Economic Risk and Sensitivity Analysis for Small-scale Hydropower Projects

IEA Technical Report

IEA Hydropower Agreement

CANADA CHINA FINLAND FRANCE JAPAN NORWAY SPAIN SWEDEN UNITED KINGDOM

OVERVIEW OF THE IEA IMPLEMENTING AGREEMENT FOR HYDROPOWER TECHNOLOGIES AND PROGRAMMES

The Hydropower Implementing Agreement is a collaborative programme among nine countries: Canada, China, Finland, France, Japan, Norway, Spain, Sweden and the United Kingdom. These countries are represented by various organizations including electric utilities, government departments and regulatory organizations, electricity research organizations, and universities. The overall objective is to improve both technical and institutional aspects of the existing hydropower industry, and to increase the future deployment of hydropower in an environmentally and socially responsible manner.

HYDROPOWER

Hydropower is the only renewable energy technology which is presently commercially viable on a large scale. It has four major advantages: it is renewable, it produces negligible amounts of greenhouse gases, it is the least costly way of storing large amounts of electricity, and it can easily adjust the amount of electricity produced to the amount demanded by consumers. Hydropower accounts for about 17 % of global generating capacity, and about 20 % of the energy produced each year.

ACTIVITIES

Four tasks are operational, they are: 1. upgrading of hydropower installations, 2. small scale hydropower, 3. environmental and social impacts of hydropower, and 4. training in hydropower. Most tasks have taken about five years to complete, they started in March 1994 and the results will be available in May 2000. To date, the work and publications of the Agreement have been aimed at professionals in the respective fields.

UPGRADING

The upgrading of existing hydropower installations is by far the lowest cost renewable energy available today. It can sometimes provide additional energy at less than one tenth the cost of a new project. One task force of the Agreement is studying certain technical issues related to upgrading projects.

SMALL SCALE HYDROPOWER

Advances in fully automated hydropower installations and reductions in manufacturing costs have made small scale hydropower increasingly attractive. The small scale hydropower task force will provide supporting information to facilitate the development of new projects.

ENVIRONMENTAL AND SOCIAL ISSUES

For some hydropower projects the environmental and social impacts have been the subject of vigorous debate. There is a need to communicate objective information to the public, so that countries can make good decisions with respect to hydropower projects. The environmental task force will provide such information on possible social and environmental impacts and on mitigation measures.

TRAINING

The availability of well-trained personnel is a key requirement in the hydropower sector. The training task force is concentrating on training in operations and maintenance, and planning of hydro power projects.

THE INTERNATIONAL ENERGY AGENCY – IMPLEMENTING AGREEMENT FOR
HYDROPOWER TECHNOLOGIES AND PROGRAMMES

ECONOMIC RISK- AND SENSITIVITY ANALYSES FOR SMALL SCALE HYDROPOWER PROJECTS

Lars Jenssen
Kåre Mauring
Tor Gjermundsen

Grøner Trondheim
Pb. 331 NO-7403 Trondheim, Norway

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Table of Contents

OTHER TECHNICAL REPORTS IN THIS SERIES

HYDRO POWER UPGRADING TASK FORCE (ANNEX 1)

Guidelines on Methodology for Hydroelectric Turbine Upgrading by Runner Replacement – 1998 (available to non-participants at a cost of US $ 1,000 per copy)

Guidelines on Methodology for the Upgrading of Hydroelectric Generators – to be completed in May 2000.

Guidelines on Methodology for the Upgrading of Hydropower Control Systems – to be completed in 2000.

SMALL SCALE HYDRO POWER TASK FORCE (ANNEX 2)

Small Scale Hydro Assessment Methodologies – to be completed in May 2000 (available to non-participants on request)

Research and Development Priorities for Small Scale Hydro Projects – to be completed in May 2000 (available to non-participants on request)

Financing Options for Small Scale Hydro Projects – to be completed in May 2000 (available to non-participants on request)

Global database on small hydro sites available on the Internet at:
www.small-hydro.com

ENVIRONMENT TASK FORCE (ANNEX 3)

Survey on Positive and Negative Environmental and Social Impacts and the Effects of Mitigation Measures in Hydropower Development – 2000 (available to non-participants on request)

A Comparison of the Environmental Impacts of Hydropower with those of Other Generation Technologies – 2000 (available to non-participants on request)

Legal Frameworks, Licensing Procedures, and Guidelines for Environmental Impact Assessments of Hydropower developments – 2000 (available to non-participants on request)

Hydropower and the Environment: Present Context and Guidelines for Future Action
Volume 1: Summary and Recommendations
Volume 2 : Main Report
Volume 3 : Appendices
– 2000 (available to non-participants on request)

Guidelines for the Impact Management of Hydropower and Water Resources Projects – 2000 (available to non-participants on request)

EDUCATION AND TRAINING TASK FORCE (ANNEX 5)

(All of the following reports are available on the Internet at www.annexv.iea.org Some reports may consist of more than one volume.)

Summary of Results of the Survey of Current Education and Training Practices in Operation and Maintenance – 1998 (available to non-participants on request)

Development of Recommendations and Methods for Education and Training in Hydropower Operation and Maintenance - 2000 (available to non-participants on request)

Survey of Current Education and Training Practice in Hydropower Planning – 1998 (available to non-participants on request)

Structuring of Education and Training Programmes in Hydropower Planning, and Recommendations on Teaching Material and Reference Literature - 2000 (available to non-participants on request)

Guidelines for Creation of Digital Lectures – 2000 (available to non-participants on request)

Evaluation of tests – Internet Based Distance Learning – 2000 – (available to non-participants on request)

BROCHURE

A brochure for the general public is available. It is entitled “Hydropower – a Key to Prosperity in the Growing World”, and can be found on the Internet (www.usbr.gov/power/data/data.htm) or it can be obtained from the Secretary (address on the inside back cover).

PREFACE

This report is the result of the work of sub-task 8.2 – Economic risk- and sensitivity analysis for small-scale hydropower projects – of the Task Force on Small Scale Hydropower. This is one of four task forces of the IEA Implementing Agreement for Hydropower Technologies and Programmes. The sub-task started in 1997 and has drawn on the resources and expertise of the participating countries in the task force.

Before a developer / investor decides to realise a hydropower-project, he wants to have a total overview of the economy of the project. This includes not only the expected costs and benefits, but also the sensitivity; i.e. the corresponding economical risk and uncertainty. Different methods have been developed to calculate and illustrate the risks and uncertainty.

We hope that this report can make a useful contribution to the economic evaluation of hydropower projects, and can also contribute to the dialogue between developers, investors and financing institutions.

The views presented in this report do not necessarily represent the views of the International Energy Agency, nor the governments represented therein.

SUMMARY

This report deals with uncertainty and economical risks related to hydropower projects. The report is divided into ten major chapters:

The first chapter gives an introduction and background.

Chapters 2-4 describe the different components that influence the economics of a project (on the benefit- and cost-side) and the uncertainty each component is burdened with.

Chapter 5 describes various methods for the calculation and evaluation of the risks associated with benefits and costs.

Chapters 6-9 present the step-by-step principle; the structure, the calculations and the results.

Chapter 10 gives an example. Two methods are used and presented. One of the methods includes a Monte Carlo simulation.

The main conclusions / results of this report are:

- A checklist of the different components that influence the profit is presented / discussed.
- Tools / programs for the uncertainty- and risk analyses that have been developed are presented and demonstrated.

1 INTRODUCTION/BACKGROUND

Basis: A small hydropower project has obtained the necessary permissions for development. The potential owner now wishes to make a final decision on whether to complete the project and also wishes to know how to finance the project.

Before realising a project it is important not only to check the risk and sensitivity of the cost side, but also the potential benefits. The benefits and costs (investment- and maintenance costs) ought to be checked for the lifetime of the plant. Special "dangerous" elements must be identified and priced. As an alternative special efforts can be made to to reduce or eliminate the risks involved.

This report systematically goes through the relevant costs and risk categories and can thus be used as a guide or checklist.

2 IDENTIFICATION OF RELEVANT COMPONENTS THAT INFLUENCE THE OVERALL PROJECT ECONOMICS

The main components that influence the profit of a powerplant are:

- The benefit obtained from the energy production
- Investment costs
- Costs of maintenance and operation

Multipurpose aspects are also considered.

The main components are shown in Appendix 1.1, 1.2 and 1.3.

3 COMPONENT BENEFITS

The various elements of a hydropower project are shown in Appendix 1.2. Even if the main income from the project will be derived from selling electricity, it is also of interest to check whether the owner can obtain other benefits (in cash or in other ways). As for larger projects the possibility of multipurpose use ought to be checked. Such uses may include irrigation, flood control, water supply and navigation. If the project is a "run-of-river" plant in a rural area, the possibility of using the "free" power (electric or direct) during the night and low-load periods should be taken into consideration. Relevant keywords – include heating, cooling, mechanical work, drying and pumping,

3.1 Production

The power actually produced is a product of the following factors:

- The plant capacity etc.; reservoir, installation, operation
- Water discharge/available volume
- Gross head
- Total efficiency (including losses in the waterway)
- Grid losses
- Delivery reliability

3.1.1 Plant capacity

The capacity of the power plant, the reservoir volume and the strategy for operating determines the water actually available for electricity production. Actual capacities and volumes must be checked if they do not appear to be reasonable.

3.1.2 Water discharge/available volume

Catchment area

Using a planimeter or GIS the catchment area is normally easy to determine (except in limestone areas, etc.).

Total runoff

Total runoff is very often one of the most uncertain points. For larger projects a gauging station will normally have been in operation for some years before the plant is built. For small projects it is normally too expensive to establish a gauging station, so other methods have to be used. In the EU a system has been developed for this purpose. In other countries where the topography may change within a small area it is more difficult to estimate the runoff without gauging. In such places the estimate of runoff, including both the specific runoff and the runoff variation through the year, is relatively uncertain. The catchment area is normally easy to estimate if maps are available, but developers should be aware of streams that run through the ground (karst, leakage).

Restrictions

Even for small hydro projects restrictions may be necessary. Keywords here are residual flow, smooth manoeuvring of the plant; i.e. not start/stop.

These restrictions will have been described and set out when the licence was given, and the uncertainty should therefore have been eliminated.

3.1.3 Gross head

This is normally easy to determine. One need only be aware of the changes in the reservoir and the tailwater. Using a simulation model it can be calculated automatically.

3.1.4 Total efficiency

This is relatively easy to estimate. It is a product of the efficiency of the turbine, the generator, the transformer and the losses in the waterways. Greater or lesser losses in the grid may also have to be taken into account. In new plants efficiency uncertainty is relatively small, while it can be higher in older plants.

3.1.5 Grid losses

A new plant will have an influence on grid losses. It is important to be aware that implementation of a new plant will not necessarily increase such losses; sometimes it may reduce them.

3.1.6 Delivery reliability

Depending of the location of the plant in the grid and consumption location, reliability of delivery may be improved.

3.2 Power value/Present value

The most important factors that should be taken into account are:

- Prices
- Present value factor (function of rates and lifetime)

3.2.1 Energy prices

In many countries this factor is one of the most difficult to estimate. Relevant questions here include Grid connection today or in the future? Alternative energy sources? General price? Firm or surplus price? Peak power price? Extra price for rotating reserve? Political aspects? Free markets?

Different scenarios should be drawn up, but the best bet is to come to an agreement with a buyer for the first critical years (for example 10 years).

3.2.2 Present value factor

The calculation rate and the lifetime of the plant determine the present value factor. The table below gives some examples of the present value factor.

Lifetime, years	Rate, %				
	3	6	9	12	15
20	14,88	11,47	9,13	7,47	6,26
40	23.12	15,05	10,76	8,24	6,64
60	27,68	16,16	11,05	8,32	6,67

3.2.3 Present value of production

The present value of production is the product of the energy output and the present value of the energy price.

3.3 Multipurpose aspects

The present value of these aspects should be included.

4 COMPONENT COSTS

The individual components are shown in Appendix 1.3. The costs can be divided into two parts:

- construction/investment costs
- operation/maintenance/refurbishment costs

4.1 Construction costs

The construction costs can be divided in civil engineering/electromechanical costs and overhead costs.

4.1.1 Civil engineering/Electromechanical costs

Appendix 1.3 shows the main cost components: diversion, reservoir, waterways and power station. Roads, transmission lines, enterprises, miscellaneous and contingencies are also included here. A systematic check of the components, including choice of materials, is essential. Special conditions at dam-sites and waterways should be paid particular interest.

4.1.2 Overhead costs.

This includes planning and administration costs during construction, taxes, compensations, financing during construction, political / environmental resistance (despite of legal permission). Normally small hydro plants have no problems with resistance, but it can happen and will cost a lot of money if you have to stop during construction.

