

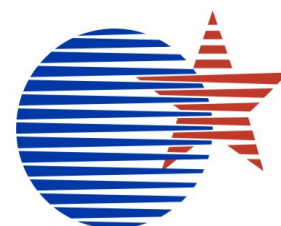
May 2007

Final Guidance

Life cycle costing (LCC) as a contribution to sustainable construction

Guidance on the use of the LCC Methodology and its application in public procurement

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Overview

This guidance document is intended to be used in conjunction with the companion document *A common European methodology for Life Cycle Costing* (the Methodology). It provides practical guidance on the potential uses and the benefits to be gained from using Life Cycle Costing (LCC) in construction, illustrated with a number of case studies from the use of LCC across Europe. It pays particular attention to the use of LCC in public construction procurement, though the principles and key elements are equally applicable to the private sector also.

The Methodology is based on a generic process that has discrete steps or stages. These are described in detail in the Methodology document. While the Methodology represents a complete process for the application of LCC in construction, in practice – and depending on the purpose of LCC and the level of detailed analysis required – some of the steps/stages may be combined and/or omitted.

This guidance document is supported by case studies of the recent use of LCC on a range of construction projects in Europe. The case studies cover different approaches to LCC in different project settings, and illustrate particular instances of the use of the Methodology. These are provided in Annex A.

1 Introduction

1.1 Background

In 2006 the European Commission appointed Davis Langdon from the UK to undertake a project to develop a common European methodology for Life Cycle Costing (LCC) in construction. The results of this work are now available as *A common European methodology for Life Cycle Costing* (hereinafter referred to as the Methodology).

The origins of the project lay in the Commission's Communication 'The Competitiveness of the Construction Industry' and, more specifically, in the recommendations of the Sustainable Construction Working Group established to help take forward key elements of the Competitiveness study. These recommendations proposed that a Task Group (TG4) be established to prepare a paper on how Life Cycle Costing could be integrated into European policy making. The Task Group's paper(2) recommended the development of a common LCC methodology at European level, incorporating the overall sustainability performance of building and construction.

The project was undertaken in recognition that a common methodology for LCC in construction is required across Europe in order to:

- Improve the competitiveness of the construction industry
- Improve the industry's awareness of the influence of environmental goals on LCC
- Improve the performance of the supply chain, the value offered to clients, and clients' confidence to invest through a robust and appropriate LCC approach
- Improve long-term cost optimisation and forecast certainties
- Improve the reliability of project information, predictive methods, risk assessment and innovation in decision-making for procurement involving the whole supply chain
- Generate comparable information without creating national barriers and also considering the most applicable international developments.

1.2 Purpose of the Methodology

The methodology provides a general framework for the common and consistent application of LCC across the EU without replacing country-specific decision models and approaches. It is aimed primarily at public sector construction clients and their project advisors, but can also be used by private sector clients and their advisors, and by contractors. Please refer to the companion document *A common European methodology for Life Cycle Costing* (the Methodology) for further details.

1.3 Purpose of this Guidance

This document provides an introduction to life cycle costing and the benefits of its application in the construction industry, along with guidance on the practical application of the methodology in a range of common circumstances. It is aimed primarily at client and explores why and how the methodology can be applied to their projects.

1.4 Definitions and terminology

Definitions in the Methodology and throughout this guidance document are as in Draft ISO15686, 2006: Part 5.

2 Introduction to Life Cycle Costing

2.1 What is LCC?

Life cycle costing (LCC) is a tool for assessing the total cost performance of an asset over time, including the acquisition, operating, maintenance, and disposal costs. Its primary use is in evaluating different options for achieving the client's objectives, where those alternatives differ not only in their initial costs, but also in their subsequent operational costs. Life cycle costing techniques can be equally applied to major constructed assets or to the individual components and materials from which they are constructed.

Life cycle costing is central to the current international drive to achieve better value for money from the buildings and constructed assets we procure and use. Governments are increasingly focusing on achieving better value from constructed assets and with this has come a recognition that better value does not mean lowest capital cost alone. Instead, the focus has shifted to the evaluation of all the costs and impacts of operating constructed assets over their life cycle, and to minimising both the life cycle costs and the environmental impact.

2.2 Benefits of using LCC

The life cycle costs over the life of an asset are widely acknowledged as a better indicator of value for money than the initial acquisition/construction costs alone. For example, the costs of owning and occupying an office building over a 30 year period are typically in the broad ratio of 1 (construction costs) to 5 (maintenance costs) to 200 (cost of the operations being carried out in the building, including staffing costs). It is therefore clear that a greater focus on the maintenance and operating costs of assets rather than on capital costs alone, can deliver significant long term financial and environmental benefits.

LCC is also a key element in the assessment of environmental sustainability in construction. It provides a tool for the economic evaluation of alternative sustainability options exhibiting different capital, operating costs or resource usage. It also provides methods for evaluating the cost benefits of incorporating more sustainable options into constructed assets. The interrelationship between LCC and environmental assessment is considered further in Sections 2.5 and 2.6 below.

Clearly the specific benefits to be gained from carrying out a LCC analysis will depend on the purpose of the exercise and the circumstances of the project, asset and client for which it is undertaken. Typical benefits can include:

- Transparency of future operational costs
- Ability to plan for future expenditure (e.g. through the establishment of sinking funds).
- Improved awareness of total costs
- Ability to manipulate and optimise future costs at the design stages
- Achieving and demonstrating better value for money in projects
- Compliance with public sector procurement requirements
- Evaluation of competing options, either for entire assets or parts thereof
- Performance trade-offs against cost (e.g. environmental performance).

2.2.1 Public Sector Drivers

Publicly funded projects to invest in constructed assets have a particular requirement for value for money and financial efficiency to be clearly demonstrated. The use of LCC is one means of achieving this and the need to evaluate the life cycle costs of a project or of investment options is now becoming firmly embedded in public procurement processes across Europe. Further guidance on the use of LCC in public procurement is provided in Section 4 of the guidance note.

2.2.2 Industry Drivers

Major construction clients have for some time been calling for better integration of LCC thinking into the procurement process as a means of achieving better performance and profitability from their core business operations. Constructed assets can have a significant impact on an organisation's operating costs and on the efficiency with which it operates. LCC methods can be used both in the identification of future costs and in their optimisation.

The following table illustrates the potential benefits of life cycle costing for various different parties in the industry.

Table 1: Benefits of Life Cycle Costing	
Public Sector Owners/Occupiers	Commercial Investors/Developers
<ul style="list-style-type: none"> • Demonstrate value for money procurement • Minimise long term running costs • Preserve asset value • Predictability of future costs • Ability to plan for future spend, e.g. sinking funds • Assess performance trade-offs against cost 	<ul style="list-style-type: none"> • Attract prospective tenants • Preserve long term asset value • Underpin funding mechanisms • Calculate service charge levels
Private Sector Occupiers	PPP Contractors
<ul style="list-style-type: none"> • Minimise operating costs • Facilitate budgeting & forward planning • Minimise disruption to business function • Preserve asset value • Satisfy leasehold requirements 	<ul style="list-style-type: none"> • Minimise operating costs • Facilitate budgeting & forward planning • Minimise disruption to business function • Ability to plan for future spend, • Assess performance trade-offs against cost • Satisfy contractual requirements

The common uses of, and outputs from the LCC process are considered further below.

2.3 Common uses of LCC

LCC may be applied in a wide range of circumstances in construction, for example in a project to invest in:

- A single complete constructed asset such as a building or civil engineering structure
- An individual component or assembly within a constructed asset
- A portfolio comprising a number of assets.

LCC may also be applied in the context of existing constructed assets, for example as a means of assessing future operational budgets or for evaluating refurbishment and renewal options.

The period of analysis adopted for an LCC exercise may similarly vary. LCC may be employed to inform decisions throughout the complete life cycle of a constructed asset (from its creation to final disposal/demolition) or for a selected limited period within it.

The purposes for which LCC may be employed can also be divided into two broad categories:

- As an absolute analysis, when used to support the processes of planning, budgeting and contracting for investment in constructed assets
- As a comparative analysis, when used to undertake robust financial option appraisals, for example in relation to potential acquisition of assets, design approaches or alternative technologies.

Fundamentally, LCC is a tool to support decision making, where the decision requires assessment of current and future costs (and revenues). The common range of applications of LCC in supporting decisions includes:

- In assessing the total cost commitment of investing in and owning an asset, either over its complete life cycle (“cradle to grave”) or over a selected intermediate period
- By improving understanding of the total cost of an asset, particularly by construction clients, and improving the transparency of the composition of these costs
- By facilitating effective choices between different means of achieving desired objectives, for example reducing energy use or lengthening a maintenance cycle
- By helping to achieve an appropriate balance between initial capital costs and future revenue costs
- In helping to identify opportunities for greater cost-effectiveness, for example selection of components with a longer service life or reduced maintenance requirements
- As a tool for the financial assessment of alternative options identified during a sustainability analysis, for example components with less environmental impact or HVAC systems with greater energy efficiency
- Overall, by instilling greater confidence in decision-making in a project.

LCC can be employed throughout or at different stages of the life cycle of an asset or a project to invest in construction; this is considered further in Section 5 below.

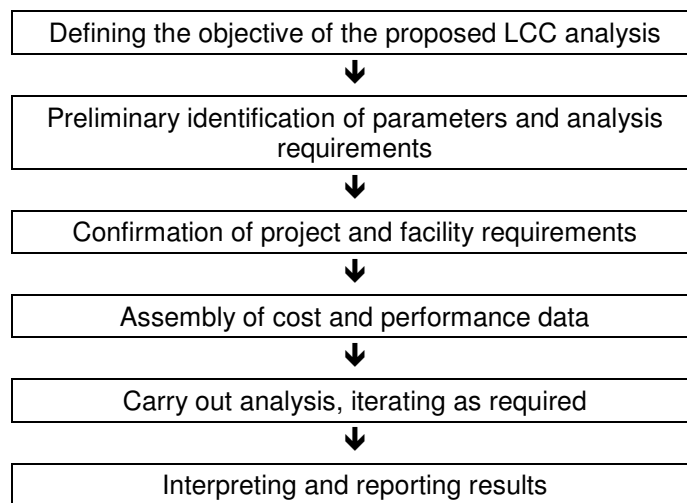
Table 2 below illustrates how LCC can be applied in a variety of circumstances, with examples drawn from a building development. The same principles apply in an infrastructure or engineering context. More detailed examples are provided in the case studies in Annex A of this document.

Table 2: Typical applications of LCC

Context and need	Typical application of LCC
During investment planning, clients will need to understand the full cost implications of operating as well as building the scheme, to establish its essential viability.	The analysis will be based on approximate data, typically historical information from similar projects, but sufficient for budgeting and option ranking to allow a decision on whether to go ahead, to reduce the scheme or stop.
During the early stages of scheme design, decisions will be required on the fundamental elements – structure, envelope, services, finishes	The analysis can draw on feasibility studies and pre-project professional advice, as well historical information, to support decisions on the key features of the scheme – its size, scope, method of construction and operation.
By detail design stage, the essential cost parameters of the scheme will be determined but decisions will still be required on details and whether, finally, to commit to construction.	Information can now be fed into the analysis based on a clear view of all primary elements of the scheme and access to related cost, service life and maintenance data from manufacturers' specifications, as well as similar projects and national price books. This allows a detailed LCC breakdown confirming the viability of the scheme and appraisal of detailed design options. Sensitivity and risk analyses may also be carried out.
Detailed design also requires final selection of materials, components and systems. Potentially, similar decisions will subsequently be required in the event of their replacement during operation and maintenance	LCC analysis can be focused on the specific component or system with the benefit of related cost, service life and maintenance data from manufacturers' specifications, as well as from similar projects and national price books. The main focus will be on option evaluation, ranking and selection.
During the operation of the completed asset refurbishment and renewal of some elements might be required, driven by (for example): <ul style="list-style-type: none"> • High operational costs • High energy consumption • Obsolescence (for example: physical, technical, economic, social) • Change in use of the asset • Components or systems reaching the end of their service life 	LCC can be applied in supporting selection of the most appropriate refurbishment or renewal option, at either an asset or component level. The analysis can be based on historic or benchmark data, or on detailed data derived from manufacturers' specifications and comparable cost-in-use data. It is essential that the analysis takes into account the impact on interdependent systems and the overall asset.

2.4 The core LCC process

Regardless of whether LCC is used to inform decisions throughout the life cycle of a constructed asset or only for a selected limited period within it, the core processes involve the same series of key steps in all circumstances. These steps are summarised below.

Figure 1: Core process of LCC

These key steps are explained in greater detail in the Methodology and are illustrated further in subsequent sections of this guide.

2.5 Interrelationship between LCC and sustainability analysis

Whilst LCC and LCA are two distinct and different processes that have developed and are practised as separate disciplines in the construction industry, there are many parallels and interrelationships between the two. For example, both:

- Are concerned with assessing the long term impacts of decisions
- Require analysis of an often diverse range of inputs
- Use similar data on inputs of materials and energy
- Take into account operation and maintenance
- Consider opportunities for recycling vs. disposal
- Provide a basis for rational decision making, particularly in appraising options.

However, the two disciplines differ in the basis of the resulting decisions:

- LCC combines all relevant costs associated with an asset into outputs expressed in financial terms as a basis for making investment decisions
- LCA enables decisions to be made on the basis of potential environmental impacts by scoring and rating on environmental criteria. Whilst costs can be firmly attributed to some environmental factors there is currently no widely agreed methodology for others and some cannot be quantified at all in cost terms.

As a result LCC and LCA do not necessarily produce a common output. Nevertheless environmental impact assessment has a key place in overall long term decision-making and consideration should be given to how to integrate it with the LCC process at the earliest stages.

2.6 How to integrate LCA and LCC

As discussed above, in LCC the primary driver in decision-making is cost and LCA informs decisions on the basis of potential environmental impacts. The use and sequence of LCC and LCA will depend on the priorities of the decision-maker. The range of approaches might cover, for example:

- Use of LCC and LCA as two of the criteria in the evaluation of a **single investment option** (such as the decision to construct an asset), where other evaluation criteria might include functionality, aesthetics, speed of construction, future investment returns etc.
- Use of LCC and LCA as two of the criteria in the evaluation of a **number of alternative investment options** (either entire constructed assets or specific components, materials or assemblies within them)
- Use of LCC to provide a financial/economic evaluation of those sustainability impacts that have a widely agreed and readily calculated monetary value
- Use of LCC to provide a financial/economic evaluation of alternative options identified in a LCA assessment
- Use of LCA as a means of identifying alternative options with a good environmental performance and then carrying out a LCC analysis on those options only
- Use of LCC to select cost effective options, then making a final decision in the light of a process of LCA carried out on those options only.

Thus it can be seen that LCC and LCA can either be used alongside each other in a broader evaluation process, or either process can form an input into the other.

3 Overview of the Common LCC Methodology

3.1 Stages in the Methodology

The key stages in the LCC Methodology and their broad sequence, are shown on the process map overleaf. The Methodology document describes the essential activities necessary to complete each stage in the process, and identifies what users can expect to have achieved having completed each stage. A summary of each stage and the outcomes that can be expected from it is provided below.

