STAG Technical Database Section 13

Risk and Uncertainty

May 2014

Transport Scotland

Version History

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Change number	Section updated	Date
1	13.6 Sensitivity Analysis	December 2009
2	13.2.4 Further Guidance on Managing and Assessing Risk – reference material updated	December 2013
3	13.6 Uncertainty Analysis (Sensitivity and Scenario Testing) [replaces Sensitivity Analysis]	May 2014

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13. Risk and Uncertainty

All risks and uncertainties associated with an option need to be fully identified and accounted for in the appraisal process. As stated in the HM Treasury Green Book (2003)[1], in appraisals it is always likely there is some difference between what is expected and what actually happens. This is the consequence of biases unwittingly inherent in the appraisal process, and risks and uncertainties that materialise. As a result, it is important to identify and mitigate risks, and make allowances for Optimism Bias.

13.1 Introduction

The aim of taking account of risks, uncertainties, and Optimism Bias is to obtain the best possible estimates of the costs and benefits of each option.

Practitioners should calculate an expected value of all risks for each option and consider how exposed each option is to future uncertainty. In addition, before and during implementation, steps should be taken to prevent and mitigate both risks and uncertainties. Risk management strategies should be adopted for the appraisal and

Table 13.1: Examples of Project Risk

Policy risk	**Legislative risk**	The risk that changes in legislation increase costs. This can be sub-divided into general risks such as changes in corporate tax rates and specific ones which may change the relative costs and benefits of different procurement routes.
	Policy risk	The risk of changes of policy direction not involving legislation.
Risk on delivering the asset	**Construction risk**	The risk that the construction of the physical assets is not completed on time, to budget and to specification. The risk of inflation differing from assumed inflation rates, particularly for any schemes where construction is not expected to start until some years in advance.
	Planning risk	The risk that the implementation of a project fails to adhere to the terms of planning permission, or that detailed planning cannot be obtained, or, if obtained, can only be implemented at costs greater than in the original budget.
	Residual value risk	The risk relating to the uncertainty of the value of physical assets at the end of the contract.
Risk on operating the asset	**Operational risk**	The risk that operating costs vary from budget, that performance standards slips or that the service cannot be provided.
	Inflation risk	The risk that actual inflation differs from assumed inflation rates.
	Maintenance risk	The risk that the costs of keeping the assets in good condition vary from budget.
Risks on demand and revenue	**Demand risk**	The risk that demand for the service does not match the levels planned, projected or assumed. As the demand for a service may be (partially) controllable by the government, the risk to the public sector may be less than that perceived by the private sector.
	Design risk	The risk that the design cannot deliver the services at the required performance or quality standards.
	Availability risk	The risk that the quantum of the service provided is less than required under the contract.
	Volume risk	The risk that actual usage of the service varies from the level forecast.
	Technology risk	The risk that changes in technology result in services being provided using non optimal technology.

Source: Department for Transport (Adapted from Technical Note No.5, Treasury Task Force 1999)

Practitioners are required to consider the impacts of different rates of cost increase from those assumed as part of the risk assessment. Risks associated with delays in schemes should also be assessed while appropriate consideration ought to be given to the combined risk of both delays and cost rises that differ from those assumed in estimating the base costs.

The risks associated with changes in scheme design should also be identified and recorded in the risk register. However, the risk of having to make significant design changes, possibly relating to a significant change in scope (where scope is defined as the specified output/objectives of the scheme) should be mitigated prior to the submission of the business case. If any unforeseen changes in scope then do occur, which significantly change costs, the project should be subject to a full re-appraisal, including reconsideration of rejected alternatives. Any decisions to proceed will need to be reconsidered in the light of the results of the re-appraisal.

The risk register should also identify who owns the identified risk. For example some risks may be transferable through insurance or financial instruments. In all cases the risk register should indicate where risks have been successfully transferred.

13.2.2.2 Step 2: Assessing the Impacts of Risk

Once risks have been identified, the impact of these risks should be assessed in terms of cost outcomes. The range of outcomes should consider both the upper and lower extremes of the possible range, taking into account any reasonable constraints.

The method used for quantifying risk will vary depending on the availability of information sources. Where possible empirical evidence should be used, otherwise it is recommended that sensible approximations are applied.

