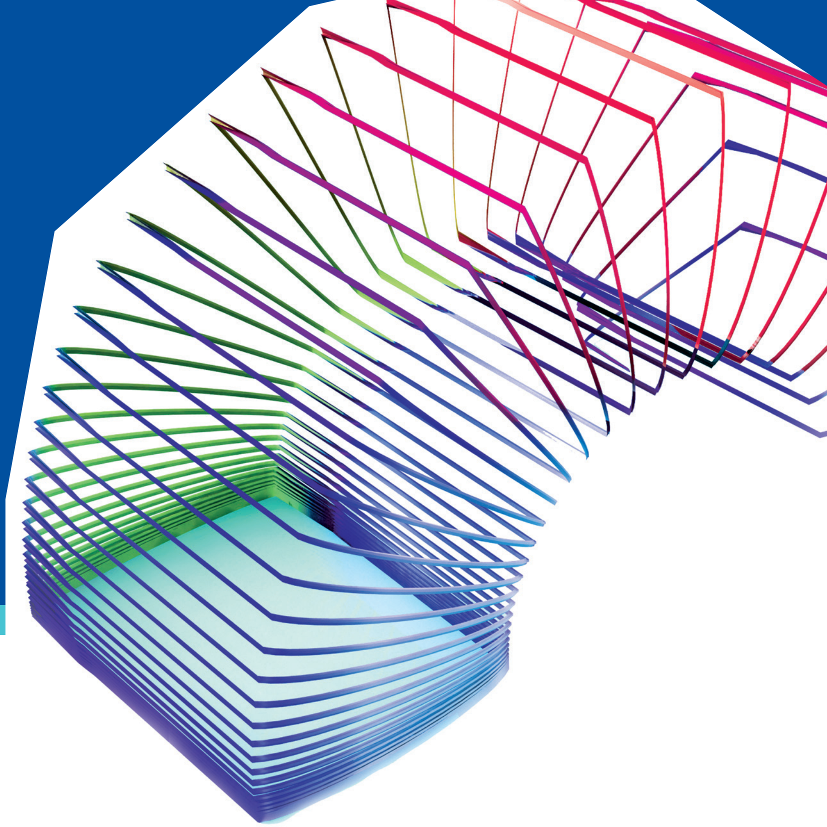

Olav Torp, Frode Drevland and Kjell Austeng

Process for cost estimation under uncertainty

CONCEPT THEME PAMPHLET **NO. 6**

About the authors:
The authors of this booklet have, over many years, held teaching and research positions at NTNU's Department of Civil and Environmental Engineering. During this time they have developed methods and tools for uncertainty analysis and management in investment projects, and have led and taken part in numerous uncertainty analyses. The booklet distils their accumulated knowledge and experience, with an emphasis on presenting the process for cost estimation under uncertainty in a simple and practical manner. This booklet is part of the Concept Theme Pamphlet series (No. 6).

Olav Torp, Frode Drevland and Kjell Austeng†
Process for Cost Estimation under Uncertainty

† Deceased. Contributed to the original Norwegian edition (2015).

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Address
Concept Research Programme
Department of Civil and Environmental Engineering
NTNU
7491 Trondheim
Norway

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1 Introduction

A project is a one-off endeavour with a defined goal and scope, executed within time and cost constraints. It may range from public investments in the billions to refurbishing a bathroom at home. A central part of project planning is calculating the project cost. A forecast of the project's total costs is called a cost estimate. Being a forecast implies it is an approximate calculation and that there is uncertainty associated with the cost estimate.

A widely used definition of uncertainty is the lack of knowledge. Uncertainty related to a project's costs can therefore be said to be characterised by a lack of knowledge, both about scope and about what individual activities may end up costing. The uncertainty may affect the project's costs both positively and negatively. The positive outcomes of uncertainty are called opportunities, and the negative are called risks.

When knowledge is lacking, it is not possible during project planning to estimate precisely how much a project will cost when completed. Cost estimation under uncertainty recognises that the project is uncertain. The fundamental principles for performing this type of cost estimation are described in Concept Theme Pamphlet no. 4 *Cost Estimation under Uncertainty*. This booklet is a follow-up to no. 4 and addresses how, in practice, one can proceed to prepare such estimates.

The aim of this booklet is to present, in a straightforward way, a process for cost estimation under uncertainty. The target group is everyone responsible for a project who needs to prepare project cost estimates. The process presented here is well-suited to both small and large projects, but the amount of work will naturally vary. An investment worth billions requires a far more extensive process than a bathroom refurbishment. Uncertainty analysis will be relevant at all stages of a project. In the early phase, estimates are typically at a very high level, whereas after the project has been fully designed, there is typically a completed *base estimate* that the uncertainty analysis uses as its starting point. There are several different approaches to carrying out the process. In this booklet, we describe a process which, based on our experience, we consider to be good practice in the field.

The booklet's structure broadly follows the sequence of a process for cost estimation under uncertainty. First, some overarching topics are presented in chapter 2. Chapters 3, 4 and 5 follow the main steps in an estimation process. Chapter 6 provides some practical guidelines on selected topics. Chapter 7 presents and discusses the results from the process.

Terminology note

In English-language practice, the term *risk analysis* is often used as an umbrella term for probability-based analyses of project cost outcomes; this is also the term used in official English translations of the Norwegian State Project Model (e.g. Circular R–108/25). In the Norwegian context, the corresponding concept is commonly referred to as *uncertainty analysis* (*usikkerhetsanalyse*), which is also the terminology used in the original Norwegian version of this booklet. For consistency with the source text, this translation therefore uses *uncertainty* and *uncertainty analysis* throughout.

2 Overview of the process

This chapter presents an overall process model for cost estimation under uncertainty and discusses key considerations before delving into the process in more detail. The focus is on describing a general model, independent of when in the project the cost estimate is performed or the purpose of the estimate. Overall, the process is divided into three phases: preparation, the estimation session, and follow-up.

The process presented in this booklet applies to projects of some size. For smaller projects, the process will follow the same main steps and the same basic principles, but it can be considerably simplified compared with what is described here.

2.1 Main purpose of the process

The primary purpose of a process for cost estimation under uncertainty is to develop the most comprehensive possible picture of costs and the uncertainty associated with a project's costs. A good cost estimate is characterised by the fact that all relevant conditions have been assessed and that the possible effects of these conditions are quantified and, to the best of one's judgement, included in the estimate.

This means that factors such as shortcomings in the planning basis, politically motivated requirements, environmental issues, and similar considerations are accounted for, and that the costs associated with potential plan changes are included in the estimate. The same applies to such topics as project overconfidence, market fluctuations, and organisational factors.

Uncertainty exists in the project regardless of how we conduct the estimation process, which methods we use, or which assumptions we base our cost estimates on. It is essential to recognise that uncertainty cannot simply be assumed away.

2.2 Fixed assumptions in a cost estimate

A cost estimate is based on a set of assumptions, particularly concerning the project's scope (what it comprises), how it will be executed (method), and the price level used. A distinction is made between *fixed assumptions* and *estimate assumptions*.

Fixed assumptions should be limited to a few central assumptions on which the entire estimate is based. If these assumptions change, the situation changes, and the estimate is no longer valid. These are often the project's boundary conditions and are not intended to change over time. Estimate assumptions are those necessary to estimate the cost of cost items, even when uncertainty remains. However, this uncertainty cannot be ignored; it must therefore be incorporated into the estimate.

Sometimes, estimates contain many fixed assumptions – a mix of vague promises and assumptions, some even based on wishful thinking. When such assumptions are examined, many are found to be uncertain. If, during the estimation process, there is doubt whether an assumption will hold throughout the project, and no one has credibly committed to covering any cost consequences should it change, the assumption must be treated as an estimate assumption, and its uncertainty must be included in the estimate.

The problem of unrealistic assumptions is evident in real projects. Unrealistic assumptions that are later revised during project execution typically lead to significant increases in cost estimates during the planning and construction phases, as it becomes clear that the assumptions do not hold. The reason such assumptions are introduced is not necessarily poor estimating methods or processes, but often the way estimation assignments are more or less formally formulated.

Many project cost estimates, even in the earliest phases, are based on estimating the cost of the project as currently planned. In our view, the assignment should be to develop the most comprehensive estimate and uncertainty picture possible of the project's ultimate cost, regardless of what has been planned so far. This latter approach recognises that the project's assumptions evolve over time, and that any changes driven by evolving needs, requirements, expectations, and tolerances will lead to scope changes and a final result that differs from what is currently planned.

2.3 Estimate structure

When estimating the cost of a project, one needs a cost breakdown – an *estimate structure*. The structure can be established in many ways. Two main principles are used: bottom-up and top-down.

The process described in this booklet follows the principles in *Concept Theme Pamphlet no. 4 – Cost Estimation under Uncertainty*. Such an estimate is developed using a top-down approach and consists of a number of cost items and a set of uncertainty factors.

- **Cost items** – The project is broken down into a set of individual elements to which costs can be attributed, often in a hierarchical structure. Cost items are to be estimated.
- **Uncertainty factors** – Groups of uncertainty drivers (sources of uncertainty) that must be considered in the estimate.