Table 3: Summary and overview of LCC Methodology

STEP	OUTCOME / ACHIEVEMENT
1 Identify the main purpose of the LCC analysis	<ul style="list-style-type: none"> • Statement of purpose of analysis • Understanding of appropriate application of LCC and related outcomes
2 Identify the initial scope of the analysis	Understanding of: <ul style="list-style-type: none"> • Scale of application of the LCC exercise • Stages over which it will be applied • Issues and information likely to be relevant • Specific client reporting requirements
3 Identify the extent to which sustainability analysis relates to LCC	Understanding of: <ul style="list-style-type: none"> • Relationship between sustainability assessment and LCC • Extent to which the outputs from a sustainability assessment will form inputs into the LCC process • Extent to which the outputs of the LCC exercise will feed into a sustainability assessment
4 Identify the period of analysis and the methods of economic evaluation	<ul style="list-style-type: none"> • Identification of the period of analysis and what governs its choice • Identification of appropriate techniques for assessing investment options
5 Identify the need for additional analyses (risk/uncertainty and sensitivity analyses)	<ul style="list-style-type: none"> • Completion of preliminary assessment of risks/uncertainties • Assessment of whether a formal risk management plan and/or register is required • Decision on which risk assessment procedures should be applied
6 Identify project and asset requirements -	<ul style="list-style-type: none"> • Definition of the scope of the project and the key features of the asset • Statement of project constraints • Definitions of relevant performance and quality requirements • Confirmation of project budget and timescales • Incorporation of LCC timing into overall project plan
7 Identify options to be included in the LCC	<ul style="list-style-type: none"> • Identification of those elements of an asset that are to be subject to LCC analysis

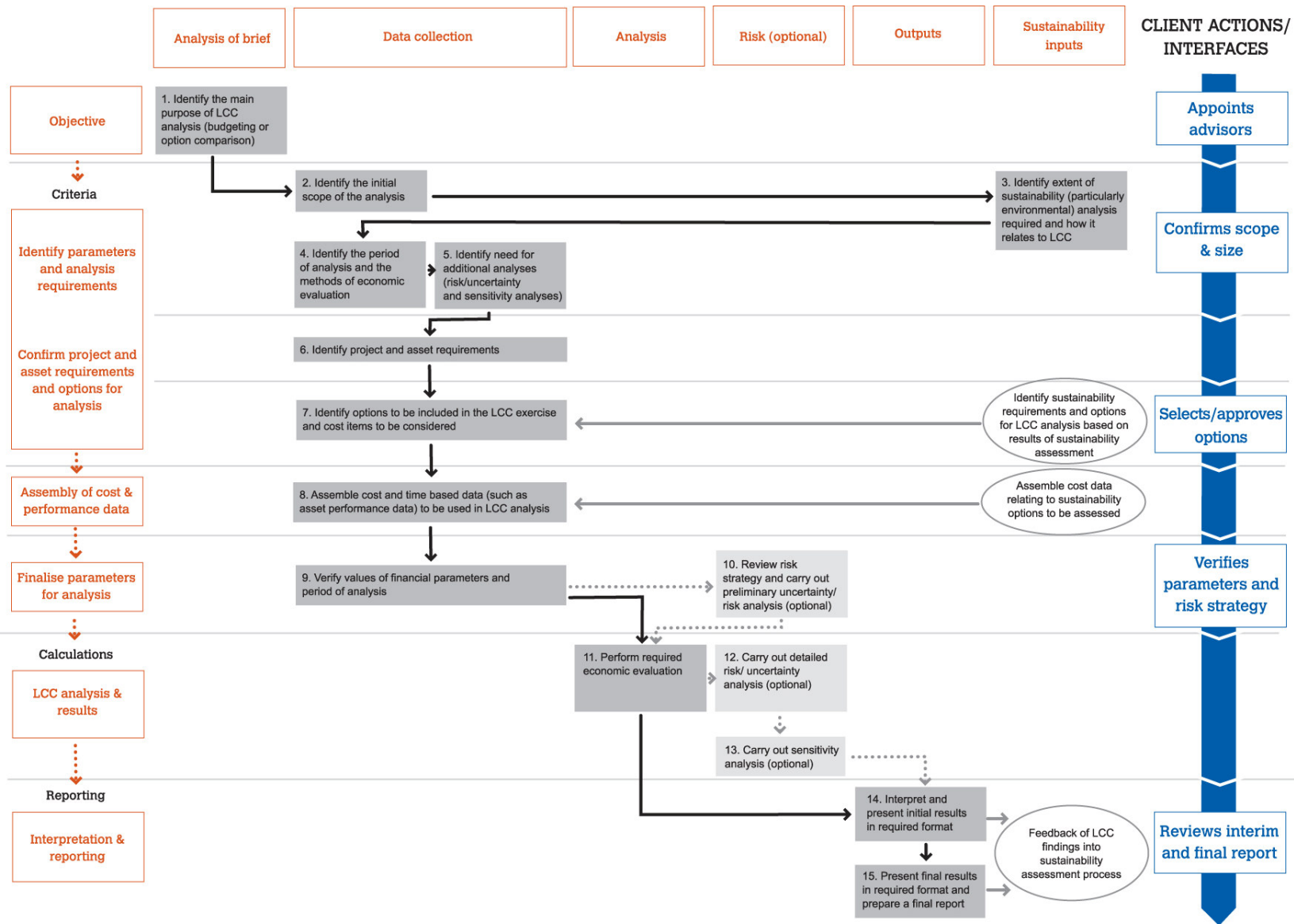
exercise and cost items to be considered	<ul style="list-style-type: none"> • Selection of one or more options for each element to be analysed • Identified which cost items are to be included
8 Assemble cost and time (asset performance and other) data to be used in the LCC analysis	Identification of: <ul style="list-style-type: none"> • All costs relevant to the LCC exercise • Values of each cost • Any on-costs to be applied • Time related data (e.g. service life/maintenance data)
9 Verify values of financial parameters and period of analysis	<ul style="list-style-type: none"> • Period of analysis confirmed • Appropriate values for the financial parameters confirmed • Taxation issues considered • Application of financial parameters within the cost breakdown structure decided
10 Review risk strategy and carry out preliminary uncertainty/ risk analysis	<ul style="list-style-type: none"> • Schedule of identified risks verified • Qualitative risk analysis undertaken – risk register updated • Scope and extent of quantitative risk assessment confirmed
11 Perform required economic evaluation	<ul style="list-style-type: none"> • LCC analysis performed • Results recorded for use at Step 14
12 Carry out detailed risk/uncertainty analysis (if required)	<ul style="list-style-type: none"> • Quantitative risk assessments undertaken • Results interpreted
13 Carry out sensitivity analyses (if required)	<ul style="list-style-type: none"> • Sensitivity analyses undertaken • Results interpreted
14 Interpret and present initial results in required format	<ul style="list-style-type: none"> • Initial results reviewed and interpreted • Results presented using appropriate formats • Need for further iterations of LCC exercise identified
15 Present final results in required format and prepare a final report	<ul style="list-style-type: none"> • Final report issued, to agreed scope and format • Complete set of records prepared to ISO 15686 Part 3

An important feature of the LCC process is its essentially iterative nature. This is partly because the process of construction design is also highly iterative, whereby proposals and solutions are identified initially and are then tested, validated and refined before becoming incorporated into the project. These processes involve decisions about choices of products, components, materials and other matters in terms of their costs, sustainability and other factors. The methodology allows for such iteration and for the progressive development and implementation of design and construction solutions, providing increasing certainty of the Life Cycle Cost of projects as they progress through design, construction and operating life.

3.2 Tailoring the Methodology to the specific project circumstances

It is important to note that in practice it will often be possible for users to combine several of the above steps in order to tailor the methodology to the size of the project, the project stage

and the level of detail required. For example, Steps 1 to 6 are concerned with defining the objectives and the analysis parameters. On smaller projects this definition exercise might typically take the form of a meeting or telephone discussion with the client and/or an exchange of correspondence. Similarly, the risk and sensitivity analyses might be incorporated into the economic evaluation exercise (Step 11) based on a small number of agreed parameters and/or the practitioner's experience of common risk issues. Regardless of the scale or scope of the exercise, the guiding principle should always be that the key issues identified in the methodology are all considered, albeit at a level of detail appropriate to the particular exercise.



4 The Common Methodology in public procurement

4.1 Key considerations for public procurers

The Common Methodology is designed to accommodate the needs of both public and private sector users of LCC on construction works projects, though the particular orientation of this guidance document is towards the public procurer.

Clearly, public and private users will have different objectives and considerations when contemplating investment/expenditure on works projects. In particular, public users may differ from their private sector counterparts in the extent of the duration of their interest in the constructed asset, and in the value they place on money, for example. The Common Methodology considers these aspects in detail, and the overall approach recognises that, whilst private and public users will put different values on these (and other) parameters, the underlying analysis processes are essentially the same for both of them.

However, the Guidance recognises that public users of the Common Methodology may wish to give special consideration to the values to be placed on particular parameters – depending of course on their own national government preferences for investment in the public arena – including:

- Low or zero real discount rates, reflecting the particular nature of public works projects as social rather than investment capital (see Step 4.4 of the Methodology)
- “Cradle to grave” (life cycle) or long periods of analysis (see Step 4.2 of the Methodology)
- Low or zero income/revenue flows
- Selection of systems and components based principally on their longevity/durability and sustainability performance (with a particular emphasis on environmental and societal impacts) – see Step 3 of the Methodology).

By using the Common Methodology, public procurers can ensure that they have taken account of all costs associated with buildings and built infrastructure over the life cycle of these assets. In this way they can and encourage the construction supply-side to be innovative in its approach and, in general, help improve the quality and sustainability of the public built environment.

4.2 Economic and regulatory context

4.2.1 Overview

Public procurement in the European Union (EU) is very significant, accounting for around 16% of the region’s GDP, equivalent to some €1,500 billion in 2005. In the construction sphere, procurement of works by public bodies accounts for some 20% of all public procurement.

The EU Procurement Directives set the legal framework for public procurement. Their purpose is to open up the public procurement market and to help ensure the free movement of goods and services within the EU. These Directives apply when Public Authorities and Utilities wish to procure building or civil engineering works, goods and/or services.

4.2.2 The Works Procurement Directive

Procurement of construction works is covered by the Works Procurement Directive (Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts). This Directive is implemented into national law across EU member states by their own legislation, and public authorities and utilities will, of course, need to be familiar with the relevant legislation in the country in which they operate.

A guide to procurement legislation is beyond the scope of this text, and interested readers are referred to http://ec.europa.eu/internal_market/publicprocurement/legislation_en.htm for further information. In particular, users of this guide should make themselves familiar with the requirements of the Works Procurement Directive in respect of:

- Bodies that are classified as Public Authorities and Utilities for the purposes of the Directive
- The contract value thresholds above which the Directive applies, and the exemptions that may be in place
- The use of Framework Agreements
- The basis on which tenders under the Directive may be invited and evaluated
- Circumstances governing the use of the Negotiated and Competitive Dialogue Procedures
- Other specific rules governing the application of the Directive.

Additionally, users should also be familiar with the wide range of EU and national legislation affecting the procurement, design, construction and operation of buildings and civil engineering structures throughout their life cycles. A discussion of all relevant legislation is well beyond the scope of this guidance document and users are referred to the Europa website (<http://ec.europa.eu/>) for further information about legislation at EU level.

4.3 Use of the Methodology in Public Procurement

This section contains general guidance on the use of the Common Methodology in public procurement in the EU. It is not intended to provide a definitive guide to the proper application of the requirements of the Works Directive. Users of this Guide should note that neither the authors nor the European Commission can be held liable for any loss, damage or expense arising from the use of the guidance in this document. Readers are recommended to take appropriate professional and/or legal advice to ensure that any proposals they may have for the use of the Common Methodology in public procurement comply with all relevant legislation.

4.3.1 Relevance

The Common Methodology is highly relevant to public works procurement and helps procurers consider all costs associated with the design, construction, operation and disposal of constructed assets. It can be used at two key works procurement stages:

- At Specification stage – the Works Directive permits the use of performance specifications, and allows sustainability and environmental issues to be included in the specifications. Specifications may also, of course, include requirements for low or optimum levels of life cycle costs; and
- At Award stage – the award of public works contracts under the Works Directive is essentially either on the basis of ‘lowest price’ or ‘the economically most advantageous

tender' (EMAT). The Common Methodology is particularly relevant to EMAT as this award basis permits life cycle costs to be taken into consideration.

4.3.2 Specifications and sustainability issues

The ability to use output or performance specifications supports competition and innovation in procurement. It allows procurers to stipulate requirements in respect of life cycle costs and sustainability/environmental considerations in particular, whilst leaving suppliers the freedom to propose how these will be delivered.

Section 4.4 below describes how the Common Methodology can be used to help take account of and improve the sustainability of construction and building.

4.3.3 Contract award and EMAT (economically most advantageous tender)

Public works contracts may be awarded on the basis of lowest price or EMAT. Note that these criteria are concerned with the contract *Award* process. Contract *Award* considers the proposals for the specific contract, and is quite separate from the *selection* or *pre-qualification* process which, under the Works Directive, considers the status and past performance of tenderers. The award of works contracts on an EMAT basis provides an excellent opportunity for procurers to take account of life cycle costs by using the Common Methodology.

The EMAT procedure was established because of concern over abnormally low tenders (ALTs) received using the lowest price option. Recent work by a Task Group¹, under the auspices of the DG Enterprise Working Group on Abnormally Low Tenders, made a series of recommendations on the award of contracts on the basis of the economically most advantageous tender. While these recommendations provide useful pointers for how LCC might be taken account of in an EMAT process, they have not generally been taken forward and currently there is no systematic guidance or methodology that is commonly in use across the EU on the evaluation of EMAT. It is important to consider briefly the main elements of an EMAT process to understand how LCC may be used effectively within it. EMAT should provide for a fair, transparent and accountable method for evaluating tender submissions, including:

- The award criteria
- The award mechanism against which tenders are evaluated
- The award procedure

Award criteria provide the principal opportunity to include life cycle costs in the Award process. This may be done by, for example, including quality and life cycle cost requirements as prominent criteria in the Award process.

The Common Methodology provides a sound and robust basis for estimating life cycle costs and fully supports the EMAT process. Costs assessed using the Methodology will be consistent and comparable, provided of course the definitions and calculation processes contained in the Methodology are clearly and consistently followed. Costs may, for ease of comparison, be broken down in accordance with the Methodology to provide a means of

¹ Report and Recommendations of the EMAT Task Group: A methodology that permits contract award to the Economically Most Advantageous Tender (Revised 15 August 2003)

assessing life cycle costs associated with the acquisition and ownership of constructed assets or facilities, for example:

- Acquisition (non-construction) costs, excluding costs beyond the control of tenderers
- Acquisition (construction) costs
- Operating costs
- Maintenance costs
- Replacement costs
- Disposal/end of life costs

The **Award mechanism** should provide a structured approach to evaluating tenders. In practice a variety of mechanisms are used to score tenders against the award criteria and to combine these scores into a (weighted) aggregate score for each tender as a whole. The **Award procedure** should provide a fair and accountable means of undertaking the award process. Guidance on appropriate mechanisms and procedures is beyond the scope of this document, but readers should note that proper application of the Common Methodology provides a transparent and consistent basis for the comparison of bids on the basis of their life cycle costs.

Note that EMAT is governed by certain rules which include publication of the criteria and the relative weightings given to each of them (or, where this is not feasible, stating the award criteria in order of importance) in order to judge which tender is the economically most advantageous. The selection of award criteria and their relative priorities/weightings is a matter for individual procurers and the reader is referred to the regulations and other relevant procurement guidance for further information.

4.3.4 The particular circumstances of PPP projects

The Methodology is likely to be particularly relevant to Public-Private Partnership (PPP) projects, which are becoming an increasingly common method for the procurement of public assets across Europe. Under a PPP project a provider contracts to provide and maintain an asset over a defined concession period (typically 25 to 30 years), for a fixed monthly fee determined prior to commencement of the project. At the end of the term the ownership and operation of the asset reverts back to the Public Sector client.

The PPP contract may require the provider to deliver some or all of the operational/FM services during the concession period; maintenance and replacement works are almost always included. A robust assessment of the relevant operational costs is therefore of prime importance to the provider.

