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Twenty-one sources of error and bias in transport project appraisal

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Abstract

Twenty-one sources of error and bias in the appraisal of transport projects are identified. These relate to objectives, definitions, data, models and evaluation conventions. Objectives may be unclear, incompletely specified or inconsistent with appraisal criteria. Definitions of study areas and scheme options for testing may bias the outcome. There are multifarious sources of data and model error. Double counting, inappropriate values, and failure to balance quantified and non-quantified items can all affect the evaluation. We suggest that there is a systematic tendency to a mega-error—that of appraisal optimism. Three antidotes to this condition are briefly suggested.

1. Introduction

Recently, critical reviews have been provided of the applications of cost–benefit analysis to transport projects in Britain (Nash, 1993) and to a wide range of investment projects in developing countries (Little and Mirlees, 1994). In this paper, we add to this literature by listing various sources of error and bias in the appraisal of transport projects, particularly with respect to British experience. Our purpose is not to argue that appraisal is so prone to bias as to be a worthless exercise, quite the reverse. The message is that appraisal cannot be a black box; critical judgement is required to probe the strength of every link in the chain of logic. This short paper is intended to raise the consciousness of some common pitfalls in the hope that these can be recognised and avoided. The points are loosely grouped from the more strategic to the more tactical, but this implies nothing about their relative importance which will anyway be context-specific.

2. Unclear objectives or conflicts between stated and actual objectives

Ideally, objectives should be clear and appraisal criteria should follow directly from them. In practice, conflicts can easily arise. Railtrack may be required to invest in safety enhancement even if this has a negative commercial return, with unclear implications for the appraisal criteria. Mega projects, e.g. Crossrail or the Channel Tunnel Rail Link may take on a life of their own; it may be unclear what appraisal criteria are to be used and why. Lack of shared objectives between partners in major projects may also lead to appraisal problems.

An example is provided by the leaked Department of Transport memo on the criteria for ranking the roads programme (Local Transport Today, 1996a). From this it appears that roads are not appraised solely on the basis of their traffic, economic and environmental performance as expressed in the Framework, but also on Government Office judgement and their importance to the overall network. Furthermore, separate cut-offs apply to projects in the core motorway programme and the more peripheral parts of the trunk road network, reflecting the need to spread expenditure more widely than a strict cost–benefit analysis approach might imply. Remarkably similar issues seem to arise in Swedish road planning (Nilsson, 1991).

3. Prior political commitment

Schemes may be difficult to reject because of the degree of political commitment they have accumulated. The Humber Bridge might be the best example in the UK. The message here is that outline appraisal needs to come sufficiently early in the project cycle for graceful withdrawal to be possible, and that commitment should not be given in a form which makes it impossible to withdraw at a later stage. Note that 'political' covers not only the commitment of politicians, but also of scheme promoters. This point makes a strong case for open-independent scrutiny of appraisals.

4. Current transport situation not accurately known

The start of any appraisal is to collect data on the existing

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travel situation. A number of problems are encountered:

1. Although road traffic flows can be relatively easily measured, precise origins and destinations are more difficult to obtain;
2. Data on bus and rail usage are commercially confidential. Surveys can be easily undertaken but suffer from a number of problems. For example:
3. Roadside/on-vehicle/at station surveys are usually undertaken on a 'typical' day in the spring or autumn. An annualisation factor is then applied to get yearly data. The problem is that there is no such thing as a 'typical' day. There may be a tendency to choose 'atypical' days where transport demand is at its greatest
4. Household surveys, particularly if they are self-completed, may be dominated by households (and days) in which a lot of travel is undertaken.

Because data are so costly to collect, studies are often based on data collected many years ago. The origin/destination matrices are then updated so that overall flows are consistent with those observed. However, this updating method fails to pick up changes in the pattern of flows.

5. The study area is incorrectly defined

This is believed to be a common source of error in road appraisal. For budgetary reasons relating to data collection and modelling costs, the study area may be quite tightly defined. This risks knock-on effects outside the study area and wide-area traffic reassignment being inadequately handled. It is believed that one of the sources of error in the M25 traffic forecasts was the underestimation of longer-distance rerouting effects.

A similar problem has been encountered in forecasting the demand for new stations. A radius of 2 km has often been used to define the study area. However, this radius may be too great for sites with poor levels of service, particularly if there are nearby stations with better levels of service. By contrast, this radius may be too small for new stations with good levels of service, particularly if bus feeders, and park and ride facilities are envisaged (Preston, 1987).