When referring to an estimate component that is either a cost item or an uncertainty factor, we use the term *element*.

Figure 1 shows how such an estimate is built up in principle. In a real estimate, there will typically be between 30 and 100 cost items and 10 to 20 uncertainty factors. Guidelines for how an estimate structure should be built in practice are provided in chapter 6.

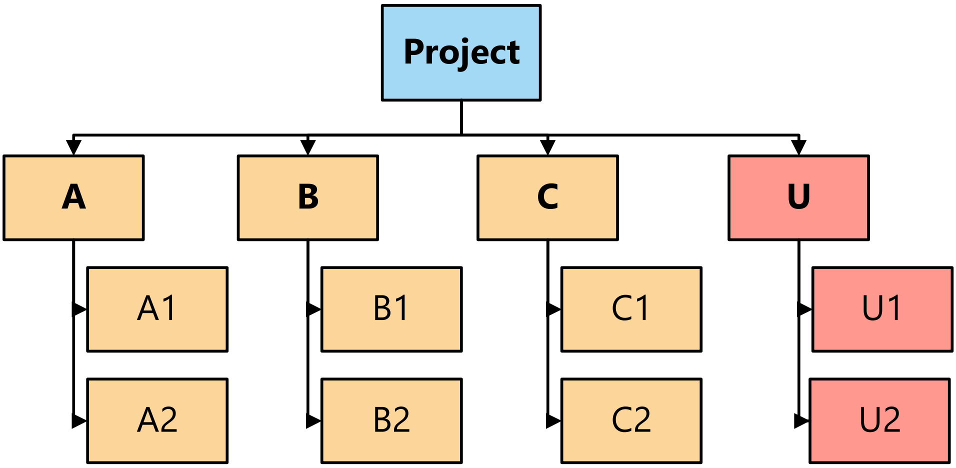

Figure 1: Estimate structure

2.4 Process flow

Projects are often complex and involve multifaceted challenges. A process for cost estimation under uncertainty requires broad technical knowledge and experience. It is therefore common to conduct this type of process as a group exercise, involving participants with diverse expertise and backgrounds. Collectively, the group's competence and experience must cover the challenges that the project encompasses.

A group process provides broader knowledge and experience, helps balance preconceptions, increases creativity, and fosters constructive disagreement to ensure that all relevant factors are considered. The estimation itself relies on subjective assessments based on the professional knowledge, experience, intuition, and best judgment of competent individuals, often combined with cost databases or other sources of empirical data where available.

A traditional process for cost estimation under uncertainty consists of a preparation phase, an execution phase, and a follow-up phase, as shown in figure 2.

Figure 2: Overall process for cost estimation under uncertainty

- **Preparations** include both practical and technical preparations related to the process. A start-up meeting between the main roles, such as the project manager and process leader, is a natural part of this phase.
- **The estimation process** is often carried out through one or more group sessions where costs and uncertainties are identified and quantified.
- **Follow-up** includes all activities after the group sessions, including completion of the report and quality assurance of its content.

The total duration of such a process varies by project and phase. Duration depends, among other things, on project size, complexity, and how the process is organised and conducted. In large projects, the process may take several months, whereas in smaller projects it can be completed within one or two weeks.

Experience shows that ample time should be allocated for preparation and for the group sessions themselves. If insufficient time is set aside, important aspects may not be adequately identified or discussed. For projects large enough to fall under the Norwegian Ministry of Finance's quality assurance (QA) scheme, at least three days should be allocated. For the largest projects, it may be necessary to have the group assembled for up to a week, either continuously or in several sessions. In a small project, the session may take half a day; if several small projects are considered simultaneously, one group can review several projects in a single day. Each phase is described in detail in the following chapters.

2.5 Roles

In the estimation process, four key roles must be filled:

- **Owner of the estimation process** – The person commissioning the cost and uncertainty analysis and ultimately owning the results. This is typically the project manager or project owner.
- **Process leader** – Responsible for executing the analysis process and for the report containing the results.
- **Secretary/data support** – Responsible for documentation during the process and for assisting the process leader before, during, and after execution.

- **Resource group** – Participants in the process who contribute their experience and expertise to identify uncertainties and estimate costs and uncertainties.

Further details on the tasks and functions of each role across the different phases are provided in the subsequent chapters.

3 Preparations

Thorough preparation is essential for a successful process. The groundwork laid during this phase largely determines the quality of the final outcome. A central part of the preparation involves assigning the key roles of process leader, data support, and resource group. The technical preparations typically include background materials and a planning note to be sent to participants. This note compiles key project information to help participants familiarise themselves with the project and prepare for the estimation session.

The process must also be prepared in practical terms with regard to duration, schedule, and suitable facilities. Experience shows that it pays to start preparations early rather than postponing the work until just before the group meets.

In our view, the preparation phase is the most underestimated of all process phases, and therefore also the one with the most significant potential for improvement.

We have observed that the preparation phase often starts too late. Naturally, everyone who needs a cost estimate wants the best process leader and data support – and, above all, the most competent participants in the resource group. These are busy people and will not be available on short notice. It is therefore vital to start recruiting resources early, ideally two to three months before the estimation session.

In addition to the difficulty of recruiting the right people under time pressure, selected participants may not have sufficient time to prepare appropriately. This can lead to poor-quality background material, a lack of shared expectations, and inadequate working conditions for the analysis group.

3.1 Group composition

3.1.1 Selecting the process leader and data support

The process leader must be engaged as early as possible. The project owner or project manager is responsible for finding the process leader. Except in the very smallest projects, the process leader should be external. They may be employed in the same organisation, but it should be avoided to use someone directly involved in the project's day-to-day work. This prevents the estimate from being influenced, consciously or unconsciously, by the process leader.

It is also advantageous to appoint the data support as early as possible. Unlike the process leader, it is less problematic if this person is part of the project. What is essential, however, is that the process leader and data support work well together and communicate effectively throughout, particularly regarding division of responsibilities.

3.1.2 Selecting the resource group

The project manager, supported by the process leader, is responsible for recruiting participants to the resource group. The resource group is the most critical factor in a reliable estimate and should be broadly composed with respect to background, experience, expertise, and personal qualities. The size and composition of the group will depend on the project, but it should include participants both from within and outside the project organisation.

The required resource group size depends on the project's scale and complexity. A large, complex project naturally requires broader expertise than a smaller, simpler one. For practical reasons, the group should not be too large. Ideally, the group should consist of five to ten participants – a mix of internal and external resources. A roughly equal distribution between internal and external members is desirable. Individuals who wish to attend merely to stay informed about the project should be referred to another forum.

Two aspects are fundamental in composing the group. First, the resource group as a whole must possess sufficient knowledge and experience across the areas covered by the project. Second, the group should reflect a balance of personal traits and attitudes – ideally with variation in age, gender, and background, and a balance between optimism and pessimism.

The phenomenon of project overconfidence frequently appears in analyses involving members of the project organisation. Nobel laureate Daniel Kahneman refers to this as the "planning fallacy" – the tendency of people and organisations to underestimate time, cost, and risk for future undertakings while overestimating the benefits, even when they have experience of overruns in similar projects. In other words, it is wishful thinking: people believe tasks will be easy and quick because they want them to be. There is always a need for a "devil's advocate" to prevent the group's tone from becoming overly optimistic. This is typically one of the external participants.

The participants' motivation strongly influences the quality of the results from the group process. When recruiting, it is generally better that members participate because they *want* to than because they *have* to.

3.2 Technical preparations

3.2.1 Establishing the estimate structure

Depending on the available data and the purpose of the analysis, the setup of the basic cost structure will vary by project. Before any cost and uncertainty analysis, the project manager, in collaboration with the process leader, must propose an estimate structure that will serve as the basis for the analysis. The proposal is presented to the resource group, and the final adjustment is made early in the group process. Practical guidelines for the estimate structure are described in chapter 6.

3.2.2 Preparing the planning note

As part of the preparations, a planning note should be prepared. This document describes the project, the estimation process framework, and how it is intended to be carried out. The planning note should be distributed to all participants well in advance.

The planning note should include:

- Description of the project, including drawings
- Objectives of the estimation process
- The resource group – list of participants
- Assumptions for the analysis
- Proposed estimate structure
- Main quantities in the project
- Agenda for the session(s)

3.2.3 Selecting material for participants

In addition to the planning note, selected material must be sent to participants. It is crucial to resist the temptation to send everything available. The material is usually so extensive that it is unrealistic to expect participants to study it in full, leading to superficial preparation. Ideally, the project or process leader should send each participant a carefully curated selection of information. Although this requires more upfront work, it is often the key to having well-prepared participants.

3.2.4 Report template

The process leader, together with the data support, should prepare a report template. This allows the data support to document directly into the report during the session(s), saving time later. As much information as possible should be entered into the report template beforehand. An example of a suggested table of contents is given in subsection Appendix C.

3.3 Practical preparations

In addition to the technical aspects, practical arrangements for the process must be made.