The PPP process and its various inputs and deliverables is complex, however the typical applications of LCC process might include:

- During the initial business cases stage, the Public Sector client uses historic LCC data to enable a broad analysis of alternative options to be made and the business case for the project to be proven.
- During the tender stages, the bidders prepare LCC models, initially using high level historic data to support early financial modelling, then developing detailed LCC models as design progresses. Several iterations of the models are likely, as the bidder refines and optimises all cost inputs. Some ‘smoothing’ of annual costs (i.e. spreading of cost peaks over two or more years to better reflect income streams) may also be necessary.

- Bidders are also likely to carry out LCC assessments of alternative design/specification options at this stage.
- During the tender stages the Public Sector client may also prepare its own LCC models based on an exemplar design (often referred to as a Public Sector Comparator), as a means of evaluating the LCC models submitted by the bidders.
- Further refinement of life cycle costs may occur as part of the short-listing of bidders. A due diligence exercise is also likely to be carried out by both the client and the bidder's funders.
- Once a preferred bidder is selected the detailed LCC models setting out the expected expenditure throughout the concession period are incorporated into project financial models and contracts. For example, the provider may sub-contract defined maintenance and replacement works to a third party, or the Public Sector client may specify replacement periods for key elements in the contracts.
- During construction and operation of the facility the detailed LCC models are updated to reflect any changes or variations in the project, or in the specification of components and materials within it.
- The LCC models are regularly updated throughout the concession period and are used as a tool for managing maintenance and replacement works and for ensuring the necessary funding for such works is in place. The client may also use the models as a monitoring tool to ensure the necessary works are being carried out.

4.4 How the Methodology supports Sustainability

Sustainability is now a critical consideration affecting the design, construction, operation and disposal of constructed assets. The LCC Methodology is a key element in supporting improvements in the sustainability of the built environment, by providing a common means for all costs associated with constructed assets to be assessed and compared on a comparable basis.

The environmental impact of constructing and maintaining the built environment is a particularly important element of sustainability. In general, the materials and products used in construction cause environmental impacts due to the interrelated processes of manufacture, transport, assembly/disassembly, maintenance and disposal associated with them. Additionally, constructed facilities generate a significant environmental impact in their own right due to the operations carried out on and within them. Taken together, these environmental impacts are highly significant and should be addressed at the design/project planning stage of works projects.

The LCC Methodology allows for the assessment of the cost effects of these impacts, so that balanced decisions can be made on the life cycle costs of mitigating/reducing environmental impact. Additionally, the Methodology identifies 'opportunity points' for the assessment of the cost impacts of the results of environmental analysis (such as Life Cycle Assessment – LCA). Whilst it is not yet possible to integrate fully the results of LCC with environmental assessment methodologies such as LCA – and this topic is covered further in Section 2.6 of this Guide – it is important to ensure that the cost implications of environmental impact are fully understood and taken account of in an LCC analysis. This will help ensure that best value solutions in both economic and environmental terms are identified.

5 Further guidance on the application of the LCC Methodology in construction

5.1 Introduction

This section provides further guidance on the effective implementation of the Methodology in the context of its three most common applications in the construction industry, namely:

- Preliminary analysis for strategic investment decisions
- Detailed analysis of an entire asset
- Detailed analysis of a system or component for option assessment

These instances do not cover all possible applications of the Methodology but are intended to illustrate a sufficiently broad range of applications to enable users to identify for themselves how they will undertake Life Cycle Costing for their particular needs and within the context of their particular project.

An overview of the three common applications is provided in Table 4 below.

Use of LCC	Purpose	When used
Preliminary analysis for strategic investment decisions	To provide a high level assessment of all relevant costs over the life cycle of an asset to support a strategic decision on whether or not to proceed with a project or to compare high level strategic options for the project	During preparation of a strategic business case. As part of strategic option appraisal process. At pre-planning & early planning stages of a project.
Detailed analysis – whole asset	To provide a detailed assessment of the life cycle costs of an entire asset for the purposes of budgeting or design/ investment decision making	At scheme/detailed design stages of a project. On completion/ purchase/ occupation of an asset. During occupancy. Prior to carrying out refurbishment/ remodelling works.
Detailed analysis – system/component option assessment	To provide a detailed assessment of the life cycle costs of one or more options for a system/component in order to support design decisions.	At detailed design stages of a project. During operational phase prior to maintenance/ replacement works. At the disposal stage.

Throughout the following guidance, users are referred to the relevant Steps in the detailed Methodology document.

5.2 Example 1: Preliminary analysis for strategic decisions

5.2.1 Overview

This use of LCC typically applies to the early planning stages of a project, where a business case is being prepared and high level strategic investment options are being considered. The LCC analysis is used to assess in aggregate all relevant costs over the life cycle of the asset to support a strategic decision on whether or not to proceed with a project or to compare high level options for the project (such as whether to build new or to refurbish an existing facility). The level of detail in the analysis is of low granularity and the period of analysis is typically long (e.g. 60 years or more).

5.2.2 Objectives of the analysis (Step 1)

The primary objective of undertaking an LCC analysis in this instance is to enable the projected life cycle costs of a proposed asset or of alternative investment options to be taken into account during the strategic decision making process. The analysis is typically undertaken at the very early stages in a project where the strategic business case is being prepared and high level decisions on whether to proceed or on the nature and extent of the project are being taken. At this stage it is unlikely that any design work will have been undertaken beyond initial feasibility studies. Therefore, the exercise will, by necessity, be carried out at a high level using benchmark data and broad assessments of future costs.

Typical objectives for the LCC analysis at this stage might include:

- To underpin strategic decisions about investment
- To plan future investments
- To forecast a portfolio's future performance
- To inform how an asset or a portfolio fits an organisation's strategy
- To set future operational budgets
- To assess the long term affordability of a proposed asset or alternative asset options
- To assess alternative funding/financial arrangements
- To budget the proposed portfolio of assets for strategic type of decisions – e.g. affordability, size of the portfolio, size of the asset, etc.
- To compare alternative strategic options for an investment, such as:
 - Alternative locations
 - Alternative asset types or mixes of use
 - Alternative project sizes and forms
 - Whether to build new or to refurbish an existing asset

5.2.3 Scope of the analysis (Step 2)

Confirmation of the precise scope and extent of the LCC exercise with the client is a key early stage in the process and should include:

- The purpose for carrying out the LCC exercise
- The timing of the exercise and any key deadlines
- Any specific reporting requirements
- How the exercise relates to the overall business case or strategic option appraisal process.

5.2.4 Identifying the key parameters for the analysis (Steps 3-6, 9)

The key parameters for the analysis will be determined to a large extent by its purpose and objectives, and by the nature of the client organisation. For example, a public sector client may be bound by national treasury requirements regarding one or more of the period of analysis, standard options to be considered, method of economic evaluation or discount rates to be used. A commercial developer on the other hand, will be constrained more by its internal requirements on investment returns or on issues relating to financing costs or market needs.

Key parameters are discussed below:

Costs to include

For strategic investment purposes in the public sector it is usually necessary to include all relevant costs relating to the acquisition, use, maintenance and disposal of the proposed asset. Private sector clients whose economic or legal interest in the asset differs from public sector clients, may decide to omit certain costs that will be borne by others (e.g. energy and certain maintenance costs to be borne by tenants). A decision will also be required on whether to include any incomes (such as rent or income from the sale of locally generated energy) in the analysis. For private sector clients it is likely that any incomes would be included in the analysis, however this will not always be the case for public sector clients.

Period of analysis

For strategic investment decisions in the public sector it is typical for a long period of analysis of 50 to 100 years to be selected, to reflect the anticipated total life-span of the asset (cradle to grave). Private sector clients may select a shorter time frame linked to the need for shorter term investment returns. If the period of analysis is unclear, the client may need to consider its likely long term interest in the project in terms of physical, economic, functional, technological and social “lives”.

Project & asset requirements

The main purpose of this stage is to gather all available information about the project and the asset. Little detailed information is likely to be available, but some broad parameters need to be discussed and agreed with the client regarding the functional use of the asset and the physical characteristics, performance requirements, design/service life, etc., if known at this stage. Identification of key project constraints is also important in order to ensure the validity of the analysis findings.

Method of economic evaluation

Net present value and payback period analysis are the most commonly used economic evaluation methods for supporting high level strategic investment decisions, with the latter being more commonly used in the private sector than in the public sector where financial returns may be of less significance. The level of discount rate used can have a significant impact on the outcome of the analysis – potentially determining whether a scheme is financially viable, or whether one strategic option is preferable to another. It is therefore of key importance to select the appropriate rate. For public sector projects the discount rate may be prescribed by national treasuries (typically 3-5%). For private sector clients the rate may be determined by the organisation’s anticipated or required rate of return, or the

‘opportunity cost’ of the capital employed. Further guidance on discount rates is provided in Section 4.4 of the Methodology.

Extent of environmental sustainability input

Since the LCC analysis at this stage is carried out at a high level before detailed project information becomes available, the inclusion of any environmental sustainability assessment data will by nature be at a high level only. However, users may wish to include allowances for the costs associated with specific environmental provisions such as achievement of a high environmental performance rating or for renewable energy targets. It is also likely that an assessment of the non-financial environmental impacts of the project will be included in the overall strategic business case assessment.

Risk & sensitivity analysis

Life cycle costs assessed at the strategic business case stage will, by necessity, be based on a low granularity of detail and will therefore contain a higher level of uncertainty than those prepared during the detailed design stages. It is essential that this uncertainty is understood by clients and is fully accounted for in the decision making process that the LCC analysis informs. For example, it is good practice to provide a range of expected life cycle costs rather than a single figure, or to state that the costs are likely to be accurate to within plus or minus a defined percentage (typically +/- 20% at this very early project stage). The LCC analysis should also be accompanied by a risk analysis setting out the key assumptions and variables, and the key causes of uncertainty and variability. This is particularly important where the LCC exercise has, as is typical at the strategic decision making stages of a project, been informed by historic benchmark data from previous projects.

Since the outcomes of the LCC exercise can have a significant influence on key strategic decisions, it is also good practice to carry out a sensitivity analysis to assess the impact of changing key variables such as discount rates, inflation assumptions and cost and time inputs. The outcome of such an exercise can have a major impact on the strategic decision making process, for example an increase in the assumed energy price inflation levels could result in one option becoming significantly more or less advantageous than another.

5.2.5 Identify options to include in the LCC exercise (Step 7)

Depending on the purpose of the LCC analysis, there may be a requirement to assess one option only, or to compare a number of defined options for achieving the client’s requirements. As part of the approval process for a project business case it is likely that the selected options for evaluation will need to include a ‘do nothing’ and/or a ‘do minimum’ option. It may also be appropriate to consider alternative means of achieving the client’s objectives which do not require a new construction project. For example, a strategic business case assessment for a new office building might include options for more efficient use of existing facilities, or for equipping staff for home-working such that a new building is not required.

Typical options considered at the strategic business case stage include:

- Alternative methods of achieving a client’s objectives
- The effects (including cost) of not carrying out the project
- Alternative uses of an asset
- Alternative investment options

- Alternative project scope
- Choice between alternative scheme designs or configurations for the asset
- Whether to adapt/refurbish an existing asset or to construct a new one.

5.2.6 Assemble data (Step 8)

Since the LCC exercise is carried out at the early strategic decision making stage of a project it is unlikely that detailed design or cost data will be available. The analysis is therefore likely to draw primarily on generic data sources, typically historic benchmark data drawn from the client's own records, the records of professional advisors and published data sets. Data is likely to be at a broad level such as cost per metre squared per annum, or per building user.

The reliability of the benchmark data and its relevance to the project in question are of paramount importance, since key decisions will be influenced by the results of the analysis.

Key considerations will include:

- The origins of the data used
- Whether the data is representative (i.e. the number of projects from which any benchmark data is derived)
- The applicability of the data to the project in question (e.g. whether the data relates to similar building types and configurations)
- The need to adjust the data to account for regional cost variations and to inflate historic costs to current levels

5.2.7 Carry out LCC analysis (Steps 11-13)

At this stage the asset and project data and the values of key parameters are input into an LCC calculation tool (typically a spreadsheet or database tool), and the analysis is carried out according to the methods of economic evaluation selected during the earlier scoping stages. At this stage users will also undertake any risk/uncertainty assessment, including sensitivity analysis of key variables.

5.2.8 Reporting (Steps 14, 15)

At this stage in a project the reporting output will be used to inform a decision on whether to proceed with a project, or on which strategic option is to be developed further. The lack of available design information prevents detailed LCC models from being prepared. Instead, the output may be a simple schedule comparing the life cycle costs of the selected or alternative options, accompanied by a summary report and a sensitivity analysis setting out the analysis parameters, any assumptions made, and highlighting the potential uncertainty and variability in the findings. The key issue at this strategic decision making stage is to alert users to the high level nature of the assessments and the inherent variability and uncertainty of the findings. The report should include information on the origins and validity of the data used in the assessments, and guidance on the reliance that can be placed on the findings.

The LCC report would typically include the NVP of each option identified, tabular and graphical analysis showing the sensitivity of the NPV to changes in key variables, and where required, a payback period analysis along with a graphical representations of the time taken to recoup any additional investment.

5.3 Example 2: Detailed analysis of an entire asset

5.3.1 Overview

The “classic” use of LCC is in the detailed assessment of the life cycle costs of an entire constructed asset as part of a more detailed design/investment decision-making or budgeting process. Such instances typically arise when the project team is in place and the design is either under detailed development or completed. This example can also suit circumstances in which major design decisions need to be reviewed. It is also applicable to the operational phase of an asset, where it can be used both as a budgeting tool and as a means of evaluating future remodelling/refurbishment options. The level of detail in the analysis is of high granularity. The period of analysis depends on the duration of the user’s interest in the asset but is typically 25 years or more.

It should be noted that the detailed LCC analysis discussed in this section is often undertaken in parallel with the detailed system/component level analysis discussed in Section 5.4 below, as part of an integrated LCC process on a project. A typical sequence of events is as follows:

- a) Indicative LCC models are prepared for the asset at the early design stages (see Section 5.2 above)
- b) Detailed LCC models for the entire asset are prepared once detailed designs and cost plans become available
- c) As part of the project value management/value engineering process, key systems/components are selected, alternative options identified and LCC analysis carried out as discussed in Section 5.4
- d) Options selected using the system/component level LCC option analysis are integrated into the design and into further iterations of the detailed LCC analysis for the entire asset.

In common with the overall design process, the above process is often iterative in nature.

5.3.2 Objectives of the analysis (Step 1)

The primary objective of undertaking an LCC analysis in this instance is to provide a detailed, robust analysis of the life cycle costs of an entire asset, based on detailed design/construction information. The analysis is typically undertaken at the detailed design stages of a project or during the occupancy stage, either to inform decisions on alternative options, or as a tool for budgeting future costs.

Typical objectives for the detailed LCC analysis of an asset might include:

- To budget the proposed asset, i.e. to identify the economic implications of owning/operating the asset over its entire life cycle or a more limited period of time such as a period of economic interest or business planning cycle
- To assess alternative design options for the asset in detail, e.g. extent of refurbishment or new building works, or alternative design solutions
- To negotiate contract details with the client (e.g. in relation to PPP or build-operate-maintain contracts)
- To establish the general impact on sustainability and environment for various options

- To budget the asset for selected stages of its life cycle – e.g. construction and short term operation, operation, maintenance (O&M), disposal only, etc.
- To prepare maintenance/asset renewal plans and FM models
- To calculate the residual value at the end of the contract

5.3.3 Scope of the analysis (Step 2)

Confirmation of the precise scope and extent of the LCC exercise with the client is a key early stage in the process and should include:

- The purpose for carrying out the LCC exercise
- The stage(s) in the project or in the asset life at which the exercise is to be carried out
- The timing of the exercise and any key deadlines
- Any specific reporting requirements

This scoping exercise is of key importance in informing future stages in the LCC process and is closely linked to the following section on identification of the key analysis parameters.

