APM – ACostE
Estimating Guide

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Foreword

Estimation and its diligent application within any project is one of the cornerstones of successful project delivery. This guide has been created to assist the current and next generation of project stakeholders to understand the core values, information sets and underpinning knowledge that, if applied diligently, will improve the clarity and robustness of an estimate, informing the organisation with transparency and clarity and supporting better decision making.

The Association for Project Management (APM) and the Association of Cost Engineers (ACostE) have collaborated to bring this guide to you. All the collaborators have an excellent understanding of the challenges faced when generating an estimate that is fit for purpose, having had the experience of real-life situations where good estimates made the difference in delivering the project, and a burning desire to share their combined knowledge for the benefit of all.

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Director of business development, ARES Corporation

Purpose and reason for this guide

The purpose of this guide is to provide a fundamental understanding of the methods of cost estimating and it explains a number of standard approaches available to promote good practice.

Estimates are critical to the project manager as they are needed to make informed decisions about projects across the different stages of the whole project life cycle, hence the cooperation of the Association of Cost Engineers (ACostE) and the Association for Project Management (APM) in publishing this guide. In project management, effective monitoring of a project's performance depends on having an appropriate, high-quality estimate against which progress can be measured.

For instance:

- Investment committees require estimates in order to predict return on investment and hence determine whether to support project proposals and the level of finance to invest in them.
- Cost estimates form part of option appraisals.
- Mature organisations often review projects at key stages and require them to meet internal governance guidelines on cost-benefit-risk.
- Organisations that manage a portfolio of projects require credible cost estimates in order to manage the spending profile of the portfolio.
- Good management practice needs to understand the impact of a project change, including risks and opportunities.

There is long-standing evidence that underestimation of project costs is a key reason for project failure. For instance, the National Audit Office's 2001 report *Modernising Construction* (Comptroller and Auditor General, 2001) found that limited understanding of the true cost was one of the main reasons that 70 per cent of public sector construction projects were delivered late or over budget. Industry surveys (KPMG, 2015) indicate that this is still the case. Academics have collected evidence for overruns costing billions of pounds in major infrastructure projects worldwide (Flyvbjerg, 2003). More recent studies (Comptroller and Auditor General, January 2017) have shown that these errors were often due to not taking estimating seriously enough, hampered by poor quality data and unrealistic assumptions (National Audit Office, December 2013).

By their very nature estimates are speculative; the word estimating is synonymous with approximation and guessing, yet estimates are vital for sound decision-making, planning and financial management.

Different techniques may be appropriate at different stages in a project's development. This guide will focus on cost estimating method and approaches. However, the advice in this guide is not limited to initial cost estimates; it is equally applicable to forecasting and to other forms of estimating, for example, time, schedule or performance.

The guide is not limited to public sector construction, infrastructure or defence projects; it is equally applicable to the private sector and a wider range of projects, for example, if you are recruiting a new member of staff, or building the world's fastest car, launching a new service, or licensing a new drug – every project needs a robust estimate.

Estimating framework

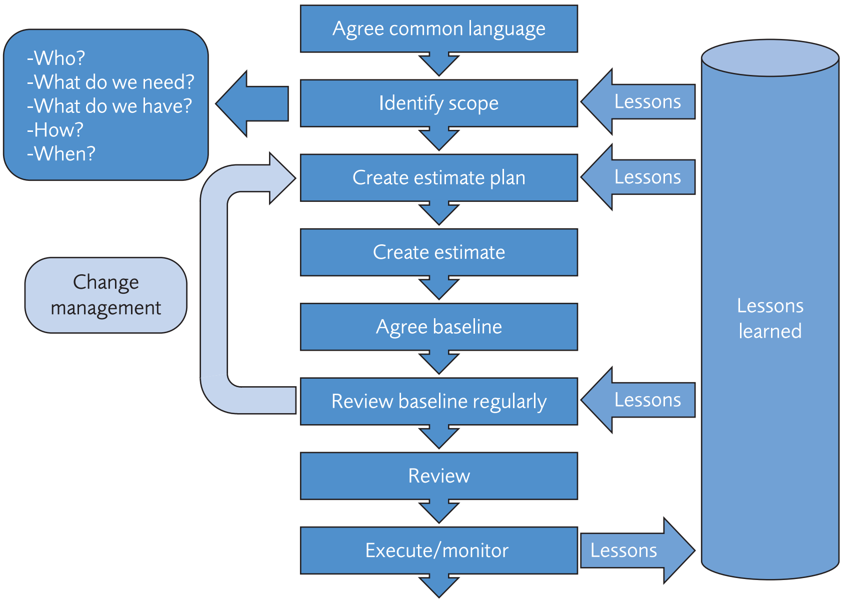

Figure 0.1 Estimating framework

Estimating consists of a number of activities, which provide a framework for generating and continuously improving an estimate. The diagram above shows a typical estimating framework, which includes the activities covered in the guide.