The most important task is to find suitable premises for the session(s). Participants are usually busy people taken out of their daily work, either inside or outside the project. It is therefore vital that they are shielded from ordinary distractions. The most common solution is to find facilities outside the regular workplace, preferably somewhere that offers accommodation. If the analysis is well prepared and all necessary information is available, this is a good option. The drawback of holding sessions away from the office is that access to project material or project personnel may be limited if new questions arise.

3.4 Participant preparations

When inviting participants to the resource group, it is essential that each individual is clearly informed about why they have been invited and what is expected of their participation. This enables them to prepare appropriately for their role in the analysis.

Participants should review the planning note and any other materials provided. In addition, they should seek relevant cost data and experiences – for example, from databases, plans, reports, or colleagues with valuable insights. They should also familiarise themselves with the working method and meeting rules.

Some contact between the process or project leadership and participants is recommended during this phase. At a minimum, the project manager should call each participant to check on their preparations, ask whether anything is missing, and remind them of expectations. If feasible, a planning meeting can be a valuable contribution to better preparation.

4 Execution of the estimation process

The execution phase includes the activities carried out while the resource group is assembled. This does not necessarily mean that the process is continuous – both practical and process-related considerations may make it appropriate to conduct the analysis over several sessions.

The initial steps are qualitative and aim to identify and describe all project conditions that may influence goal achievement. The result of the qualitative phase is a structured overview of the project's cost items, along with the identified uncertainties. The process then proceeds to quantitative steps, where the effects are expressed in measurable terms, most often in time and/or money.

The execution takes place step by step and comprises the following:

- Start-up
- Identification of uncertainty factors
- Establishment of baseline assumptions for the uncertainty factors
- Quantification of the cost items
- Assessment and quantification of the uncertainty factors
- Assessment of covariation (correlation)
- Evaluation of the result
- Refinement of the analysis
- Obtain the resource group's advice for the way forward, including proposed measures

This description assumes that the estimate structure has already been established as part of the preparations.

4.1 Start-up

The group session usually begins with the project manager clarifying the analysis's purpose and objectives. The project manager, or another project representative, presents the project's goals, scope, existing plans, decisions, and specific requirements; investigations conducted (e.g., on ground conditions and geology) and their results; known stakeholders; and uncertainties already identified. Any fixed assumptions or boundary conditions on which the project is based are also presented.

To ensure that the estimate rests on the best possible foundation, certain activities that strictly belong to the preparation phase may nevertheless be carried out at the start of the session if this is more practical. Examples include reviews of ambition levels (for instance technical standard, environment, aesthetics, safety), SWOT analyses, maturity assessments, and stakeholder analyses. These preparatory activities are not discussed further here – it is up to the process leader to decide which exercises or tools to use.

To initiate reflection and discussion about uncertainty, the process leader may use a *situational map*. As the name implies, this provides an overview of the current status of central aspects of the project that may be associated with uncertainty. An example is shown in figure 3. The aspects can be adjusted, added, or removed as appropriate.

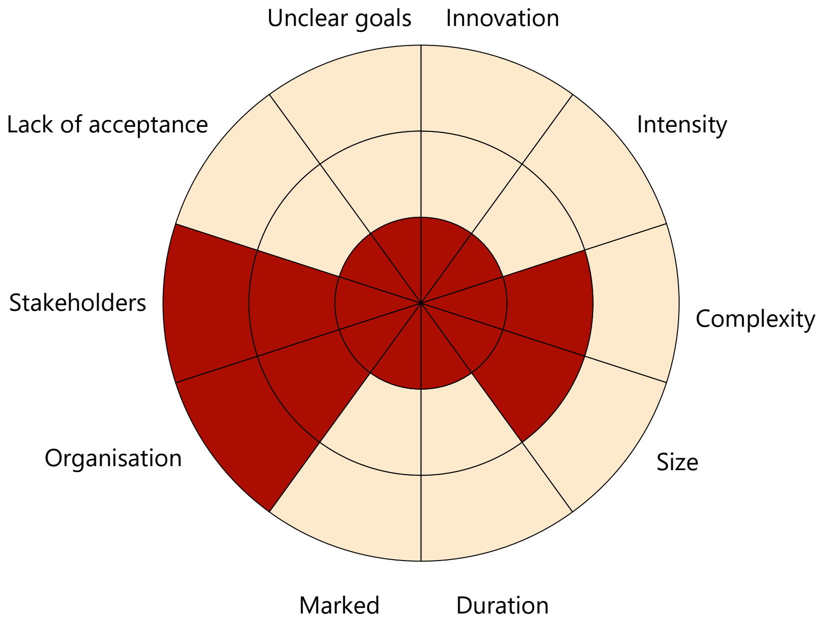

Figure 3: Situational map

The group spends a few minutes reflecting and consulting their intuition before assigning, after a short discussion, a score (for example 1–3) to each aspect. For duration, a long project – where the time span itself increases uncertainty – might be given a score of 3, whereas a short project would be given 1. A project with unclear objectives would be scored 3 on ”unclear objectives”. Other scales may be used if the group prefers. The score indicates how much each aspect may contribute to the project's overall uncertainty. In the example, the group's intuition is that the project organisation and stakeholders represent high uncertainty, while the objectives are firm and clear, and the need for innovation will not pose significant challenges.

In addition to providing a shared understanding among participants, the situational map also offers an overview of the group's intuitive perception of the project's uncertainty – a perspective that is useful to revisit when the results are later summarised and assessed.

4.2 Identification of uncertainty factors

Every project has several conditions that contribute to overall uncertainty and affect both implementation and costs. We call these underlying causes *uncertainty drivers*. There will typically be many such drivers, too many to model and handle directly in an estimate. In practice, therefore, they are grouped into a limited number of *uncertainty factors*.

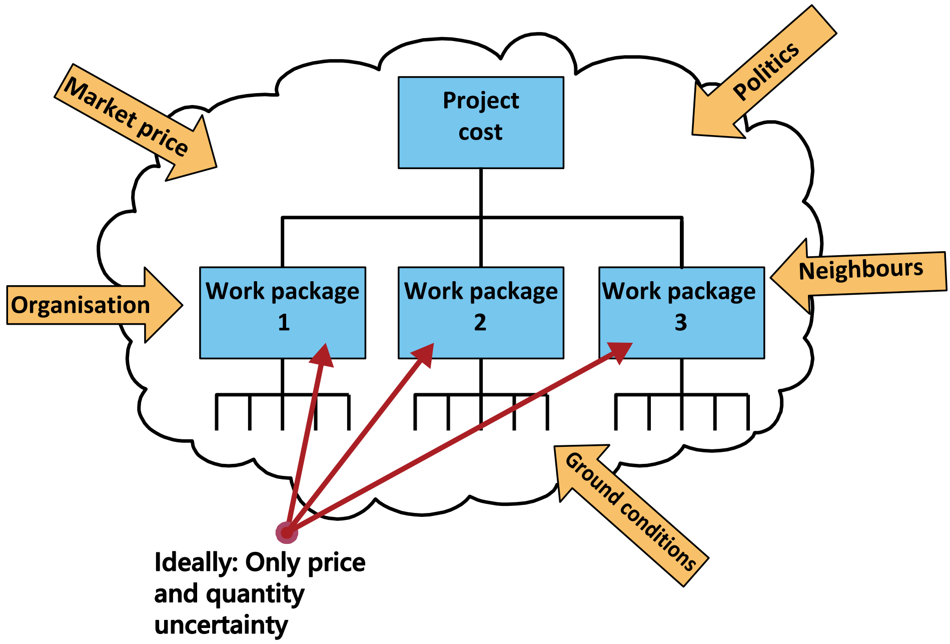

Figure 4: Uncertainty factors

The method described here is a group-based brainstorming process in which uncertainty drivers are first generated and then grouped into uncertainty factors.

4.2.1 Types of uncertainty

Uncertainty drivers have many origins. To ensure that everything is considered, it is important to be aware of the following main categories:

- **Internal (operational) uncertainty:** related to execution and to factors largely within the project's own control. This includes the project's and the organisation's delivery capability, technology, production plans, and the quality of planning and design.
- **External (contextual) uncertainty:** related to the environment surrounding the project and to factors that are wholly or mainly outside the project's control. Examples include the natural environment, market developments,

and the influence of external stakeholders.

- **Uncertainty linked to changes in objectives and decision criteria:** objectives, criteria, and their relative importance may change – particularly in long-term projects. Society's expectations of what is desirable or acceptable may also shift, resulting in a project that differs significantly from the current plan (for example, expansion from two to four lanes or more tunnelling). In the early phases, the choice of concept will typically dominate this category.
- **Analysis uncertainty:** linked to the analysis itself and to how the results are interpreted (not to be confused with concept uncertainty). This includes the resource group's understanding of the problem, the adequacy of the model, unrealistic fixed assumptions made to limit budgets, and general optimism or pessimism in assessments.

4.2.2 Conducting the brainstorming

The group should conduct a brainstorming session to identify the uncertain conditions that may affect the project. Brainstorming can be completely open, with ideas written down as they arise, or more structured – for example, each participant writes their ideas individually before sharing them in turn until no one has anything further to add.