When assessing the consequences of any risk, the analysis should include both direct and indirect effects. This requires care, as there could be interaction between different risk events. Some risks will affect the costs of either the construction or operation of the project. For example if a purchase of required land is not available on time, the possible indirect (knock-on) effects could include:

- Costs associated with looking at alternative sites;
- Lost management time as a result of litigation/seeking Compulsory Purchase Orders;
- Inability to meet contractual commitments;
  Increased input costs resulting from cost increases during scheme delay.

13.2.2.3 Step 3: Estimating the Probability of Outcomes Occurring

Estimations of the probability of outcomes occurring should be based on experience of past events, taking account of any foreseeable changes or developments, rather than arbitrary estimates. Practitioners may have compiled databases of past schemes including details of the reasons for any cost changes. Where available these could be useful in reaching conclusions as to the likely occurrence of different risks.

Estimating probabilities is not an exact science and inevitably assumptions have to be made. However, any assumptions made in the assessment should be sensible clearly documented for auditing and integrity checks by Transport Scotland.

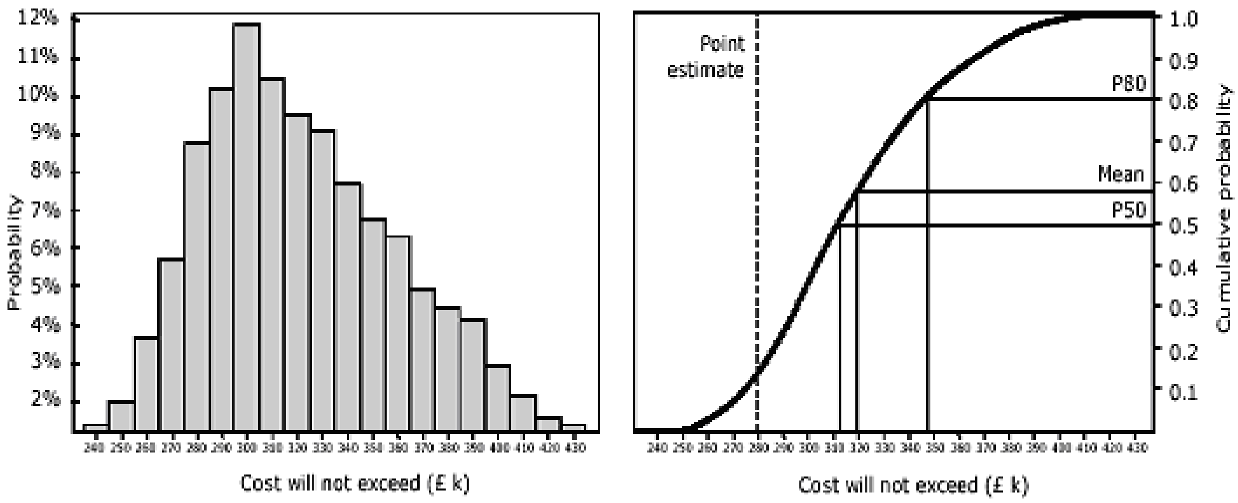
13.2.2.4 Step 4: Deriving Probability Distributions

A QRA allows a probability distribution around the costs of the scheme to be derived and enables the expected risk-adjusted cost estimate to be obtained. This expected outcome, also known as the 'mean' or 'unbiased' outcome is the weighted average of all potential outcomes and associated probabilities. This is the risk-adjusted cost of the scheme, and it is to this that the Optimism Bias will be applied. Operating Costs and Capital Costs should all be based on expected values of the cost of the scheme.

Many risks are linked or correlated, i.e. if one risk occurs another risk is likely to occur. Modelling these relationships is easier with appropriate software, e.g. using Monte Carlo simulation to establish the range of costs. Cost risk relating to time delays is often significant and Monte Carlo simulation can also take account of this.

Several methods can be employed to derive the probability that the total project cost (the sum of all the activities considered in the QRA) will not exceed a particular value. The graph on the left in Figure 13.1 shows an example standard probability distribution. This can provide useful information to derive the cumulative probability distribution or S curve (shown to the right). This gives the probability of the scheme cost estimate being less than or equal to any specified value.

