



Full Cost and Benefit Calculation

Methodology

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Executive Summary

The costs and benefits for the three base- and integrated cases are calculated in WP 4. The cost-benefit methodology for each case study is based on Net Present Value (NPV) calculation, and sensitivity of important parameters will be included. Risks identified in the qualitative analysis will be the input values to the construction of the model to address the uncertainties that will impact the NPV.

Uncertainty in the estimates for costs and benefits is included in all inputs in the model; the objects will always be a range, which is based on Monte Carlo simulation techniques by assigning probability distributions to items in the model. Quantification of the different parameters will be dependent on estimates since there is a lack of available historical data for costs, benefits, statistics for failures, repair time etc. By modelling uncertainty different outcomes will be taken in account; uncertainty in price trends, markets, and unforeseen events and factors that may affect the project.

The quantities can be presented graphically; the Monte Carlo simulation model will return results as S-curve and tornado plots to illustrate the range in NPV and which item that will have the most impact on cost/benefits.

1 Introduction

In this paper, the cost and benefit calculation methodology that will be used in the NorthSeaGrid project is developed. The methodology is based on Net Present Value (NPV) calculations to estimate the costs and benefits for each case study. This methodology will be used in the full cost calculation to summarize the results and make a clear and structured overview over the costs.

DNV GL is leading WP 4 in the project. The costs and benefits for the three base and integrated cases will be calculated in this work package. The work includes the development of a methodology for calculation of capital and operational costs. The benefits to enhanced transmission capacity will also be evaluated. The methodology will also include the costs of various types of risks and uncertainties such as variation in the prices of raw material, installation costs, and regulatory frameworks. Moreover, sensitivity of important aspects including failure statistics, component costs, and electricity prices will be taken into account. Uncertainty in the estimates is included in all inputs in the model, which is based on Monte Carlo simulation techniques.

2 Methodology Qualitative and Quantitative Risk Analysis

Figure 1 illustrates and sums up the methodology that is explained in this paper. The cost objects will always be a range, and if there is a long tail in the shown graph, it means that there is a large uncertainty in the costs. Moreover, uncertainty will affect many of the cost factors; i.e. if market drops by 5% all the cost items will drop by 5%. The rest of the paper will describe the elements in

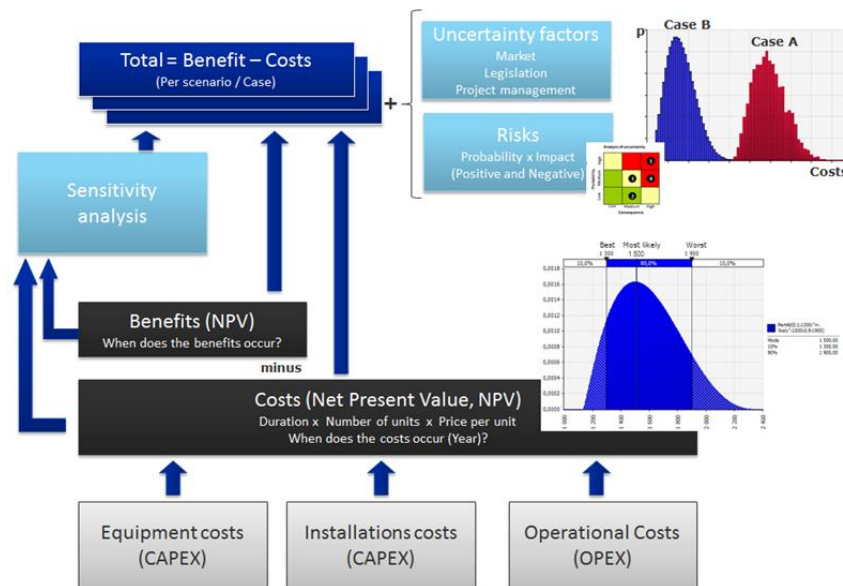


Figure 1: Integrated cost, benefit, and risk model

3 Uncertainty analysis

A quantitative uncertainty analysis helps to establish realistic limits and schedules for project cost- and completion time. In addition, a full assessment of the risks that threaten the project's goals provides an increased probability of project success. When deciding for a concept, an uncertainty analysis is also a good basis for a robust decision.