Ample time should be set aside for this – the most important and creative thoughts do not always appear immediately. For a two-day session, allocate at least two to three hours.

Experience shows that the group's responses are influenced by how the questions are asked. To ensure that all relevant aspects are captured, it is advisable to vary the prompts. The following five rounds are often effective:

- Think of everything that may have consequences (particularly cost-related) for the project. This often results mainly in risk-related factors.
- Think of opportunities in the project. This perspective is less familiar, but ideas can spread through group synergy.
- Think of changes relative to today's plan. Such changes are often the largest contributors to cost increases, yet are frequently overlooked.
- Think of events – conditions that may or may not occur, with either high or low probability. This often brings new aspects to light.
- Consider what the worst that could happen (possible showstoppers) is. This helps uncover the "unthinkable" and identify potential "black swans".

A common aid is a matrix showing the *types* of uncertainty on one axis and *where* in the project they arise on the other. The brainstorming results can be entered into this matrix. Imbalances in the number of entries may indicate areas requiring special attention; see figure 5.

	Technical	Human	Economic
External	• Emission requirements • Technological solutions	• Political priorities • Environmental activism/campaigns • Media	• Sulfuric acid market • Sulphur taxes • Environmental taxes • Oil price • Electricity price • Biofuel price
Organisation	• Interaction with new technology	• Downsizing/lay-offs • Prioritisation of energy-efficiency measures • Investment appetite • Future strategy	• Future energy demand • Rationalisation gains
Project	• Scope/boundaries • Level of ambition • Adaptation/ integration of new and existing technology	• Project management • Resource availability • Competence	• Contract strategy • Lead times • Decommissioning costs • Estimation methods • Optimisation of fuel mix

Figure 5: Brainstorming matrix

4.2.3 Structuring into uncertainty factors

After the brainstorming, there may be anywhere from 50 to 150 uncertainty drivers. These must be organised into uncertainty factors. The group should sort, group, and, where appropriate, prioritise the identified drivers. For practical reasons, the number of uncertainty factors should be kept to a maximum of about 20, preferably between 10 and 12.

One method is to hold an open discussion in which the group agrees on a set of overarching headings or categories under which all drivers are grouped. A faster method is for each participant to select the 3–5 drivers they consider most important. The process leader and data support can then, during a break, consolidate these inputs and propose a set of uncertainty factors for subsequent group discussion and agreement.

It is crucial to ensure a clear distinction between the uncertainty factors – they must be mutually exclusive so that effects are not counted more than once.

4.3 Baseline assumptions for the uncertainty factors

Uncertainty represented by the uncertainty factors must not be included in cost items. It is therefore essential to establish *baseline assumptions* for the uncertainty factors before the cost items are quantified. This ensures that all participants assess the cost items on the same basis. Ideally, the uncertainty for an individual cost item should be limited to price and quantity. Whether the baseline assumptions for the uncertainty factors hold true will later be reflected in the subsequent assessment of the uncertainty factors.

Baseline assumptions should reflect as closely as possible the project reality that is envisaged. In some cases this may be difficult, and an assumption may have to be defined even if confidence in it is limited. When the uncertainty factor is later quantified, this will result in a wide spread, and the most likely effect for the factor may be either positive or negative.

Figure 6 shows a form used to describe and quantify uncertainty factors. The fields below "baseline assumption" are completed during the quantification of the factors (subsection 4.5). A completed example is provided in subsection Appendix D.

(Name of uncertainty factor, e.g. Market)

Uncertainty
Uncertainty drivers included in the factor

Baseline assumption
Description of the situation to be assumed

Hope for
Possible positive elements

Fears
Possible negative elements

Believe
Description of the most likely situation

Affects
Which cost items the factor affects

Percentage

Low	*Most likely*	*High*

Figure 6: Form for description and quantification of uncertainty factors

4.4 Quantification of the cost items

Once the baseline assumptions for each uncertainty factor are established, the cost items can be quantified. The estimate structure comprises a set of cost items defined during the preparation phase. The probability distribution of each cost item is determined using a *three-point estimate* from each process participant – a lower value (very often the 10 % quantile), an upper value (very often the 90 % quantile), and a most likely value, which represents the estimate the participant believes to be the best. The most likely value is typically based on figures from databases, comparable projects, or pre-existing calculations. Determining the upper and lower values is more demanding and requires sound, relevant experience and some statistical intuition. A genuine assessment of spread should always be made for each cost item; avoid schematic or arbitrary spreads such as simply using +/-10 % of the most likely value.

Typically, the process leader collects three-point estimates for each cost item from all participants. The group then has a set of low, most likely, and high values for each cost item, as illustrated in figure 7. The question then becomes: what should the group's joint three-point estimate be? One approach is to systematically select the smallest low value and the largest high value. This approach may initially feel unrealistic, but if the resulting uncertainty appears too large, the items with the most significant impact will stand out at the top of the uncertainty list and can be re-examined later. Underestimating uncertainties, on the other hand, is more problematic – important elements may then disappear from attention altogether.

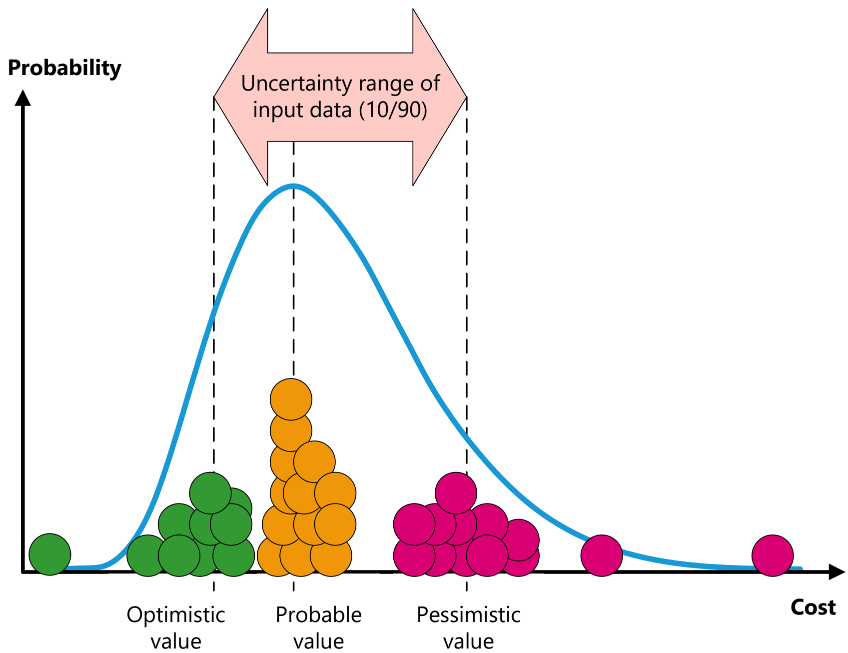

Figure 7: Input data for a three-point estimate

Another approach is to ask the participants who provided the extreme values to justify them. If no convincing justification emerges, the next most extreme estimate is discussed, and so on, until the group identifies a rationale that is at least not unreasonable. The agreed most likely value is often a consensus figure, such as the average of the participants' assessments.

In the early phases of a project, a top-down estimate structure with few cost items is used. As the project basis becomes more detailed, the structure can be refined. If the estimate includes many cost items, it is useful to quickly identify which ones warrant attention, which are relatively insignificant relative to the total, and which are sufficiently certain. For a quick initial pass, the smallest low values and the largest high values can be used; this often reveals which items or factors dominate the total uncertainty and warrant a more thorough review.

4.5 Assessment and quantification of the uncertainty factors

Once the cost items have been quantified, the uncertainty factors are assessed and quantified – i.e., what may occur beyond the baseline assumptions and how that could affect the total estimate. The effects are expressed either as percentage adjustments on selected cost items or as absolute amounts.

Each uncertainty factor is first described by specifying what is hoped for, what is feared, and what is considered most likely (see figure 6); the baseline assumption is already stated. These qualitative descriptions form the basis for the numerical assessments that follow.

The quantification of uncertainty factors is performed in the same way as for the cost items, but the discussion should be even more open to input from all participants, not just the subject-matter experts, since these judgements also rely heavily on intuition and professional judgement.

4.6 Assessment of covariation (correlation)

Covariation (correlation) arises because cost items share the same cost drivers, or because uncertainty factors that affect costs influence each other or vary together. After quantifying cost items and uncertainty factors, any remaining dependencies that have not yet been captured should be considered.

Ideally, cost items that have the same underlying cost cause should be assessed together. For practical, process-related, or analytical reasons, however, this is seldom possible. Related items are often divided into sub-items and estimated separately. A common mistake is then to treat all items as independent after the division, without discussing or modelling the covariation that exists between them. Figure 8 illustrates how uncertainty "disappears" when a cost item is divided into two equal parts with the same relative uncertainty – the variance is halved.