6. Incorrect definition of the base and do-something cases

In most cases, the base case will not be a simple 'do-nothing' scenario, but a 'do-minimum' scenario. For example, without the major modernisation of the West Coast Mainline, considerable investment in renewals and expenditure on maintenance would still be required in order to maintain current levels of service. Alternatively, if 'do-nothing' means continue to spend on renewals and maintenance that which have been spent on in recent years, it is likely that train services would suffer from reduced speeds, increased late running, deteriorating ride quality, etc. which would have impacts on demand, and on user and non-user benefits. 'Do-nothing' would really mean 'do-worse'. A plausible baseline case is essential to the realism of the appraisal. Another source of error is the omission of some do-something options, especially low-cost alternatives. For example, investments in guided bus and, indeed, conventional buses are rarely compared to investment in light rapid transit. Where comparisons are made they may not be fair. For example, light rapid transit has segregated right of way, conventional bus does not (or, if it does it is achieved at the expense of other road traffic). Similarly, light rapid transit and guided bus schemes may follow exactly the same route, thus negating the guided bus's advantages in terms of flexibility and reduced need for interchange. In road schemes, junction improvements and improved maintenance tend to get neglected at the expense of new road building (especially by-passes).

7. Gold plating of the 'do-something' option/cost over-runs

The option that is chosen may be over-engineered, either at the time or subsequently. Examples include the provision of excess capacity and, more contentiously, 'over-provision' for disabled access and for safety and security. The latter are believed to be one of the main causes for the cost over-runs on the Channel Tunnel, with out-turn costs, at £10 billion, being double those forecast (Szymanski, 1995). A more common cause of cost over-runs relates to engineering problems which result in construction costs being underestimated. Both the Humber Bridge and the Channel Tunnel were adversely affected by geological problems. Such problems may lead to over-runs in the construction period and delays in achieving full service. This is particularly important to Private Finance Initiative (PFI) projects given the high rate of discount.

8. Errors in planning assumptions

Many schemes may be dependent on planning decisions. For example, the M65 was built on the assumption that Central Lancashire New Town would be fully developed. Concorde was developed under the assumption that supersonic flights would be granted access to inland air space throughout the world. One of the problems with the Sheffield Supertram is that a housing scheme it was designed to serve has been demolished. This was due to long planning timescales. The data used to forecast Supertram demand were nine years old by the time the system opened (Local Transport Today, 1996b). As a result, the overall size of the public transport market in the corridors served was overestimated and initial out-turn demand was 8 million passengers per annum, compared to a forecast of 22 million.

9. External factors incorrectly forecast

Most transport forecasts are in turn dependent on forecast of external factors, e.g. population, income, economic activity and car ownership (which ought to be an internal factor but is usually measured exogenously). These are rarely forecast accurately, particularly for schemes with long planning periods and long project lives. For example, the shortfall in forecast demand for the Tyne and Wear Metro (opened in the late 1970s/early 1980s) was attributed to being based on over-optimistic forecasts of living standards and hence the propensity to travel on Tyneside, which had their origins in studies undertaken in the 1960s (Fullerton and Openshaw, 1985).

10. Transport inputs incorrect

This may result when travel speeds, service frequencies and fares are not as forecast. For example, Sheffield Supertram was forecast to have a speed advantage over rival bus services. However, due to junction delays and route variations, these speed advantages have not materialised. When public transport infrastructure is being provided, a particular problem is in determining the frequency of service, speed of the services, other service quality attributes and the fares that operators will introduce (see, e.g. Nash, 1992).

11. Model error

The models used to forecast the impact of transport investments may contain substantial error. Apart from measurement error (discussed above), common sources of error include:

1. Specification error. The models used may fail to take into account the impact of key explanatory variables, e.g. income or may mis-specify the effect of an explanatory variable (e.g. the elasticities have been wrongly measured). The use of global averages (e.g. a price elasticity of -0.3) may be particularly misleading.
2. Lack of transferability. A model successfully developed in one area at a certain point of time may not be transferable to another area and/or another point of time.
3. Aggregation error. Models, e.g. the logit, are often calibrated with disaggregate data but applied with aggregate data. This will lead to bias as the average of a set of non-linear functions will not be the same as a non-linear function of a set of averages (Westin, 1974).
4. The scale factor problem. Models based on stated preference data and the logit model may be affected by this technical problem (see Bates, 1988). The upshot of this is that although relative valuations will be unbiased, forecasts are likely to be biased.

These errors will not be a problem if they are random, as they will cancel out and there may be a trade-off between measurement and specification error, with the former increasing and the latter decreasing as model complexity increases (Alonso, 1968). However, these errors will be a problem if they are systematically in one direction or another. In practice, model errors are difficult to detect as they are often swamped by input data errors (see Sections 4 and 5, Sections 9 and 10 above).

