
Summary:

Handling and presenting uncertainty in cost-benefit analysis

TOI Report 1443/2015

*Authors: Paal Brevik Wangsness, Kenneth Løvold Rødseth and Harald Minken
Oslo 2015, 93 pages Norwegian language*

Uncertainty can be referred to as the difference between the information that is required to make a reliable decision and the information available at the time of the decision. The problem of uncertainty in cost-benefit analysis (CBA) is thus that the decisions cannot be 100% secure, since the information is not 100% complete. Uncertainties should be analysed, presented and handled in a way that improves the choice between project alternatives, and facilitates risk mitigation. We review 19 country (or state/province) guidelines for transport appraisal, and contrast and compare their recommendations of methods for analysing uncertainty, which uncertain variables are to be analysed and how uncertainty is presented in the CBA. Together with the findings from this literature review and recommendations from an expert workshop held during this project, we also provide recommendations on how to present uncertainty in cost-benefit analyses.

The Norwegian Public Roads Administration (NPRA) is currently revising its Impact Analysis Manual (V712 Konsekvensanalyser), and has therefore commissioned the Institute of Transport Economics to conduct a literature review of how other countries handle uncertainty in cost-benefit analyses. This report will also shed light on how uncertainty can be presented in a way that contributes to better decision making when choosing between project alternatives, with regards to the revision of Manual V712.

This report focuses on the uncertainty associated with the monetised impacts of the CBA. The assignment comprises four main tasks:

1. The problem of uncertainty in CBA: We provide a definition of uncertainty and a description of how different types of uncertainties arise in CBAs of road projects.
2. The main uncertain elements: Here we give a review of the main elements (consequences, values or input parameters) that are inherently uncertain. We describe different types of uncertainties related to each element, and assess the need for including them in the uncertainty analyses.
3. How uncertainty should be presented in the CBA: We advise on how uncertainties should be presented in a CBA in order to provide meaningful information to the decision maker in an effective manner.
4. A literature review of how other countries treat uncertainty in CBA.

Uncertainties in the analysis

All aspects of the CBA are uncertain, both benefits and costs. We distinguish between the following main types of uncertainty in the CBA:

1. Uncertainty about economic growth, or systematic uncertainty
2. Technological uncertainty
3. Demographic uncertainty
4. Uncertainty about observable prices (relative prices)
5. Political uncertainty, national
6. Political uncertainty, local
7. Uncertainty about local/regional businesses and employment
8. Uncertainty about the residual value of infrastructure
9. Inherent uncertainty in transport models/CBA tools
10. Uncertainty about models for driver's licence holding and car ownership
11. Uncertainty about the applied (non-observable) parameters
12. Cost uncertainty

Uncertainty Type 1 represents what we call **systematic uncertainty**, or uncertainty related to economic growth. The other ten are **non-systematic uncertainties**. These can be classified in various ways:

- Some of the uncertainties are specific to the project being analysed. This applies to types 6, 7, 8 and 12. Some of the uncertainties are project-overreaching, i.e., the same uncertainties can apply to many independent road projects. This applies to types 2-5 and 9-11.
- The different types of uncertainties can also be classified into *scenario uncertainty* (types 2-8) and *method uncertainty* (9-11). The former covers the uncertainty about what the future actually looks like, while the latter covers the uncertainty of to what degree do the applied methods produce accurate results. Uncertainty type 12 contains both scenario uncertainty and method uncertainty.

The relative importance of these uncertainties vary from project to project. On the cost side, cost uncertainty is clearly important. For estimations of benefits, predictions of future traffic are fundamental since they affect the user benefits, operating benefits and external costs. The uncertainty in these predictions is affected by both method uncertainty and scenario uncertainty.

How uncertainty is assessed in 19 country guidelines for CBA

We have reviewed CBA guidelines for transport projects from 19 countries (or states/provinces). We contrast and compare the recommendations of methods for analysing uncertainty, which uncertain variables are to be analysed and finally how uncertainty is presented in the CBA. Key findings are:

- Of the 19 guidelines, 18 of them recommend at least one method to analyse the uncertainty in the CBA. Sensitivity analysis is recommended by all of these 18 guidelines. We also find that simple and / or simulation-based scenario analysis is recommended quite often as well.
- All of the countries in the sample recommend uncertainty analysis for construction costs. This is not always found in the guidelines for CBA, but in those cases it can be found in the guidelines for project management.
- Besides construction costs, the variable most often recommended for uncertainty analysis is predicted traffic growth, which is recommended / mentioned in 15 of 19 guidelines.
- The most common way to assess systematic uncertainty is by sensitivity analysis of the discount rate. This is recommended in 8 of the guidelines.
- Of the 19 guidelines, 7 recommend that uncertainty should be highlighted in the summary table of the CBA (however in different ways in different guidelines).

