INTRODUCTION

In developed countries, for which improvement of the transport systems is no longer an essential condition for economic development, the anticipated benefits of investing in transportation infrastructure must be weighed carefully against the possible detrimental impacts, particularly on the environment. For this reason, most European countries require potential transport investments to be appraised with respect to many criteria, including those related to the economy, the environment, safety and travel time savings, among others. See Bristow and Nellthorp (2000) for an overview of current practice in Europe.

Cost benefit analysis has been seen to have strength as a framework for the collection of data but to be problematic in its reliance of the monetisation of costs and benefits. Other forms of multicriteria analysis permit the retention of the useful accounting framework but permit a variety of alternative approaches to the determination of the relative importance of criteria.

Uncertainties

Uncertainty may be present at many stages in a multi-criteria appraisal process. These include the nature of the problem to be solved, the policy objectives to be addressed, the assessable criteria to be used in measuring a project’s achievement of those objectives, the estimates of each candidate option’s performance with respect to the various criteria and the relative importance to be attributed to each of the criteria in weighing them against one another.

The research described in this paper addresses the last of these areas in the context of a linear additive value function approach to multi-criteria appraisal. In this robust and widely-used approach (Stewart, 1992) each criterion is assigned a weight and for each option, a single measure of its overall value is derived by summing the weighted performance ratings. These overall scores may then be used to find a rank order of the candidate projects.

Why is there uncertainty about the criterion weights and why does it matter? It matters because the values of the criterion weights determine which project is deemed to offer the best solution (except in the unlikely event where one candidate project dominates the others). The uncertainty may have a number of sources. The cognitive problems faced by individuals in dealing with questions of this complexity are pervasive and not always
acknowledged. Some of the criteria that are rightly taken into account are not marketed (or marketable) and there is no consensus over the appropriate weights for them. Diverse interest groups are likely to have differing views on the relative importance of the criteria and would contest weights that run counter to their perspective. The local context of each appraisal exercise may influence the weight assigned to certain criteria, making a nationally applied weight unduly and inappropriately rigid.

The fact remains, however, that decisions have to be made and the choice of option has inescapable implications about the relative importance attributed to the criteria, even if this is not made explicit. The absence of a clear statement of the reasons behind such decisions is likely to undermine public confidence in the decision process. A sensible framework for finding suitable weights, in which uncertainty can be recognised and dealt with, could increase the transparency, accountability and public acceptability of the decision process. Such a framework is described below.

Framework for finding the overall values of projects

The approach described below follows a number of general principles in its treatment of uncertainty. These are:

- to avoid spurious precision, when far greater confidence can be placed in a vaguer statement;
- to keep to a minimum unwarranted bias (Jessop, 1999) whereby projects are favoured or discriminated against, with no explicit justification; and
- to identify the areas where the level of uncertainty needs to be reduced in order to reach a decision and not to waste time on aspects that have little influence on the outcome.

These principles will be the subjects of the next three sections.

Avoiding Spurious Precision

There is an intimate link between the weights assigned to the criteria and the acceptable trade-offs between them. Given a set of weights, the inherent trade-off relationships can be found by looking at the ratios between pairs of weights. Conversely, if acceptable trade-off relationships between pairs of criteria are defined, these act as constraints on the feasible values of the criterion weights. In their classic text, Keeney and Raiffa (1976) propose methods for identifying the criterion trade-off relationships acceptable to the decision-taker. These methods find precise trade-off values but are criticised for being very labour intensive, and perhaps more appropriate to situations where there is a single decision-taker, than those where a diversity of opinions exists. The trade-off relationships may be relaxed so that they are constrained to lie within a range of values rather than to take a single precise value. This has the potential advantage of reconciling groups with differing views, who may be able to agree on a less rigid formulation of the criterion trade-offs. In the case where the criteria involved are measured on a subjective scale, the decision-takers may be able to place greater confidence in this vaguer form of trade-off statement than in a precise one. Of course, if a more precise trade-off relationship can be confidently adopted, as would be the case for criteria which can be assigned an agreed monetary value, then this would be more appropriate than an unnecessarily vague formulation.
The practice of incorporating imprecise trade-off relationships into the decision process is well-established in multi-criteria analysis (an overview is given in DETR, 2000, Appendix 4).

The following example illustrates these ideas.