Where the detailed LCC analysis is to be carried out as part of the design stages of a project its timing will require careful planning. The exercise is best undertaken once sufficiently detailed designs, specifications and cost plans are available, but before they have been ‘frozen’, in order that any cost optimisation measures identified as part of the LCC exercise can be fed back into the design process in a timely manner.

5.3.4 Identifying the key parameters for the analysis (Steps 3-6, 9)

The key parameters for the analysis will be determined to a large extent by its purpose and objectives, and by the nature of the client organisation. For example, a public sector client may be bound by national treasury requirements regarding one or more of the period of analysis, method of economic evaluation or discount rates to be used. A commercial developer on the other hand, will be constrained more by its internal requirements on investment returns or on issues relating to financing costs or market needs.

Key parameters are discussed below:

Costs to include

The costs to be included in the exercise will depend on the stage in the asset life cycle at which the exercise is carried out, the objectives of the exercise, and the client’s economic and legal interest in the asset. For example, a public body that is to own and occupy an asset is likely to require all acquisition, use, maintenance and, depending on the time-frame, disposal costs to be included. However, a private sector client with a different economic or legal interest in the asset may decide to omit certain costs that will be borne by others (e.g. energy and certain maintenance costs to be borne by tenants). Similarly, a PPP provider might omit some facilities management costs if these activities are to be carried out by the public sector occupier.

A decision will also be required on whether to include any incomes (such as rent or income from the sale of locally generated energy) in the analysis. For private sector clients it is likely that any incomes would be included in the analysis, however this will not always be the case for public sector clients.

Period of analysis

As with the costs to be included in the analysis, the period of analysis may vary according to the client's economic and legal interest in the asset. A public body that owns and occupies an asset would typically select a longer analysis period of 50 years or more to reflect the anticipated total life-span of the asset (cradle to grave). Private sector clients may select a shorter time frame linked to the need for shorter term investment returns, or to the length of their financial interest in the asset. A PPP provider, for example, would typically select a period of 25-30 years to match the length of the PPP concession (it is also common for PPP clients to require a further 5 years of life cycle costs to be modelled beyond the concession period in order to evaluate their future cost burden when the asset is returned to them).

It should be noted that national guidance on the appropriate period of analysis varies from country to country. In some EU countries a 'cradle to grave' definition of the term 'life cycle' is adopted in order to promote sustainable development, whilst in other countries shorter periods may be selected.

Project & asset requirements

The main purpose of this stage is to gather all available information about the requirements for the project and the asset, including the required functions and physical requirements, the quality requirements and any project constraints such as budget and programme. This information is key to the identification of alternative options to be assessed as part of the LCC exercise.

Method of economic evaluation

Discounting to net present value is the most widely used economic evaluation method for both public and private sector clients. Payback period, and to a lesser extent, internal rate of return analysis, are commonly used in the private sector, where incomes and investment returns are typically included in the LCC analysis. The level of discount rate used requires careful consideration, particularly where LCC is being used in the evaluation of alternative design solutions, where it can have a significant impact on the outcome of the analysis. As stated in Section 5.2 above, discount rates of 3-5% are commonly prescribed for use in the public sector, while private sector clients often opt for a higher rate to reflect their anticipated or required rate of return, or the 'opportunity cost' of the capital employed. Further guidance on discount rates is provided in Section 4.4 of the Methodology.

Extent of environmental sustainability input

At the detailed design stages it is likely that the LCC analysis will be required to include an assessment of environmental sustainability issues. This may include modelling of energy costs or of other quantifiable environmental 'costs'. It may also include identification of the additional life cycle cost 'premium' arising from the use of more sustainable products, or of the payback period for sustainable options that generate cost savings or income streams (e.g. renewable energy sources that generate a surplus which is sold back to a utilities provider).

The links between LCC and environmental sustainability are considered further in Sections 2.6 and 4.4 of this guidance note.

Risk & sensitivity analysis

The extent to which risk and sensitivity analysis are incorporated into the LCC analysis process will depend on the specific client and project requirements and on the uses to which the LCC data are to be put. While LCC models prepared at the detailed design stages will, by their nature, contain a lower level of uncertainty than those prepared during the early project stages, it is important to recognise that an element of uncertainty and variability in the prediction of the future costs and timings of works will always remain. It is important that clients are made aware of this and that appropriate steps are taken to quantify and, where relevant, mitigate these risks.

Depending on the client requirements and the scope of the LCC exercise, the risk analysis might range from a simple schedule of potential risks, to a detailed qualitative and/or quantitative risk assessment using techniques such as Monte Carlo Analysis (see Section 5 of Methodology). However, in all cases it is important that the client is made aware of the potential variability and uncertainty inherent in the LCC analysis, in order to prevent undue reliance being placed on the data and to encourage mitigation such as inclusion of contingency allowances in the model.

It is always good practice to include some form of sensitivity analysis in the LCC exercise, in order to assess the impact of changing key variables such as discount rates, inflation assumptions and key cost and time inputs. The key objective is to test whether any one variable has a significant effect on the overall findings. This is particularly important where two or more design solutions are being assessed in the LCC analysis and where a minor change in one variable may alter the relative ranking of different options.

5.3.5 Identifying options to include in the LCC exercise (Step 7)

In this context of the use of LCC in analysing the life cycle costs of an entire asset, the identification of options to include in the exercise is likely to be limited to alternative design solutions put forward for analysis by the design team. The client brief would identify whether or not alternative design solutions are to be evaluated as part of the exercise.

Typical examples might include:

- Designs which differ significantly in form or layout
- Designs which differ in construction methods such as structural frames, cladding methods etc.
- Designs with significantly different mechanical and electrical solutions
- Alternative designs for the refurbishment or replacement of an asset.

Note: the evaluation of alternative design options for individual systems and components is discussed in Section 5.4 of this guidance note.

5.3.6 Assemble data (Step 8)

The design, specifications and cost plans for the project are typically the starting point for the LCC exercise. These enable a schedule of works, cost items and quantities to be assembled, which forms the basis of the LCC model. For operational assets, this data may be supplemented or replaced by condition survey data.

Data on operating costs such as facilities management is generally obtained either from a build up of the likely facilities management resources and costs, or from historic benchmark

data from similar projects. Similarly, energy usage data may either be calculated for the specific project, or derived from historic benchmark data or norms.

Data on the service lives and maintenance requirements of specific systems and components can be obtained from manufactures and suppliers, published reference sources, historic data or from professional advisors' own records.

Further guidance on data sources and on the identification of relevant on-costs such as site preliminaries and management costs is provided in Section 8 of the Methodology.

5.3.7 Carry out LCC analysis (Steps 11-13)

At this stage the project data identified above, along with the key parameters, is input into an LCC calculation tool (typically a spreadsheet or database tool), and the analysis is carried out according to the methods of economic evaluation selected during the earlier scoping stages. At this stage, users will also undertake and risk/uncertainty assessments, including sensitivity analysis of key variables.

Once an initial LCC model has been generated it is common for the user to refine and adapt the model in consultation with the client. This process might typically include minor changes to variables such as maintenance intervals or component service lives to reflect client requirements, 'smoothing' of peaks in expenditure in order to reflect likely income streams, or grouping of key life cycle works into defined remodelling/refurbishment exercises. This refinement reflects the iterative nature of the LCC modelling process.

5.3.8 Reporting (Steps 14, 15)

In addition to a written report setting out the key analysis parameters, assumptions, data sources and findings, the reporting output from this detailed LCC exercise might include one or more of the following:

- Detailed LCC models setting out total costs over the required analysis period
- Maintenance plans setting out future maintenance and renewal costs
- Cost advice (NPV) for comparison of design options
- Risk assessment report and sensitivity analysis on key parameters
- Schedule of replacement cost items with life expectancies
- Cost advice for optimising the performance of an existing asset during the remaining period of its life cycle
- Cost advice for optimising design, construction and operational costs
- Results from other economic evaluation methods – for example, Payback Analysis, Net Savings/Net Benefit, Savings to Investment Ratio, Annual Cost and Annual Equivalent Value (see Methodology, Section 11.5).

Detailed guidance on the content of LCC reports is provided in Sections 14 and 15 of the Methodology. Sample tabular and graphical outputs from LCC exercises are provided in Annex A of the Methodology and in the case studies included as Annex A of this guidance note.

5.4 Example 3: Detailed analysis for evaluation of system/component options

5.4.1 Overview

This example applies to the analysis of individual systems, components or assemblies, typically during the detailed design phase or during the operational phase when planning maintenance or replacement works. It is most commonly used as a means of evaluating alternative options, for example in design, specification, materials or configuration. The analysis can be applied to entire systems or components within an asset (e.g. a HVAC system, a wall cladding installation, or the like) or to individual parts within a system or component (e.g. fans, pumps, roof and wall finishes). Assessments may be required for the whole asset life cycle (cradle to grave), for the life cycle of the individual system or component, or for some other period related to the client's interest in the asset. The purpose of LCC in this instance is to enable the total costs of alternative options for the design and specification of components and systems to be assessed, in order that design decisions can be made. The level of detail in the analysis is of high granularity.

It should be noted that the detailed system/component LCC analysis discussed in this section is often undertaken in parallel with the detailed LCC analysis of an entire asset discussed in Section 5.3 above, as part of an integrated LCC process on a project. A typical sequence of events is as follows:

- a) Indicative LCC models are prepared for the asset at the early design stages (see Section 5.2 above)
- b) Detailed LCC models for the entire asset are prepared once detailed designs and cost plans become available (see Section 5.3 above)
- c) As part of the project value management/value engineering process, key systems/components are selected, alternative options identified and LCC analysis carried out as discussed in this section
- d) Options selected using the system/component level LCC option analysis are integrated into the design and into further iterations of the detailed LCC analysis for the entire asset.

5.4.2 Objectives of the analysis (Step 1)

The primary objective of undertaking an LCC analysis in this instance is to provide a robust assessment of the life cycle costs of alternative design or specification options at a system or component level, based on detailed design/construction information. The analysis is typically undertaken either at the detailed design stages of a project or during the occupancy stage, as a tool for comparing the total costs of alternative options over a defined analysis period. It can also be undertaken to evaluate a single option, for example in order to assess the additional costs and/or payback period for additional expenditure on a system/component with an improved environmental sustainability profile. Manufacturers and suppliers may also use LCC to evaluate specific products as part of their technical backup or marketing activities.

5.4.3 Scope of the analysis (Step 2)

Confirmation of the precise scope and extent of the LCC exercise with the client is a key early stage in the process and should include:

- The purpose for carrying out the LCC exercise
- The stage(s) in the project or in the asset life at which the exercise is to be carried out
- The timing of the exercise and any key deadlines
- Any specific reporting requirements

Where the detailed LCC analysis is to be carried out as part of the design stages of a project its timing will require careful planning. The exercise is best undertaken once sufficiently detailed designs, specifications and cost plans are available, but before they have been ‘frozen’, in order that the preferred options identified as part of the LCC exercise can be fed back into the design process in a timely manner.

Since this particular use of LCC is most commonly concerned with assessment of alternative design or specification options, it is often carried out within a workshop setting, either as a specific LCC workshop or as part of a broader Value Management or Value Engineering workshop. Project stakeholders including the design team and often the client and building users and managers are assembled in a workshop setting to identify which systems/ components are to be assessed, and to identify a number of design/specification options for each. The detailed LCC analysis is then usually carried out outside of the workshop setting and results are fed back to participants. Clearly, LCC is likely to form one of a number of criteria in the option assessment process, with others potentially including aesthetics, functional performance, environmental sustainability, ease of construction, etc.

5.4.4 Identifying the key parameters for the analysis (Steps 3-6, 9)

The key parameters for the analysis will be determined to a large extent by its purpose and objectives, and by the nature of the client organisation. For example, a public sector client may be bound by national treasury requirements regarding one or more of the period of analysis, method of economic evaluation or discount rates to be used. A commercial developer on the other hand, will be constrained more by its internal requirements on investment returns or on issues relating to financing costs or market needs.

Key parameters are discussed below:

Costs to include

The costs to be included in the exercise will depend on the stage in the asset life cycle at which the exercise is carried out, the objectives of the exercise, and the client’s economic and legal interest in the asset. For example, a public body that is to own and occupy an asset is likely to require all acquisition, use, maintenance and, depending on the time-frame, disposal costs to be included. However, a private sector client with a different economic or legal interest in the asset may decide to omit certain costs that will be borne by others (e.g. energy and certain maintenance costs to be borne by tenants). Similarly, a PPP provider might omit some facilities management costs if these activities are to be carried out by the public sector occupier.

A decision will also be required on whether to include any incomes associated with the system/component (such as income from the sale of locally generated energy, or recycle

value) in the analysis. For private sector clients it is likely that any incomes would be included in the analysis, however this will not always be the case for public sector clients.

Period of analysis

As with the costs to be included in the analysis, the period of analysis may vary according to the client's economic and legal interest in the asset. A public body that owns and occupies an asset would typically select a longer analysis period of 50 years or more to reflect the anticipated total life-span of the asset (cradle to grave). Private sector clients may select a shorter time frame linked to the need for shorter term investment returns, or to the length of their financial interest in the asset. A PPP provider, for example, would typically select a period of 25-30 years to match the length of the PPP concession (it is also common for PPP clients to require a further 5 years of life cycle costs to be modelled beyond the concession period in order to evaluate their future cost burden when the asset is returned to them).

It should be noted that national guidance on the appropriate period of analysis varies from country to country. In some EU countries a 'cradle to grave' definition of the term 'life cycle' is adopted in order to promote sustainable development, whilst in other countries shorter periods may be selected.

Where the LCC analysis is to be carried out for a single system or component, it may be appropriate to select an analysis period that is identical to its predicted service life. This would enable a 'cradle to grave' analysis to be carried out. However, where two or more systems or components are to be evaluated it is usually more appropriate to select an analysis period linked to the design life of the asset or to a client's financial or legal interest in it.

Project & asset requirements

The main purpose of this stage is to gather all available information about the requirements for the project and the asset, including the required functions and physical requirements for the system/component under review, the quality requirements and any project constraints such as budget and programme. This information is key to the identification of alternative options to be assessed as part of the LCC exercise.

Method of economic evaluation

Discounting to net present value is the most widely used economic evaluation method for both public and private sector clients. Payback period, and to a lesser extent, internal rate of return analysis, are commonly used in the private sector, where incomes and investment returns are typically included in the LCC analysis. The level of discount rate used requires careful consideration, particularly where LCC is being used in the evaluation of alternative design solutions, where it can have a significant impact on the outcome of the analysis. As stated in Section 5.2 above, discount rates of 3-5% are commonly prescribed for use in the public sector, while private sector clients often opt for a higher rate to reflect their anticipated or required rate of return, or the 'opportunity cost' of the capital employed. Further guidance on discount rates is provided in Section 4.4 of the Methodology.

Extent of environmental sustainability input

As stated previously, LCC is commonly used as a means of comparing alternative design/specification options with differing environmental sustainability ratings. It enables any 'sustainability cost premium' for more sustainable options to be identified, and, where

relevant, for the payback period to be assessed for sustainable options that generate cost savings or income streams (e.g. renewable energy sources that generate a surplus which is sold back to a utilities provider). A common use of LCC in this context is in identifying the ‘break-even’ point for an option such as a heating or cooling system which may have a higher capital cost but lower energy or operational costs.

The links between LCC and environmental sustainability are considered further in Sections 2.6 and 4.4 of this guidance note.

Risk & sensitivity analysis

The extent to which risk and sensitivity analysis are incorporated into the LCC analysis process will depend on the specific client and project requirements and on the uses to which the LCC data are to be put. While LCC assessments made at the detailed design stages will, by their nature, contain a lower level of uncertainty than those prepared during the early project stages, it is important to recognise that an element of uncertainty and variability in the prediction of the future costs and timings of works will always remain. It is important that clients are made aware of this and that appropriate steps are taken to quantify and, where relevant, mitigate these risks.