4.2 Operation/Maintenance/Refurbishing/Force majeure-costs

4.2.1 Operating and maintenance costs

These include the normal costs of operating the plant and will normally be relatively constant from year to year. If the river has a heavy sediment load, special attention should be paid to the implications.

4.2.2 Taxes and fees

The expected stability of the taxload in the country concerned should be estimated. Possible fees should also be considered.

4.2.3 Upgrading/refurbishment/enlargement

The present value of this ought to be calculated and included especially where the plant will be operating under particularly wearing conditions.

4.2.4 Force majeure

Relevant keywords here include seismic activity, unstable political system (nationalisation), landslides, etc., etc.

If the environmental impact of the project turn out to be more serious than expected, the plant may have to be shut down. The probability of such an eventuality should be estimated.

5 EVALUATION OF THE RISKS ASSOCIATED WITH BENEFITS AND COSTS

Various methods are available to provide an overview of the risks involved.

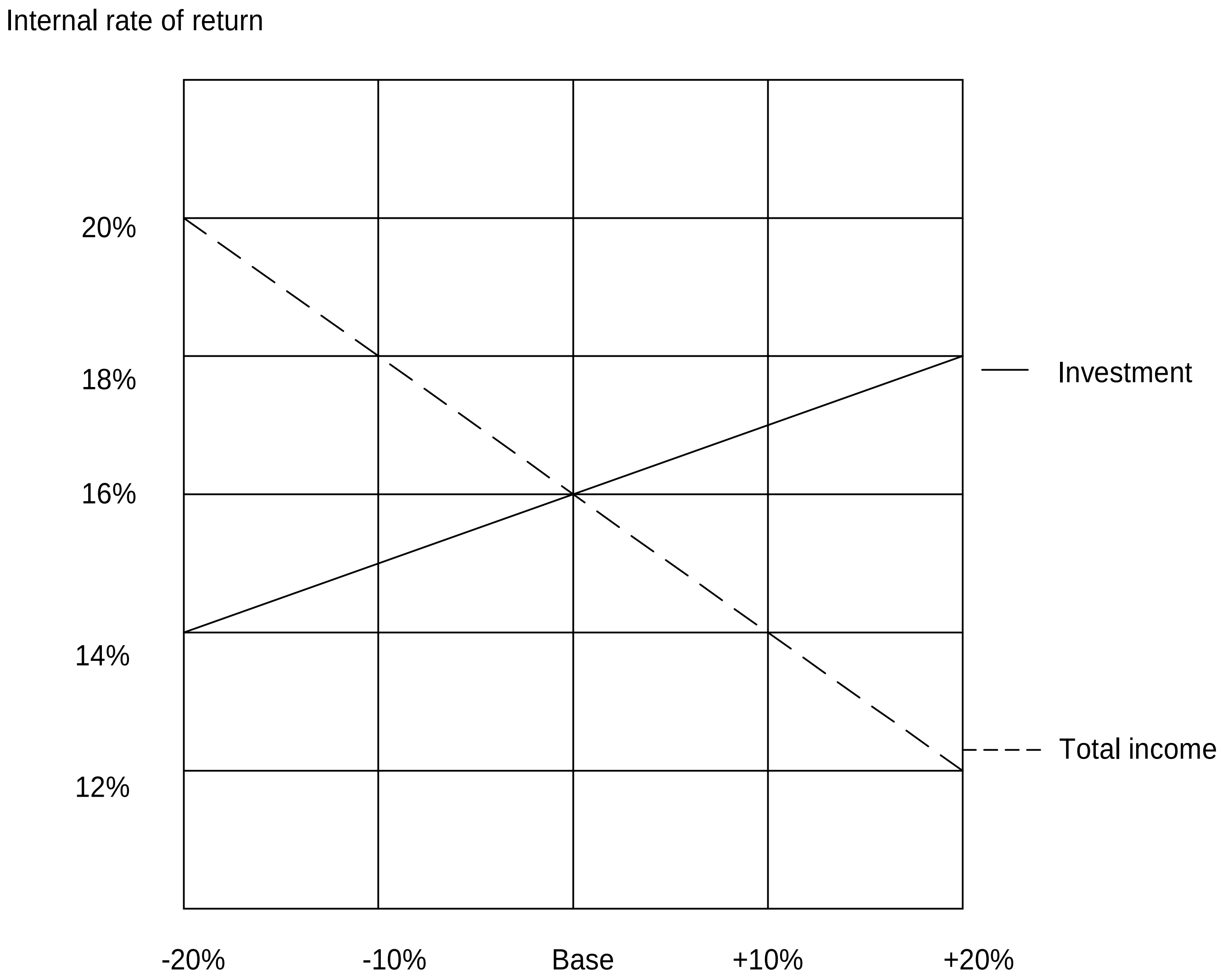
5.1 Add an item for "unforeseen costs"

The traditional approach to accounting for risk is to add an item for "unforeseen costs" in the cost estimate. The amount added depends on the developer's "gut feeling."

5.2 Sensitivity analysis

Probably the most common way of handling project risk in practice is to carry out a sensitivity analysis. The developer makes his best estimate of the revenues and costs involved in a project, calculates the project's NPV, and checks the sensitivity of the NPV to possible errors in the estimation of power production and the various cost items.

The results of the sensitivity analysis are often presented in a diagram. An example is shown below. If the lines are flat the NPV is relatively insensitive to changes in the cost item. Steep lines indicate that uncertainty in the item may strongly affect the project. The developer should take great care in predicting these items.



Star Diagram

5.3 Standard deviation as a measure of risk

The variance, or the standard deviation, measures the dispersion around the mean value of a particular item of measurement. It provides information about the extent of potential deviations from the expected value.

The expected cost and standard deviation of an item can be estimated from a cost database, if available. An alternative is to ask the opinion an experienced group of professionals on the expected cost of the item in question; a maximum cost and a minimum cost. If the probability distribution is known (or assumed) it is then possible to estimate the standard deviation of the item.

If the expected value and standard deviation of each cost (or revenue) item are known and the items are independent, calculation of the total project costs (or revenues) and their variance is straightforward:

$$C = \sum_{i=1}^{n} C_i$$

$$\sigma^2 = \sum_{i=1}^{n} \sigma_i^2$$

where:

C = expected project cost
C_i = expected cost of the *i*th item
σ = standard deviation of the project cost
σ_i = standard deviation of the *i*th item.

In many cases each cost item is calculated on the basis of number of units and unit price, for example the quantity of concrete poured and its price per m^3. In this case the expected cost and variance of the cost item is calculated by:

$$C_i = cm$$
$$\sigma_i^2 = (c\sigma_m)^2 + (m\sigma_c)^2 + (\sigma_m\sigma_c)^2$$

where:

C_i = expected cost of the *i*th item
c = unit cost
m = number of units
σ_i = standard deviation of the *i*th item
σ_m = standard deviation of the number of units
σ_c = standard deviation of the unit cost

In many cases the costs of the individual items are not independent. For example if steel prices increase, so will the cost of the penstock, the cost of reinforcement bars and the cost of mechanical equipment. This may be taken into account by including the covariance between the different items when calculating the standard deviation of the project cost. In practice, however, it is difficult to quantify how individual items fluctuate together, i.e. to quantify the covariance.

The problem of dependence may be handled by identifying conditions that will influence a large portion of the project and treating them individually.

5.4 Step-by-step calculations

Detailed cost calculation is a time-consuming and expensive process that involves dividing the project into a large number of cost items, and estimating the expected value and standard deviation of each and the project as a whole. This may not be feasible in the early stages of the project.

It is important to focus early on cost items and conditions that strongly influence the risks involved in the project. This is the background for the “step-by-step” procedure that was introduced by Lichtenberg (1978). The main steps in this procedure are:

- The project cost is divided into a number of independent items.
- The expected value and variance of the cost (or revenue) is calculated for each item.
- In order to reduce the uncertainty, the item with the largest uncertainty, i.e. the largest variance, is divided further into a number of independent sub-items.
- The expected value and variance of the cost (or revenue) is calculated for each sub-item.

The procedure is reiterated until the overall uncertainty in the cost/revenue estimate is regarded as satisfactory, or until further improvement is impossible. The method is described in detail in section 7 of this report.

5.5 Monte-Carlo simulation

The economic outcome of any project depends on a large number of factors. If the factors are interdependent the methods described above may not be suitable. In such cases, Monte-Carlo simulation may be used instead. Using Monte-Carlo simulation makes it possible to take interdependencies into account. The simulation provides a complete frequency distribution of the project outcome, rather than only the standard deviation. This may be important when the distribution is highly skewed.

Before the simulation can be carried out the analyser must make a model of the project. This model must include all relevant cost and revenue items, and their interdependencies. Each item is described in terms of its expected value and probability distribution.

The simulation involves selecting a single value for each item and calculating the resulting project value using the selected values. This is repeated many times and the results are used to calculate the expected project value, the standard deviation and the distribution of the outcomes.

Model building and simulation are normally done with the aid of a computer program. Building a model and running a simulation is relatively easy with a modern, user-friendly computer program. The real problem is to assess the expected value and probability distribution of each item, and to evaluate their interdependencies.

The example in section 11 demonstrates how Monte-Carlo simulation can be used to assess risk in hydropower project.

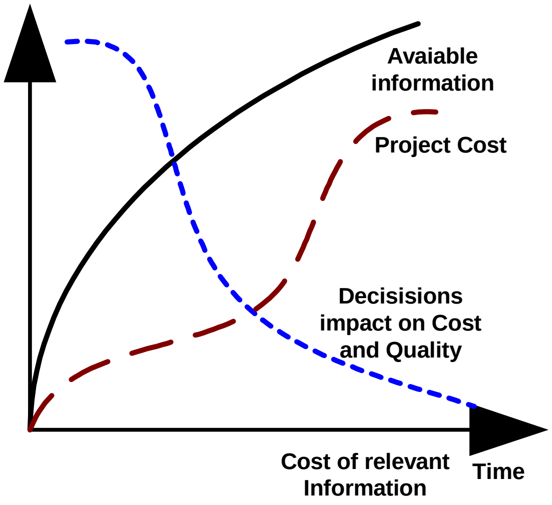
6 THE STEP-BY-STEP PRINCIPLE

6.1 Introduction

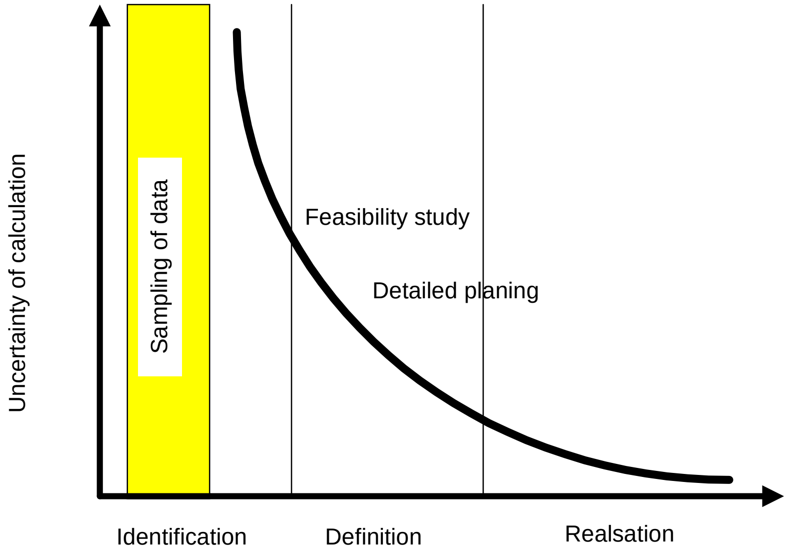
The step-by-step method is a "top-down approach" that is suitable for order-of-magnitude estimates with focus on relevant information as a basis for making early-stage decisions.