<table>
<thead>
<tr>
<th></th>
<th>Criterion A</th>
<th>Criterion B</th>
<th>Criterion C</th>
<th>Criterion D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>6</td>
<td>7</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Option 2</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Option 3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

The numbers on the table indicate the expected performance of each option with respect to the four criteria. No one option dominates the others. Each has its strong and weak areas and the choice of option will depend on the relative importance of the criteria. Let us suppose that there is a well-established relationship between criteria A and C, such that 1 unit of A is of equal value to 2 units of C. This places a strict constraint on the weights of A and C (the weight of A must be twice the weight of C) and reduces by one the degrees of freedom. All criteria should be involved in the set of trade-off constraints. Any that are not bound by such a constraint could be assigned any weight (including zero or very large) and it is reasonable to assume that if a criterion is part of the evaluation process, the decision-takers must have some idea of the magnitude of its influence. Turning to criteria B and D, let us suppose that they are not as easily defined. Perhaps a statement to the effect that 1 unit of B is worth between 0.5 and 1 unit of D could be made with some confidence, as could a statement that 1 unit of D has equivalent value to between 7 and 10 units of C. These constraints (together with a requirement that one of the weights should equal 1, to avoid multiple equivalent weight sets) are sufficient to narrow down the acceptable weight-sets, although not to indicate a single weight set that would give a unique option ranking.

**MINIMISING UNWARRANTED DISCRIMINATION BETWEEN OPTIONS**

The question of how to choose from the potentially large number of feasible weight sets that comply with the trade-off constraints described above can be answered by appealing to the principle of minimum discrimination between the options. Although the ultimate aim of the decision process is to choose one (or a subset) of options, this choice should be firmly grounded in the explicit judgments made by the decision-takers about the relationships between the criteria. Until this point is reached, no unjustified bias should be shown to any of the options. Thus, the weight set chosen for inspection should be the one that gives the options the most equal scores. This may be done in a variety of ways, such as by maximising the entropy of the scores or by minimising the sum of the squared differences of the scores from the mean score. If the overall option scores are indeed equal, this indicates that the trade-offs that have been used to constrain the values of the weights are insufficient to discriminate between the options. Further constraints should be added or existing ones “tightened” in order to distinguish between the options. This is likely to be an iterative process, in which the trade-offs are refined, until no further progress can be made. There is, unfortunately, no guarantee that a single rank order of options will emerge at this stage, although there are likely to be fewer feasible rank orderings and it is possible that only one
rank order is possible. Unless this is the case, a further stage of the decision process will help to inform the final choice.

IDENTIFYING CRITERIA WITH A PIVOTAL ROLE

To recap, the decision-taker has articulated a number of acceptable trade-offs between pairs of criteria and these act as constraints on the values that may be assigned to the weights of the criteria. In certain circumstances, however, they may not constrain them sufficiently to narrow down the possible rank orders of options to one. Sampling the weights in the feasible region, either deterministically or using Monte Carlo simulation, will provide an overview of the frequencies of the different possible rank orders and will also indicate which criteria play a pivotal role in determining the rank order of options. The performance ratings and criteria trade-offs relating to these criteria could then be subjected to closer examination. If no single rank order can be obtained, the person ultimately responsible for taking the decision is, at least, informed about the nature of the choice to be made.

Some a priori indication of which criteria affect the rank of each option most strongly may be obtained by examining the performance ratings. In the simple example given above, Option 1 will head the ranking if Criteria A and D have a higher weight, while criterion B is likely to have most overall effect as the performance rating have the biggest spread.

Sensitivity analysis, involving performance ratings and trade-offs which are likely to have a significant influence on the rank order of options and over which there is some uncertainty, will highlight the areas needing further research (for example, estimates of option performance based on a crude model may need to the redone). It will also indicate the crucial value preferences and their implications to the person ultimately responsible for arbitrating between the options.

CONCLUSION

It is essential to acknowledge and deal with the uncertainties that arise in the process of multi-criteria transport investment appraisal. If they are ignored, either by insisting that a precise weight be assigned to each criterion, or by refusing to implement any systematic method for aggregating the diverse arrays of performance data, then the whole decision process risks losing credibility in the eyes of those involved in it and those who observe it (and bear its consequences). This paper has described a number of strategies which allow uncertainty and only require it to be resolved if that is essential in making the final decision. Recognising and incorporating uncertainty into the process can make it more flexible and robust, especially where conflicting views must be reconciled. In addition, the deliberate attempt to avoid, or at least minimise, the effects of unwarranted bias make this approach less likely to arrive at an unjustified conclusion and less susceptible to the effects of favouritism, whereby one option is promoted more strongly than is warranted by the explicit value judgments.

REFERENCES