Depending on the client requirements and the scope of the LCC exercise, the risk analysis might range from a simple schedule of potential risks, to a detailed qualitative and/or quantitative risk assessment using techniques such as Monte Carlo Analysis (see Section 5 of Methodology). However, in all cases it is important that the client is made aware of the potential variability and uncertainty inherent in the LCC analysis, in order to prevent undue reliance being placed on the data.

Since the outcome of the LCC analysis is likely to influence the selection of a system or component, it is recommended that a sensitivity analysis is carried out on the findings in order to assess the impact of changing key variables such as discount rates, inflation assumptions and key cost and time inputs. The objective is to test whether any one variable has a significant effect on the overall findings. This is particularly important where two or more design solutions are being assessed in the LCC analysis and where a minor change in one variable may alter the relative ranking of different options. In such a case, the sensitivity issues would form a key component of the LCC report provided to the client.

5.4.5 Identifying options to include in the LCC exercise (Step 7)

The list of system/component options to be evaluated in the LCC exercise may be determined by the client and/or its design team, by the persons carrying out the LCC exercise, or by a combination of these. As stated above, this identification process is often carried out within the context of a design review workshop or a Value Management/Value Engineering process.

The number of options to be assessed will depend on the circumstances and on the number of potential options available for comparison. If numerous potential options are available, or if the scope of the LCC exercise has been limited by the client, it may be appropriate to carry out an initial filtering exercise to arrive at a shortlist of options. Any such filtering should be carried out in a robust way using criteria agreed with the client.

Similarly, when identifying how many of the asset's systems or components should be included in the overall scope of the LCC exercise, it is sensible to apply the '80-20' principle, by selecting a manageable list of those systems/components that are likely to have the greatest overall impact on the asset's life cycle costs. The size of this list is likely to be influenced by the project size and the resource/fees available for the LCC exercise.

5.4.6 Assemble data (Step 8)

Unlike the detailed LCC model for an entire asset discussed in Section 5.3 above, the cost, design and specification data for this exercise will not be readily obtainable from the project design and cost data. Instead, data will need to be assembled for each of the options under consideration. Much of this data is typically provided by the existing project team.

Data on the service lives and maintenance requirements of specific systems and components can be obtained from manufactures and suppliers, published reference sources, historic data or from professional advisors' own records.

Data on operating costs such as facilities management is generally obtained by creating a build up of the likely facilities management resources and costs for each option, as little historic benchmark data is likely to be available at the system/component level.

Further guidance on data sources and on the identification of relevant on-costs such as site preliminaries and management costs is provided in Section 8 of the Methodology.

5.4.7 Carry out LCC analysis (Steps 11-13)

At this stage the project data identified above, along with the key parameters, is input into an LCC calculation tool (typically a spreadsheet or database tool), and the analysis is carried out according to the methods of economic evaluation selected during the earlier scoping stages. At this stage, users will also undertake and risk/uncertainty assessments, including sensitivity analysis of key variables.

Once an initial LCC model has been generated it is common for the user to refine and adapt the model in consultation with the client. This process might typically include minor changes to variables such as maintenance intervals or component service lives to reflect client requirements, 'smoothing' of peaks in expenditure in order to reflect likely income streams, or grouping of key life cycle works into defined remodelling/refurbishment exercises. This refinement reflects the iterative nature of the LCC modelling process.

5.4.8 Reporting (Steps 14, 15)

The reporting for the LCC exercise typically includes;

- Detailed LCC models for each of the options evaluated
- A tabular and/or Graphical summary and analysis of the findings. The graphical analysis would typically include a single graph comparing the annual LCC profiles over the analysis period for each option (see example in Figure 20 of the Methodology).
- A written report setting out the key analysis parameters, assumptions, data sources and findings
- A sensitivity analysis showing the effects on the outcomes of varying key analysis variables.

- Results from other economic evaluation methods – for example, Payback Analysis, Net Savings/Net Benefit, Savings to Investment Ratio, Annual Cost and Annual Equivalent Value (see Methodology, Section Step 11.5).

Detailed guidance on the content of LCC reports is provided in Sections 14 and 15 of the Methodology. Sample tabular and graphical outputs from LCC exercises are provided in Annex A of the Methodology and in the case studies included as Annex A of this guidance note.

Appendix A: Case Studies of Common Uses of LCC

6 Introduction to case studies

The case studies have been assembled in order to test and validate the feasibility of the proposed methodology. The six case studies presented here are a representative sample from different Member States and include five representing public procurement and one representing a private project.

The aim of applying the proposed methodology to the case studies was to:

- outline any special requirements to adapt the methodology according to the type of project and/or construction assets concerned
- outline any special requirements to adapt the methodology according to different national contexts
- underpin the selected examples in the ‘Guidance on the use of the methodology’.

The following case studies were submitted for “testing” of the methodology:

- Project **INSPIRE for a FM company in the UK** comprising 2 buildings, one new build and one refurbishment. This case study represents application of LCC in private sector and underpins the example in the Guidance for selected stages of the facility’s life cycle.
- Project **Digi-house (Digitalo)** comprising the development of office accommodation in **Otaniemi, Finland** for a public client by VTT (Technical Research Centre of Finland). This case study represents the use of LCC for all stages of the facility’s life cycle with strong focus on sustainable performance.
- Project for the college **Maximilien Perret of Alfortville, France** comprising a large, multi-functional building to support many forms of adult and professional education. The building represents modern, cutting-edge design and the case study represents the application of LCC to selected stages of the facility’s life cycle. The LCC exercise was commissioned by a public sector client with a focus on the application of LCC to challenging designs and was carried out by the CSTB (Centre Scientifique et Technique du Bâtiment).
- Project for office accommodation commissioned by a public client in the **Netherlands** and designed and costed by the Ministry for VROM (Housing, land-use planning and environmental management). This case study represents the use of LCC for a selected 15 year stage of the overall life cycle. The project represents the application of LCC to a project with extensive site restrictions.
- Project of hospital accommodation in **Porsgrunn, Norway** carried out for a public client and assessed by Statsbygg (**The Directorate of Public Construction and Property**). This project reflects example from the Guidance Note which underpins the use of LCC initially for strategic assessment of the asset and then for more detailed assessments and calculations.
- Use of LCC to select systems to ensure the optimal environmental performance in the **Museum of World Culture in Gothenburg, Sweden**. This project corresponds to the example from the Guidance which describes calculating LCC for selected systems and components.

7 Application of LCC methodology to a project for two facilities (new - build and refurbishment) for major FM provider in the UK

Project description

Project title - INSPIRE

Category – New laboratory building and refurbished office accommodation for private sector.

General project information – Serco Group plc ("Serco") has been selected as preferred bidder by the Defence Science and Technology Laboratory ("Dstl") for a 15 year strategic partnership contract called 'Project INSPIRE'. Serco has selected Building Design Partnership (BDP) as its design leader and Sir Robert McAlpine Limited as its construction partner.

The contract aimed at providing and support new and refurbished laboratory and office accommodation. As a strategic partner and prime contractor, Serco is responsible for providing comprehensive facilities management services across Dstl's estate for 15 years from August 2006. In the first 2 years, Serco is also managing the design and build of new facilities and refurbishment of others and is migrating approximately 1500 Dstl staff to them. The innovative new facilities and supporting services range from laboratory set-up to travel management services.

Year of construction - 2006-2008 (under construction)

Gross internal floor area (GIFA) – 20,390 m²



Aims and objectives of LCC analysis

A model has been prepared in order to illustrate likely future expenditure required on both buildings of the project (new build and a refurbishment).

A rigorous methodology has been adopted in the development of replacement cycles, and the model has been presented as a 'first cut', that is, without extensive smoothing of the expenditure profile.

Three models were produced for each site; the first, the 'likely' scenario plus two variants reflecting favourable and unfavourable scenarios below and above the 'likely', referred to as the 'best' and 'worst' case scenarios.

The models represented results from the research of data and cost options extracted from a variety of databases. They included the upper, lower and middle values the range of expected outcomes.

LCC process

Objective

The savings from comparing options were mainly related to the capital costs and were assessed at the initial design and design refinement stages by the design team and the client without taking into account the LCC. Therefore when the LCC was carried out it was mainly for budgeting purposes with input of the “best”, “least favourable” and then calculating the “middle” estimates.

The model was prepared at a certain point in time and thus could not be assumed to be a ‘catch-all’ solution. The model will require updating in the light of any future design development and during procurement of the Construction/Transition stage.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved the total asset and refinements and upgrades were made throughout the design. The level of detail was at system/component level and was pre-determined at the design stage. The LCC was carried out for essentially one set of recommended choices of components.

The Appraisal Period instructed for the Model was 50 years. This reflected the design life of the buildings as advised by BDP (design). Whilst the term of the proposed contract was 15 years, the 50 year model was presented in order to illustrate a consistent approach to the whole life of the facilities and to demonstrate that there was no undue expenditure following the hand-back to Dstl. The method of economic evaluation required by the client was NPV only.

At the design stage many trade-offs were made to select more environmental solutions at the systemic level. Environmental considerations were high on the client’s agenda and a BREEAM (UK BRE Environmental Assessment Method) rating of “excellent” was a target for these buildings.

Risk assessment was carried out for the performance of the facilities rather than the LCC and concentrated on formal risk assessment. The analysis of three LCC options (best, worst and the middle values of costs and selected financial parameters) were considered to be sufficient to provide robust sensitivity information.

Confirmation of project and facility requirements

The facility’s requirements were selected among the design team to enable the combination of parameters, such as NPV, environmental performance, budgetary restrictions and suitability to be achieved within the project programme. The assessment was not carried out using the LCC analysis or models.

The main environmental options tested using LCC were selected as traditional air conditioning systems versus use of chilled beams. The identification of the two systems was carried out by environmental specialists.

With regard to project requirements, there was no fixed budget as such but selected options were costed and decisions were made based on the relative impacts, costs implications and performance at the design stages. The site constraints and project constraints were agreed and acted upon between the client and the design team. The same applies to the quality requirements.

Assembly of cost and performance data

All costs were itemised and costed using the BCIS classification system. The cost data was derived from BCIS databases (UK’s Building Cost Information Service), Davis Langdon (cost consultants) internal databases, contractor’s databases and other available published data. The main exercise was carried out for two options of HVAC solutions. At the time of calculations, the capital costs that fed into the Model were in cost plan form only (contractor’s MPTC figures), thus with only generic information on the works being undertaken, assumptions were made as to the quality of the materials and workmanship.

Values of financial parameters were identified as follows: discount rate of 3% (real - as advised by Treasury Green Book) and no inflation. This allowed for the fact that the opportunity cost of money meant that monies spent in the future were worth less in present day terms.

The model was indexed to reflect any inflation between the date of the costs and the start date of the model. The source prices included an allowance for indexation up to and through the Construction period. To allow to present 2005 prices for the Maintenance and Asset Replacement cost streams, a deflator has been used for the annual costs, which was published by the BCIS and typically used for these types of calculations.

Replacement timings for the assets were assessed using a combination of Davis Langdon’s own database and published information on the likely life expectancy of various assets. Refinement of this was made by adjustment of the percentage of the capital cost which was allowed at each replacement cycle. For instance, on average, windows may be expected to last around 20 – 35 years, dependent on quality of materials and workmanship. However, the likelihood was that many will last considerably longer, whilst some may fail early. Two mechanisms were used to account for this. Firstly, a percentage of the capital cost was allowed at the earlier published life expectancy, and secondly, the expenditure was spread over more than one year, allowing some money to be drawn down early, should it be necessary.

The desired redecoration cycle for the facilities was carefully considered. Another asset that required consideration was loose furniture, as this could add considerably to the cost of a facility over time. The ‘norms’ used on other office accommodation projects at Davis Langdon were used.

Different types of obsolescence were of importance in assessing asset lives. For instance, whilst office fit-out components might not become physically obsolete for 20 or more years, if carefully maintained, it was commonly understood that they may become functionally, or aesthetically obsolete within a much shorter timescale. Thus a realistic assessment of life cycle costs had to take into account these aspects in addition to the physical durability.

Cost add-ons which were listed included certain costs associated with the replacement work, all necessary scaffolding, temporary access and temporary works, as well as removal of the components to be replaced and testing/commissioning of plant and equipment. Exclusions which were listed broadly included the following: contingencies, VAT and other relevant financing charges and rates, certain management fees, business interruption costs/unavailability, backlog charges, hard and soft FM services, relocations and insurances.

Approach to sensitivity comprised identification of maximum and minimum values published or used as common practice and calculating "the middle" value of selected parameters, which were: selected cost data and selected financial parameters.

An external risk register was produced by the design team; however it was not directly linked to the LCC calculations.

LCC analysis and results

All the financial parameters were applied uniformly to all cost groups. No allowance has been made within the Model for any financial advantages that may be gained via Capital Allowances, etc.

All the values were input in the IT tool (internally developed Davis Langdon tool) for calculating the financial performance over the selected life cycle period.

Auxiliary analyses (risk & sensitivity) – optional

No formal quantitative risk analysis was carried out as it was difficult to assess the probability distributions of uncertain parameters.

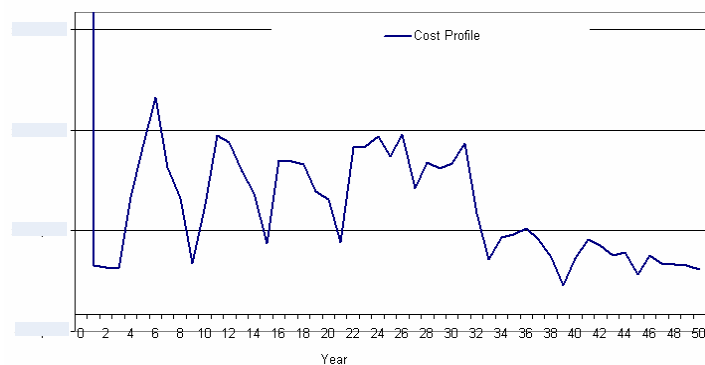
For each building, three alternative models were provided giving a 'likely' scenario plus two variants reflecting favourable (best) and unfavourable (worst) scenarios below and above the 'likely' one.

Interpretation and reporting

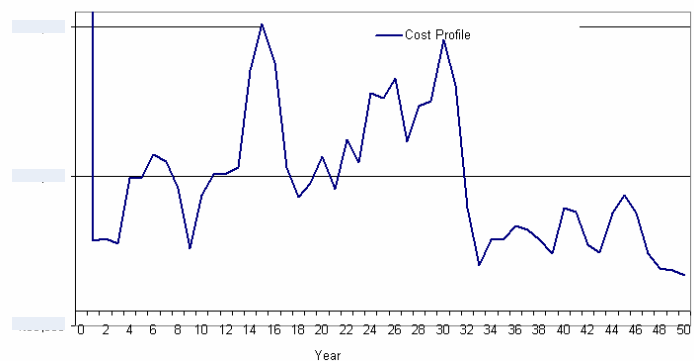
Preliminary results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile.

The formal report for the client was structured according to the headings in ISO 15686 – Part 5.

Results – Refurbishment



Results – New Build



Results (continued)

The average annual spend per metre square of Gross Internal Floor Area (GIFA) was slightly lower for a refurbished building than for the new one. This might be partly due to the fact that certain building elements, such as internal doors and partitions, to be kept during the refurbishment had not been quantifiable at this stage, and thus whilst an assessment of their impact had been made, this may not be as accurate as in the situation where a full cost plan for a new build is available.

The lower overall figures for a 13 year model (a quarter of the 50 year “life”), as opposed to a 50 year model were a natural consequence of the fact that the majority of building components, and particularly the more expensive items of plant, would have an expected life greater than 13 years.