Figure 2 illustrates an efficient process for conducting uncertainty analysis. The process is supported by tools specifically adapted for use in investment projects within different sectors and types of projects. In the NorthSeaGrid project it is outside scope to plan mitigating actions and how to implement them.

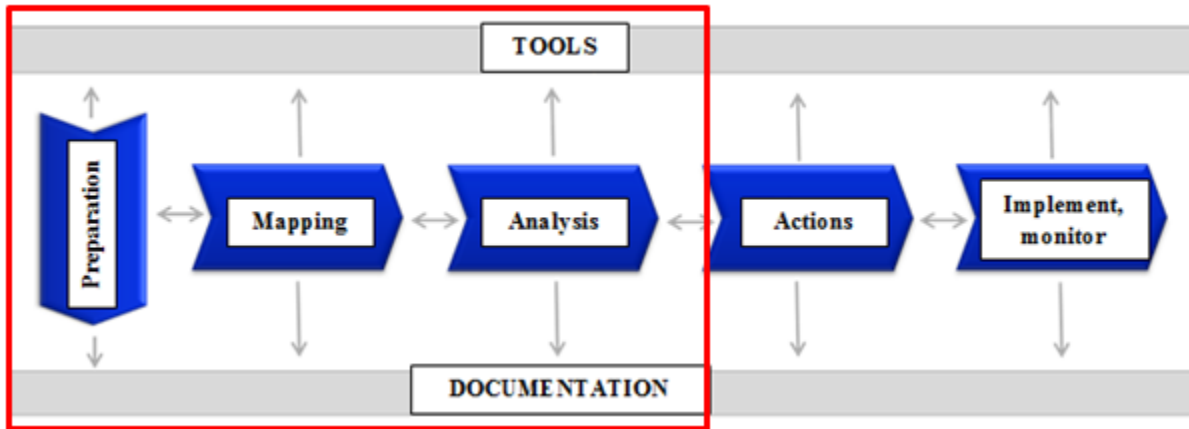


Figure 2: Generic process for uncertainty analysis

A quantitative analysis usually begins with a qualitative identification of risks; uncertainties and events. The identified risks are potential threats to project goals (i.e. something that lead to significantly higher costs than planned). A risk event has a cause that leads to a consequence.

Normally, the analysis of project risks includes identifying risks that may affect the cost, time, quality/ performance and possibly reputation. In order to have a structured approach to analyse the identified risks for NorthSeaGrid, an excel sheet (risk register) is filled in by experts (project participants) with detailed information.

The risks have impact on one or several of these aspects:

- Schedule/timeframe
- CAPEX
- OPEX
- Benefit

By modelling uncertainty it is possible to take different outcomes in account, high and low estimates, uncertainty in price trends, markets, and unforeseen events and factors that may affect the project. The model shows the decision-makers what effect the sum of all the uncertainty costs will have on the budget target.

The qualitative risks are summarized in a risk matrix, illustrated in **Figure 3**, where risks are prioritized according to their criticality based on the identified probability and consequence. The priorities form the basis for the risk mitigation measures. Risks identified in the qualitative analysis will be the input values to the construction of the cost and benefit calculation model.