A definition of the terms used in the diagram above can be found in the glossary and are explained throughout this guide.

2

Creating the base estimate

2.1 Estimate management

2.1.1 Iterative process

Before starting any cost estimate, it is important to understand that it will be an iterative process. It is extremely unlikely that all information will be available at the same level of maturity at the start of the project. This means that the estimator must manage the estimating process as an iterative one. The estimator will progress through the various stages of the estimating process (see Figure 0.1: Estimating framework), and at each stage the individual's knowledge will develop as more up-to-date information becomes available. If the estimator plans for an iterative process and operates configuration control, it will facilitate these changes in a controlled manner.

2.1.2 Configuration control

A key principle of cost estimating is the ability to trace and document all aspects of the analysis, from raw data to final outputs. To achieve this, robust configuration control is required. Considering that estimating is an iterative process, configuration control will provide a method to ensure that the most current information is used. It is important to tailor the extent of configuration management required. For a simple project with a small number of data points, a simple naming convention could be sufficient to control the configuration (e.g. yyyy.mm.dd [name] v1.n). Whereas for more complex projects, full baseline management and change control may be required to ensure all information is configured appropriately. APM provides comprehensive guidance on configuration management which can be tailored to the needs of the estimating process; see *APM Body of Knowledge 7th edition* (APM, 2019).

2.2 Estimating approach

An estimating approach is the direction, or means of arriving at an estimate, and to some degree implies the level of detail at which the estimate is created. With complex projects, it is often considered to be good practice to create an estimate using more than one approach as a means of providing a greater level of confidence in the output advised, thereby testing the robustness and interpretation of the data, the assumptions and the methodologies employed.

2.2.1 Top-down approach

In a top-down approach to estimating, the estimator reviews the overall scope of a project in order to identify the major elements of work and characteristics (drivers) that could be estimated separately from other elements. Typically, the estimator might consider a natural flow down through the work breakdown structure (WBS), product breakdown structure (PBS) or service breakdown structure (SBS).

The estimate scope may be considered as a whole, or broken down to different high levels of WBS as required (see Figure 2.1). The overall project scope must be covered by the range of non-overlapping work packages selected, although not all work packages need to be estimated at the same level of WBS. This allows the estimator to use the maturity and/or uncertainty in the key information available to produce the most appropriate level of estimate. The overall project base estimate would be created by summing these high level estimates. This should not be confused with the bottom-up approach where all the lower levels would be aggregated.

Over the life of the estimate these higher-level work packages and the associated higher-level estimates may be broken down into more detailed or more refined elements, which ultimately will facilitate a bottom-up approach (see Figure 2.2).

A top-down approach is frequently used for creating rough order of magnitude (ROM) estimates, otherwise known as ball-park estimates, where the level of detail available is limited. As a general rule, a top-down estimate requires less time and effort to produce than one produced using a bottom-up approach. Top-down estimates are appropriate at the beginning of the life cycle when large numbers of alternative options need to be estimated and considered. As the solution matures and more information becomes available, there is an increased opportunity to produce bottom-up figures. However, a top-down approach

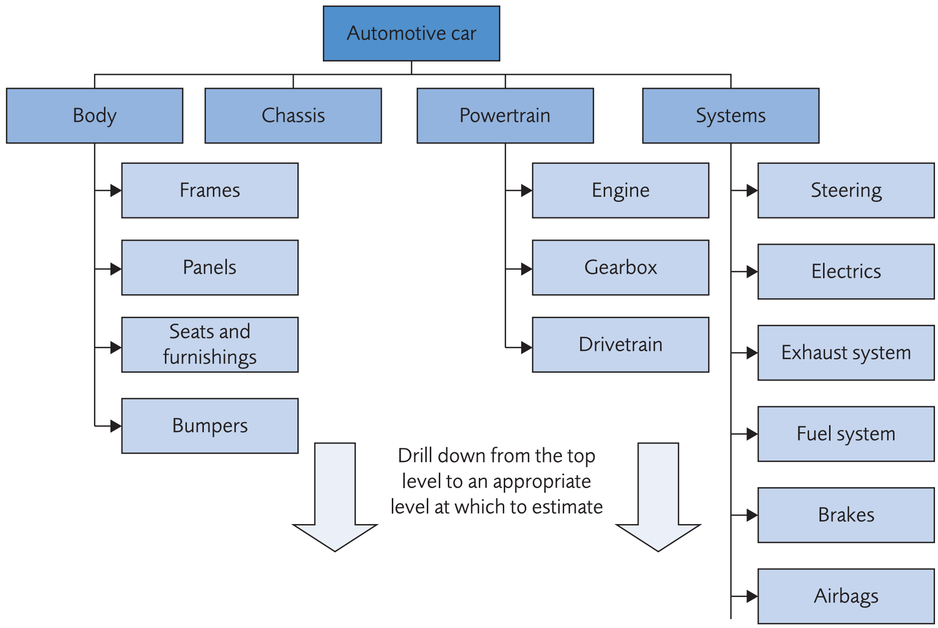

Figure 2.1 Top-down example
Source: © *Alan R Jones 2019*

can still be useful throughout the life cycle of a project, e.g. for validation purposes.