The basic problem at an early stage of the project is illustrated below:

- There is a lack of relevant information
- The cost of relevant information is high
- The decision impact of cost and quality is high

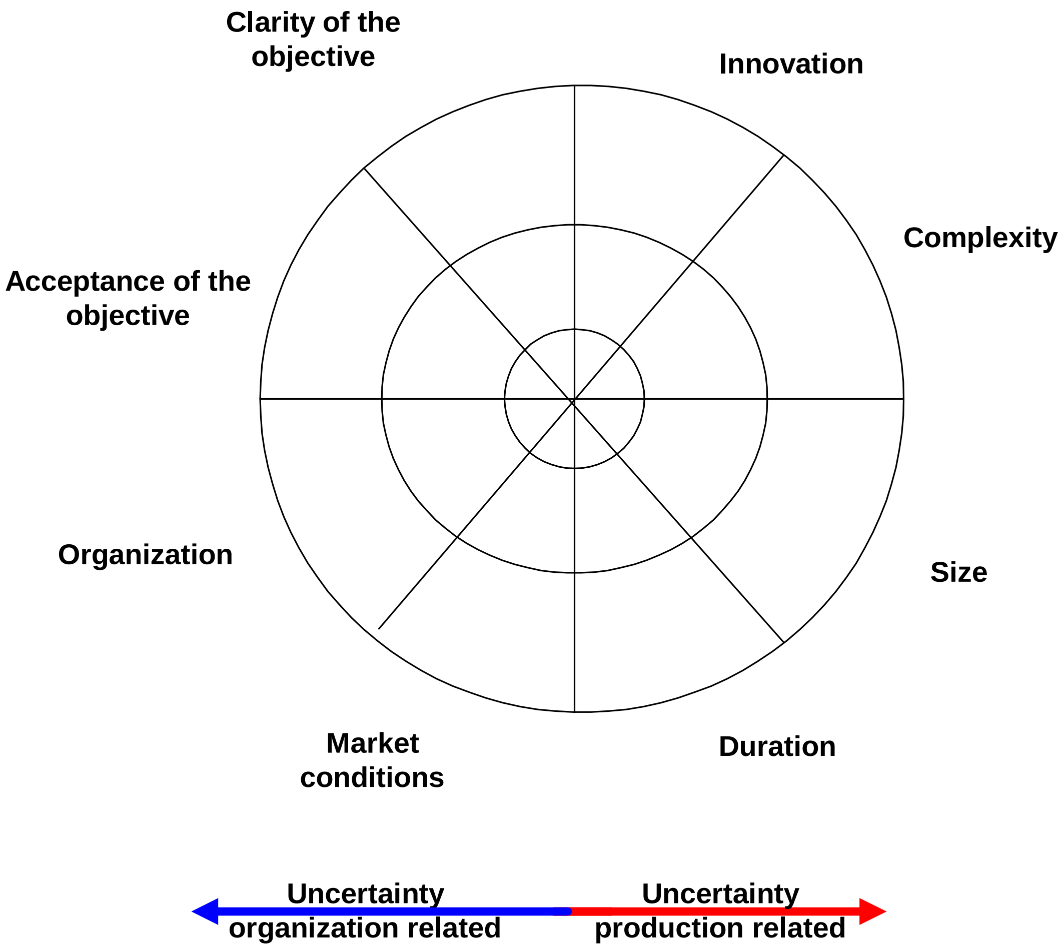


Typical uncertainty figures:



Screening	40%
Feasibility study	30%
Budget	20%

6.2 The situation map



The situation map can be helpful in the process of quantifying and visualising the characteristics of the situation in which the information is valid. The sectors represent possible causes of uncertainties.

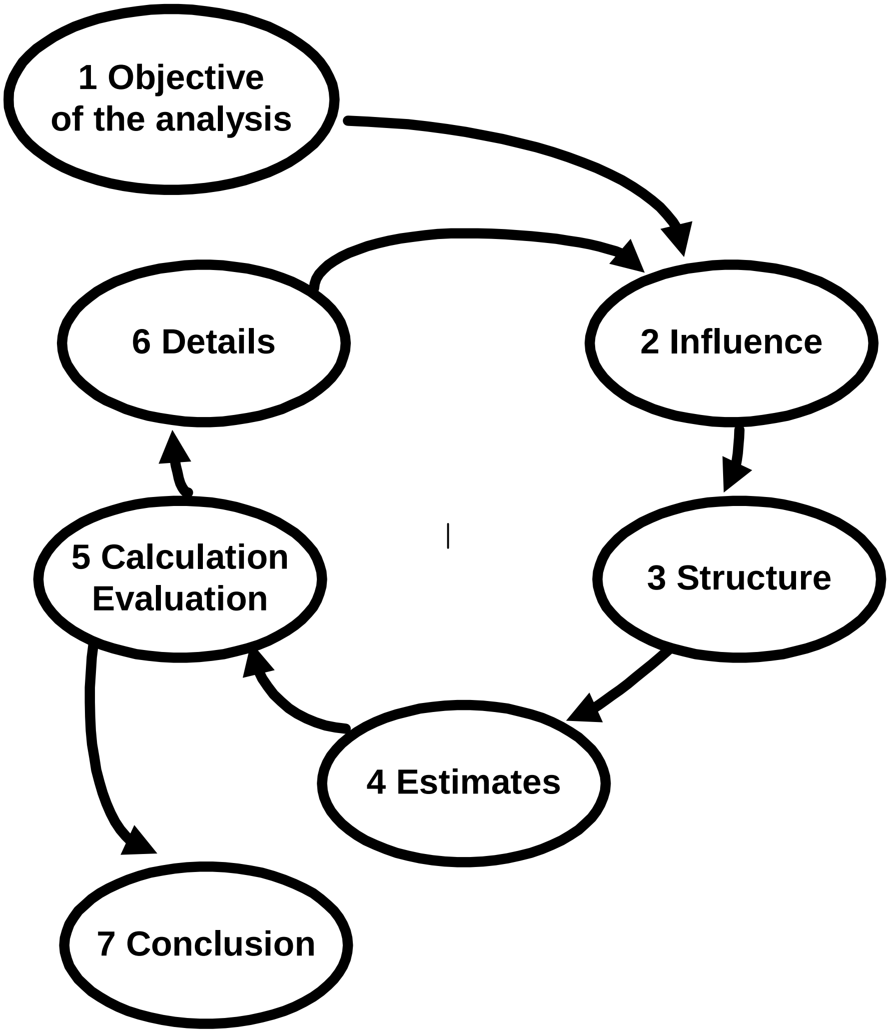
The situation map should be filled in by intuition. The degree of shading of the sectors is used to illustrate the exposure to uncertainties.

- Predominantly dark shading in the right half of the circle indicates mainly production-related uncertainty.

- Predominantly dark shading in the left half of the circle indicates mainly organisation-related uncertainty.

The situation map intuitively illustrates the results of the subsequent planning session should reflect and document the uncertainties that.

6.3 The working procedure of the step-by-step principle



1. Defining and limiting the objective of the analysis
2. Identifying the overall influence factors
3. Structure, i.e. work-breakdown structure
4. Cost estimates
5. Cost calculation
6. If necessary, detailing the work breakdown structure and a loop to 2-5 , or
7. Conclusion

This working procedure forces the resource group to
- Work ”top-down”
- Reduce uncertainty systematically
- Add relevant information only where the planning effort really matters

6.4 The resource group

The number of participants in the resource group should be adapted to the magnitude of the project.
- Minor projects

A resource group of two or three persons should be sufficient. The group must consist of the most experienced professionals, who should be capable of effectively analysing the available information in order to identify the financial risks.
- Major projects

A resource group of four to six persons will be required to produce a successful analysis of the financial risks involved.

The resource group should consist of
- Key persons with direct influence on the decisions
- Professionals and experts.

The planing session should start with a project start-up workshop
During the session it is important to focus on:
- Establishing a creative process and communication.
- The equality of all participants regardless of formal position.
- The awareness of all participants of the previous point, and their acting in accordance with it
- No participant being allowed to dominate the session.

During the planing session a moderator should guide the resource group.

6.5 The moderator

The moderator is responsible for:
- Guiding the resource group so that the planning process is efficient and systematic
- Support communication, co-operation and the creative process
- Document evaluations and estimates made in the session.

6.6 The planning session

The planning session should be an active, motivating, interesting and teambuilding event that should be carefully prepared. The success factors comprise promotion of:
- Creativity
- Communication
- Co-operation.

Material describing the background and objective of the project should be prepared and distributed to participants before the session. The primary objective of the session is to establish clarity and acceptance of the project objectives.

A creative part of the session should follow, bringing frank and open ideas regarding any elements that might influence the project in any way. No elements are irrelevant; all should be regarded positively at this point.

After most ideas appear to have been identified, the elements need to be structured and judged. Relevant elements must be related to the respective accounts.

Consensus regarding the elements must be established within the group:

- Whether they are relevant or irrelevant
- The magnitudes of the triple estimates of cost overall influence factors and income.

Each element should be briefly but adequately commented on for the sake of having proper and traceable documentation of the decisions made, even the irrelevant ones.

7 STRUCTURE

In order to calculate the potential profitability of a project a suitable list of accounts must be provided, corresponding to a work breakdown structure (WBS). The list of accounts should contain as few elements as are essential to reduce the financial uncertainty to an acceptable level.

7.1 Master structure

A suitable list of accounts is adapted to the work breakdown of
Civil engineering, mechanical and electromechanical work by examples:

- Reservoirs
- Diversions
- Waterways
- Power station, civil engineering works.
- Power station, mechanical and electro-mechanical installations
- Roads and transmission lines
- Temporary and permanent buildings, storage, workshops
- Mitigating measures.

Overhead
- Planing and administration
- Taxes
- Compensation
- Finance during construction

Operational costs
- Operation
- Maintenance

Overall influence factors
- Political
- Geographical
- Product-related
- Organisational

Benefits:
- Power price (and power production)
- Discount factor
- Other sources of income

Even at the earliest stage several of these elements should be grouped and only separated when their contribution to overall uncertainty is unacceptably high.

7.2 The overall influence factors

In the early stages of the project certain overall influence factors are of significance. These factors can be arranged into the following four categories:

Overall influence matrix	
Political aspects	**Geographical aspects**
Examples: Government policy Local regulations	*Examples:* Mass properties Climatic conditions
Product-related aspects	**Organisational aspects**
Examples: Complexity Duration	*Examples:* Contracting form Number of contractors

Due to the fact that these factors may have a great influence on uncertainty, they must be properly identified and their influence estimated.

8 CALCULATIONS

The calculations are based on triple estimates of all cost elements, overall influence factors and income elements. Two different ways of calculating the results may be suggested:

Calculation by means of

- A spreadsheet program, such as Microsoft Excel

The local mean value and standard deviation for each element are determined by means of Erlang functions.

To simplify the calculations:

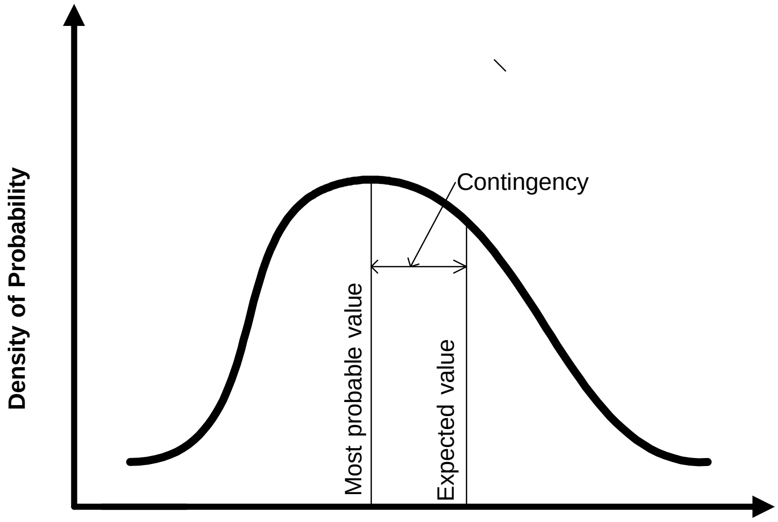
Mean value: $E\ mean = (e_{max}+3e_{est}+e_{min})/\ 4.95$

Standard deviation: $\sigma = (e_{max}-e_{min})/\ 4.6$

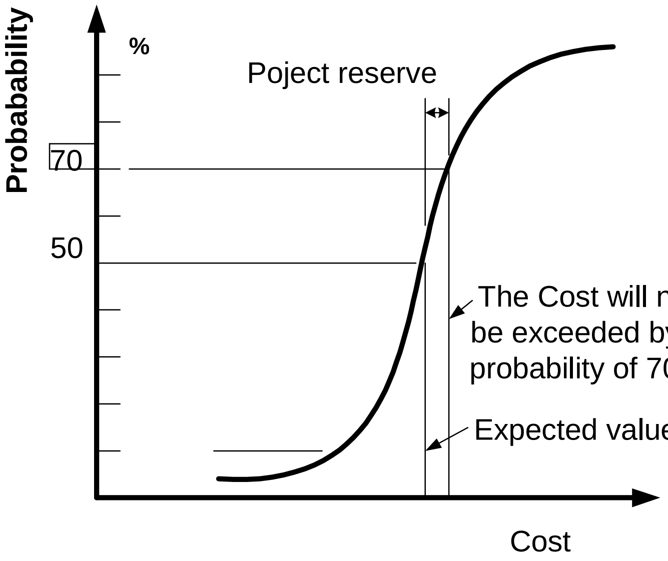
Results obtained from this method have satisfactory accuracy and they are quite close to results obtained using Monte Carlo simulation.

9 Results

The calculations reveal the contingency, i.e. budgetary provision discrepancies in the base estimate assumptions.