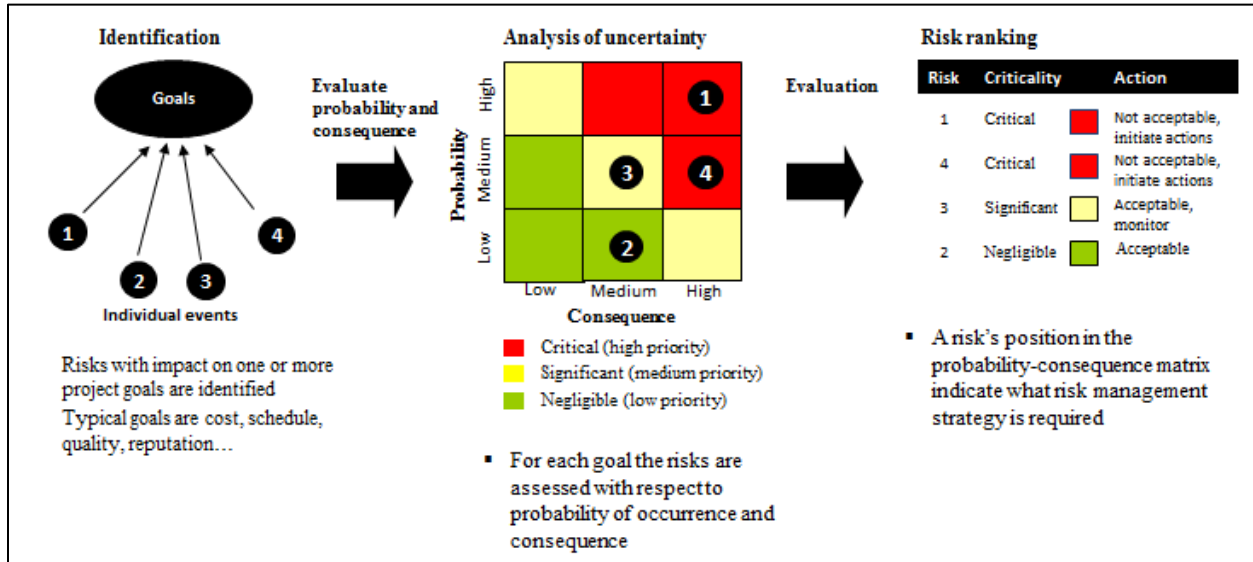


Figure 3: Qualitative risk analysis

The quantitative part of the analysis involves a review of the original calculation or plan with the inclusion of estimated uncertainty through triple projections, and then quantifying the impact of uncertainties and events. Events are quantified by combining probability of occurrence and their impact. The assessments have to be documented and made a part of the project documentation for traceability.

The structure and elements in the quantitative risk analysis are shown in **Figure 4**. Moreover, the figure shows how the identified events or factors are modelled appear as items in the estimate. The model for uncertainty calculation is constructed on the basis of the project's original cost estimate.

Uncertainty analysis is a simple way to test the robustness of the original estimates. Uncertainty in project costs is handled by assigning probability distributions to items in the cost model. As shown in **Figure 4**, uncertainty is incorporated in the cost analysis model through estimate of uncertainties, factors and events. Certain items may be correlated, and this has to be taken into account in the model either directly through modelling or indirectly through the use of correlation factors.