How uncertainty should be presented in the CBA

With regards to minimizing uncertainty in future CBAs we consider regularly improving, validating and assuring the quality of transport models and analysis tools to be of high importance, such that model uncertainty is as small as possible. In the long term, given that it becomes technically possible, it would be desirable to incorporate uncertainty aspects directly into the modelling tool so that it will be possible to make simulations which allow presenting the results using probability distributions rather than point estimates. In the meantime, we recommend sensitivity and scenario analyses, where the results from the CBA for each option are presented in the summary table alongside the best and worst case scenarios. We recommend testing key uncertain variables one by one in a sensitivity analysis for each option, and simultaneously in a scenario analysis. See Section 4.1.2 for further elaboration of such a scenario analysis. Sensitivity analysis is performed to see which parameters are the most significant, which will give an indication of where risk management efforts should be allocated. Scenario analysis is performed to present the range of outcomes in the CBA summary table for decision maker.

Based on a relatively clear conclusion from the expert workshop held during this project and on recommendations from Mouter et al. (2015) and Salling and Banister (2009), we recommend that the CBA summary table presents the results from the Best Case and Worst Case scenario alongside “the most likely point estimate”. We believe this will be an improvement from the practice of merely presenting “the most likely point estimate”. We also recommend that the summary table should distinguish between investment costs and other costs and benefits. The main reasons given in the expert workshop for why this is preferred over the current way and other alternatives for presenting the CBA results are:

- It provides a good illustration of the range of outcomes / uncertainty for each project alternative in the CBA
- It may help to illustrate whether there can be long tails in the distribution in direction of either the best case or worst case.
- The inclusion of cost estimates in the summary table is often explicitly requested by decision makers - they often wish to evaluate the cost separately, not just the net benefits

On the basis of these recommendations we have made a proposal for a new summary table of CBA that may be considered in the revision of the Manual V172. This table proposal is presented in Table 1.

Conducting scenario analysis can be somewhat more demanding than simple sensitivity analysis. A minimum solution would be to conduct simple scenario analysis on the following variables:

- Investment costs, in the form of quantile estimates P15, P50 and P85. We also recommend to include operating and maintenance costs to include uncertainty in the lifecycle.
- Traffic growth - which in turn affects changes in user benefit, operator benefit and other societal costs and benefits.
- The project's impact on traffic safety.
- Carbon price developments over the time period.

Several variables can be included in scenario analysis. If the number of variables is the subject of priorities, we propose the following general guidelines for the selection of variables:

- Changes in variables must be sufficiently impact the CBA results.
- Variables which outcomes can be observed at a later date (e.g. minutes saved and the number of people exposed to noise and local pollution), should take precedence over variables that cannot be observed (e.g. value of time, value of statistical life).

We do not expect the costs of conducting CBA to substantially increase with such a solution for uncertainty analysis, compared to the sensitivity analyses recommended in the current version of the NPRA guidelines. However, a simple scenario analysis and an orderly presentation of the results, will inform the decision maker about the uncertainty in the CBA in a more meaningful and effective manner.

Table 1: Proposed new summary table for CBA

	Alt. 0	Alt. A			Alt. B			Alt. C		
Monetized impacts										
		P85	P50	P15	P85	P50	P15	P85	P50	P15
Investment costs										
		WC	MLC	BC	WC	MLC	BC	WC	MLC	BC
Net benefits, excl. investment costs										
		WC	MLC	BC	WC	MLC	BC	WC	MLC	BC
Net benefits (NPV)										
Benefit-Cost ratio										
I. Ranking of monetized impacts per alternative by scenario										
Non-monetized impacts										
Overall assessment										
II. Ranking of non-monetized impacts										
Overall socio-economic assessment										
III. Overall socio-economic ranking										

WC = Worst Case, MLC = Most likely case, BC = Best case

P15, P50 or P85 = The value of a stochastic variable (e.g. a cost estimate) where there is 15 %, 50 % or 85 % probability of NOT exceeding this value.