The main benefit of working at a higher level is that there is a tendency to use more holistic data from previous projects or products, including unmitigated and unforeseen risks, and scope creep. This can reduce the risk of emerging work activities or costs being overlooked. As a result, top-down estimates are typically greater than those created by a bottom-up approach.

Base estimates created by a top-down approach should exclude consideration of additional risks and opportunities. These should be considered separately by either a top-down or bottom-up approach as part of the formulation of the project baseline estimate. See section 3.

It is considered good practice to express an uncertainty range around a top-down estimate, based on the maturity of the information available, and the estimating methodologies employed. According to the *NAO survival guide to challenging costs in major projects*, (National Audit Office, 2018) "Early cost estimates should be presented as a range and never a point estimate". Note that APM and ACostE believe this should apply to all cost estimates.

3

Risk, opportunity and uncertainty assessment

3.1 Assessing uncertainty in the baseline activities

There will always be uncertainty (or a lack of exactness) in the cost estimate of projects. This happens for various reasons, including uncertainty about the detailed scope of work and uncertainty about the levels of productivity that will be achieved. In addition to these factors, there will be risks and opportunities; these are things that may or may not happen, but if they do they will impact the estimate. Risks are discrete events that will have a degree of uncertainty over the exact value. Baseline tasks will occur, but the actual value will have uncertainty. For example, while driving home (baseline task), the journey time is ***uncertain*** due to variable traffic conditions (i.e. traffic lights). However, in addition there could be a ***risk*** of a delay of ***uncertain*** duration due to an accident.

Uncertainty is the inherent and potentially uncontrollable variability in estimating the actual cost and schedule. It can be considered as a tolerance band on the understanding of the scope. Uncertainties arise because the organisation does not have a complete understanding of the proposed task or the solution. An uncertainty is an expression of something that will happen; the actual project value will not be known but is expected to lie within a defined range. Some uncertainties will express natural variation; for example, my journey home each day varies by maybe five minutes less or 10 minutes more.

Most baseline tasks in a work breakdown structure will have uncertainty, which can be expressed as three values: the minimum (unlikely to be less than), most likely value and maximum (unlikely to exceed). The 3-point estimate should express the range of uncertainty – excluding risks or opportunities.

Where there is uncertainty in the scope definition of the baseline activities, the 3-point estimate can be used to express the extremes of a minimum (or simplistic scope requirement) and a maximum (or complex scope requirement). Alternatively, any potential but improbable extreme in the scope requirements might be expressed as a risk or opportunity. Care must be taken not to duplicate or overlap any extremes expressed in both ways.

3.2 Link to the risk management process

The evaluation of the net effect of risks and opportunities cannot be performed in isolation from the baseline activities, nor can they be evaluated in isolation from the project's risk management process (i.e. do not re-invent the wheel). Most of the data requirements to manage risks and opportunities are also needed to evaluate their net impact; for example, 3-point estimate of the individual risk or opportunity cost impact, probability of occurrence, risk retirement date, mitigation plan, etc. In addition to these parameters, in order to evaluate their net impact, there is a need to express the 3-point estimate range of potential values as a probability distribution. This then allows probabilistic modelling of the risks and opportunities to be performed in Monte Carlo simulation in conjunction with baseline activities.

Risks and opportunities are discrete events whose occurrences are expressed by a probability of occurrence, modelled by a Bernoulli distribution.

The most common forms of probability distributions to model uncertainty include normal, lognormal, exponential, triangular and uniform.

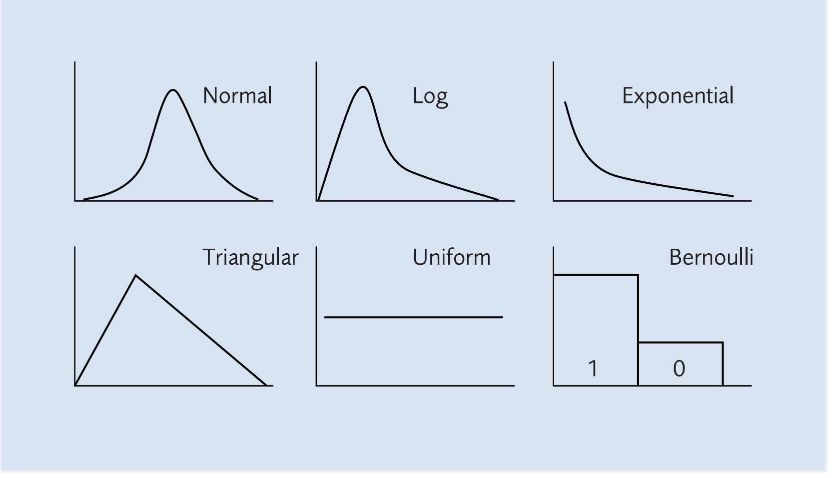

Figure 3.1 Different types of distribution

When to use these different types of distribution:
Normal distribution:

> This symmetrical distribution often represents the spread and frequency of values in naturally occurring observations in nature, such as the height of adult males or females of a given ethnicity. It can also represent the distribution of values from man-made systems such as the accuracy and/or precision of machining operations. The distribution can often be used to represent the range of values for system or sub-system level costs, even where the constituent elements of those systems or sub-systems are not normally distributed. The scatter or deviation of values around a linear cost estimating relationship is also expected to be normally distributed.

Lognormal distribution:

> This distribution can be used in reliability analysis to model the repair time of items, in particular in relation to the fatigue-stress characteristics of mechanical systems. It is often an empirical distribution observed in natural growth or human behaviour systems. When a variable is deemed to be lognormally distributed in linear space, its values will be normally distributed in logarithmic space. As a consequence, the scatter or deviation of values around a power or exponential cost estimating relationship is expected to be lognormally distributed.

Triangular distribution:

> The triangular distribution is frequently used as a default distribution where there is some knowledge or perception of a most likely value, and also an appreciation of the likely minimum or maximum values of a variable. In cost and schedule scenarios, data is more likely to be positively skewed; i.e. where the difference from the most likely to the maximum is greater than the difference between the most likely and the minimum. Aggregated system level variables are more likely to be symmetrically distributed.

Uniform distribution:

> The uniform distribution is frequently used as a default distribution where there is some knowledge or perception of the likely minimum or maximum

6

Ethics in estimation

The estimating codes of conduct lay down the behaviours we would like to see from both the estimator and the customer of those estimates. The customer is defined in this guide as the person who asks for the estimate: project manager, chief engineer, etc.

1. No individual employee, team, organisation, project (or programme), or vendor shall be required to develop, submit or certify any estimate for which they do not have appropriate confidence.
2. There shall be means to address without retribution any concerns about the integrity or ethics in the development of any estimate and those means shall be communicated clearly.
3. In order to protect the integrity, security, image and reputation of the company, senior leadership will confirm the compliance of their respective organisations to estimation policy and standards, be held accountable for the same, and shall delegate as appropriate levels of assurance and compliance to the estimation policy and standards.
4. Any known impacts to estimates, including those for remaining costs of projects in progress, shall be documented and reported as quickly as possible, and no later than in accordance with documented policy.
5. Estimate values, changes and associated impacts shall be communicated honestly, ethically and on a timely basis, to all customers, both external and internal.
6. At all times, the estimator and customer shall create an environment of mutual trust and respect. They shall provide open feedback and views without criticism. At no time shall bullying, intimidation or disrespectful behaviour be tolerated.

All professional bodies have a code of conduct which their members are expected to follow. These include, but are not limited to:

ECUK Spec – Engineering Council www.engc.org.uk/ukspec
APM – Association of Project Management www.apm.org.uk

Glossary

The terms in this glossary represent the views of both APMBok (APM, 2019), ACostE and the authors of the guide.

3-point estimate/ three-point estimate	[APM] An estimate in which optimistic best case, pessimistic worst case and most likely values are given. [ACostE] A three-point estimate represents three cases produced by estimating. Some organisations (and this guide) refer to these as the minimum, the most likely and the maximum. The three-point estimating technique is used for the construction of an approximate distribution representing the uncertainty of future events; this will ensure the estimate is credible.
Accuracy	The correctness of an estimate. This can be measured as the percentage error between the estimate and actual. In the case of 3-point estimates, an estimate is considered accurate if the actual cost/schedule lies inside the estimate uncertainty range.
ADORE	Assumptions, dependencies, opportunities, risks, exclusions (Shermon D, 2017)
Assumptions	A statement that is taken as being true for the purposes of estimating, but which could change later. An assumption is made where some data is not available or facts are not yet known.
Baseline	The reference levels against which a project, programme or portfolio is monitored and controlled.
Bottom-up estimating	[APM] An estimating technique that uses detailed specifications to estimate time and cost for each product or activity. Also known as analytical estimating. *This should not be confused with the 'Estimating Method of Estimating by Analogy' (Section 2.3.1).* [ACostE] An approach to estimating all individual work packages or activities with appropriate level of detail, which are then rolled up to higher-level estimates. The accuracy of bottom-up estimating is improved when individual work packages or activities are defined in more detail. *See section 2.2.2*.