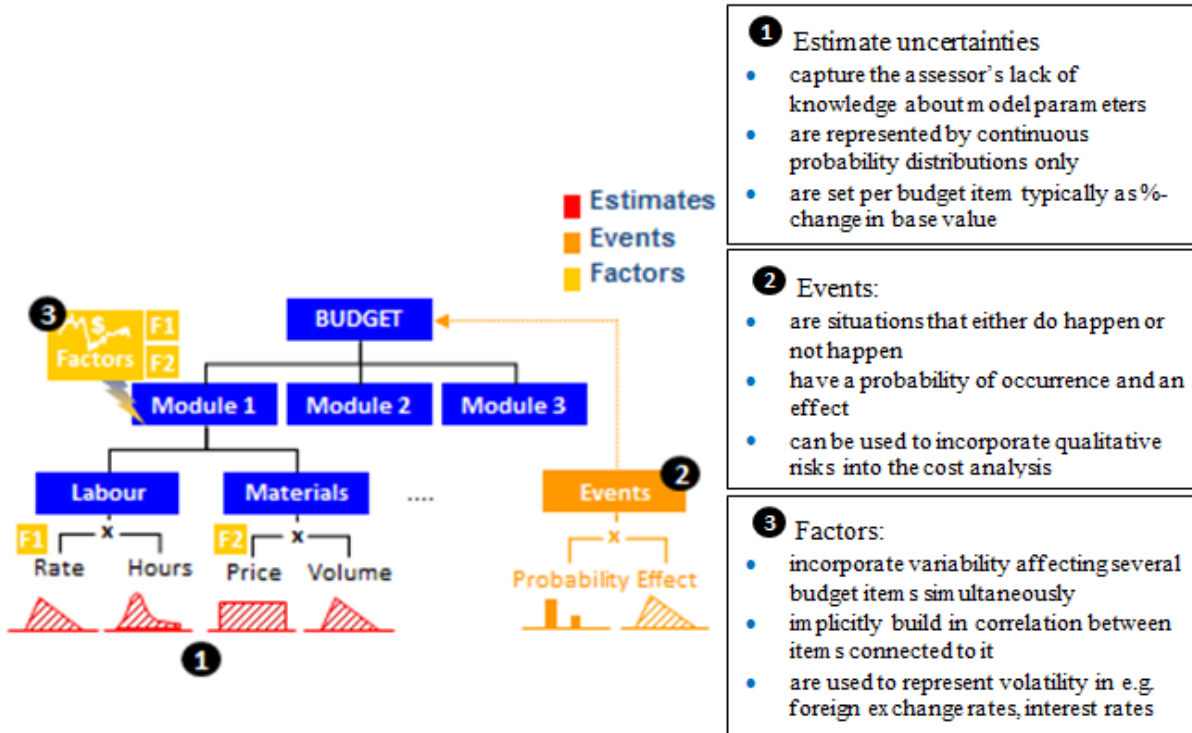


Figure 4: Uncertainty Model

Tools

There are a number of tools that can be used for quantitative assessment of risk. This includes among others the present value analysis, Monte Carlo analysis, and portfolio theory. The analysis can be done in an MS Excel-based tool developed by DNV GL. From the input values the model is evaluated with Monte Carlo simulation (see **Figure 5**). All input values are given a probability distribution described with triple estimate - P10, mode and P90.

DNV GL has developed models and Excel-based tool that uses incremental calculation to estimate the uncertainty in cash flows and with an optional addition of a @ RISK Application of Monte Carlo simulation.