Overall, the costs, when adjusted to mitigate the various unusual aspects of the project fall broadly in line with industry benchmarks for life cycle costing exercises.

Conclusions and benefits

The main benefits were twofold, firstly the FM provider was able to show to their client that they are planning to invest during the O&M stages and they are planning the relevant expenditure and secondly Serco gained a practical insight into not only future costs but also their timings so they could plan their financial strategy to suit.

Whatever figure was budgeted for, it was underpinned by a robust management plan which was then implemented and will be regularly reviewed throughout the life of the building.

The other benefits included:

- Setting out a clear strategic approach to asset management.
- Benefiting from putting in place an effective management regime
- Ability to communicate the actuality of which/when assets will be replaced during the term
- Development of a clear mechanism for identifying the circumstances when an asset should be replaced, or when its life can be ‘sweated’ further
- Informed participation of all parties concerned

Contact details

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8 Digi-house (Digitalo) – office building in Otaniemi for Senate Properties in Finland

Project description

Project title Digi-house (Digitalo)

Category – New-build office building

General project information – VTT Digi-house has space for 270 employees. The project was implemented using the project/construction management method. The work was divided into several contracts, deliveries and procurements. The target was to design an office building, where the versatility of the office space and life cycle and environment issues were taken into account.

Client: Senate Properties

User: State Technical Research Centre (VTT)

The design was carried out by using integrated CAD. The steel structures of the hanging floors in the central hall were designed three-dimensionally using the Tekla Structures software.

Year of construction: January 2003 - commencement of design, January 2004 - commencement of construction, September 2005 - construction completed

Gross internal floor area (GIFA) – 8,800 m²



Aims and objectives of LCC analysis

The main objective was to achieve an office building of superior functionality and quality, with improved infrastructure, representing added value for the customers and designed with application of proven solutions for improving environmental performance.

This was achieved by comparing various aspects of a traditionally designed and built office building with the solution which included many improvements (mainly upgrading the sustainability performance) in order to optimise LCC.

An additional objective was to assemble all essential building and economic information in one place, to calculate realistic life cycle costs for rental (initial 15 years plus an additional 15 years) and to record the influence of the factors mostly affecting life-cycle costs (space-effectiveness, heating and electricity energy, inner climate and modification rate of these parameters).

LCC process

Objective

To compare two options – one built using traditional technologies and methods and the second utilising modifications for optimising the environmental performance and LCC. The analysis was required to produce not only figures for comparisons but also an assessment in aggregate of all relevant costs.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved the total asset including the pre-construction, design and construction, operation, maintenance and replacement. As the refinements and upgrades were made throughout the design the level of details was systemic/componential.

The period of analysis was assumed to be 15 years for the LCC calculations however the depreciation period for the asset was considered to be 30 years. The methods of the economic evaluation were NPV and Payback (PB).

The assessment of selected environmental indicators (to be finalised at later stages) will need to take place and accompany the LCC as stand-alone data. A separate environmental assessment was carried out by external experts and both options were assessed against the above criteria. No attempt was to be made to associate costs and results.

Risk assessment was to include risk identification and basic sensitivity assessment of probable, optimistic and pessimistic values. The decision on the choice of sensitivity parameters could not be taken at this stage.

Confirmation of project and facility requirements

The facility's requirements were selected in order to optimised the Digi-house's performance regarding selected location, existing services in site, services the asset was expected to deliver (office accommodation, restaurant, parking, sheltered cycle stand, etc.), time of use, maintainability, recyclability, spatial solutions, energy economy, indoor conditions and flexibility for future modifications.

The assessment of the following environmental indicators was decided upon: consumption of heating energy, consumption of facility energy and CO₂ emissions. One of the ultimate requirements was to select an HVAC system which was life-cycle optimised.

Project requirements were focused on effectively supporting innovative work space design, energy savings and life-cycle economics.

Assembly of cost and performance data

All costs were itemised and costed using the Nordic classification. The model for maintenance was a follow-up, planned maintenance including technical and functional renewing.

Values of financial parameters were identified as follows: discount rate of 3% (nominal), inflation rate 2%, and funding rate 35% over 15 years (real price of money).

There is no data on the sensitivity analysis being carried out.

General risk statement included risk identified as: advancement of resale-value, permanence of performance, maintainability and chances of valuation and compatibility of systems with further needs for facility management, mistakes concerning building planning, accessibility of building products, operative experience, risk of damage and way of use.

In the production process risks identified were: insufficiency of professionals, problems with acquisitions, actions and transfer of project start towards winter time.

In use and maintenance risks were: under-pricing in planning phase, defaults of use and maintenance directions, unexpected increases in prices, excessive and careless use of systems, unexpected damage and problems with usability in case of user changes and faults and lack of maintenance actions.

LCC analysis and results

All the financial parameters were applied uniformly to all costs. There were no tax advantages considered when selecting the design.

All the values were input in the IT tools SeneCost for calculating the financial performance over the selected life cycle period.

Auxiliary analyses (risk and sensitivity) – optional

Critical risks were included in the risk register.

There was no case identified for carrying out sensitivity analysis.

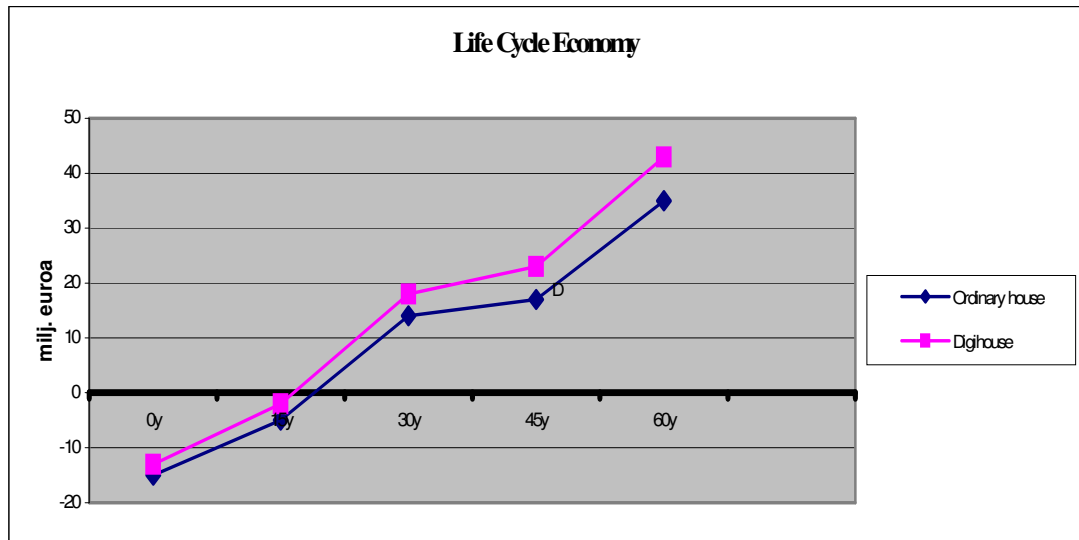
Interpretation and reporting

The main sections of the preliminary outputs from the software calculations were cash flow and profit estimates presented as tables and cumulated cost curve.

The main sections and format of the final report presented to the client were as follows: object description, target and technical solution descriptions and some further explanations for the user.

The final report could be easily adjusted to follow to the headings in ISO 15686 – Part 5.

Results



Results (continued)

The calculations enabled the client to foresee real cashflows and show the real economical meaning of life-cycle issues.

Based on the usefulness of the LCC calculations in Digi-house, similar calculations are carried out in each investment project (new buildings and renovations) of Senate Properties on 4 phases (preparation of project, planning, construction and use).

Conclusions and benefits

Life-cycle economical, energy economical, eco-efficient, healthy and social factors are quite similar: durable, energy-saving and desirable with functional, change-flexible and unrestricted spaces and reliable, advantageous, undamaged recyclable systems, other products and materials.

A real life-cycle optimisation is necessary in parallel to individual building planning.

Life-cycle optimised Digi-house meant:

- Reduction of heating and electricity energy making it easier to optimise energy management and increase importance of renewable energy resources.
- Increase of both GNP and employment and transferring labour inputs from energy producing countries to native countries and from wasting to recycling services.
- New kind of business possibilities (for example building concepts, coating structures, recycling products).

The update to the LCC analysis and calculations will be carried out after 3 years from the completion of the project.

Contact details

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9 Application of LCC methodology to a project for Maximilien Perret College for Region Ile-de-France in Alfortville, France

Project description

Project title – College for Higher Technical Education for Ministry of Education

Category – New college accommodation for public sector.

General project information – The client is Région Ile-de-France, which is the executive organisation acting as an owner of buildings used for educational purposes in Paris and its neighborhood.

The architecture for the college Maximilien Perret of Alfortville, was created between 1995 and 1997 by the Italian architect and town planner Massimiliano Fuksas. The spaces allocated to different functions (teaching, technical, administrative, etc...) are organised around long curved footbridge and an atrium with views to the city.

The materials used, predominantly rough concrete, which returns to the industrial architecture are moderated by large windows and elements painted in vivid colours.

It is built on grounds of the vocational school created in 1887 to satisfy the requirements for skilled workers in construction. The college Maximilien Perret evolved/moved progressively with the industrial needs and the institutional changes. It comprises a general-purpose college with technological and professional sections.

Year of construction – 1997 (opened)

Gross internal floor area (GIFA) – 26,426 m²



Aims and objectives of LCC analysis

The LCC analysis for that building has been prepared in order to illustrate likely future expenditure required to build and exploit the building providing a variety of functions supporting adult education. The building's design was very modern and unconventional which provided another intangible parameter in LCC calculations.

The regional requirements of Local Authorities in the region Ile-de-France were the basis for undertaking the LCC exercise. Due to the prestigious and non-standard characteristics of the building, carrying out the LCC was considered in itself as a risk identification and mitigation experience.

LCC process

Objective

The main objective was to budget an option which was selected after extensive consultations between the design team and the client (Region Ile-de-France) as well as according to the architectural requirements resulting from unconventional design. Designers were brought on board to manage the LCC calculations and assessment. LCC also formed part of the decision for the procurement route and sustainable objectives. Maximilien Perret was the first French high school built with environmental standards.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved the total asset and all the stages of facility's life from costs of concept design which were not insignificant on this project (world famous architect) to demolition. The level of detail has eventually reached detailed design after many design iterations even during construction.

The duration of the life cycle was assumed as 60 years and costs of demolition were included in 1997 calculations, although this did not mean that the building was designed and built to last 60 years only. 60 years is a standard period of analysis, but there isn't any specific justification for it. A calculation based over 10 years (2 for the construction and 8 for maintenance) was also carried out to define the budget of the construction company. The methods of the economic evaluation required by the client were NPV only.

The Region's database contains also a basic assessment of the environmental performance for the majority of the entries, therefore at the design stage the environmental considerations were taken into account when making the selection decisions. However no separate sustainability assessment was decided upon.

No separate risk or sensitivity analyses were envisaged.

Confirmation of project and facility requirements

Exceptional facilities (30 rooms equipped for specialized teaching - 11 workshops for design and assembly, 20 workshops of 250 m² each allowing the use of up-to date equipment in realistic situations, a multimedia room, a conference room, an information and documentation centre, a technical resources centre including information technology self service facilities, facilities for catering, etc.) were specified by the local authorities. The aspects such as quality, impact, aspect, access, etc. were high on the agenda and list of requirements was drafted to a high level of detail.

Sustainability provisions were considered to be made when a selection of building components was decided upon. The decision to use low temperature heating by geothermics and double flow heat recovery provided the improved energy performance of the building. LCC calculations were carried out alongside LCA.

Project requirements – there was no fixed budget but options were selected according to their prices during the design stages. The site constraints and project constraints were agreed and acted upon between the client and the design team (restricted site, adjacent buildings, architect's vision, etc.). The same applied to the quality requirements of the selected systems and components.

Assembly of cost and performance data

All costs were itemised using the French classification system UNTEC. The cost data was derived from quantity surveyor's internal databases which are linked to contractor's databases and other available published data. The main exercise was carried out for one option which has emerged from the design stages. Initially all areas were classified for their functionality (internal and external) and calculated. Various cost indices were then applied to different areas. Generally the costs were grouped for final calculations into costs relating to: cost of design, Capex, use & maintenance, labour and demolition. A separate spreadsheet referred then to the replacement regimes and to the maintenance frequencies. All relevant costs were applied accordingly.

Values of financial parameters were assumed as follows: discount rate of 4% (real - as advised by French Ministry of Finance), 2% general inflation rate and 4% inflation rate applied to costs related to energy.

Replacement timings for the assets were assessed using a combination of constructor's own database and published data on the likely life expectancy of various assets.

Sensitivity analysis was not carried out as a separate exercise. An external risk register was produced by the design team; however it was not directly linked to the LCC process.

LCC analysis and results

All the financial parameters were applied uniformly to all cost groups, except for the inflation rate which was applied as 4% to all cost related to energy and 2% to all other costs.

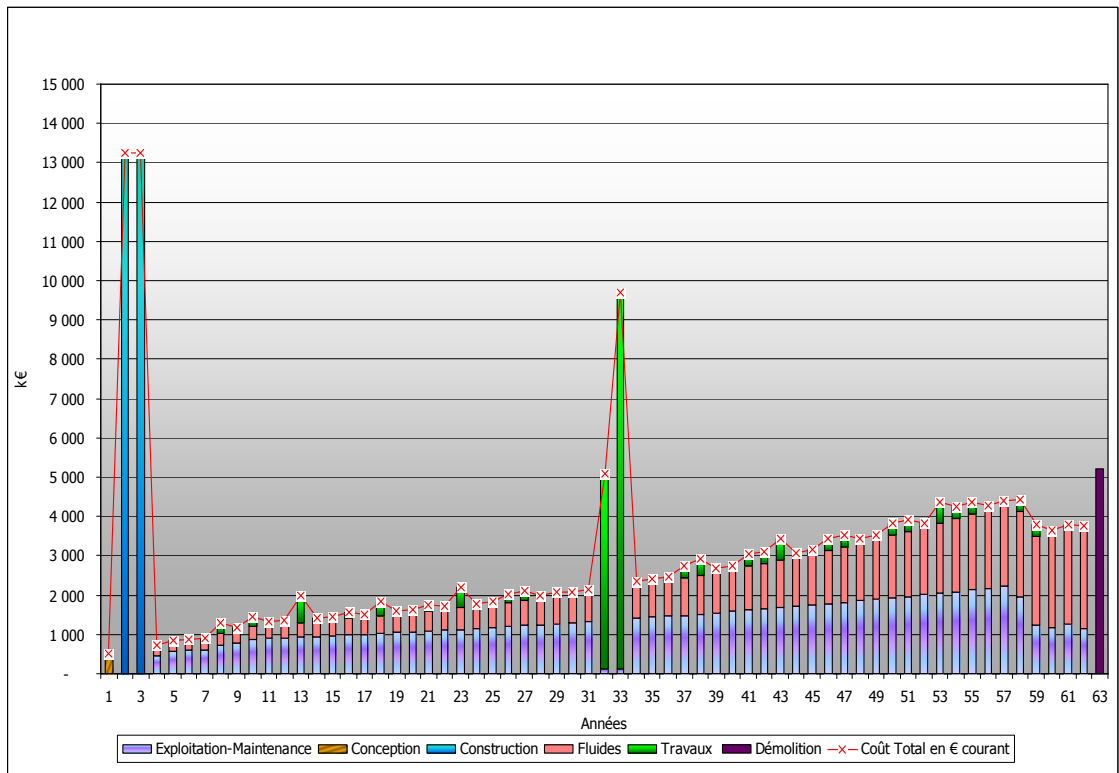
All the values were input in the IT tool (internally developed for CSTB).