The cumulative probability distribution shows the project costs:



- The cost will exceed the expected value with a probability of 50%
- The determination of the acceptable probability gives the cost budget and the project reserve.

Separate calculations of the project cost should be made as a first step towards obtaining the magnitude of the individual costs.

Including the income elements in the calculations reveals the profitability of the project.

10 MONTE CARLO SIMULATION. EXAMPLE

10.1 Input

All cost and income items considered relevant to the project economy are included in the Monte-Carlo model. The model structure is shown in appendix 3.1 and 3.2. A “node” (filled circle) represents each cost item. The expected value, an upper- and lower bound, and the type of probability density function to represent the node, i.e. log-normal describe the statistics of each item (node). An example of node input is shown in appendix 3.3. The figure shows a skewed probability distribution that is typical for cost items. The graphical user interface makes it easy to construct a simulation model, but the user should be familiar with statistic methods.

10.2 Results

The results of the simulation may be presented in various ways:

- Histograms
- S-curves

- Overview of the influence of each component.

It is important to remember that this method can be used at different stages of a project. At an early stage Monte-Carlo simulation may be used for a rough estimate of the project risk, and to identify the main sources of uncertainty. Work can then be done on these components to reduce the uncertainty and/or improve the project.

As the project develops further, the model is refined and extended. Different items will dominate uncertainty at different stages of the project. By continuously refining and updating the model it is possible to monitor the project uncertainty, and to focus risk management efforts on the most important sources of uncertainty at each stage.

10.3 Examples

Appendix 1
App. 1.1 Project Structure, Main Elements
App. 1.2 Project Structure, Benefits
App. 1.2 Project Structure, Cost

Appendices 2 and 3
Uncertainty assessment is illustrated by means of an Excel spread sheet and by Monte-Carlo simulation using the computer program "Definitive Scenario". The example concerns a hydropower project with an estimated production of 39 GWh/year. The results from using the two different methods, e.g. spread sheet and Monte-Carlo simulation) are shown below.

	Excel spread sheet mill NOK	Monte Carlo simulation mill NOK
Total investment	64	68
Total cost	70	73
Total income	111	114
Project profit	41	41

(1 $=8.40 NOK).

Appendix 2 Calculations in Excel spread sheet
App. 2.1 Table with input and results
App. 2.2 S-curve project profit

App. 2-2 shows the main contributing items to cost uncertainty

- The uncertainty in waterways (28 %) is mainly related to assessing the need for tunnel support.
- Politically related uncertainty (28%) is due to restrictive legislation practices and probable local resistance to the project

- Organisational aspects (11%) are due to uncertain contracting form.

App. 2-3 shows the main contributing items to income uncertainty
- Power price (67%) is frequently the item that dominates uncertainty
- The risk associated with annual power production (15%), in relatively small in this case, the reason being flow gauging station close to the proposed intake site.

Appendix. 3 Calculations using Monte-Carlo simulation (Definitive Scenario)

App. 3.1 Main structure
App. 3.2 Sub structures
App. 3.3 Example of node input
App. 3.4 Summary of Input
App. 3.5 Results Basic Statistics
App. 3.6 S-Curves, Project Profit / Total Project Cost / Total Project Income
App. 3.7 Costs uncertainty. Waterways dominate contribution to uncertainty
App. 3.8 Cost / Profit uncertainty
App. 3.9 Histograms, Project Profit / Total Project Cost / total Project Income

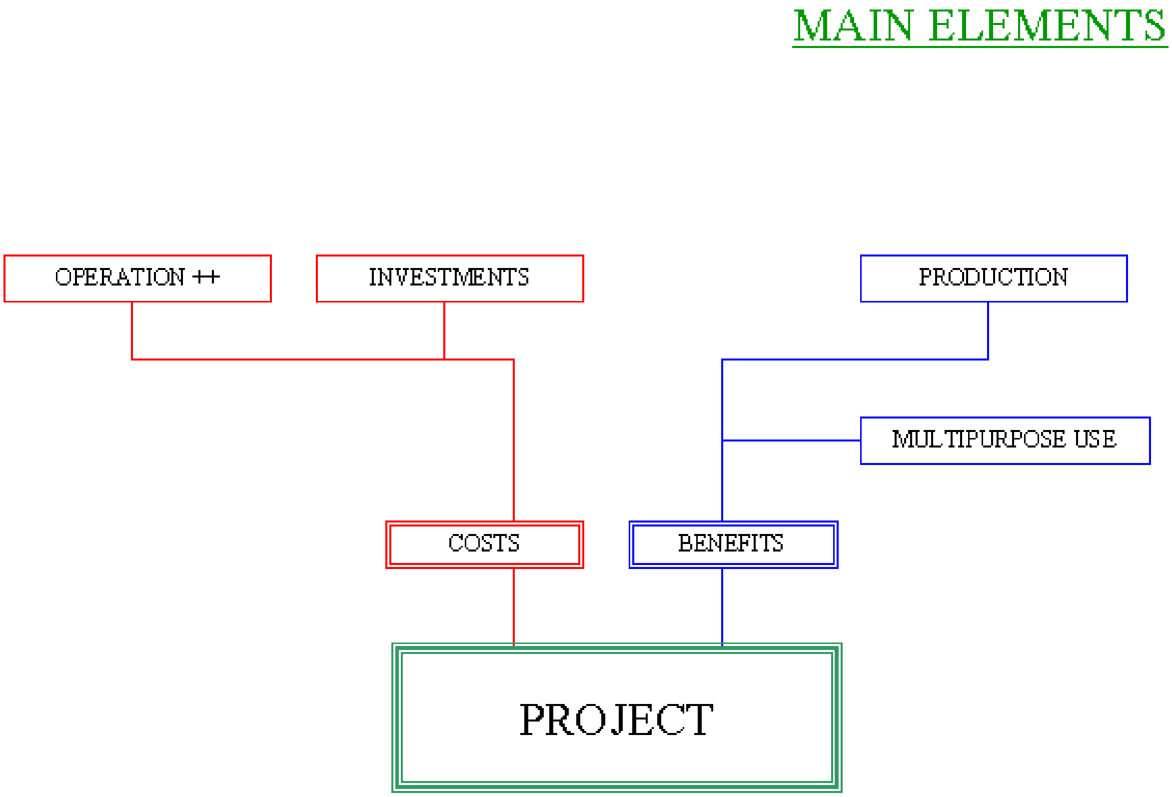
10.4 Conclusions

If the project is still interesting after an acceptable estimate of the benefits, costs and risks, it is time to get the project properly financed. Of course, in many cases the question of financing will be taken into account at an earlier stage.