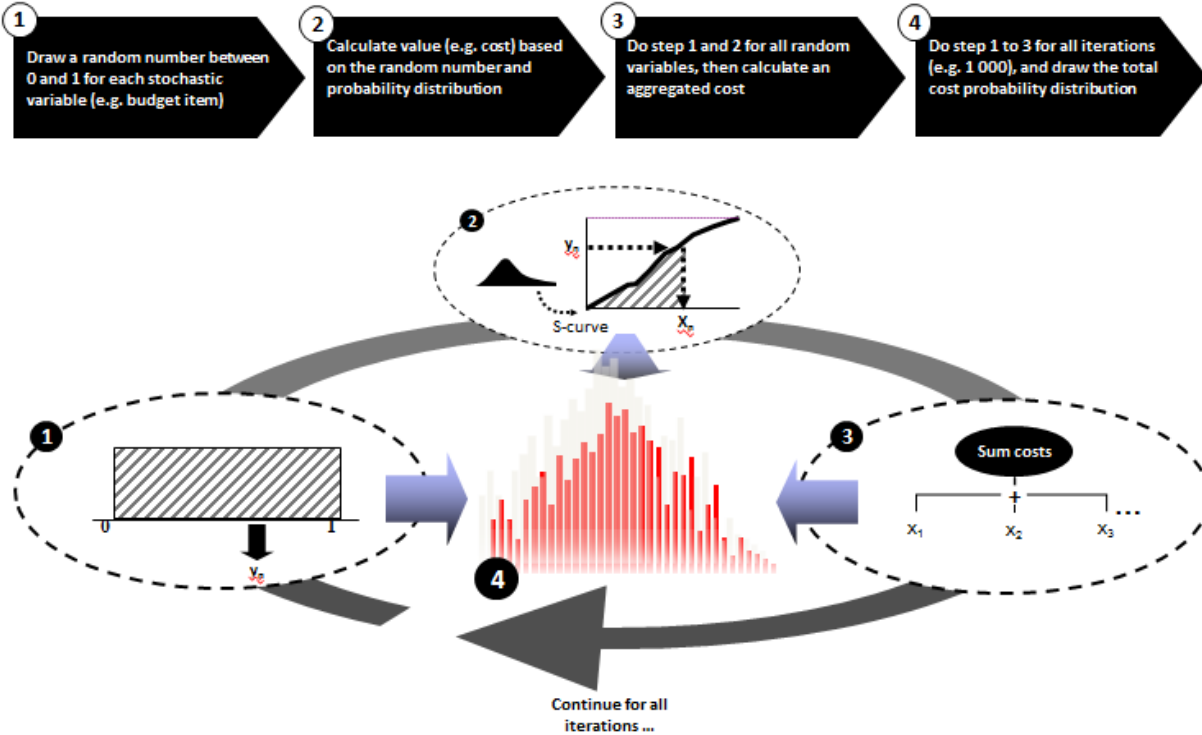


Figure 5: Overview of Monte-Carlo simulation technique

4 Net present value

Cash flows are calculated in the model as a function of selected technical and economic drivers. Uncertainty in the drivers and the probability and consequences of risks are calculated as input to the model. Monte Carlo simulation results can be graphically represented in the form of probability distribution functions, cumulative distribution functions (S curves) and other relevant statistics for NPV. This enables a better estimate of expected cash flows and an assessment of the robustness of the investment decision and the projects “risk appetite”.

Figure 6 shows how cash flows may be distributed over the project lifetime time for different cases in NorthSeaGrid. Potential risks for the time period may impact the total cost/benefit profile. The construction period will have the most significant costs whereas benefits will start to be realized after commissioning.

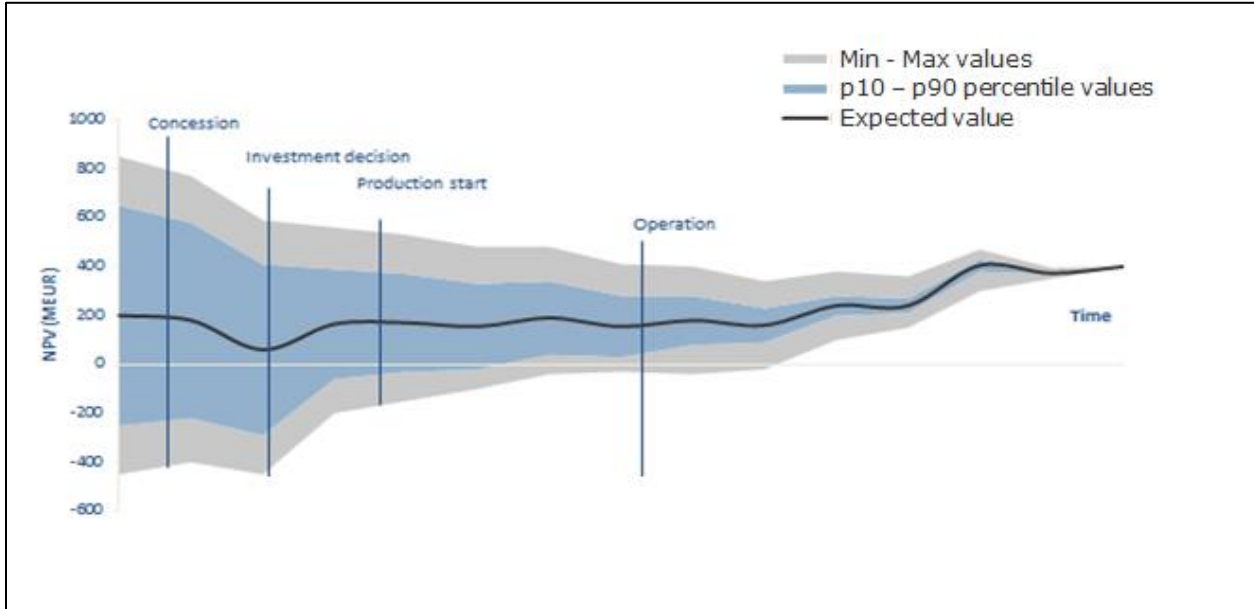
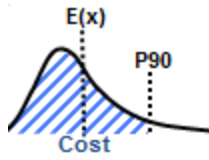