12. Interactions not taken into account

Many transport investments will have effects on rival transport markets. The response of these operators will be difficult to forecast. One of the features of the Sheffield Supertram has been the vigorous competition from the rival bus companies which was not envisaged at the planning stage. Similarly, it seems that the Eurotunnel failed to anticipate the degree of competition it would face from rival ferry companies. Many studies of light rapid transit systems fail to take into account the impact of re-congestion on the road network, despite evidence that around 35% of those who are initially forecast to switch from road to rapid transit will switch back (HFA, 1991, Preston, 1994). A particular problem for even major public transport schemes is that the effects on the parallel road network are likely to be marginal and temporary, and hence difficult to measure (Younes, 1995).

There may also be important interactions within the transport market served by a transport investment. A new road may initially reduce congestion on parallel roads, but the reduced journey times on the parallel roads will attract traffic back from the new road (this is usually taken into account) and attract brand new traffic (induced demand—which until recently has not been taken into account) [see Coombe, 1996]]. The release of latent road traffic demand is believed to be one of the dominant features of the M25. Similarly, an upgrade of a rail line (e.g. the West Coast Main line) would need to take into account the reaction of rival operators on other lines (e.g. on the East Coast Main line for London–Glasgow traffic or on the Chiltern line for London–Birmingham traffic).

13. Dynamics not taken into account

There are a number of issues here. Firstly, disruption may have important effects. For example, it was forecast that all suburban railway users would transfer to the replacement Manchester Metrolink service. In the event, only around three-quarters did so. This was believed to be due to the fact that the suburban rail service was suspended for over a year whilst the Metrolink was being built. Some rail users found alternatives which they continued to use after the Metrolink was opened (Vaughan and Gane, 1994).

Secondly, any new product may be expected to build up demand over time. This is referred to as the product take-off curve. This is often neglected. For example, for new stations in West Yorkshire, ex-post evaluation found that it took demand up to five years to reach its equilibrium levels, with demand in year 1 only being 57% of that in year 5 (Preston, 1987). Such a learning curve is particularly important to include in PFI projects, as relatively high interest rates will discount benefits in future years.

Thirdly, where new technology is introduced, the 'bath-tub' effect is often ignored. This phenomenon describes the effect of unreliability over time. Initially, this is high as the technology exhibits teething problems. However, over time, unreliability rapidly decreases only to rise gently over time as the asset wears out (Godward, 1992). It is likely that the appraisal of Eurostar rail services did not take this into account.

14. Project life incorrectly assessed

Project lives are usually based on the expected technical life of the asset. In some cases, these may be misjudged. The 50 year project life used to assess the Victoria line now looks excessive. However, given discounting, extensions of project lives from say 30–50 years are unlikely to have a major impact on appraisal. More problematic is where the economic or market life of a product is substantially less than the technical life of the project. An example of the former is the investment in steam locomotives in the British Rail modernisation plan of the 1950s whose economic lives were cut short by advances in diesel and electric locomotion technology. An example of the latter is the Bradford Interchange. There was a demand for this facility as a bus station and depot, whilst the bus industry was publicly owned and controlled. The reforms of the bus industry following the 1985 Transport Act effectively took away the market for this facility.

15. Quantifiable impacts omitted

In some instances, impacts which could easily be quantified are excluded from the analysis. For example, the disruption effects in terms of congestion, loss of business, etc. of the construction of the Sheffield Supertram were not included in the scheme appraisal, nor was the loss of goodwill towards the scheme that the disruption caused (although this is more difficult to measure). Similarly, walking times were omitted from the appraisal of the Bradford Interchange, even though these were likely to increase as a result of the scheme. Perhaps the most obvious example of a quantifiable impact being excluded is the exclusion of user benefits in urban rail appraisal in the UK (see, e.g. Nash and Preston, 1991). This policy seems likely to be continued by the Office of Passenger Rail Franchising (OPRAF, 1996).