Figure 13.1: Probability Distribution Example



Source: Department for Transport (Adapted from SRA 2003)

The cumulative probability distribution shows different cost adjusted risk estimates in correspondence to different levels of certainty about the occurrence of cost overrun. For instance, in the example illustrated in Figure 13.1, the P50 is the budget estimate associated with 50% probability that the project will be delivered within budget. In this example, the P50 estimate is equal to £312k. In a similar way, the P80 estimate represents an 80% likelihood that the project will be delivered within a budget of £348k. The expected value is the mean transport cost estimate, and the value to be used when forming the appraisal cost estimate, is £320k. This suggests that the expected transport scheme estimate lies between the P50 and P80 estimate which is the weighted average of the distribution of costs. It is possible to infer the probability that the scheme is delivered to the base cost. In the case represented above, the base cost point estimate is equal to £280k. The cumulative probability distribution shows that there is only a 12% probability that the scheme stays within the budget of £280k.

13.2.3 Preventing and Mitigating Risks

Following the identification and analysis of risks, the generation of a risk-adjusted expected value, and an assessment of options' exposure to uncertainty, practitioners are also required to demonstrate that they have adopted a systematic approach to responding to risk, including strategies to prevent and mitigate risks and uncertainties. The Green Book suggests that the following may be adopted:

- **Consulting early** – Helps to identify relevant stakeholders and risk mitigation;
- **Avoiding irreversible decisions** – Through understanding causes of delay, and further investigation and improved reliability of project plan;

  Carrying out pilot studies – Acquire more information on risk affecting projects with many unknowns;

Building in flexibility from the start – Designs adaptable to future changes are less adversely affected by risk than design only suited to one outcome;

- **Taking precautionary action** – Precautionary action required to mitigate severe risks;
- **Transferring risk through contractual arrangements** – Risk contractually transferred to other parties;

Developing less risky options – Including making less use of leading edge technology;

Reinstating or developing different options – Alternative options may be considered if current options are found to be more risky than initially perceived; and

Abandoning options – Option may be so risky that it is worth abandoning due to adverse risk

By responding to and reducing risks and uncertainty in these ways, the risk-adjusted costs of an option are lowered. It is crucial that the implications of decisions taken to respond to risks are factored into the estimates of base costs and the risk assessment that are submitted.

13.2.4 Further Guidance on Managing and Assessing Risk

Further detailed guidance on performing a risk assessment is in *Value for Money Assessment Guidance* (Scottish Futures Trust, 2011), Technical Note 5[3]. Annex 4 of *The Green Book* (HM Treasury, 2003)[4] and the *Quantitative Assessment User Guide* (HM Treasury, 2004) also provide further guidance on quantifying and clarifying risks. *The Orange Book* (HM Treasury, 2004)[5] provides broader guidance on the principles of risk management that are valid and applicable across all modes.

13.3 Optimism Bias

13.3.1 General

There is a demonstrated, systematic tendency for project appraisers to be overly optimistic. This tendency is known as Optimism Bias – a worldwide phenomenon that affects all types of projects, including transport, in both the private and public sectors. The available evidence[6, 7] suggests that many project parameters are affected by optimism – appraisers tend to overstate benefits, and understate timings and costs, both capital and operational, particularly in the early stages of development.

To redress this tendency, practitioners should make explicit adjustments for this bias when appraising projects. These will take the form of increasing estimates of the costs and decreasing and delaying the receipt of estimated benefits. However, in current transport appraisal guidance it is only provided for cost risk adjustment. As detailed in Section 13.1, risks associated with patronage or benefits should be accounted for by applying sensitivity or scenario testing around the central case. Sensitivity testing should be used to consider uncertainties around the adjustment for Optimism Bias.

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[3] http://www.scottishfuturestrust.org.uk/files/publications/Value_for_Money_Assessment_Guidance_-_Capital_Programmes_and_Projects_(October_2011).pdf

[4] The Green Book Supplementary Guidance on Optimism Bias, HM Treasury http://www.hm-treasury.gov.uk/media/885/68/GreenBook_optimism_bias.pdf

[5] The Orange Book, Management of Risk – Principles and Concepts, HM Treasury (2013) https://www.gov.uk/government/publications/orange-book

[6] Review of Large Public Procurement in the UK, Mott MacDonald (July 2002)

[7] Procedures for Dealing with Optimism Bias in Transport Planning, Flyvbjerg, B. (2004)

Adjusting for optimism bias should provide a better estimate of key project parameters early in the appraisal process. The application of these adjustments is designed to complement and encourage, rather than replace, existing good practice, in terms of calculating project specific risk adjustments. They are also designed to encourage more accurate costing.