Figure 6: Example of NPV risk exposure

5 Cost Items and sensitivity

Figure 7 exemplifies the impact of different risk factors on CAPEX/OPEX/benefit in different time periods. For instance the risk *R-0002 Under-performing HVDC circuit breakers* will have a significant impact on OPEX because it will result in additional downtime and repair costs. This risk has a probability and consequence that decides where it is placed in a risk matrix and is quantified with uncertainties.



		NPV	Time
CAPEX Activity	1	$-\sum_1$	Cost Item X
	2	$-\sum_2$	-----
	3	- .	-----
	.	- .	
	.	- .	-----
	n	$-\sum_n$	
OPEX Activity	1	$-\sum_1$	-----
	2	$-\sum_2$	-----
	3	- .	-----
	.	- .	-----
	.	- .	-----
	n	$-\sum_n$	
BENEFIT Activity	1	$+\sum_1$	
	2	$+\sum_2$	-----
	3	+ .	-----
	.	+ .	-----
	.	+ .	-----
	n	$+\sum_n$	

Per Case: $\sum_{Cost} = \sum_{Tot} - \sum_{Benefit}$

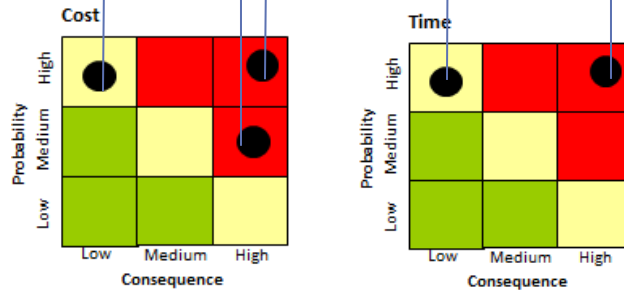


Figure 7: Risk associated with cost items

After the inputs are given and the simulation is executed, the tornado graph shown in **Figure 8** illustrates the sensitivities of an output to different inputs; the impact of uncertainty in a single item on the overall uncertainty in the total project cost. The tornado plots show the cost items that add most uncertainty to the project and they are displayed in a descending order. The bars shows the impact to the NPV when the 10% and 90% percentile of the cost item occurs.

When comparing which items will affect the project costs the most, separate sensitivity analyses can be performed on the most important items. Single parameters are varied in the defined intervals to collect and analyze the results.

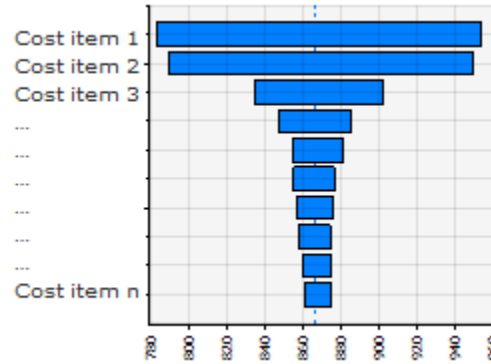


Figure 8: Cost item 1 introduces maximum uncertainty to project costs

6 Cash flow results when comparing cases

This chapter shows how the quantities can be presented graphically; the Monte Carlo simulation model will return results as S-curve (Figure 9) and tornado plots (Figure 8).

The S-curve (cumulative probability density curve) can provide the probability that the cost does not exceed a given amount. It is common that percent values such as P15, P50 and P85 are interesting and looked more into.