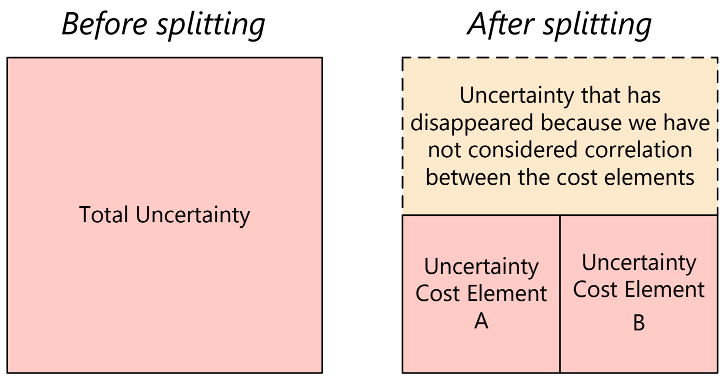

Figure 8: Consequence of dividing estimate elements

For two elements, A and B, that covary, the variance of their sum is given by

$$\sigma^2_{\text{Tot}} = \sigma^2_A + \sigma^2_B + 2\rho\,\sigma_A\sigma_B$$

where ρ is the correlation coefficient. If A and B are identical ($\sigma_A = \sigma_B = \sigma$), this simplifies to

$$\sigma^2_{\text{Tot}} = 2(1+\rho)\,\sigma^2$$

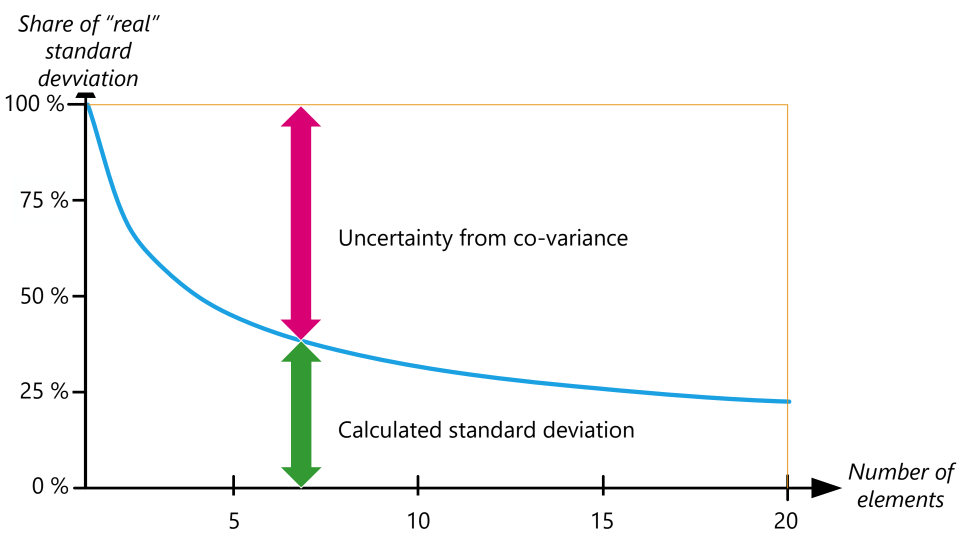

Figure 9: Share of uncertainty that disappears if covariation is ignored as the number of elements increases

Costs arise from the consumption of resources. When cost items depend on many of the same resources, the costs will exhibit significant covariation. Nevertheless, many calculations still assume that all items are statistically independent. If the method or tool used allows covariation to be modelled, the analysis should identify which items covary, how strongly, and encode this directly by linking cost items and uncertainty factors to correlation coefficients.

If the tools used do not support covariation, one approach is to identify shared resources or other common causes affecting multiple cost items and assess the variation for each such cause. These, in turn, contribute to the project's total spread. To compensate for the lack of independence, the uncertainty associated with the shared cause can be extracted and treated as a separate uncertainty factor.

For example, labour costs are calculated as the number of hours multiplied by the hourly wage rate. The number of hours varies with working conditions and workforce competence – this naturally belongs with the individual cost item. The wage rate, however, affects many types of work simultaneously. It may therefore be appropriate to extract wage-rate uncertainty as a common uncertainty factor for all (or several) cost items. Its effects are then estimated separately, thereby capturing the covariation that would otherwise be lost.

4.7 Evaluation of the result

Once the estimate structure is established and all elements are quantified, the estimate can be calculated. The software normally handles the calculation itself and will not be discussed further here (see *Concept Theme Pamphlet no. 4 – Cost Estimation under Uncertainty*).

After the calculation, the results should be assessed with respect to reasonableness and quality. The most important outputs are the total cost and its uncertainty range, typically presented as an S-curve, and an uncertainty profile that shows which cost items and uncertainty factors contribute most to the total uncertainty (see chapter 7).

In general, consideration should be given to whether the process objectives have been met, whether the group has remained focused on the task, and whether the participants are satisfied with the results. The total cost level, its spread, and the shape of the uncertainty profile should all be evaluated.

Regarding cost level, the main question is whether the result appears realistic. It should be compared with rough benchmark figures from similar or comparable projects. For the uncertainty range, assess whether the calculated uncertainty is realistic. If the project has set a limit for acceptable uncertainty, it should be checked whether this is met. Equally important is whether the uncertainty may, in fact, be too small. Experience shows that calculated uncertainty is often lower than the uncertainty that later materialises. Some possible reasons are:

- Too few uncertainty factors included
- Too little emphasis on opportunities
- Extremes (boundaries) set too narrowly
- Over-division of cost items introducing additional covariation
- Correlation effects not included
- Unrealistic assumptions or reservations

The typical magnitude of uncertainty depends primarily on the project phase, but also on project type, size, and complexity. In the early phases, a standard deviation of about 30 % to 50 % is common. Based on a completed preliminary design, a standard deviation of about 10 % to 20 % is typical. If the calculated uncertainty lies outside these intervals, the deviation should be explained.

Large projects typically have a smaller *relative* standard deviation than smaller projects. Random events carry more weight in smaller projects, and there is less opportunity to correct errors along the way.

The uncertainty profile should also be reviewed to determine whether the prioritisation of the most important factors and items appears realistic. Have all relevant risks and opportunities been captured? Are the truly critical aspects sufficiently visible in the results?

4.8 Refinement of the analysis

If the result appears unsatisfactory or unrealistic, the analysis should be refined. If the uncertainty is too large relative to the requirements, consider obtaining additional information to reduce uncertainty in the input data. However, one should not split cost items, remove uncertainty factors, or take similar actions merely to reduce calculated uncertainty – unless there is a factual basis for doing so; such adjustments only remove uncertainty on paper.

If, on the other hand, the total uncertainty appears too small, the estimate structure and the assessments of the individual cost items or uncertainty factors should be revisited. It may also be necessary to introduce additional uncertainty factors or to include covariation in the analysis.

4.9 Recommendations for the way forward

The resource group has now, over the course of several days, assessed the project's most uncertain aspects. The knowledge gained through this process should inform the project manager on how to reduce risks and exploit opportunities. Suggestions for measures often emerge during the discussions of individual elements, and the process leadership should therefore make a point of noting these continuously. Towards the end of the session, it is useful to return to the topic and summarise possible measures.

This important part of the process is often given short shrift – commonly, half an hour is set aside at the very end of the last day with instructions to produce an action list. That is of course better than nothing, but in practice it provides too little time and comes at an unfortunate moment when the participants are tired after the session.

A recommended approach is to use the time at the end of the process to clarify what is being sought and how the group can contribute, and then arrange a new session of, for example, half a day with the aim of producing the best possible advice on how the uncertainty profile should be managed and what should happen in the project in the time ahead. If this is not possible, the time after lunch (about three hours) on the final day of the session should be set aside for the same purpose.

5 Follow-up and report

The report should contain the necessary factual information about the project and summarise the analysis process. It should reflect the resource group's view of the project and be a neutral presentation, independent of any particular interests in the decision-making process. At the same time, it should be an important part of the decision basis for subsequent choices and a support for the project management in the further work. It is therefore necessary that the most important findings and conclusions are clearly visible and readily understandable.

Cost estimation under uncertainty is useful in all phases of a project. If the report is prepared in an early phase, the analysis will often encompass several alternatives. In that case, the report should make the differences between the alternatives visible. If the analysis is carried out on based on a completed preliminary design, and before a final decision on financing and start-up, the report will typically focus on the project's expected cost and the magnitude of the uncertainty. In addition, the report should include a list of the most important uncertainties and indicate whether any issues warrant halting the project until these are clarified, along with the resource group's advice. Regardless of when in the process the analysis is conducted, the report should include a chapter in which the process leadership expresses its view of the process just completed and whether the group has managed to provide assessments of high quality and relevance.

Quality assurance of the report itself is important. The best aid here is to circulate the report for comment to group participants, asking them to state their views on the results and conclusions and to assess the report against a set of criteria. The project manager should be one of the consultees, regardless of whether they are part of the resource group. The questions are: "Does the report contain what you need to take it further to your superiors, and does it provide adequate support for decisions about action?"

While the report is being prepared, it is important that both the project management and the resource group are available to answer any questions that may arise, so that matters can be clarified while they are still fresh in mind. The process leadership should conduct its own "quality assurance" during drafting.