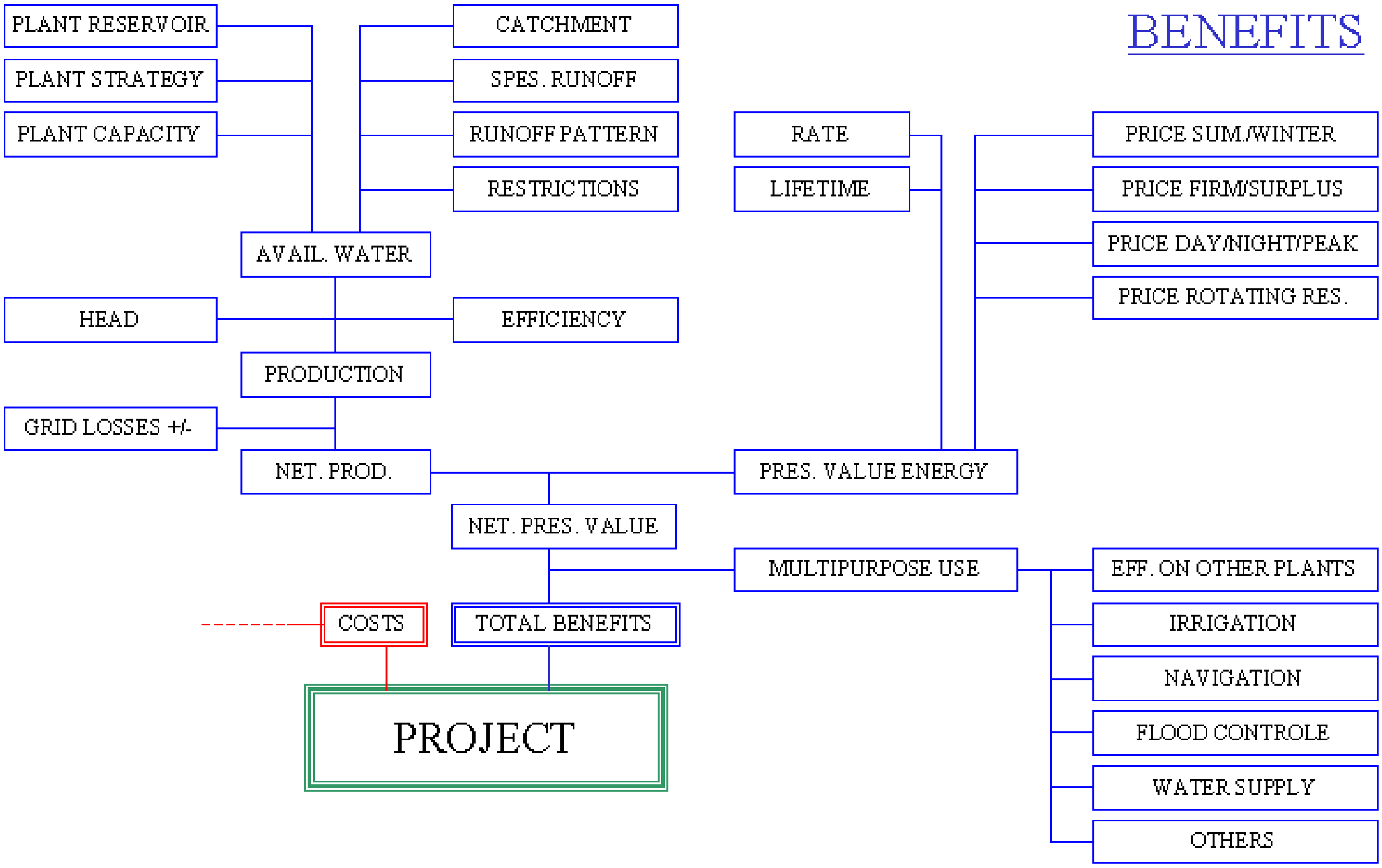
Appendices

Appendix 1

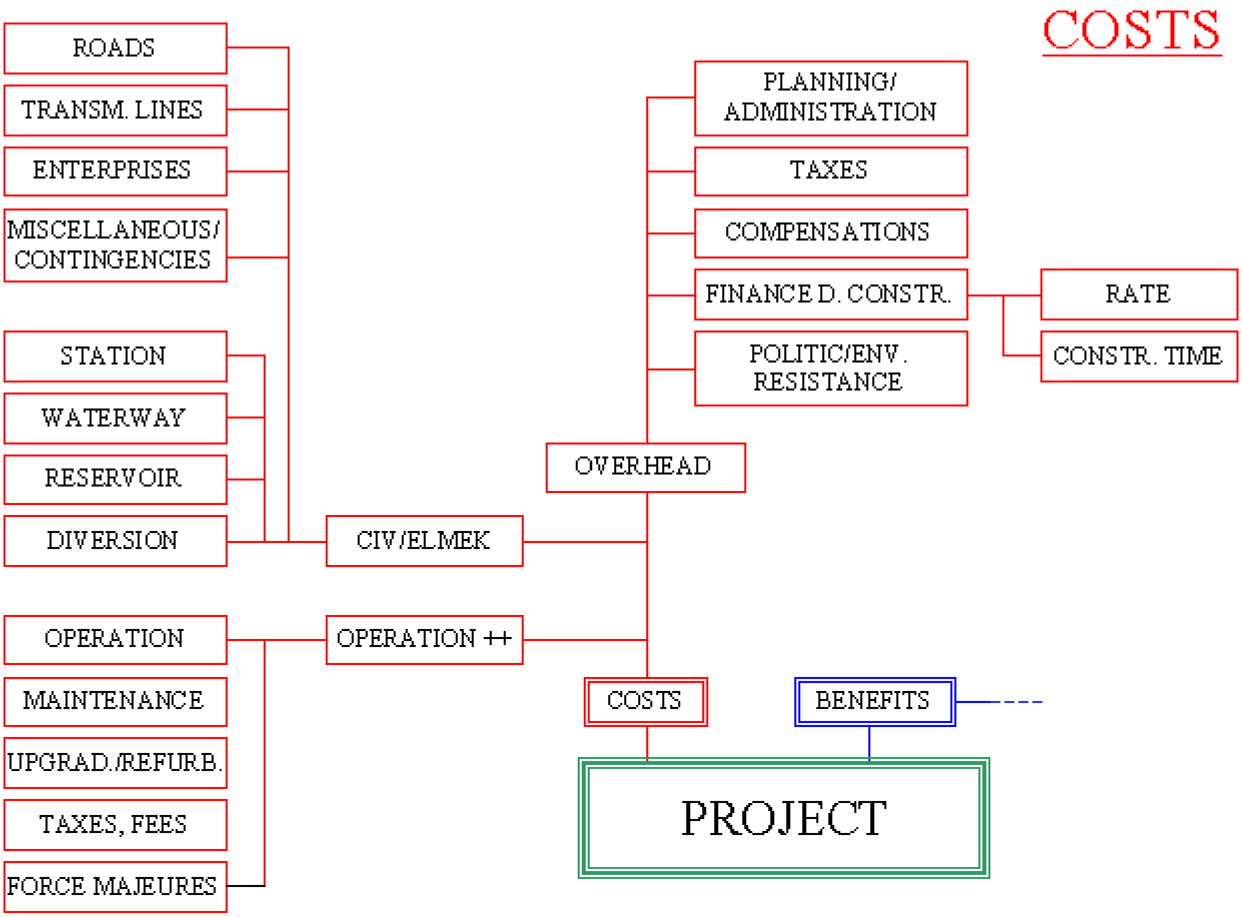
App. 1.1 Project Structure



App 1.2 Project Structure



App. 1.3 Project Structure

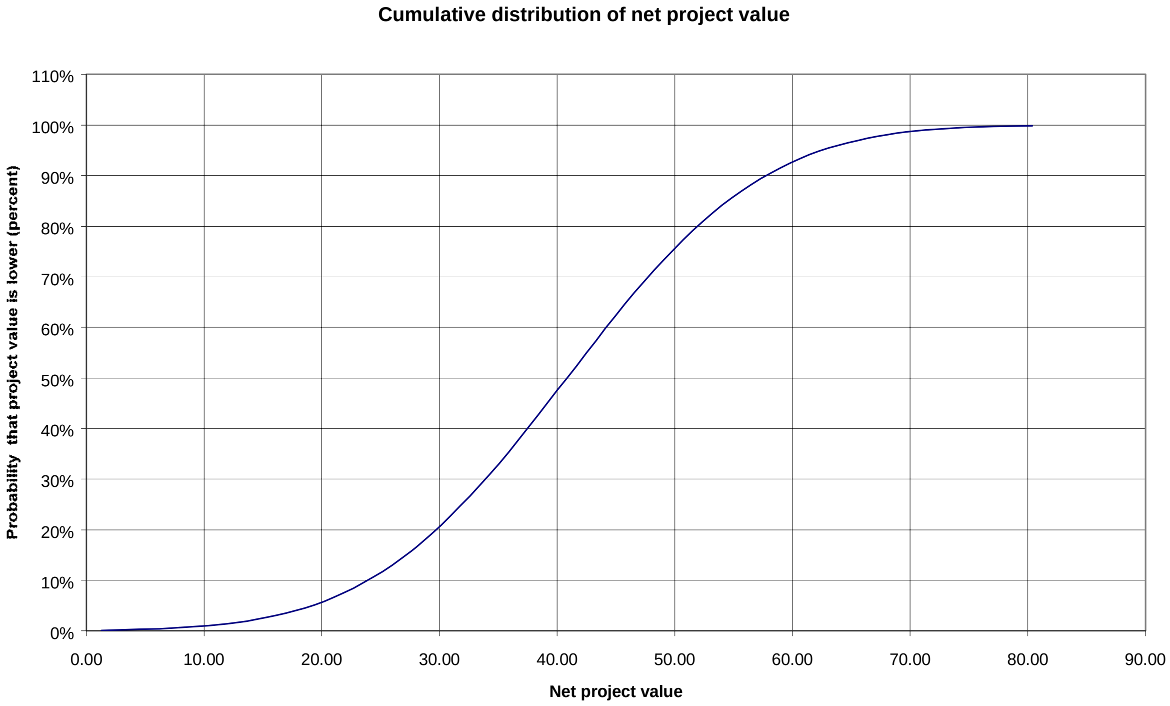


Appendix 2

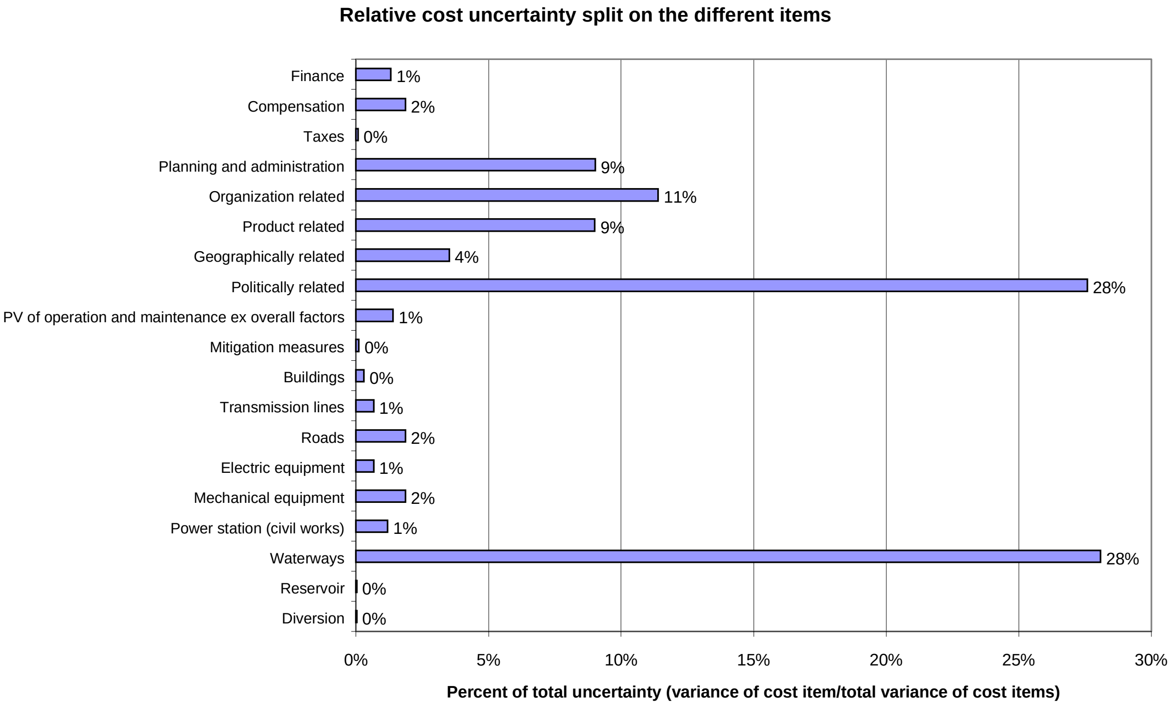
App. 2.1 Excel Spread Sheet Calculation

Cost/income group	Cost/benefit estimate by user			Computed values			
	Low	Most probable	High	Expected value	Standard deviation	Variance	Variance/total variance of cost or income
Civil, mechanical and electromechanical cost							
Diversion	0,2	0,3	0,5	0,32	0,07	0,00	0 %
Reservoir	0,18	0,2	0,5	0,26	0,07	0,00	0 %
Waterways	14,8	17,4	24,5	18,31	2,11	4,45	28 %
Power station (civil works)	3,5	4	5,5	4,20	0,43	0,19	1 %
Mechanical equipment	12	13	14,5	13,10	0,54	0,30	2 %
Electric equipment	6	6,9	7,5	6,84	0,33	0,11	1 %
Roads	4	4,5	6,5	4,80	0,54	0,30	2 %
Transmission lines	3	3,5	4,5	3,60	0,33	0,11	1 %
Buildings	0,5	1	1,5	1,00	0,22	0,05	0 %
Mitigation measures	0,4	0,5	1	0,58	0,13	0,02	0 %
			Sum	53,01	2,35	5,51	35 %
Overhead cost							
Planning and administration	3,7	4,5	9,2	5,29	1,20	1,43	9 %
Taxes	0,3	0,5	0,8	0,52	0,11	0,01	0 %
Compensation	0,5	1	3	1,30	0,54	0,30	2 %
Finance	2,5	3,2	4,6	3,34	0,46	0,21	1 %
			Sum	10,45	1,39	1,95	12 %
Operational cost							
Operation	0,278	0,368	0,413	0,36	0,03	0,00	0 %
Maintenance	0,015	0,022	0,038	0,02	0,01	0,00	0 %
			Sum	0,38	0,03	0,00	0 %
Overall factors that influence costs							
Politically related	0,96	1	1,1	1,01	0,03	0,00	
Geographically related	0,98	1	1,03	1,00	0,01	0,00	
Product related	0,97	1	1,05	1,00	0,02	0,00	
Organization related	0,97	1	1,06	1,01	0,02	0,00	
Present value							
Factor for calculating PV	12	13,33	15	13,40	0,65	0,43	
Total cost ex overall factors							
Total investment cost ex overall factors				63,47	2,73	7,46	
PV of operation and maintenance ex overall factors				5,13	0,47	0,22	1 %
			Sum	68,59	2,77	7,68	
Cost of overall influence factors							
Politically related				0,83	2,09	4,37	28 %
Geographically related				0,14	0,75	0,56	4 %
Product related				0,28	1,19	1,43	9 %
Organization related				0,42	1,34	1,80	11 %
			Sum	1,66	2,86	8,15	51 %
Total cost, overall influence factors included							
Total cost				**70,26**	**3,98**	**15,83**	**100 %**
Annual income from power production							
Annual power production (kWh)	35	39,2	43	39,12	1,74	3,02	
Power price (value/kWh)	0,18	0,2	0,27	0,21	0,02	0,00	
	Annual income from power production			8,22	0,85	0,72	
Annual income from other sources							
Other income (annual value)	0,05	0,07	0,1	0,07	0,01	0,00	
Present value of power production							
Annual power production					4,90	23,97	15 %
Power price					10,26	105,17	67 %
Factor for calculating PV, infuence on income from power revenue					5,36	28,73	18 %
	Present value of power production			110,12	12,56	157,87	100 %
Present value of income from other sources							
Other income					0,15	0,02	0 %
Factor for calculating PV, influence on revenue from other sources					0,05	0,00	0 %
	Present value of income from other sources			0,96	0,15	0,02	0 %
Present value of total income							
	Present value of total income			**111,09**	**12,57**	**157,89**	**100 %**
Net present value of project							
Present value of income				111,09	12,57	157,89	91 %
Present value of cost				70,26	3,98	15,83	9 %

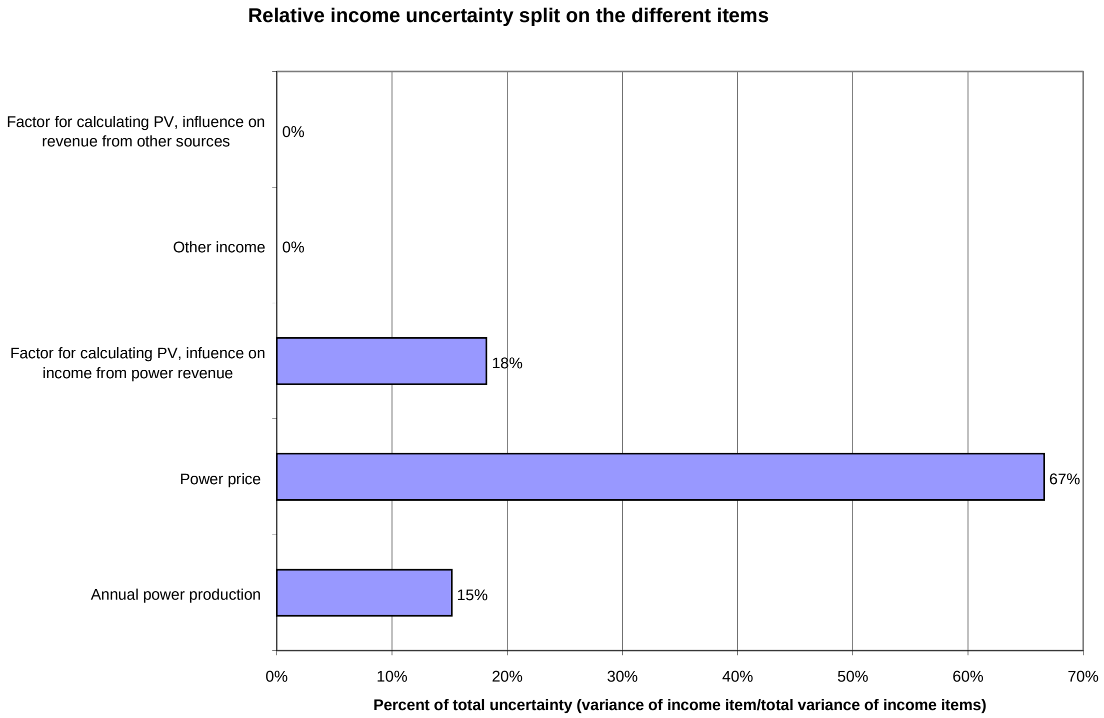
App 2.2 Spread Sheet Diagram - S-Curve Project Value