Auxiliary analyses (risk and sensitivity) Interpretation and reporting

No separate quantitative risk analysis was carried out.

Results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report to the client was structured according to French guidance but essentially it contained all the information which was easy to adjust to follow to the headings in ISO 15686 – Part 5.

Results from recent update to LCC with 1997 cost levels



Orange checked – Cost of design
 Blue – Construction costs
 Violet – Use & maintenance
 Green – Replacement
 Pink – Variable costs (geothermics, water and electricity)
 Dark purple - Demolition

Results (continued)

The project is currently undergoing updates to the life cycle costing exercises because its initial maintenance contract is coming to an end. It is difficult to confirm the financial performance as cost data from the market place is not yet fully available and the up-to-date data will be commercially sensitive.

The main reasons for the LCC exercise were to justify environmental design and to define the procurement process. The high school was built under a global contract including construction and 8 years of maintenance.

A geothermic HVAC option was also selected.

Conclusions and benefits

The main benefits were specifically connected to the building as a prestigious landmark for the region Ile-de-France:

- Cost monitoring during the construction and exploitation with aims to achieve further savings.
- Exploiting environmental HVAC options within a modern and controversial design solution
- Improvement of the indoor climate efficiency
- Special focus on maintenance and replacement costs throughout the exploitation phase due to potential obsolescence of some of the present options due to their innovative use and selection often without the support of the historical data on performance and costs.

Contact Details

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10 Application of LCC methodology to a project for an office building for Ministry of Finance in the Netherlands

Project description

Project title – Office Building for Ministry of Finance

Category – New office accommodation for public sector.

General project information – The client is the Dutch Government Buildings Agency (GBA), which is the executive organisation for developing and operating real estate, and acting as the largest owner of buildings used by the Dutch national Government. The building is developed for the Ministry of Finance.

The building is intended to provide standard office accommodation of a medium to high quality. The facade has to be robust and the interior transparent in terms of the functionality, so it can be easily adjusted. The floor plans have to be suitable for a flexible office concept, with allocation of spaces allowing for open plan working, meetings, catering services, etc.

Year of construction - 2006-2008 (under development)

Gross internal floor area (GIFA) – 7,350 m²



Contact details

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Aims and objectives of LCC analysis

The main objective was to budget an option which was selected after extensive consultations between the design team and the client as well as according to the characteristics included in the category “medium to high quality” as specified within the departmental regulations and performance specifications.

The LCC analysis for that building has been prepared in order to illustrate likely future expenditure required to build and exploit the proposed office building. The analysis was also to be used to confirm the market prices for selected systems and components.

LCC process

Objective

The main objective was to budget an option which was selected after extensive consultations between the design team and the client as well as according to the characteristics included in the category “medium to high quality” as specified within the departmental regulations.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved the total asset and all the stages of facility’s life from design to partial operation for 15 years. The level of detail has eventually reached detailed design after many design iterations.

The duration of operation was related to the clients’ interest in the building as well as reliability of the results over a limited period of 15 years. After that period the ownership of the building will be transferred to a consortium. The methods of the economic evaluation required by the client were NPV only.

All the systems and components included in the GBA’s database have a basic assessment of their environmental performance, therefore at the design stage the environmental considerations were taken into account when making the selection decisions.

There is a standard approach to risk management within the GBA’s process. Selected risk categories with weighting factors are assembled in a database. The relevant categories are then selected and scored by the user group according to project’s characteristics.

Confirmation of project and facility requirements

The facility’s requirements were selected among the design team to optimise client’s requirements for medium to high quality of office accommodation. All structural elements and services were selected including the external areas and parking lots by the building’s ultimate owner. The occupier has then superimposed their additional requirements. In this case they related to furniture and preferred types of HVAC systems.

The risk categories relevant to the building were selected (among others, complexity and possibility of damage). The decision was made to further select and analyse these at later stages.

Project requirements: there was no fixed budget but options were selected according to their prices during the design stages. The site constraints and project constraints were agreed and acted upon between the client and the design team. Due to the presence of the rail line and tunnel as well as limited plot size certain design restrictions were imposed. The same applies to the quality requirements of the selected systems and components.

Assembly of cost and performance data

All costs were itemised and costed using the Dutch classification systems NEN 2634 and NEN 2748. The cost data was derived from GBA’s internal databases, cost analyses and other available published data. The main exercise was carried out for one option which was selected throughout the design stages on “as you go” basis.

Values of financial parameters were assumed as follows: discount rate of 3% (real - as advised by Dutch Ministry of Finance), no inflation. However the risk-related discount factor was added to the nominal one and the total discount rate used was 7%. Because the risk factors are also in-built into the value of the discount rate, a more detailed and focused risk analysis was necessary at this stage of the LCC process. This did not affect the integrity of the LCC process proposed in the methodology.

Replacement timings for the assets were assessed using a combination of GBA’s own database and published historical information on the likely life expectancy of various assets.

Inclusions which were listed reflected certain costs associated with maintenance of the exterior and interior of the building, reinvestments on the interior of the building during the contract period, maintenance of the site, all catering activities, security of the property, cleaning of the interior and exterior, all furniture, FM costs

The main item listed in exclusions was ICT.

Sensitivity analysis was not carried out as a separate exercise. It was assumed to be part of the overall risk assessment. The risk categories were selected and their impact on the project and asset was assessed.

An external risk register was produced by the design team; however it was not directly linked to the LCC process.

LCC analysis and results

All the financial parameters were applied uniformly to all cost groups. However allowances for risk impact were made throughout the calculation through the significant adjustment of the discount rate.

All the values were input in the IT tool (internally developed for VROM), which is widely available on the market and free to use on commercial projects as well.

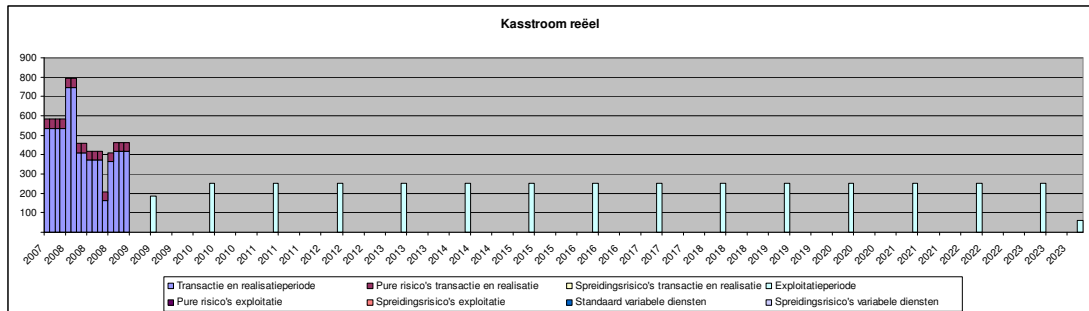
Auxiliary analyses (risk and sensitivity) – optional

The risk categories were selected and their impact on the project and asset was assessed. Some risks are included in the risk premium on top of the discount rate. These are the risks that are sensitive to the economic situation. Other risks are uncertainties in the cost calculations. These risks are included in the model as probability distributions. The last category of risks in the model includes the risks that are an extra cost item. They are priced by multiplying the chance of the occurrence of the risk and the consequences of that risk. The total of the last two categories is added to the total costs of the project.

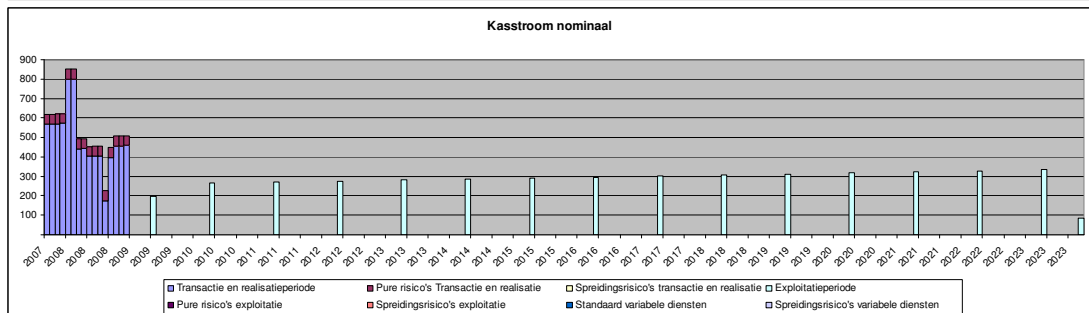
Interpretation and reporting

Results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report to the client was structured according to GBA's guidance but essentially it contained all the information which was easy to adjust to follow to the headings in ISO 15686 – Part 5.

Results Real



Results Nominal



Blue – Capex; Violet – Cost of Risk; Green – Exploitation costs (annual)

Results (continued)

The project is currently undergoing further life cycle costing exercises at the detailed design stage and it is difficult to confirm the financial performance as cost data from the market place is not yet available.

Conclusions and benefits

The main benefits were in many ways typical for the LCC model utilised in the Netherlands:

- Itemisation of all costs and pricing using the Dutch standards and GBA's database of costs allowed to consistency of granularity with other projects
 - Following the standard, well-refined cost assessment process for public procurement
 - Access to government-supported databases of prices, costs and standard design solutions contributed to the optimisation of solutions.
 - Access to benchmark data and reasonably accurate historical data reduced risks.
 - Analysis of the results led to procurement using public/private cooperation.
 - Using the standard model and GBA's software allowed for development of the consistent model and reliable outputs.
- Future expected benefits are the synergies between the different disciplines (design, O&M).

11 Application of LCC methodology to a hospital building in Porsgrunn - for Norway's Directorate of Public Construction - Statsbygg

Project description

Project title – Hospital Building in Porsgrunn for the client - Southern Norway Regional Health Authority the tenant -Telemark Hospital

Category – New psychiatric hospital wing for public sector

General project information – The name of the project is "DPS Porsgrunn" (DPS = district psychiatric hospital)

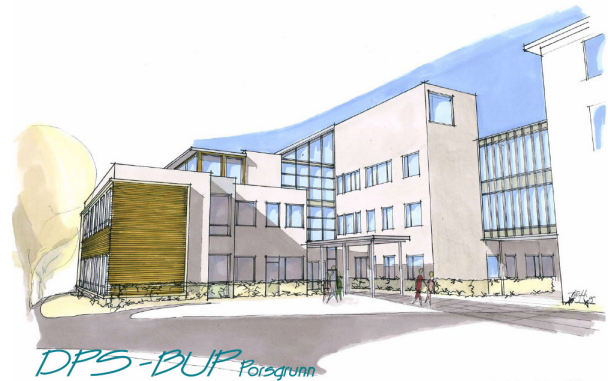
Architect: Ottar Architects
Consulting engineer: Ramboll Norway

A LCC calculation was carried out in the pre-project phase. The LCProfit model was chosen, and the aim was to get an overview of the total capital and MOMD (management, operation, maintenance and development) cost of the project. The results was compared to best practice and benchmarked against the existing regulations.

Year of construction - 2006-2007 (under development), with completion date Aug. 2007

Gross internal floor area (GIFA) – 4,846 m²

Heated gross internal floor area (GIFA) – 4,496 m²



Contact details

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Aims and objectives of LCC analysis

The aim of the calculation was to obtain an estimate of the total LCC (capital + MOMD) at an early project stage (pre-detail phase). The MOMD costs were then benchmarked against best practice.

In 1998, Statsbygg, Norway's Directorate of Public Construction and Property, instituted a requirement for annual cost calculations for all projects in the pre-design phase. This means that project designers are contractually obliged to submit annual cost calculations along with the other pre-project materials. Later this practice was implemented in the law on public procurement.

The input data was taken from budget estimates at the pre-detail phase, i.e. the calculations were done on a "coarse" costing level. Other assumptions for the calculation were taken from the MOMD-database "Holte FDV" (from "Holte Byggsafe") and from Ramboll Norway's own experience and data on LCC-calculations.

The LCProfit model does not handle "likely", "best" and "worst" case scenarios well (one set of assumptions has to be used for each case). The calculations in the case study are done based on "likely" values.

LCC process

Objective

The main objective was to budget an option which was developed at the pre-detail design stage. This initial budgeting exercise was subject to verification at later stages as to whether the rent will cover the actual annual costs, or whether the Directorate is likely to make a profit or loss on the project.

Selected choices regarding the structure and M&E system were made based on experience and past cost data for similar projects throughout the preliminary design stages.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved the total asset and all the stages of facility's life (no disposal costs).

The appraisal period was set to 40 year as instructed by the project owner. The recommended appraisal period of a new build was 60 years (public buildings). This has to be taken into account when comparing to best practise (benchmarking). Calculations for an appraisal period of 60 years was also done for comparison.

The methods of the economic evaluation required by the client were NPV only and this is the main calculation method in the software LCProfit which supports the NS 3454 – Annual Costs for Buildings.

"Holte Byggsafe" which publish the "Holte FDV" database, is a well established firm in Norway that develops calculation tools for the building industry as well as databases with building and cost data. FDVU is the Norwegian acronym for MOMD (management, operational, maintenance and development). Their product/cost databases do not contain the environmental performance data (LCA), therefore the environmental considerations were reduced to benchmarking the energy use against best practise and the new requirement on energy use in buildings (as of 01.01.2007).

Confirmation of project and facility requirements

The facility's requirements were selected among the design team to optimise client's requirements for the hospital building with the purpose of holding a psychiatric ward with capacity for 75 patients (of which a capacity of 15 patients on day-and-night care, and the rest poly-clinical). As this was an additional building to an existing hospital complex the asset's requirements had to take into account fitting into the existing complex not only architecturally but also from services perspective. All structural elements and services were confirmed, including the external areas and parking lots, by the building's tenant.

The choice of HVAC systems was a trade-off between current environmental performance, cost and possibility of future replacements with a more efficient system. The energy use was also compared to existing statistics and the requirements in the revised law on energy use in buildings as a result of the new EU directive on energy use in buildings. It was suggested to the client that a more thorough energy calculation should be carried out, as well as a second LCC analysis with a building solution with better/more insulation, low energy lighting system and focus on building details.

Project requirements – there was a fixed budget of 107.8 million NOK and the options were selected according to their prices during the design stages. The site constraints and project constraints were agreed and acted upon between the client and the design team. The quality and performance requirements had to correspond to Norwegian standards for hospitals.

Assembly of cost and performance data

Annual costs were calculated according to NS 3454. The capital cost was expected to be higher than best practise. The MOMD-cost may be higher/lower depending on the chosen solutions. Capital costs (investment costs) are only part of the annual costs associated with owning, operating and maintaining a building. MOM costs comprise 35-50% of the total annual costs of Statsbygg's buildings, meaning they have a significant impact on rents.

The discount rate was selected according to the recommendation from the "Norwegian government calculation committee" (similar to the Treasury Green Book) and set as 6% (to be confirmed if real/nominal).

Replacement timings for the assets were assessed using a combination of Ramboll's own database and the "Holte FDV" database.

The residual value was not taken into account, as this has not been practised in public projects so far.

An external risk register was produced by the design team; however it was not directly linked to the LCC.