Below is a list of criteria that may be used as a basis both during report writing and during the circulation for comment:

- **About the basis**
  - Do we consider the project sufficiently mature relative to the planning phase it is in?
  - Are the reference projects relevant to this project?
  - Are all factual details correct and adequate?

  - Have the results from the stakeholder analysis been taken into account further in the analysis?

- **About the group and the process**
  - Has the group composition covered the need for competence and the need for diversity?
  - Has the need for balance between different perspectives (cf. optimism and pessimism) been met?

- **About the results**
  - Is there reasonable correspondence between the “gut feeling” from the situational map and the analysis results and, if not, is this something that should be commented on?
  - What is the participants’ view as to whether the analysis results are representative of the project’s real situation?
  - Is there dissent regarding this view?
  - Can we stand by this result after the session?
  - Are the cost and uncertainty picture sufficiently clear for our purpose?
  - Has the need for decision support been met?
  - Does the ordering of the elements in the uncertainty profile give a correct picture of the overall situation and a message that is adequate for the report’s readers?

- **About the report**
  - Is a separate explanation required as to why the uncertainty level is so small – or so large?
  - Is a separate explanation required regarding the level of detail?
  - Are there any particular points that should be highlighted in the report?
  - Are there any readers who need specific information or clearer emphasis on points?

6 Practical guidelines for estimation work

Estimation in practice requires an overview of the project scope and the uncertainty profile. In addition, it requires knowledge of the tasks and experience from the roles to be covered. It is also essential that participants have some knowledge of the pitfalls inherent in estimation processes.

In this chapter, we address some of the challenges that the estimation team may encounter.

6.1 Building the estimate structure

The estimate structure should provide an overview of what the project consists of by breaking the scope down into elements to which costs can be attached – so-called *cost items*.

6.1.1 Estimate breakdown

There are principally two different approaches to breaking costs down into cost items, as shown in figure 10.

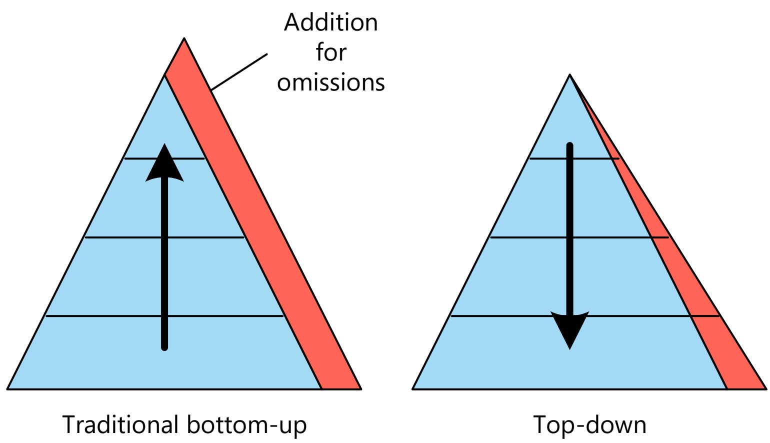

Figure 10: Approaches to breaking down the cost estimate

Traditionally, the bottom–up approach has been used: the project is broken down into detail, and each detail is then estimated. Costs are summed according to a hierarchical structure. One starts at the bottom and sums upwards – hence the name bottom–up.

The other principle for the estimate structure is top–down, which means breaking the project into a few overarching cost items and estimating the costs associated with them. Some cost items are further broken down as needed. Most often, the uncertainty in the items determines what is broken down in greater detail.

As a basic principle, cost estimation under uncertainty should follow the top–down approach. At the same time, there is in principle an assumption that the elements in the structure are statistically independent of each other. The project should therefore be broken down into as few high-level cost items as possible.

For different types of projects there are usually one or more standard breakdowns, or the breakdown is based on tradition. For buildings, for example, there are Norwegian standards used as a basis for cost breakdown (NS3453 and NS3451). Road and railway projects have their own process code. Other project types typically have corresponding standard breakdowns.

6.1.2 Degree of detail

An aim of the entire process is to ensure everything is included and that the focus remains on the key items. With an overly detailed structure, it is easy to spend just as much time discussing small cost items as large ones. Small and unimportant matters thereby receive the same attention in the process as large and very important matters. This can be partly avoided by the choice of breakdown structure and partly by process leadership, ensuring the correct prioritisation of time. The division should also be as appropriate as possible relative to the purpose of the estimate. The purpose of the estimate also guides the choice of structure.

In general, the breakdown structure should align with the participants' experience. If participants have experience at a very detailed level, while the estimate structure is kept at a coarse level, this will create a problematic situation in which participants cannot leverage their experience.

An overly detailed division will often lead the group to lose sight of the whole, and matters to fall between two stools. There is also a risk that uncertainty disappears when it is spread across many elements. A detailed structure also increases the time required in the process, as the group needs more time to estimate additional items. A detailed structure with many cost items entails more interdependencies and interfaces and indicates that one should also have more *uncertainty factors*.

Above, we have focused heavily on the dangers of excessive detail. This is clearly one of the most important reasons the uncertainty picture often does not align with reality. Too coarse a division occurs less frequently, but there are examples where the use of large lump-sum items or overly composite element descriptions can result in estimates that are difficult to trace, and where the uncertainty picture is so imprecise that it has little value for planning measures. To find a workable balance in the division, it may be helpful to keep in mind the rule that the analysis can be *calculated* in detail and *presented* at a coarse level, but not the other way around. The estimate structure must therefore be planned with a view to how the result will be presented and used; here, too, the picture presented should provide a clear, relevant, and reliable basis for decision-making.

6.2 Roles and tasks of the process management

The process management team consists of the process leader and the data support. The project owner or project manager engages the process management team to conduct a cost estimation process under uncertainty. The aim is to present as comprehensive a picture as possible of the project's costs and associated uncertainty.

The process management team's tasks are to plan the process, ensure it is well prepared, executed to a high standard, and documented effectively. Below is a list of important tasks that the process leader has in connection with the preparation and implementation of the process:

In the preparation phase

- Together with the project manager, plan the process (time, place, use of tools and methods).
- Together with the project, prepare the planning note.
- Take part in selecting participants for the resource group.
- Support the project manager in the work on the estimate structure.
- Together with the project staff, select the necessary material for the participants. This must be done in good time so that the participants are able to prepare themselves.
- Establish the report template, and insert the estimate structure and as much information as possible into the template and any data aid.
- The process management or the project manager must follow up the participants in the resource group in the period before implementation to ensure that they prepare themselves as well as possible. Typical topics of conversation are whether the material sent out is good enough, why exactly they have been asked to participate and what they are expected to contribute in particular, and whether they need any support to free up enough time for the preparations.

During implementation

- Ensure that the group process has progress and goals.
- Keep to the agreed time frame.
- Get everyone to put forward their viewpoints.
- Ensure that the rules of the process are followed.
- Ensure the correct framing of the uncertainty factors.
- Ensure documentation.

- Ensure that the analysis is kept up to date along the way.
- Ensure that the results can be presented for evaluation along the way.

The report

- The report is entirely the responsibility of the process management. The most important quality assurance consists in the resource group being given the opportunity to go through the report before it is presented. The project manager has direct influence on and responsibility for only one matter regarding the report, namely that all factual information about the project is correct.

During the process it is important that the process leader and the data support function as one team. They must work together and complement each other. The process leader must constantly keep in mind that the data support is able to keep up with what is happening, and make room for the data support to have enough time to update the documentation and the figures. The data support, for their part, shall support the work of the process leader by helping to keep the time, sensing the mood in the group and raising issues where the group seems uncertain.

6.3 Use of existing base estimates

In (almost) all cases where a process for cost estimation under uncertainty is to be carried out, there will exist a more or less detailed cost basis supporting the assessment of the most important cost items. The cost basis may be a fully developed base estimate or estimated costs for the main cost items.

A challenge with using such a base estimate or previously estimated costs is that one often does not know the assumptions underlying these estimates or the extent of uncertainty already embedded in them. As previously discussed, an estimate must be based on assumptions about production methods and conditions related to the project and its environment (represented by the uncertainty factors). Since the base estimate is prepared before the estimation session, the uncertainty factors will not yet have been established. This may lead participants in the base estimate process to have different mental pictures when making their estimates, and what is included as “extra” to cover, for example, uncertainty about geology, ground conditions, or the market, will vary widely. Even if coordination among those who prepared the base estimate was achieved, the understanding will rarely be communicated to participants in the uncertainty analysis.

The advantage of identifying uncertainty factors before estimating cost items is that their assumptions can then be fixed, ensuring that all parties share a common understanding when assessing the main cost items. The cost consequence of the fixed assumptions’ uncertainty is then linked to each individual uncertainty factor.

This ensures that uncertainty is captured only once and that its causes are visible and manageable.

At the same time, this approach may have weaknesses compared with the systematic documentation and traceability provided by maintaining a robust, well-prepared base estimate.

Coordination and knowledge transfer over time in cost estimation work involving many people are also significant issues, particularly in uncertainty assessments, but we do not have space to discuss this further here.