13.3.2 Relationship between Optimism Bias and Risk Assessment

Adjustments for Optimism Bias may be reduced over time as more reliable estimates of relevant costs are developed and project specific risk work is undertaken. As it becomes possible to better quantify and value risks, it should also be possible to better capture the factors that contribute to appraisal optimism within the risk management process. Accordingly, as risk analysis improves as the scheme develops, we would expect that, on average, the risk adjusted scheme cost estimate will increase, while the applicable level of Optimism Bias will decrease. Optimism Bias will, therefore, be highest at the Strategic Outline Business Case stage of a transport project and then decrease over time through the Outline Business Case and Final Business Case stages.

As a scheme progresses through these stages, there are techniques for reducing Optimism Bias uplifts through increased certainty on cost estimates, the use of mitigation measures, and independent reviews of Risk and Optimism Bias. Any reductions in the Optimism Bias adjustments from the recommended values should be clearly justified and documented for auditing purposes.

13.3.3 Applying Optimism Bias Factors

As defined by the Green Book, adjustments for Optimism Bias should be empirically based (e.g. using data from past projects or similar projects elsewhere) and adjusted for the unique characteristics of the project in hand. The level of Optimism Bias is proposed by the practitioners in line with Green Book guidance and reviewed by the Scottish Government and/or Transport Scotland. The Government and/or Transport Scotland comments but ultimate responsibility for setting the level of Optimism Bias lies with the practitioner. In reviewing the level of optimism bias, one of the factors that Transport Scotland considers is how comprehensive, how well-managed and how realistic the QRA and Risk Management strategy are.

In transport, the recommended Optimism Bias adjustment factors have been derived from a general Mott McDonald study (2002) into the size and causes of cost and time overruns in large UK procurement and the transport specific research produced by Bent Flyvberg (2004) (a slightly different position is adopted for rail projects and this is discussed below). The recommended uplift factors refer to cost overruns calculated in constant prices and should be applied to investment costs, including the allowance for the expected value of risk. This is illustrated by the following formula in Figure 13.2 (the conceptual reasons for Optimism Bias apply equally to spot cost and risk assessment, hence the reason for applying OB multiplicatively).

$$\textit{Risk and Optimism Bias adjusted } \cos t = (\textit{Base } \cos t + \textit{Risk Adjustment}) * (1 + \textit{Optimism Bias Factor})$$

The term Base Cost refers to all capital investment costs, as defined in Section 12.2. Optimism Bias factors are given below in Section 13.3.3.3.

Practitioners should apply the four-step process as outlined below. This is consistent with DfT guidance and is based on the principles of the Green Book, tailored to the requirements of transport appraisal. The four steps of the process are as follows:

- Step 1: Determine the nature of the project;
  Step 2: Identify the stage of scheme development;
  Step 3: Apply the recommended Optimism Bias factor to the risk adjusted transport cost estimate; and
- Step 4: Provide sensitivity analysis around the central estimate

13.3.3.1 Step 1 – Determining the nature of the project

The Green Book identifies six specific classifications of project type, each with different Optimism Bias uplift factors. These are: standard buildings; non-standard buildings; standard civil engineering; non-standard civil engineering; equipment/development; and outsourcing.

Careful consideration must be given to the characteristics of a project when determining its project type. The majority of transport projects will be classified as either standard or non-standard civil engineering projects. For example, the building of new roads and the up-grading of existing roads will usually be classified as standard civil engineering. Meanwhile, more unique projects such as building a tunnel for a railway would be classified as non-standard civil engineering. Comparing these two types of projects, the evidence suggests that the Optimism Bias for non-standard civil engineering tends to be higher than for standard civil engineering. For further information on the upper and lower bounds of Optimism Bias for the different classifications of projects, reference should be made to Mott MacDonald's report on large-scale public procurement in the UK.