App. 2.3 Spread Sheet Diagram - Cost Uncertainty



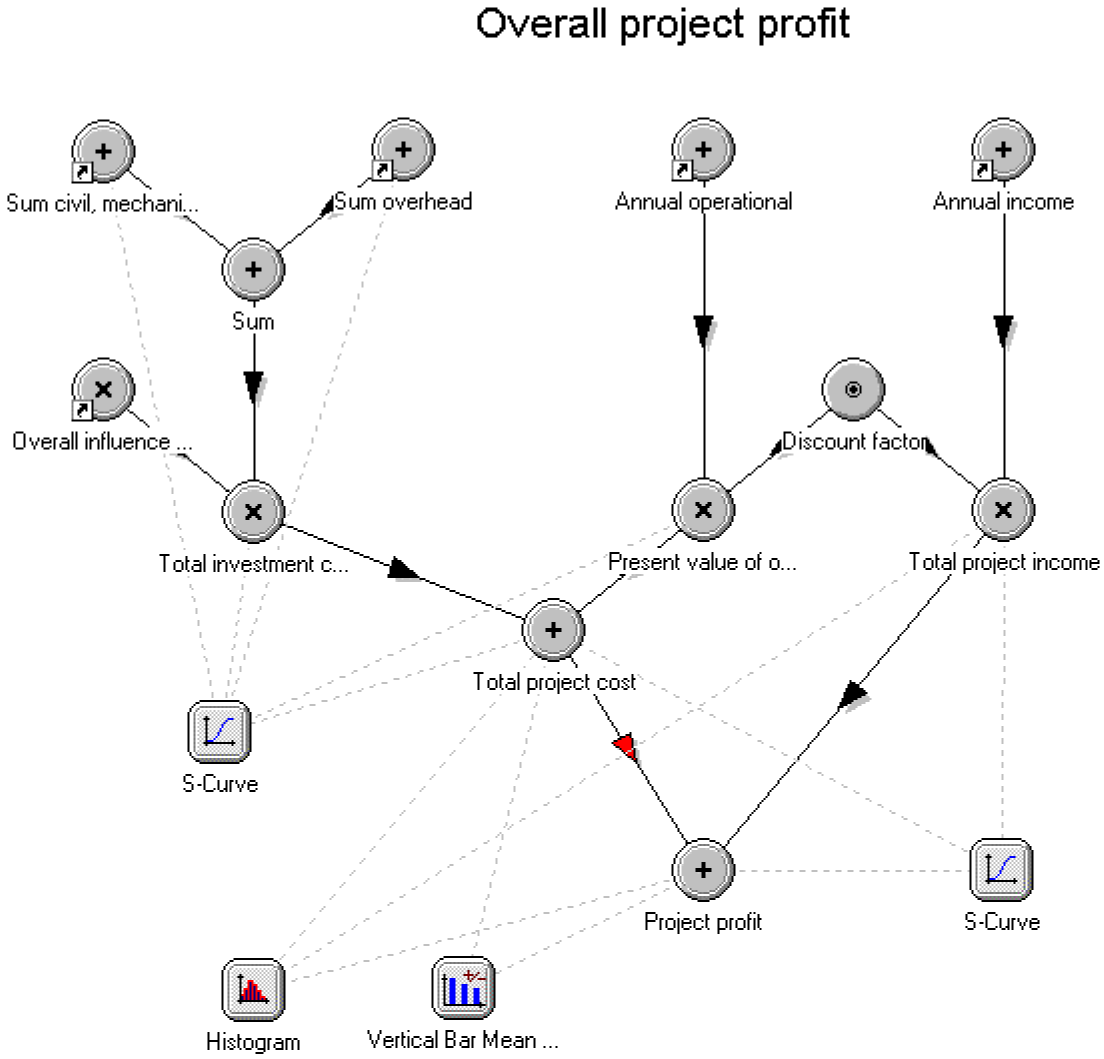
App. 2.4 Spread sheet diagram Income uncertainty



Appendix 3

App. 3.1 Definitive Scenario Calculation (Monte-Carlo Simulation)

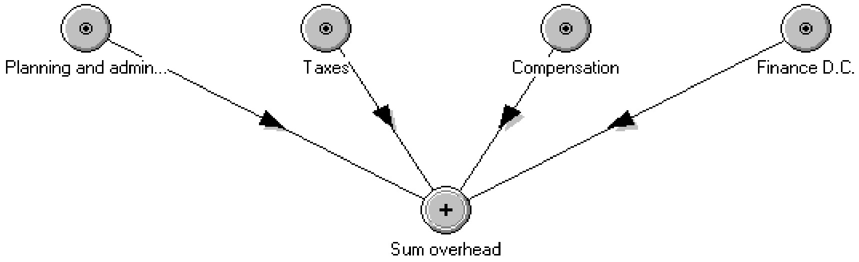
MAIN STRUCTURE



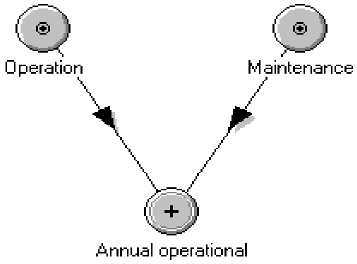
App. 3.2 Definitive Scenario Calculation (Monte-Carlo Simulation)

SUB STRUCTURE

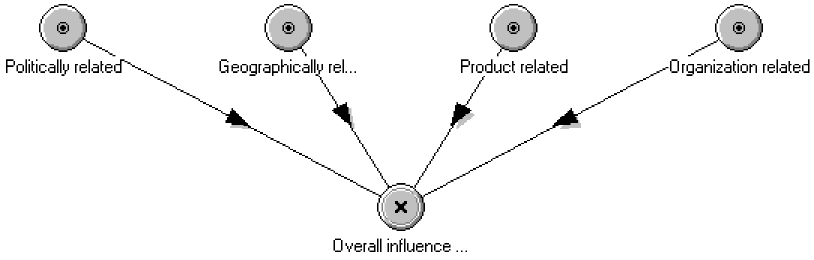
Overhead cost

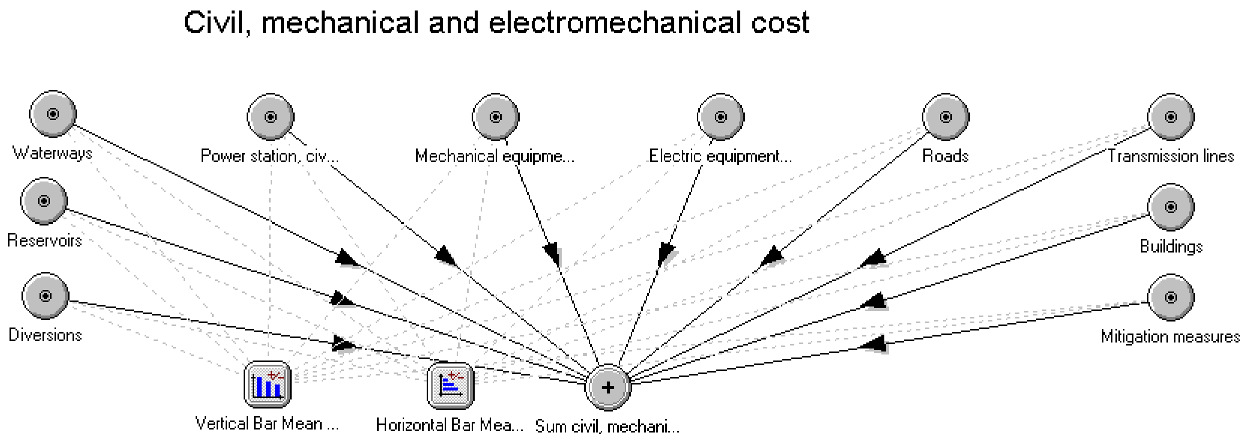


Operational cost



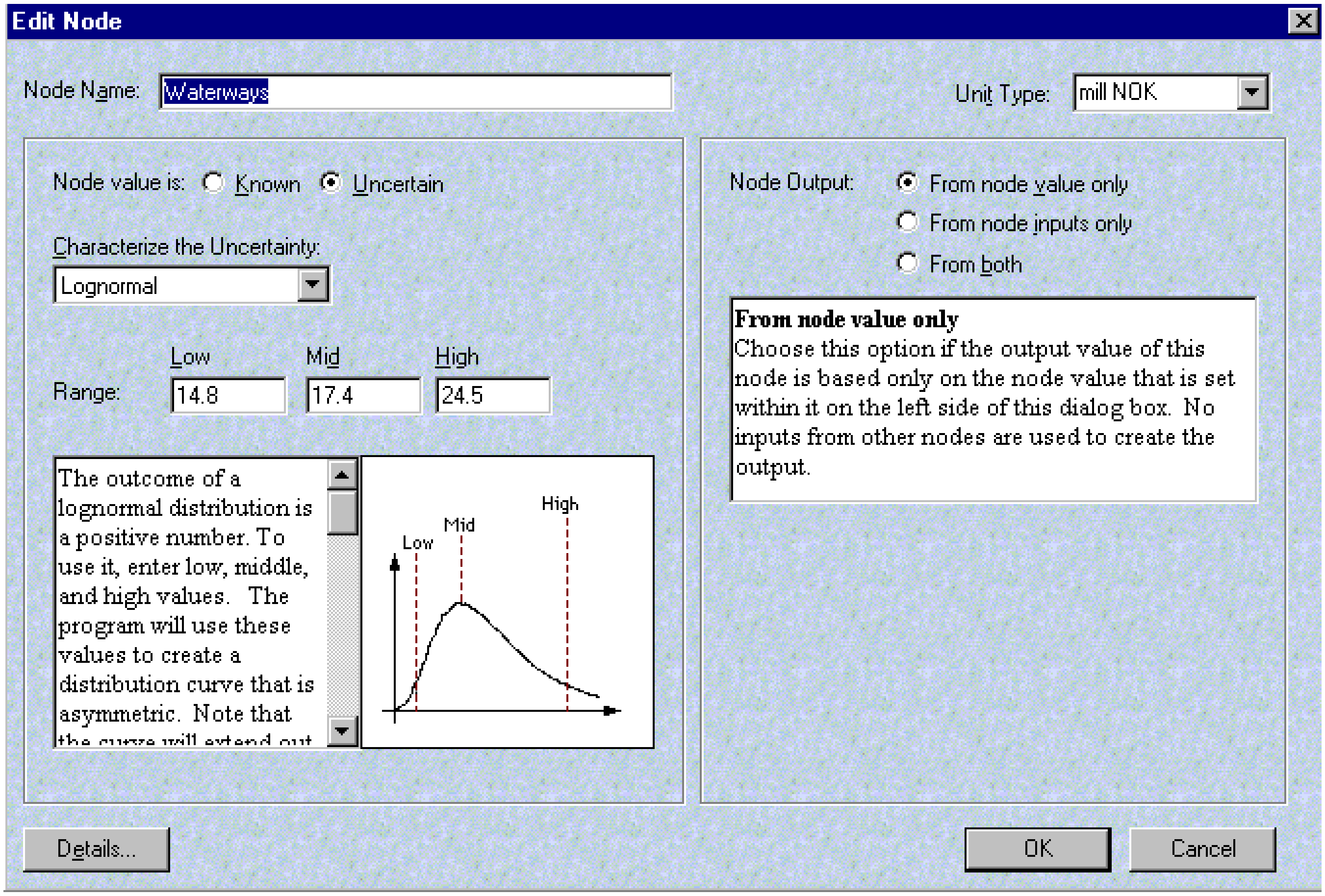
Overall influence factors




Civil, mechanical and electromechanical cost
Waterways
Power station, civ...
Mechanical equipme...
Electric equipment...
Roads
Transmission lines
Reservoirs
Buildings
Diversions
Mitigation measures
Vertical Bar Mean ...
Horizontal Bar Mea...
Sum civil, mechani...

App. 3.3 Definitive Scenario Calculation (Monte-Carlo Simulation)

EXAMPLE NODE INPUT



Node Name: Waterways

Unit Type: mill NOK

Node value is: ○ Known ● Uncertain

Characterize the Uncertainty: Lognormal

Range: Low 14.8 Mid 17.4 High 24.5

The outcome of a lognormal distribution is a positive number. To use it, enter low, middle, and high values. The program will use these values to create a distribution curve that is asymmetric. Note that the curve will extend out

Node Output: ● From node value only ○ From node inputs only ○ From both

From node value only
Choose this option if the output value of this node is based only on the node value that is set within it on the left side of this dialog box. No inputs from other nodes are used to create the output.