6.4 Handling of events

Everything that happens in projects is, at its core, an event. Most of these events are, however, the result of our plans, decisions, and targeted work, and are therefore expected with a probability close to 100 %. The uncertainty related to these events is linked to the costs or, potentially, the revenues of the outcomes, often referred to as estimate uncertainty. What we will look at a little more closely in the following are those events that occur more or less randomly, and thus with much lower probability. The uncertainty here concerns whether the event will occur and what consequences it will have, and in addition, what these may come to mean for the project result, positively or negatively.

Identification of possible events is therefore part of identifying uncertainty, and their handling will vary based on type, probability, and the significance of the consequences. We generally distinguish between three types: opportunities, threats, and catastrophes.

Figure 11 shows a risk matrix used to sort possible threats with regard to probability and consequence. Opportunities can be treated in the same way in an opportunity matrix. Both axes of the matrix are divided into fields, often described using semantic variables such as small, medium, large, and very large. What is small and what is large depends, among other things, on the size of the project, the organisation’s risk attitude, and the level of loss that can be tolerated, and must be determined for each project. When assessing the probability of threats, it is common to say that if it exceeds 50–60%, we expect it to occur.

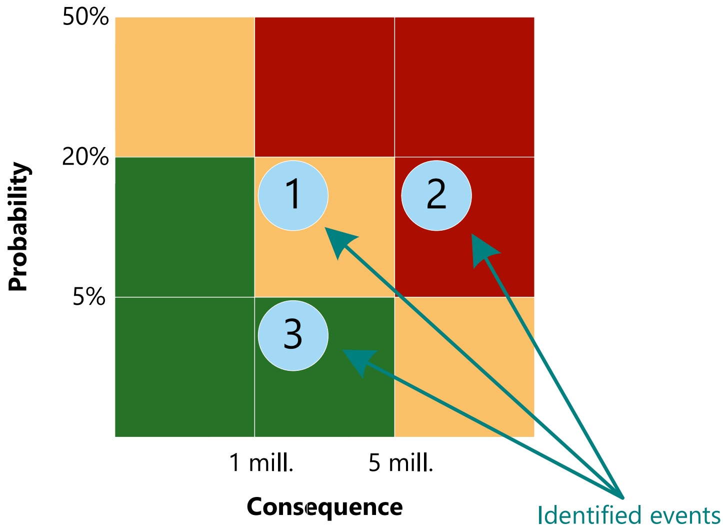

Figure 11: Risk matrix

Events often have consequences beyond cost, and we can use multiple matrices (e.g., time, quality, reputation, health, safety, and environment) as needed. Possible events are accounted for in the quantitative uncertainty picture (and cost estimate) by multiplying each cost consequence by its probability.

Some events are of the type ”the worst that can happen”. The consequences can be almost catastrophic, and if the probability is too high, the project must be stopped until measures have been implemented that reduce the probability or consequence to an acceptable level. Certain catastrophic possibilities that are very rare – for example, of the type thousand-year flood or similar – we usually just have to live with. Measures here will primarily involve monitoring the situation and, if necessary, implementing contingency plans to evacuate personnel. The economic consequences will most often have to be borne by society at large.

The expected value of events with very small probabilities, each with enormous economic consequences, yields amounts that are meaningless in this context. A thousand-year flood estimated to cost one billion has an expected value of one million per year. If this amount is added to the budget of a project lasting five years, there is a 99.5 % probability that it will not be needed – at least not for the intended purpose. However, should the flood occur and the major consequences materialise, five million more or less will make no difference.

For the number of identified possible events with foreseeable probabilities and reasonable consequences, it is useful to calculate the expected values and sum them to determine the amount that contributes to the project’s expected cost. If, in addition, one can calculate the spread of this variable, it will also contribute to a greater uncertainty allowance.

6.5 Pitfalls in the estimation process

In estimation contexts, it is important to be aware of which pitfalls may exist, even when one has access to a group of experts with relevant knowledge and even when a good group process is carried out. We will not go into depth on this topic but will limit ourselves to highlighting some of the most common challenges encountered.

For those who wish to explore the issue further, we refer to the literature on estimation and decision psychology, and recommend starting with Concept Report No. 17, *"Decisions based on scant information; challenges and tools during the front-end phases of projects"*, chapters 5 and 9.

Experience shows that two aspects are particularly important to be mindful of during the process. The first is to avoid mixing the analysis situation with the project's decisions. Such mixing occurs when the process management team and the resource group are too closely linked to the project, creating a conflict of interest between the need for neutrality and the desire to have the project prioritised in the budget context.

The second aspect that requires a conscious attitude is the one already mentioned in chapter 3, where we discuss the composition of the resource group – namely, the tendency to be too optimistic about one's own ability to make good estimates as well as the ability to carry out the operations properly. This is what Kahneman calls the *planning fallacy*. Both of these pitfalls probably share a common denominator in what is known in the professional community as *project love*.

The literature uses concepts such as *judgement bias* and *decision bias*. These can be defined as ways of thinking that cause us systematically to deviate from what we perceive as rational assessment and decision-making.

The causes of such systematic errors are many, and we shall limit ourselves to mentioning a few typical ones in addition to those already described:

- Lack of statistical understanding among participants. This often leads to estimates being too narrow, in the sense that the estimates of, for example, P10 and P90 in reality become P25 and P75. Understanding that the relative spread in the probability distribution of costs for individual elements increases sharply with subdivision is also often lacking.
- Confidence in irrelevant or unreliable information. All information that is presented is regarded as important, and there is no reflection on where it comes from and whether it is relevant to the assessment.
- Exaggerated trust in data that are too uncertain or too poorly founded.
- Wishful thinking — an unconscious inclination to choose data or assumptions that support a desirable outcome.

- Anchoring — the tendency to let oneself be influenced by earlier assessments, round figures, or values that have been mentioned in the discussion.

The process management team should therefore have a conscious relationship to these pitfalls and actively counteract them through how the process is planned and implemented. Ensuring diversity in the resource group, facilitating open discussions, and challenging the group on assumptions and logic are important measures in this regard.

7 Results

In this chapter, we will summarise some of the results from the analysis described. The analysis has intrinsic value for those who participated, as it illuminated the project through discussion and exchange of views. The benefit for everyone else comes from the knowledge and analysis results informing decisions and practical action.

The S-curve

The most requested result from the analysis is usually the estimate itself. In stochastic cost analyses, this is shown as a cumulative probability distribution. From this, a numerical value can be determined based on the level of certainty one wants that the total cost will not be exceeded. See figure 12.

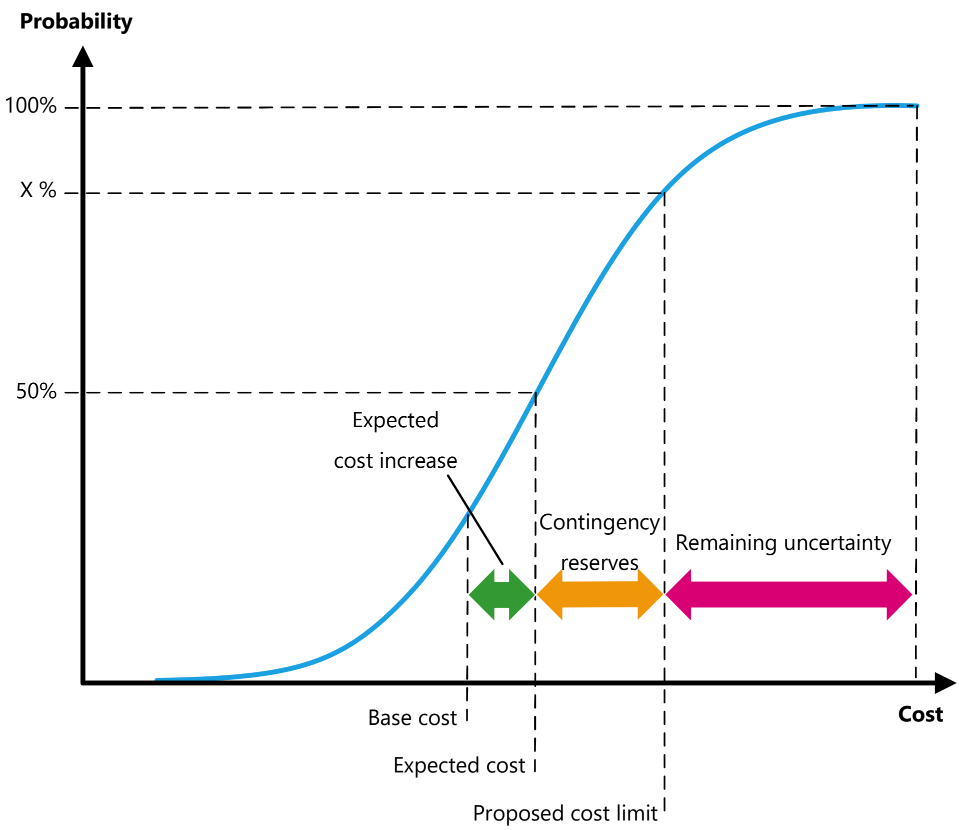

Figure 12: The S-curve

Uncertainty profile

The uncertainty profile identifies the cost items and uncertainty factors that contribute most to total uncertainty and should therefore receive the highest priority for measures.