Table 13.2 illustrates the typical project categories specifically for transport appraisal, derived from the Bent Flyvberg (2004) work.

Table 13.2: Project Categories

Category	**Types of Project**
Roads	Motorway Trunk roads Local roads Bicycle facilities Pedestrian facilities Park and Ride Bus lane schemes Guided buses on wheels
Rail	Metro Light rail Guided buses on tracks Conventional rail High speed rail
Fixed Links	Bridges and tunnels
Building Projects	Stations and terminal buildings
IT Projects	IT system development

Source: Flyvbjerg (2004)

For ferry schemes, it should be noted that the cost of purchasing ferries is not considered an infrastructure investment, and therefore is not subject to Optimism Bias. Practitioners may wish, however, to perform sensitivity tests to their cost estimates. The costs of building ferry infrastructure such as slipways should be subject to the standard building projects Optimism Bias levels.

13.3.3.2 Step 2 - Identify the stage of scheme development

The Department for Transport has identified three main stages in the life of a transport project and provided default uplift values for each (uplift values for rail projects are presented separately in Section 13.3.4). These stages are illustrated in Table 13.3. Practitioners should note that these stages are indicative of the quality of Risk Assessment and cost estimate typical of schemes at the different stages of development.

Table 13.3: Scheme Development Stages

Category	Stage 1	Stage 2	Stage 3
Local authority and Public Transport Schemes	Programme Entry	Conditional Approval	Full Approval
Major Road Schemes	TPI entry/ Preferred Route Decision	Order Publication/Works Commitment	Works Commitment

13.3.3.3 Step 3 - Applying the recommended Optimism Bias factor

Practitioners should then apply the appropriate value for Optimism Bias relevant to the project category and stage of development. These are presented in Table 13.4. Practitioners are also required to apply Optimism Bias uplifts at other stages of project development other than those listed below. No formal guidance exists on these uplifts and practitioners are requested to use suitable judgement and provide supporting evidence in the written documentation. However, it is expected that the appropriate uplift factor should generally be higher for stages prior to those in Table 13.4 and lower for those after.

Where a project includes significant elements of the different project types identified above, it might be considered a combined project, with the differing elements representing sub-projects. The relative size of each sub-project should be determined and the appropriate uplifts should be identified and applied to that part of the project. After this has been done, the adjusted costs for each sub-project should be aggregated to establish the total cost for the overall project.

Table 13.4: Recommended Optimism Bias Uplifts

Category	Types of Project	Stage 1	Stage 2	Stage 3
Roads	Motorway Trunk roads Local roads Bicycle facilities Pedestrian facilities Park and ride Bus lane schemes Guided buses on wheels	44%*	15%	3%*
Fixed Links	Bridges and Tunnels	66%*	23%	6%*
Building Projects	Stations and Terminal buildings	51%*	-	4%*
IT Projects	IT system development	200%*	-	10%*

Sources: Flyvbjerg (2004) and Mott MacDonald (2002)*

13.3.3.4 Step 4 - Provide sensitivity analysis around the central estimate

Practitioners should also provide a sensitivity analysis around the core uplift value in order to examine the impact of a range of other possible levels of Optimism Bias on the cost estimates reported in the TEE and PA tables.

13.3.4 Optimism Bias and Rail Projects

This methodology is consistent with that presented above but uses rail specific uplifts from previous Strategic Rail Authority (SRA) guidance and evidence from Network Rail. The Project Development Level and recommended Optimism Bias uplifts are presented in Table 13.5.

Table 13.5: Recommended Risk and Optimism Bias Adjustments for Rail Projects

Project Development Level*	Level 1	Level 2	Level 3	Level 4	Level 5
Activity	Pre-feasibility	Project Definition	Option Selection	Single Option Refinement	Design Development
	Capital Expenditure				
QRA	No	No	No	QRA at mean estimate	QRA at mean estimate
Optimism Bias (% of present value capex)	66%	50%	40%	18%	6%
	Operational Expenditure				
QRA	No	No	No	QRA at mean estimate	QRA at mean estimate
Optimism Bias	41% of present value opex	1.6% per annum#	1% per annum#	Evidence based	Evidence based

Sources: Mott MacDonald 2002, Review of Large Public Procurement in UK (HM Treasury website), SRA and Network Rail research
* Definition of project development levels is consistent with Network Rail's project development definition in GRIP (Guide to Rail Investment Projects)
# Added to each set of operational costs in the year that they occur. Not to be taken as a cumulative.