App. 3.4 Definitive Scenario Calculation (Monte-Carlo Simulation)

SUMMARY OF INPUT

Name	Unit	Distribution	Node value
Reservoirs	mill NOK	LOGNORMAL(0.18; 0.20; 0.50)	
Diversions	mill NOK	LOGNORMAL(0.20; 0.30; 0.50)	
Waterways	mill NOK	LOGNORMAL(14.80; 17.40; 24.50)	
Power station, civil works	mill NOK	LOGNORMAL(3.50; 4.00; 5.50)	
Mech. equipM. in power station	mill NOK	LOGNORMAL(12.00; 13.00; 14.50)	
Roads	mill NOK	LOGNORMAL(4.00; 4.50; 6.50)	
Transmission lines	mill NOK	LOGNORMAL(3.00; 3.50; 4.50)	
Buildings	mill NOK	NORMAL(0.50; 1.00; 1.50)	
Mitigation measures	mill NOK	LOGNORMAL(0.40; 0.50; 1.00)	
Sum civ, mech. and electr	mill NOK		1.00
Electric equipm. in power station	mill NOK	LOGNORMAL(6.00; 6.90; 7.50)	
Planning and administration	mill NOK	LOGNORMAL(3.70; 4.50; 9.20)	
Taxes	mill NOK	LOGNORMAL(0.30; 0.50; 0.80)	
Compensation	mill NOK	LOGNORMAL(0.50; 1.00; 3.00)	
Finance D.C.	mill NOK	LOGNORMAL(2.50; 3.20; 4.60)	
Sum overhead	mill NOK		1.00
Maintenance	mill NOK	LOGNORMAL(0.01; 0.02; 0.04)	
Operation	mill NOK	LOGNORMAL(0.28; 0.37; 0.41)	
Annual operational	mill.NOK		1.00
Politically related		LOGNORMAL(0.96; 1.00; 1.10)	
Geographically related		LOGNORMAL(0.98; 1.00; 1.03)	
Product related		LOGNORMAL(0.97; 1.00; 1.05)	
Organization related		LOGNORMAL(0.97; 1.00; 1.06)	
Overall influence factor			1.00
Power price	NOK/kWh	LOGNORMAL(0.18; 0.20; 0.27)	
Annual power production	GWh	NORMAL(35.00; 39.20; 43.00)	
Other income		LOGNORMAL(0.05; 0.07; 0.10)	
Annual income	mill NOK		1.00
Annual production value	mill NOK		1.00
Sum civ., mech. and electrmill NOK		1.00	
Sum overhead	mill NOK		1.00
Annual operational	mill.NOK		1.00
Overall influence factor			1.00
Annual income	mill NOK		1.00
Sum	mill NOK		1.00
Total investment cost	mill NOK		1.00
Discount factor		LOGNORMAL(12.00; 13.33; 15.00)	
Present value of operational cost	mill NOK		1.00
Total project cost	mill NOK		1.00
Total project income	mill NOK		1.00
Project profit	mill NOK		1.00

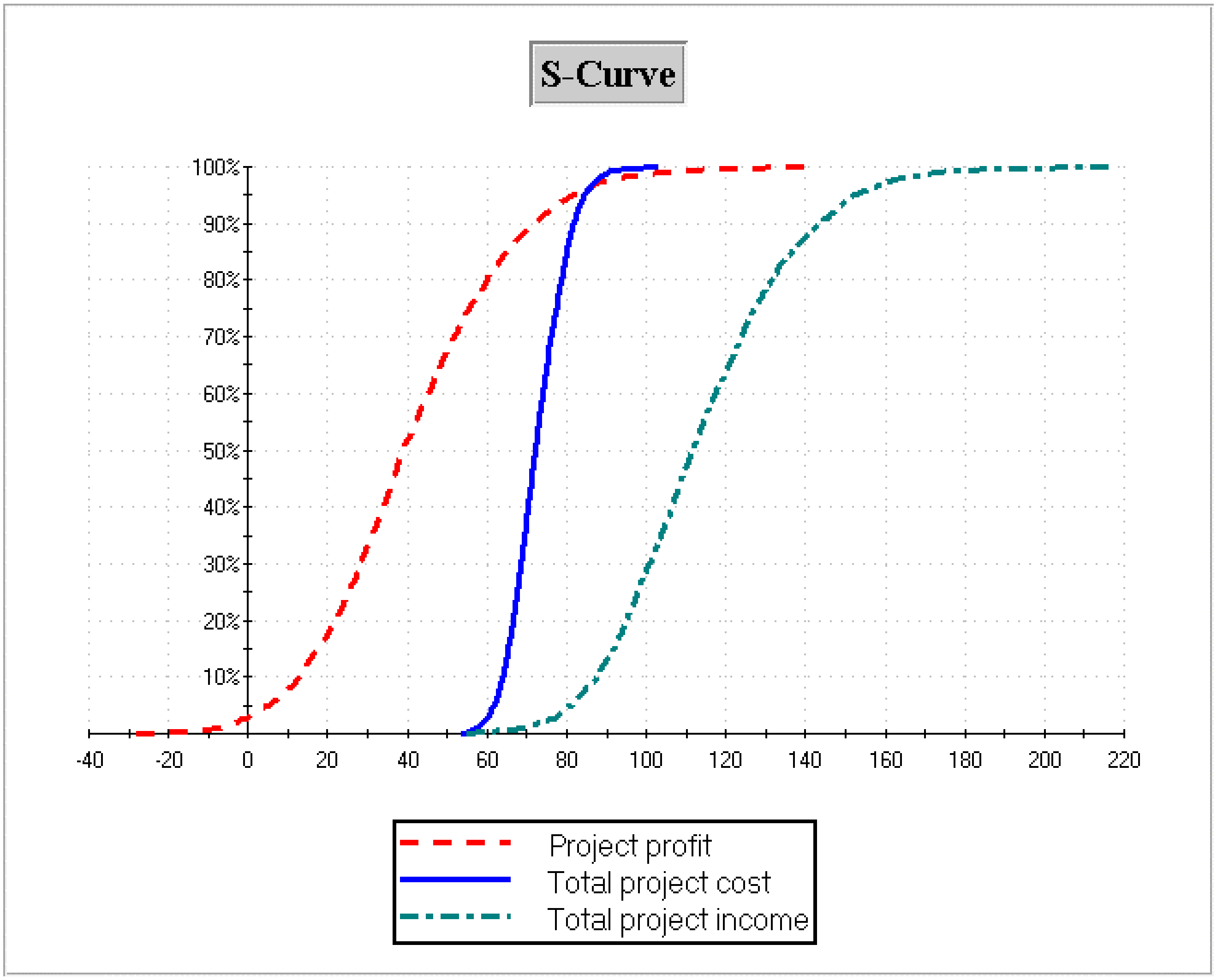
App. 3.5 Definitive Scenario Calculation (Monte-Carlo Simulation)

RESULTS: BASIC STATISTICS

Name	Unit	Mean	Std. Dev.	Min.	Max.
Project profit	mill NOK	**41.15**	**23.38**	-28.01	142.76
Total project income	mill NOK	**113.79**	**22.17**	54.88	217.75
Total project cost	mill NOK	**72.64**	**7.06**	53.57	103.32
Present value of operational cost	mill NOK	5.07	0.88	2.76	9.81
Discount factor		13.40	1.16	10.07	17.83
Total investment cost	mill NOK	67.57	7.04	47.51	97.79
Sum	mill NOK	65.13	4.74	53.01	86.06
Annual income	mill NOK	8.49	1.49	4.32	14.94
Annual production value	mill NOK	8.42	1.49	4.22	14.87
Other income		0.07	0.02	0.03	0.20
Annual power production	GWh	39.08	3.11	28.30	49.78
Power price	NOK/kWh	0.22	0.03	0.12	0.37
Overall influence factor		1.04	0.08	0.82	1.39
Organization related		1.01	0.03	0.90	1.14
Product related		1.01	0.03	0.91	1.11
Geographically related		1.00	0.02	0.94	1.07
Politically related		1.02	0.05	0.85	1.22
Annual operational	mill.NOK	0.38	0.06	0.23	0.66
Operation	mIll NOK	0.35	0.06	0.21	0.63
Maintenance	mill NOK	0.02	0.01	0.01	0.09
Sum overhead	mill NOK	11.12	2.53	5.54	27.48
Finance D.C.	mill NOK	3.44	0.84	1.49	7.00
Compensation	mill NOK	1.47	1.14	0.08	9.98
Taxes	mill NOK	0.53	0.22	0.14	2.40
Planning and administration	mill NOK	5.69	2.08	1.59	21.20
Sum civil, mechanical and electrical	mill NOK	54.01	4.02	42.16	73.30
Electric equipment in power station	mill NOK	6.81	0.59	4.99	8.75
Mitigation measures	mill NOK	0.63	0.23	0.17	2.06
Buildings	mill NOK	1.01	0.39	-0.32	2.33
Transmission lines	mill NOK	3.66	0.59	2.22	6.32
Roads	mill NOK	4.96	0.94	2.38	10.62
Mechanical equipment in power station	mill NOK	13.15	0.96	10.45	16.74
Power station, civil works	mill NOK	4.32	0.76	2.39	8.13
Waterways	mill NOK	18.85	3.59	8.14	37.59
Diversions	mill NOK	0.33	0.12	0.08	1.36
Reservoirs	mill NOK	0.28	0.12	0.07	1.06

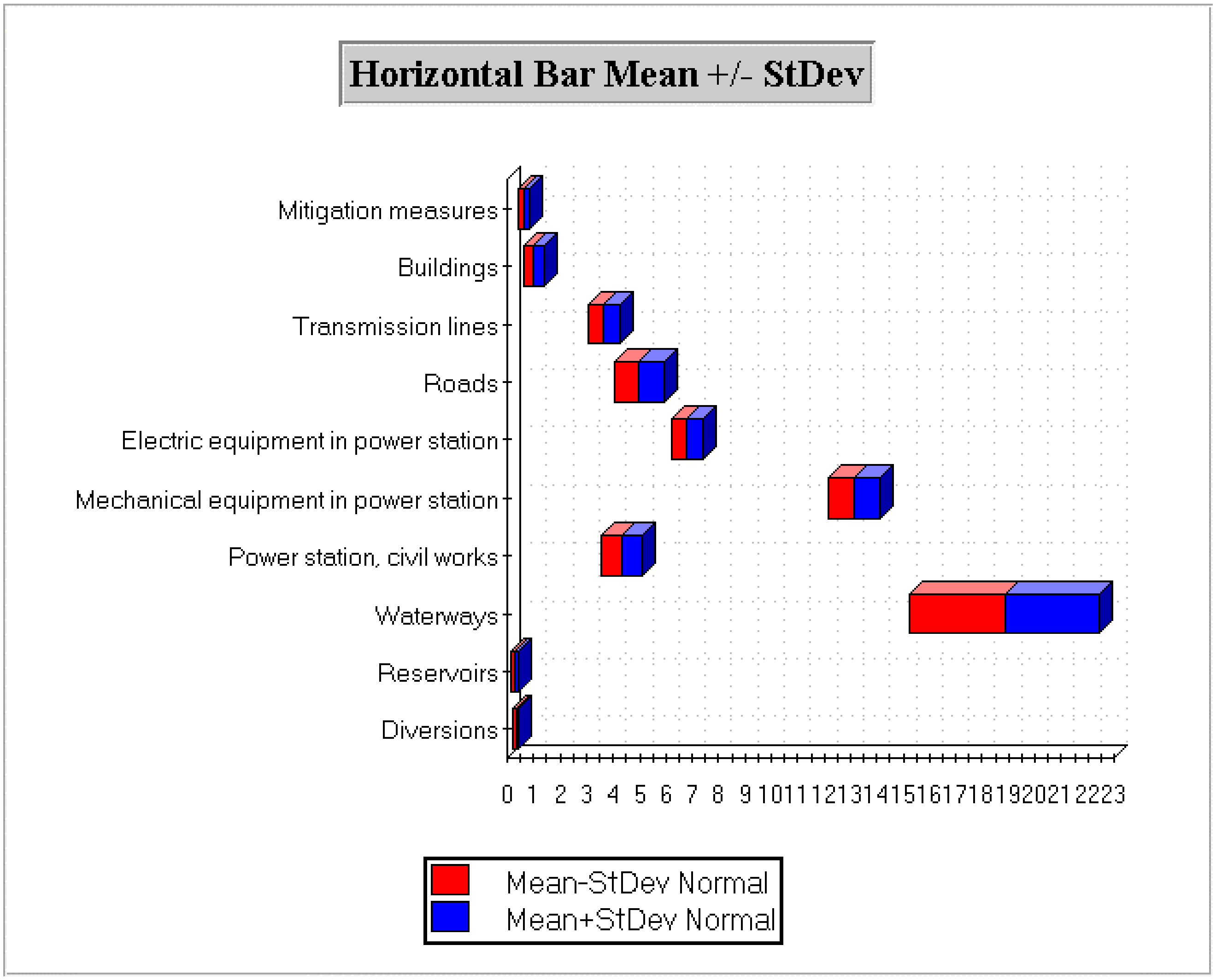
App. 3.6 Definitive Scenario Calculation (Monte-Carlo Simulation)