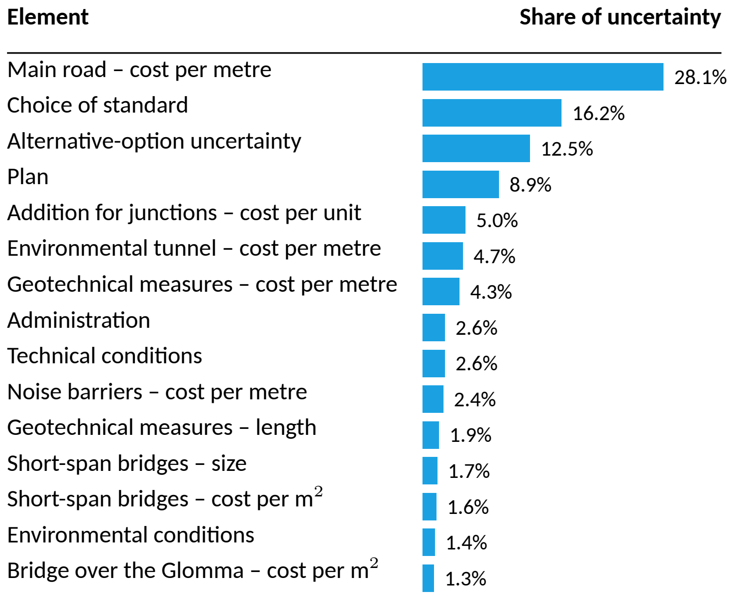

Figure 13: Uncertainty profile

Possible events

Events are often placed in a probability/consequence matrix. The consequences may, for example, be costs in kroner, time delays in weeks, or less measurable effects expressed qualitatively.

The knowledge

A structured group process over time generates knowledge about the project beyond the concrete cost and uncertainty picture. Here, there may have been discussion around, for example, production methods, contract forms, remuneration forms, and incentive models, and the members from the project organisation have “got the project under their skin”, as one says when one becomes truly familiar with something.

The advice and proposals for measures

All the experience that the participants possess, together with knowledge that has been generated in the process, has (hopefully) been utilised to give the project organisation advice both on measures in relation to the uncertainty and concrete advice on, for example, implementation model, working methods, management interventions, and other matters.

The gut feeling (comparison with the situation map)

At the start of the group meeting, we created a picture of the group's gut feeling about key aspects of the project—the situation map. Comparing the analysis results with this gut feeling is a good quality-assurance step; if there are significant differences, the group should assess why and, if appropriate, bring the final results closer to the situational map.

8 Summary

The primary purpose of a process for cost estimation under uncertainty is to obtain as comprehensive a picture as possible of the project's investment cost and associated uncertainty.

What characterises good cost estimates is that "all" factors have been assessed, and that possible effects of these factors have been quantified and, to the best of one's judgement, included in the cost estimate. Changes in the uncertainty picture are most often achieved through measures, either by prevention, increased preparedness, or as actions to increase necessary knowledge and insight. It is important to remember that uncertainty usually cannot be assumed away.

Cost and uncertainty analyses are essential to most project decisions, but it should be a main principle that the analysis is conducted as neutrally as possible, so that the results are not influenced by considerations related to later decisions.

A traditional process for cost estimation under uncertainty begins with a preparation phase that involves assembling a resource group, preparing and distributing materials to participants, and providing practical facilitation. An important part of this phase is the participants' own preparations. The next step is called the estimation phase. This covers the implementation of a group process with calculation, uncertainty assessment, and evaluation. The final phase covers follow-up work, including finalisation of the report and quality assurance of the content.

In carrying out the process, four important roles must be covered. The role of the owner of the estimation process is covered by the person who commissions the cost and uncertainty analysis and who owns the analysis results. The process leader is responsible for conducting the analysis and producing the report with the results. The secretary/data support is responsible for documentation during the implementation of the process. The last and most crucial role is to make one's experience and competence available to identify uncertainties and estimate associated costs and uncertainties. A resource group covers this role.

Several heads think better than one. A group process provides a broader base of knowledge and experience, helps balance preconceptions, increases opportunities for creativity, and facilitates exchanges of opinion that are necessary to ensure that "all" factors are assessed.

The group process comprises a qualitative and a quantitative component and begins by identifying uncertainty through a brainstorming session.

The breakdown of the project scope should follow the top-down approach. At the same time, it is desirable that the elements in the structure should be stochastically independent of each other. The project is broken down into as few overarching cost items as possible.

Experience shows that two matters are particularly important to consider during the implementation of an estimation process. The first is to avoid mixing the analysis situation and the decisions in the project. Such mixing occurs when the process management team and the resource group are too closely linked to the project, leading to a conflict of interest between the need for neutrality and the interest in ensuring that the project is prioritised in the budget context.

The second matter that requires a conscious attitude is the tendency to be overly optimistic about one's ability to make sound estimates and to carry out operations properly.

When a group has assessed the most uncertain aspects of the project in a process lasting several days, the knowledge and insight about the project that they have acquired in this time should be utilised so that the project manager can receive some advice on what is essential to address in order to reduce the risks and exploit the opportunities that have been identified.

The analysis concludes with a report summarising the process. It shall reflect the resource group's view of the project and present it neutrally. It shall be an important part of the decision basis for the subsequent choices, and a support for the project management in further work.

Appendices

A. Example agenda for a group session

B. Example contents of the planning note

C. Example contents of the cost estimate report

D. Example form for uncertainty factor

E. Example form for cost item

Appendix A Example agenda for a group session

This is an example agenda for a group session in a medium-sized project.

Day 1

Time	Resp.	Agenda
10:00	PL	Welcome; purpose; introductions
10:30	NN	Project overview; planning status; cost analysis basis
11:00	PL	Methodology; ground rules; aims; analytical assumptions
11:15	PL	Start: situation map; maturity assessment
12:00		Lunch
12:45	PL	Brainstorming (uncertainties)
14:30		Break
14:45	PL	Structure the uncertainties; define baseline assumptions
15:30		Break
15:45	PL	Estimation structure
16:00	PL	Estimate cost items
17:00		Close of day

Day 2

Time	Resp.	Agenda
08:00	PL	Recap of Day 1; participant reflections
08:30	PL	Estimate cost items (cont.)
10:30	PL	Estimate uncertainty factors
11:30		Lunch
12:15	PL	Estimate uncertainties (cont.)
13:30		Break
13:45	PL	Review cost items and quantification (cont.)
14:15	PL	Assess results
14:45	PL	Refine results
15:00	PL	Actions to reduce uncertainty
16:30		Close of day

Appendix B Example contents of the planning note

Appendix C Example contents of the cost estimate report

Appendix D Example form for uncertainty factor

U1 Market conditions

Uncertainty:

- Number of contractors interested in the work.
- Whether the contractors have strong delivery capability.
- Many concurrent projects competing for resources.
- Key resources – capacity for such competence is uncertain.
- Several projects are in the planning phase.
- The market understands the needs.

Baseline assumption:

- Exempt from the Public Procurement Act.
- Current market conditions are used when pricing cost items.

Hope for:

- Good competition for the work at good prices; timing is favourable.
- Adequate capacity in the right areas; more competitive bids.
- Sufficient knowledge level.
- Key resources are available.

Fear:

- Weak competition increases prices; poor timing versus competing assignments.
- Insufficient market capacity.
- Inadequate knowledge level.
- Shortage of key resources.

Assessment: Expect market fluctuations, but not large deviations from today's conditions.

Impact: Everything.

Percentage	*Minimum*	Most likely	Maximum
	-10%	0%	$+15\%$

Appendix E Example form for cost item

C1 – Tunnel excavation

Description:

- Length: 4 470 m
- Profile T9.5, cross-section 72.5 m^2
- Tunnel class F
- Directly beneath a settlement
- **Quantities:**
  - Tunnel blasting: 72.5 m^2 × 4 470 m = 324 075 m^3
  - Niches: 8 × 1 200 = 9 600 m^3
  - Cross passages: (8 × 10 × 20) = 1 600 m^3
- **Total:** 335 300 m^3

Assumptions:

- Favourable phyllite conditions along the entire alignment
- Geology as described in the geological report
- Current market conditions form the pricing basis

	Low	Most likely	High
Quantity, m^3	335 300	335 300	335 300
Price per m^3	160	200	240

Concept Theme Pamphlets

Concept Theme Pamphlets that have been translated to English.

Pamphlet no.	Title	Author(s)	Published
4	Cost estimation under uncertainty	Frode Drevland	2013 (EN 2025)
6	Process for cost estimation under uncertainty	Olav Torp Frode Drevland Kjell Austeng	2015 (EN 2025)

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The Concept research program aims to develop know-how to help make more efficient use of resources and improve the effect of major public investments. The program is designed to follow up on the largest public projects over a period of several years, and help improve design and quality assurance of future public projects before they are formally approved.

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The Concept Research Program
Department of Civil and Environmental Engineering, NTNU, N-7491 Trondheim, NORWAY

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