annual benefits (ie before discounting) declined continuously and became negative in year 25.

* The nominal annual resource cost saving declined continuously and became negative in year 12.

It is inconsistent with economic theory that a greater supply of travel opportunities (additional road capacity) should lead to a higher cost of travel as a result of the expansion of demand. With a conventional demand curve, greater quantities are consumed only if the price is lower.[a]

This impact can be minimised by adopting a forecast year as late as possible in the evaluation period.

CONCLUSION

Simplifying assumptions made in road project evaluation can induce significant errors, especially where projects will have impacts on travel behaviour other than through route choice.

Economic theory provides an unambiguous framework for evaluation of such projects. Existing travel and traffic models can provide the necessary values for application of that framework. It is essential, however, to recognise that the economic theory deals with trips and the traffic models with travel distance and vehicle flows.

Application of the economic framework to traffic model estimates for a major urban bridge and road project has shown that the level of benefits was around half that estimated by the simple resource cost differential method. The size of this difference indicates that there is a greater need than previously recognised for use of the full economic evaluation methodology, even for projects which are smaller than the one in this case study.

At a second-order level, both underperception of resource costs and carrying out a third assignment had as great an impact on the level of benefits as the inclusion of a value for private time, indicating greater significance than further refinement of the value of private time.

There is also a need for more adequate treatment of forecasting of traffic growth and user perception of costs for urban road project evaluation, in the context of welfare economics, which is the basis of benefit-cost analysis.

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[a] Whilst it may well be that the additional road capacity induces changes in the demand function (eg through changes in land use), the models being discussed do not encompass such effects.

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