S-CURVE PROFIT / TOTAL COST / INVESTMENT



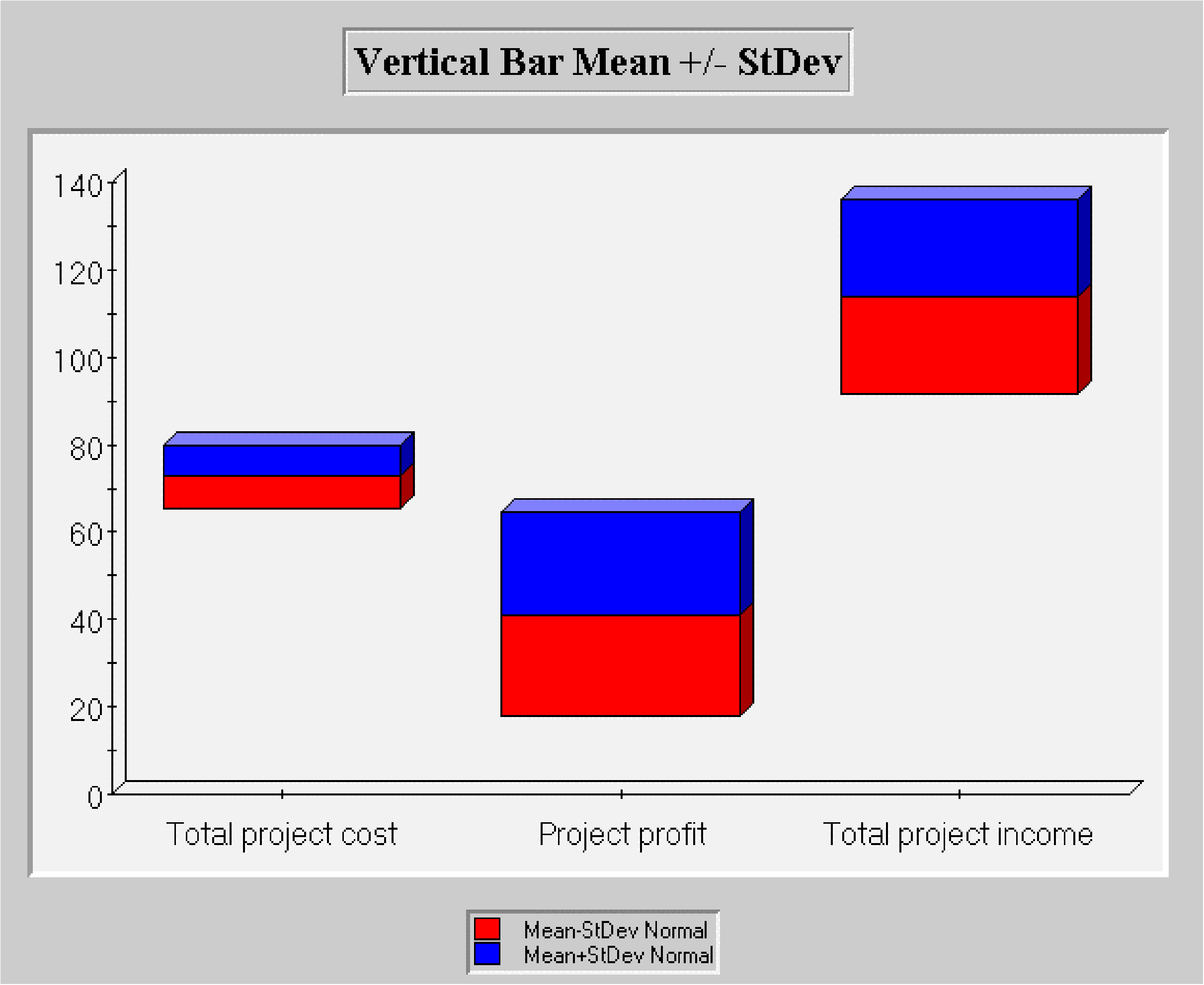
App.3.7 Definitive Scenario Calculation (Monte-Carlo Simulation)

COST UNCERTAINTY



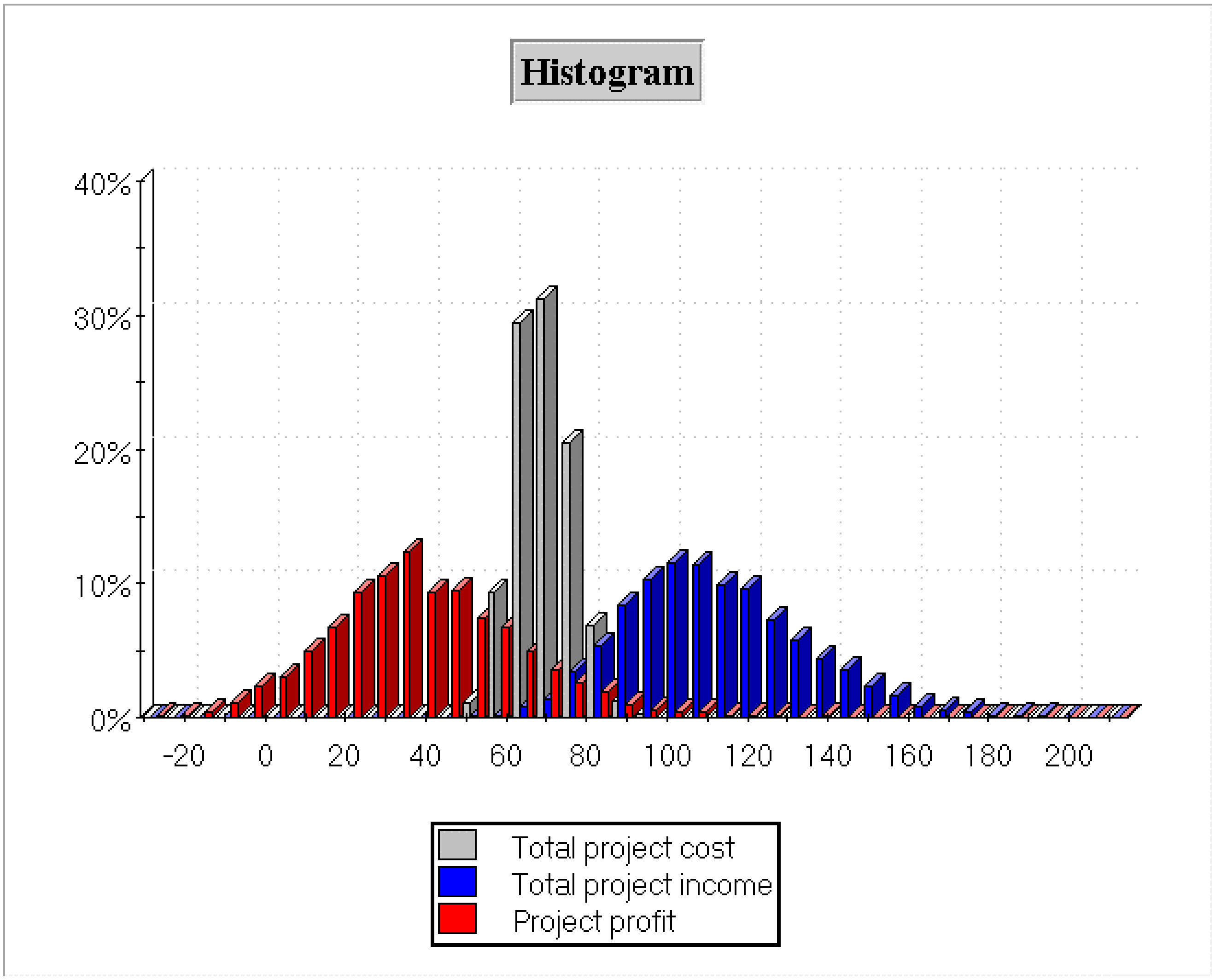
App. 3.8 Definitive Scenario Calculation (Monte-Carlo Simulation)

COST / PROFIT UNCERTAINTY



App. 3.9 Definitive Scenario Calculation (Monte-Carlo Simulation)

HISTOGRAM COST / INCOME / PROFIT



List of references

Lichtenberg, S. (1978) Projektplanlægning – i en forandelig verden (Project planning in a changing world), Polyteknisk Forlag, Denmark

EXECUTIVE COMMITTEE:

CHAIRMAN
Mr. Ulf Riise
Norwegian Electricity
Federation Association of
Producers
P.O. Box 274
1324 Lysaker, NORWAY

INTERNATIONAL ENERGY AGENCY
Mr. Hanns-Joachim Neef
International Energy Agency
9, rue de la Fédération
75739 Paris, FRANCE

SECRETARY
Mr. Frans H. Koch
5450 Canotek Rd, Unit 53
Ottawa,
CANADA K1J 9G3
Tel: (1) 613 745-7553
Fax: (1) 613-747-0543
E-mail: fkoch@gvsc.on.ca

CANADA
Mr. Jacob Roiz
Canadian Electricity Assoc'n
1155 Metcalfe Street
Sun Life Bldg, Suite 1600
Montréal, H3B 2V6
CANADA

(alternate)
Mr. Tony Tung
Natural Resources Canada
580 Booth Street
Ottawa, Ont. K1A 0E4
CANADA

CHINA
Mr. Tong Jiandong
Hangzhou International Center
on Small Hydro Power
P.O. Box 607
4 Baisha Road
Hangzhou 310006
P.R. CHINA

FINLAND
Mr. Antti Aula
Kemijoki Oy
Valtakatu 9-11
P.O. Box 8131
FIN-96101 Rovaniemi
FINLAND

FRANCE
Mr. Gérard Casanova
Electricité de France
77, Chemin des Courses
31057 Toulouse, FRANCE

JAPAN
Mr. Shoichi Murakami
New Energy Foundation
Shuwa Kioicho Park Building 3-
6, kioicho, Chiyoda-ku, Tokyo
102
JAPAN

(alternate:)
Mr. Shinichi Sensyu
CRIEPI - Central Research
Institute of Electric Power
Industry
6-1 Ohtemachi 1-chome,
Chiyoda-ku, Tokyo 100
JAPAN

NORWAY
Mr. Alf V. Adeler
NVE - Norwegian Water
Resources and Energy
Directorate
P.O. Box 5091, Majorstua
N-0301 Oslo, NORWAY

SPAIN
Mr. Angel Luis Vivar
UNESA
Francisco Gervas 3
28020 Madrid, SPAIN

(alternate:)
Mr. Juan Sabater
ENDESA
Príncipe de Vergara 187
28002 Madrid, SPAIN

SWEDEN
Mr. Lars Hammar
Elforsk AB
101 53 Stockholm
SWEDEN

(alternate:)
Ms. Maria Malmkvist
Swedish National Energy
Administration
P.O. Box 310
SE-631 04 Eskilstuna
SWEDEN

UNITED KINGDOM
Mr. J. W. Craig
Energy Technology Support
Unit (ETSU)
Harwell, Didcot
Oxfordshire OX11 0RA
UNITED KINGDOM

(alternate:)
Mr. Eric M. Wilson
Wilson Energy Assoc. Ltd.
Sovereign House, Bramhall
Centre
Bramhall, Stockport, Cheshire
SK7 1AW
UNITED KINGDOM

OPERATING AGENTS:

ANNEX 1
Mr. Jean-Paul Rigg
Hydro Québec
3320, F.X. Tessier
Vaudreuil-Dorion, (Québec)
CANADA J7V 5V5
E-mail: Rigg.jean-paul@hydro.qc.ca

ANNEX 2
Mr. Tony Tung
Natural Resources Canada
580 Booth Street
Ottawa, Ont. K1A 0E4
CANADA
E-mail: tung@NRCan.gc.ca

ANNEX 3
Mr. Sverre Husebye
NVE - Norwegian Water Resources and Energy Directorate
P.O. Box 5091, Majorstua
N-0301 Oslo, NORWAY
E-mail: shu@nve.no

ANNEX 5
Mr. Tore S. Jørgensen
International Centre for Hydropower (ICH)
Klæbuveien 153
N-7465 Trondheim
NORWAY
E-mail: Tore.S.Jorgensen@ ich.ntnu.no