13.4 Contingency Allowances

Previous STAG Appraisal guidance recommended the addition of contingency figures to the expected value to account for unanticipated risks, in effect to allow for residual Optimism Bias. This approach is no longer endorsed. For appraisal purposes, where a risk can be identified and is likely to be material to the cost of the scheme, then it should be quantified and included in the QRA, even if the probability distribution or value of that risk is uncertain.

13.5 Assessing Uncertainty

An expected value is a useful starting point for understanding the impact of risk between different options. However no matter how well risks are identified and analysed, the future is uncertain. Therefore it is also essential to consider how future uncertainties could affect the choice between options.

13.6 Uncertainty Analysis (Sensitivity and Scenario Testing)

Uncertainty analysis is a fundamental part of a STAG study. It is used to test the vulnerability of the options being tested to future uncertainties which are unavoidable. Through analysing the range of inputs and the values that key variables may take, uncertainty analysis allows any resultant effects on options to be examined.

The identification of future uncertainties which, if realized, would cause a scheme to perform poorly, should not be viewed as a negative; rather, it provides decision makers with the important information regarding the robustness of the modelled results, and highlights areas where mitigation can be put in place to ensure a positive outcome.

The calculation of switching values can show by how much a variable would have to fall or rise to make it not worth undertaking an option. This may be a useful input into the decision as to whether an option should proceed.

Therefore it should be the norm rather than the exception, to carry out uncertainty analysis for the transport projects considered during Part 2 Appraisal. These variables will usually have a significant impact on either the overall cost or benefit of the project. For example, forecast demand for a proposed new railway line would play a crucial role in justifying whether or not the line would cover the operating costs and/or contribute sufficiently to the capital costs of the project.

Uncertainty Analysis may be developed in a number of different ways using Scenario and Sensitivity Tests. Any assumptions in either transport or land-use forecasts should be subject to such testing.

Scenario Tests

A Scenario is the set of model assumptions that a transport intervention (or set of interventions) is tested against. This includes land use and economic growth assumptions but also the set of transport schemes that are assumed to be present (i.e. the Do Minimum). Scenario Tests could include for example:

- Development is higher or lower than forecast in the do-minimum (e.g., including all 'reasonably foreseeable' factors, or only 'near certain' factors);
- The interventions planned but on a smaller/larger scale;

Sensitivity Tests

A Sensitivity Test is aimed at identifying the relative effects of the various parameters on the outcome of a scheme appraisal. In particular, where the model parameter values are uncertain, it is important to know how sensitive the appraisal results are to these uncertainties, so that confidence can be invested in the conclusions. Sensitivity Tests could include for example:

Higher or lower trip rates per development.
Higher or lower fuel price growth rates.

Where there is uncertainty surrounding the appropriate Scenario or Sensitivity tests to be used in an appraisal, liaison with Transport Scotland is recommended to agree the relevant assumptions.

13.7 Participation and Consultation

It is important that the participation and consultation activities adopted as part of the STAG Process feed into the risk and uncertainty analysis undertaken by transport planners. It will be useful to engage with stakeholders and specialists during the early stages of the STAG Process through to the STAG Part 2 analysis in order to identify, control and mitigate risks identified.

13.8 Reporting

The practitioner should be able to demonstrate in the STAG Report the steps taken to identify, control and mitigate risks identified. It should also be clear what allowances have been made for Optimism Bias. It is a requirement that all capital costs used in the Part 2 Appraisal and reported in the ASTs have been adjusted for Optimism Bias and an explanation of the methodology adopted to do this and the outcome should be clearly and concisely reported.

Sensitivity testing of key variables for a given option is also required to demonstrate the robustness of the option to the assumptions made. It should be made clear what key variables were selected for sensitivity analysis and also what the outcomes there were from this analysis and the implications for the option under consideration. It is expected that explicit consideration of risk and uncertainty will feed back into the feasibility, affordability and public acceptability analysis undertaken during Part 1 Appraisal.

Practitioners should seek the advice of the Scottish Government and/or Transport Scotland where further clarity is required.