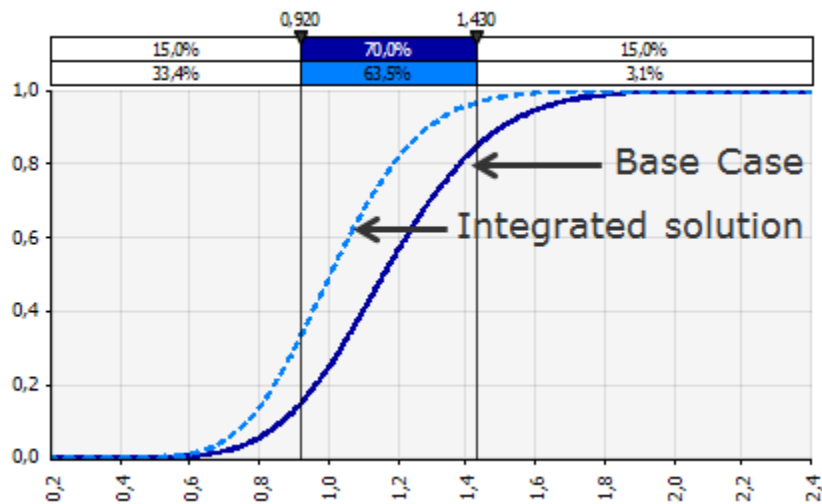


Figure 9: Examples of comparison of costs for base- and integrated-case

One of the objectives of the NorthSeaGrid project is to analyse whether the integrated case can be cheaper than the base cases for the 3 selected implementations. The difference of the sum of total costs and benefits between integrated case and base case answer this question. **Figure 10** and **Figure 11** illustrate two possible scenarios for the costs (X-axis) with different probability distributions (Y-axis).

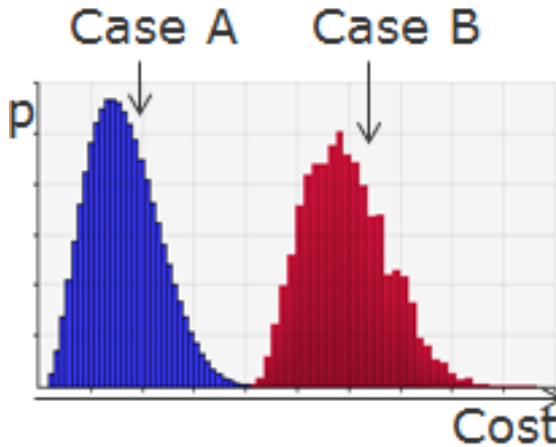


Figure 10: Scenario 1: One case costs significantly less than the other

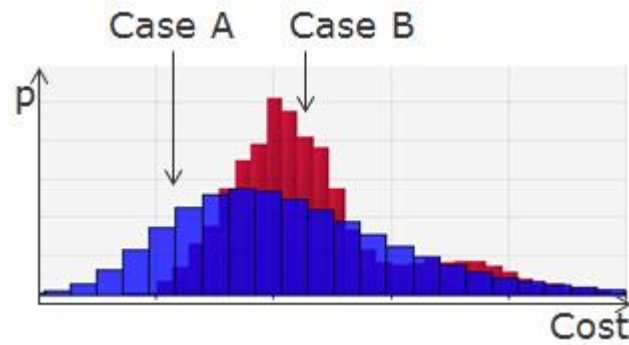


Figure 11: Scenario 2: The probable cost of case B is more than that of case A but with high certainty

For scenario 1 it is most probable that one case is less costly than the other. For scenario 2 the cost spread is larger for one case than the other. This means that it is more uncertain how large/small the costs are going to be for one case.

7 Conclusion

The steps for cost-benefit assessment are described in this paper and will be used in the other tasks in WP 4. The methodology includes a risk assessment to address the uncertainty related to costs and benefits. Quantification of the different parameters will be dependent on estimates since there is a lack of available historical data for costs, benefits, statistics for failures, repair time etc. Monte Carlo simulation techniques are used to address the uncertainty in the costs and benefits, find the NPV for the cases, and to compare the base case with the integrated cases. The simulation allows sensitivity analyses of the most important items.