16. Treatment of non-quantifiable impacts

One of the main criticisms of cost–benefit analysis is that impacts which are difficult to evaluate in money terms are excluded. However, this may be addressed by using qualitative approaches (often politically driven) to take these impacts into account. The problem of what Mishan (1988)] calls 'horse and rabbit stew' then occurs. If you take one horse and one rabbit, no matter how you combine them the taste of horse dominates the stew. Similarly, if you take one set of quantifiable impacts and one set of non-quantifiable impacts in an appraisal, one set may dominate. Examples include the Channel Tunnel rail link where conventional cost–benefit analysis favoured the south London route, but where environmental and economic developmental (and political) factors favoured the east London route. Similarly, although conventional cost–benefit analysis in the 1960s indicated that rail lines, e.g. the Cambrian Coast line, should be closed, non-quantifiable factors, e.g. developmental factors and non-use values (particularly existence values), ensured that no such decision was taken. Conversely, it is often argued that road projects depend excessively on the quantified COBA (the Department of Transport's Cost–Benefit Analysis computer program) results with inadequate weight being given to the environmental impacts. What we are arguing is that the problem is not so much with including non-quantifiable impacts, but in assessing their relative importance vis-à-vis quantifiable impacts. Multi-criteria analysis may assist in this respect.

17. Incorrect values used

Although the impacts of a scheme may be correctly appraised, their valuation may remain controversial. In terms of values of time, controversies still exist regarding the use of equity or behavioural values, or some mix of the two, the split between working and non-working time (and, in particular, the latter's division between commuting and other non-work time), and the treatment of small time savings. In terms of the value of life, the main debate is between the use of lost output or willingness to pay approaches, or some combination of the two. Similarly, in terms of environmental valuation, the main controversy revolves around the use of standards driven or willingness to pay approaches. Possibly the classic example of the use of wrong values was in the third London Airport inquiry when the Norman Church at Cublington was valued by its fire insurance value, creating a focus for derision of the entire Cost–Benefit Analysis approach (Self, 1970).

18. Double counting

There is a possibility that certain impacts may be included twice or possibly three times in an appraisal. For example, the primary impact of a transport scheme may be the reduction in travel times. The secondary impact is improved accessibility to work, schools, shops and leisure facilities. The tertiary impact is the increased economic activity that the transport scheme has promoted. Provided generated travel has been correctly forecast, all of the secondary impacts and most of the tertiary impacts are merely downstream manifestations of the primary impact. Those tertiary impacts that are not directly related to primary impacts may be related to a multiplier effect. This may be considered a transfer in that a similar investment elsewhere would have a similar multiplier effect.

19. Transfers

These need to be correctly identified. Examples of transfers which are often not identified include taxes, grants and subsidies, revenue, reductions in wage rates (a gain to employers, a loss to employees) and increases in property prices (a gain to property sellers but a loss to property buyers) [Mohring, 1993]]. Employment effects may often reflect transfers of jobs from one area to another rather than net gains. This may depend on the definition of the study area (see Section 5). From a national perspective, if the East–West Crossrail scheme linking London's Liverpool Street and Paddington stations helps to attract jobs to the City of London which otherwise would have gone to Paris or Frankfurt, this is a net benefit. From a European perspective, this is a transfer with zero benefit. Trans-boundary projects, e.g. the Paris–Brussels–Amsterdam high speed rail line often encounter problems of this kind.

20. Treatment of systems effects

An example of this is where a series of by-passes are appraised in isolation from each other. However, collectively they may represent a major upgrade of a trunk road, but the re-routed (and generated) traffic that the trunk route attracts is not taken into account in the individual by-pass appraisals. The appraisal of schemes on the A65 and A650 Leeds/Bradford–Skipton–Kendal route is a relevant case. Another example concerns airport planning. Typically, airport development plans are made in isolation from each other, that is assuming the attractiveness of other airports in the system remains constant. An improvement at airport A may be partly justified by the diversion of traffic from airport B, but the economic effects on B are not considered in the appraisal. This may be further compounded if airport B is also contemplating expansion. There has been some concern that Liverpool and Manchester airports are in this situation.

Conversely, some infrastructure may be built in anticipation of a systems effect that does not materialise. For example, one of the reasons for the low traffic levels on the Humber Bridge is that it is not connected to the motorway network. Indeed, the existence of the Humber Bridge was one of the driving forces behind the call for an East Coast motorway.

21. Rules change during the planning period

An example is the Manchester Metrolink (see Table 1). This in turn relates to the long planning periods for major transport infrastructure (see also Sections 8 and 9). In the case of the Manchester Metrolink scheme, the planning period is some 10 years, whilst the concept of a Picc–Vic link in Manchester has a planning history of some 100 years. As a result of these long planning periods, transport schemes are vulnerable to political, financial and economic risk including changes in the appraisal criteria in the middle of the planning process. The Birmingham Northern Relief Road has also been affected by rule changes concerning the financial and funding environment.

22. Appraisal optimism

This is arguably the greatest problem of all and has been well documented by [Walmsley and Pickett (1992)], and Pickrell (1989)], particularly for urban rail. It stems from benefits being overestimated and costs underestimated. Looking at the 20 problems we have already identified, we believe the following may contribute:

1. Prior political commitment (Section 3);
2. Overestimates of existing travel volumes (Section 4);
3. Full range of low cost 'do-something else' options omitted; performance of base case unrealistically poor (Section 6);
4. Subsequent gold plating of the 'do-something' option (Section 7);
5. Overestimate of population and economic growth (Section 9);
6. Overestimate of the performance of the new transport facility, particularly in terms of speed (Section 10);
7. Underestimate of the reaction of rival transport operators and infrastructure owners (Section 12);
8. Failure to take into account the slow build-up in demand (Section 13);
9. Asset lives overestimated (Section 14);
10. Quantifiable costs excluded (Section 15);
11. High valuations attached to scheme benefits (Section 17);
12. Benefits counted twice or even three times in different parts of the appraisal (Section 18).

It is our judgement that these 12 problems tend to act systematically so as to promote appraisal optimism. The eight other problems, in our judgement, are less likely to act systematically to promote appraisal optimism:

1. Unclear objectives may help promote or reduce the prospects of a scheme going ahead (Section 2);
2. If the study area is defined too tightly, this may reduce forecast net benefits (e.g. park and ride schemes) or increase them (M25 —recongestion effects not taken into account) (Section 5);
3. Planning bias may arise due to developments that were expected to take place but did not happen (e.g. Central Lancashire New Town) or were not expected to take place but did (e.g. commercial development around the M25) (Section 8);
4. Model error may lead to under- or over-estimates of impacts (Section 11);
5. Problems with transfers most commonly occur when an impact is treated as a net benefit but is in fact a transfer. However, in some cases a net benefit may be treated mistakenly as a transfer [as occurred with rail revenue from non-bus users in the Cambrian Coast line closure study (Section 19), Sugden, 1972]];
6. Omission of non-quantifiable impacts (Section 16) and systems effects (Section 20) may go either way;
7. Rule changes during the planning period may increase or reduce the chances of a scheme going ahead, with the latter being the more common (Section 21).

23. Conclusion

The above checklist suggests to us that appraisal optimism is the greatest danger in transport investment analysis. Appraisal optimism happens because the information contained in the appraisal tends to be owned by scheme promoters who have obvious incentives to bias the appraisal—deliberately or unwittingly—in one or more of the ways described above. This is a particularly acute problem if the scheme is in the public rather than private sector, since the normal commercial checks and balances on excessive optimism do not apply.

We can suggest three antidotes. The first is to have within-organisations, groups whose function it is to own the appraisal regime rather than the projects, and to ensure that the appraisal is honest. The second is to expose projects to open scrutiny at public inquiries, with adequate resources available to cross-examine the scheme promoters. The third is to spend a lot more on ex-post evaluation than is currently done. Systematic checking of what actually happened relative to forecast is an important discipline.

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Table 1
Evaluation of marginal costs and benefits of LRT compared to existing public transport (£ million, discounted 30 year values)

	1984	1987	Tyson
Capital costs	26.31	28.20	45.56
Operating costs	– 5.55	– 5.61	– 38.29
User benefits	25.52	29.80	
Revenue	6.93	7.62	
Non-user benefits			8.00
Benefit:cost ratio	1.44	1.53	1.01

Appendix A. Changing rules during the planning period: an illustration

The Metrolink scheme underwent two evaluations related to grant submissions in 1985 and 1987 (GMPTE, 1985] GMPTE, 1987). These are shown in Table 1, along with a later, unpublished, evaluation undertaken by Bill Tyson.

The 1984 and 1987 submissions were broadly similar, although the latter had more adequately taken into account the effects of bus deregulation. Both give a benefit:cost ratio of around 1.5. The main benefit is that of time savings to users of the Metrolink. However, new government funding rules meant that such user benefits can not be taken into account (Department of Transport, 1989). In Tyson's evaluation, user benefits are excluded, as are rail operating costs and revenues, presumably on the basis that revenues and costs will be perfectly matched. In Tyson's evaluation, the main benefit is the reduction in subsidy due to withdrawal of Section 20 support for the Bury and Altrincham rail lines, equivalent to £36.98 million over 30 years (the remaining £1.31 million of operating cost savings are due to withdrawal of tendered bus services). The other main benefits are non-user benefits, of which £6 million are due to congestion relief and £2 million due to accident reductions. Under these new evaluation rules, the Metrolink scheme just has a benefit:cost ratio greater than unity. It is noticeable that non-user benefits are estimated as only being around 30% of user benefits. It also seems likely that a large element of user benefits has been captured as revenue in the Tyson evaluation, largely as the result of higher peak fares.

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