LCC analysis and results

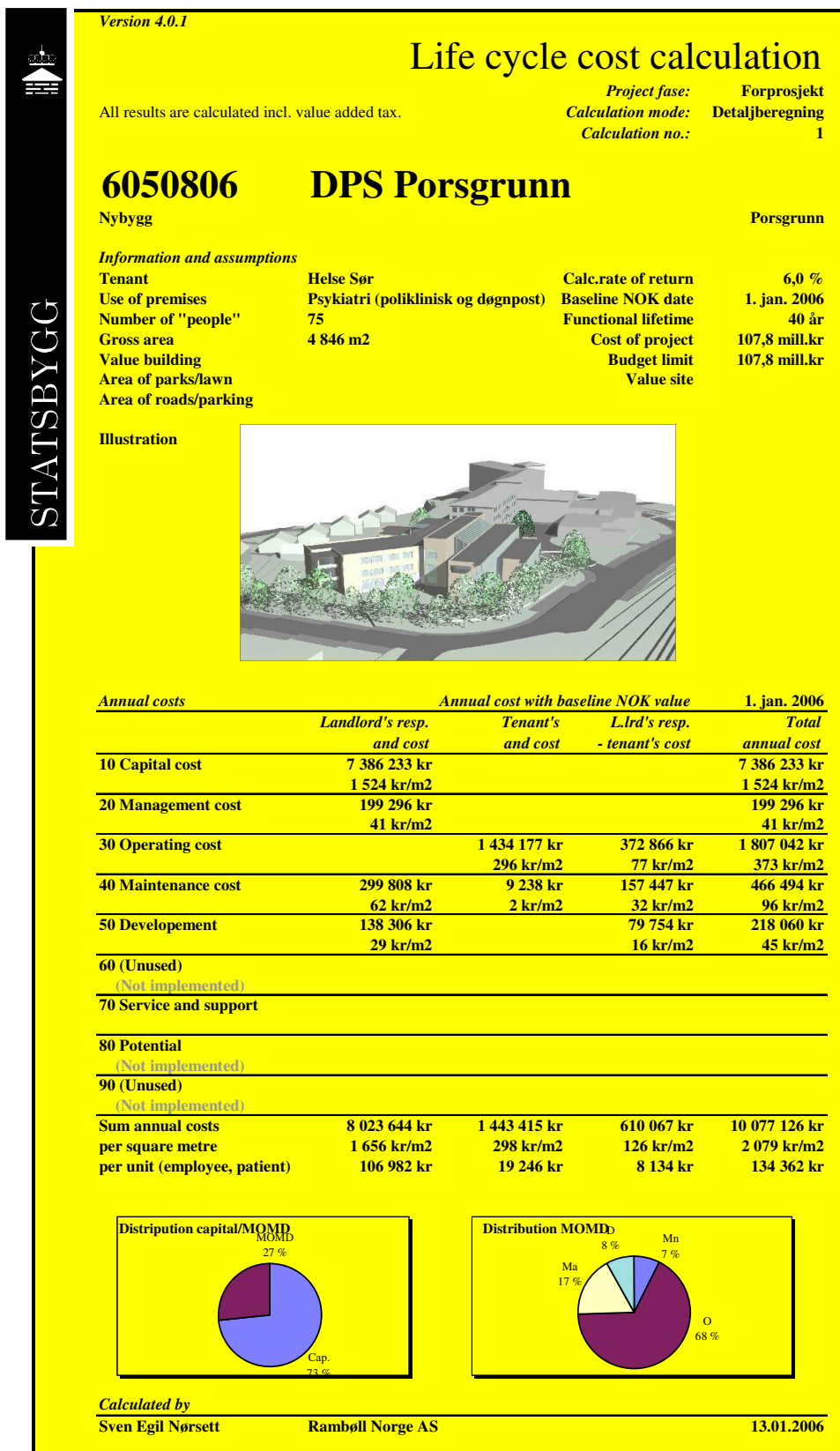
All the financial parameters were applied uniformly to all cost groups. LCProfit was used as calculating tool. The results were presented to the owner in a report in accordance with NS 3454 with recommendations for further analysis and conclusions.

Auxiliary analyses (risk and sensitivity)

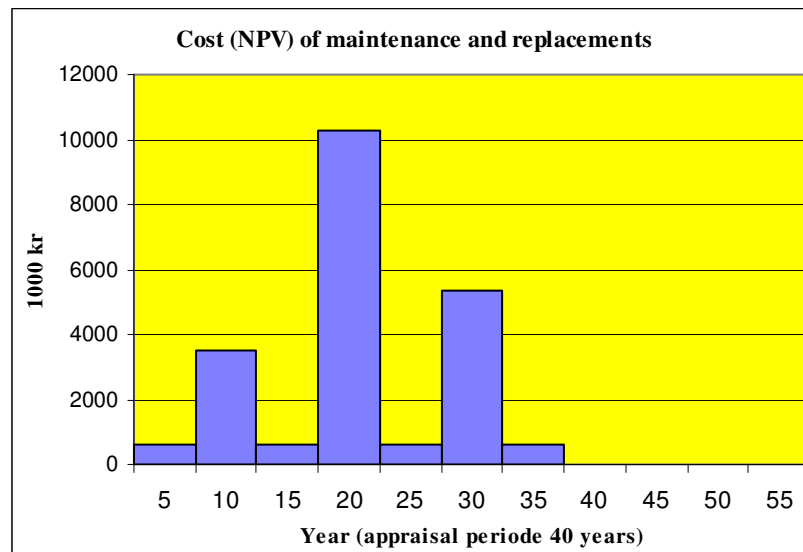
There are no calculation capabilities within LCProfit for risk or sensitivity analyses and the client has not requested a separate one.

Interpretation and reporting

Results included the outputs from the LCProfit, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report to the client was structured according to LCProfit's outputs and guidance from NS 3454 but essentially it contained all the information which was easy to adjust to follow to the headings in ISO 15686 – Part 5.

LCC results
(main
figures)

Cost (NPV) maintenance and replacements



Results (continued)

The results constituted an overview of individual cost components' contributions to annual costs, and their apportionment with regard to responsibility and cost. This apportionment is in accordance with Statsbygg's standard lease.

A similar overview, calculated on a square metre basis, accompanies the first results. Further on there are sheets showing the detailed calculation.

Management costs include property tax, water and sewer fees, refuse collection and disposal, insurance and administration. Energy use and cost is a main focus. Energy for heating (building, ventilation and hot water) is supplied by district heating. Electricity is assumed for all other purposes. The energy price was based on existing contracts (in accordance with the owner). These prices were quite low, and a sensitivity analysis was recommended for further work.

Conclusions and benefits

The main conclusion from the LCC analysis recommended a stronger focus on energy use. The architectural and technical design at the pre-project phase would give higher energy use than best practise and in comparison to the new regulations on energy use in buildings.

Due to costs and progress of the project, the conclusions of the analysis was only partly taken into action.

12 Application of LCC methodology to Museum of World Culture in Gothenburg in Sweden

Project description

Project title – Museum of World Culture in Gothenburg, Sweden

Category – Museum building for public sector – National Property Board.

General project information – The design by architects Cecile Brisac and Edgar Gonzalez gives the Museum of World Culture a robust frame for its activities. The building has already been awarded Sweden's Kasper Salin Prize for architecture. The cement and glass building, located on a slope, is graceful, compact and modernistic. Its four-storey glass atrium looks out on mountains and woods. The exhibition halls are in the closed part of the building. The upper storeys hang five metres over a footpath. A 43-metre long section of a display window provides passers-by with a view straight into the largest exhibition hall.

The National Property Board's Role has been to manage the entire project, ensure that all of the museum's requirements have been fulfilled and to steer the project within the economic framework allocated by the government.

Exhibition area: 2,600 m², six storeys, five exhibition halls, research library and offices.
Cost: SEK 305 million

Year of construction – 2001-2004 (opened 29th December)

Gross internal floor area (GIFA) – 11,000 m²



Aims and objectives of LCC analysis

The main objective was to support the design of the prestigious landmark structure (museum) with continuous LCC calculations of selected systems based on the combination of cost and their environmental performance. The most important of the studied systems and some of the building structures (insulation, windows) were analysed with LCC during the design stage.

Energy efficient procurement principles based on the ENEU[®] concept (Energy Efficient Procurement) were applied with LCC and also introduced as part of the purchasing routines.

Investments with long pay-off time were made profitable when calculating with ENEU[®] concept and LCC. On the museum project HVAC systems cooling and heat pump systems as well as circulation pumps were procured using the ENEU[®] concept, which was developed by Bengt Dahlgren AB in 1994 and today it works almost as a standard in Sweden and also in other Scandinavian countries.

Consultants have carried out environmental reviews throughout the project, in order to guarantee that the established environmental demands have been followed. The environmental demands on the project included requirements for environmental and health reviews of material, environmentally educated personnel, waste and materials management, and handling of chemicals. The use of energy is one of the most important things in these analyses.

LCC process Objective

The main objective was to follow the principles of the winning design by prestigious architects and at the same time allowing for design and selection of systems which would provide optimal environmental performance. Options which were selected during the design stage were put together based on LCC assessment and LCA.

Preliminary identification of parameters and analysis requirements

The scope of the analysis involved assessing LCC for selected systems identified based on their environmental performance. Carrying out the LCC for the whole constructed asset is not a common practice in Sweden. The costs of disposal of the selected systems and potential income from recycling were not included. The assessments and decision selection took place throughout the design phase.

All LCC for the systems were calculated based on the NPV method of economic evaluation. The financial parameters considered were real interest rate above inflation and the duration of selected stages of life cycle – as 20-30 years depending on the data on the system.

The systems subjected to LCC were heating, cooling, ventilation, insulation, etc. namely all systems responsible for the energy use and for the indoor climate. The protection of the exhibits was a significant factor in the selection.

Because the environment was a strong decision criterion during the architect competition, the cubic shape of the building was chosen as it leads to a lesser energy consumption than of e.g. loaf shaped building. All the built-in materials had to be reviewed from an environmental and health aspect. Building declarations had to be provided for all the materials used.

Risk analysis was carried out separately from LCC and focused on quality of air, fire protection, energy price, using ammonia in the cooling systems etc.

Sensitivity analysis was carried out for the prices of energy and for the increase of the energy prices for electricity and for district heating.

Confirmation of project and facility requirements

The facility's requirements were selected among the design team to optimise client's functional and environmental requirements. All structural elements and services were selected including the external areas based on a combination of architects' design and environmental performance.

All the built-in materials have been reviewed from an environmental and health aspect. Building declarations have been provided for all the materials used.

Project requirements – there was a fixed total budget from the Swedish Government, but options were selected according to the optimal balance between the cost and environmental performance. The site constraints and project constraints were agreed and acted upon between the client and the design team. The quality requirements of the selected systems and components were also an important factor.

Assembly of cost and performance data

All costs were itemised using an expert on cost calculations of buildings and installation systems within the design team.

Costing of the items of preferred environmental performance and LCC analysis, resulted in e.g. selection of a heat pump, with ten rock (bore) holes, 185 meters down into the rock, which partly heats the museum in the wintertime and cools the museum during the summertime.

Values of financial parameters were assumed as follows: real interest rate (above inflation) of 6.5%, an yearly real increase of the price for electricity 1.5% , for the district heating with 1.3% and for the maintenance 0.5% (as agreed between the client which was National Property Board and by the LCC practitioners) and depending on the system they were applied to – local solar cells for electricity production, heating and cooling systems, the size of the HVAC-units, the thickness of the thermal insulation etc.

Sensitivity analysis was not carried out as a separate exercise. It was assumed to be part of the overall risk assessment. The risk categories were selected and their impact on the project and asset was assessed.

The energy use was calculated by using an advanced simulation tool, which also take into account the interaction between the building structure and the HVAC-systems and the internal loads as heat gains from the sun, people and from different machinery.

LCC analysis and results

The financial parameters were not applied uniformly to the cost groups. The duration of the life cycle varied from 5 to 30 years (insulation). Mostly it was 20 – 25 years. See details in the previous section.

All the values were input in the IT tool, which is internally developed for the purpose of the company.

Auxiliary analyses (risk and sensitivity)

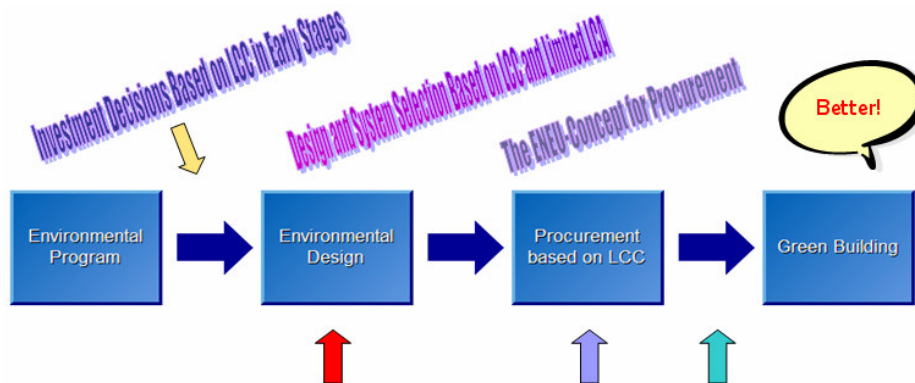
Risk analysis was carried out by the specialist engineers. An external risk register was produced by the design team; however it was not directly linked to the LCC process.

The sensitivity analysis was carried out for different values of the interest rate and the increase of the energy price.

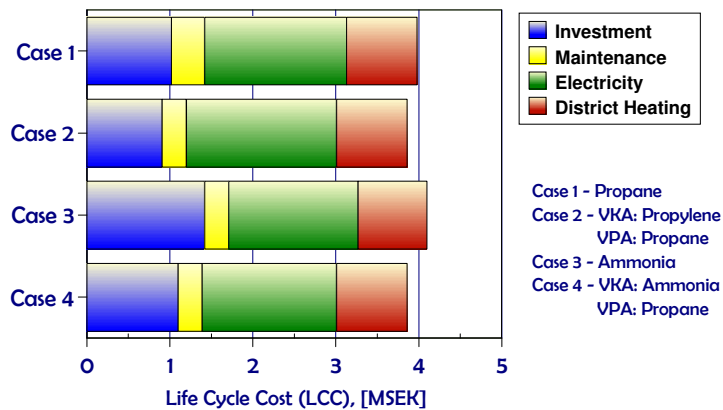
Interpretation and reporting

Results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report to the client was structured according to Swedish standards but essentially it contained all the information which was easy to adjust to follow to the headings in ISO 15686 – Part 5.

Model for use for LCC Analysis in the Design Process used in the project.



Results Analysis of Cooling Systems



Results (continued)

The impact of the ENEU[®] concept and LCC analysis of selected systems had a significant influence on the overall design of the museum building. Combining information from systems environmental assessment, the demands from the users of the building and the overall LCC performance generated an optimal solution.

Conclusions and benefits

The main benefits were in many ways typical for the LCC model utilised in Sweden:

- All the built-in materials have been reviewed from an environmental and health aspect. Building declarations have been provided for all the materials used.
- There has been a big focus on the indoor environment, with the intention of 'P-marking' the museum - this is a rating given to a building that meets specified standards for the indoor environment. These demands include thermal comfort, air quality, damp, radon, light, noise, as well as electrical and magnetic fields. It is also required that there are established routines for indoor environment controls.

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13 Integration of LCC into tenders for infrastructure projects – e.g. A4 Burgerveen - Leiden for Dutch Ministry of Transport, Public Works & Water Management

Project description

Project title – Integration of LCC into tenders for infrastructure projects e.g. A4 Burgerveen – Leiden in Netherlands

Category – Infrastructure projects for Ministry of Transport, Public Works & Water Management in Netherlands

General project information – The Dutch Ministry of Transport, Public Works and Water Management (Rijkswaterstaat) has awarded the widening of the A4 motorway between Burgerveen and Leiden to BAM Civil. Van Oord Nederland realises the design and execution of some 1,600,000 m³ of ground works in a subcontract. To accelerate the consolidation process, 1.5 million m of vertical drainage will be installed. The total value of the contract is around EUR 300 million. Van Oord Nederland is responsible for a share of approx. EUR 22 million. The contract is a design & construct contract regarding the northern and southern part of the widening of the A4. The award was for two parts, which include the widening of about 14 kilometres and the adjustment and construction of several structural works (15 new bridges, 1 new aqueduct and 12 new sound barriers).

At Rijkswaterstaat a new approach for tendering contracts has been developed - the "LCC tender" and has been used on this project. Instead of the lowest capital cost bid, the lowest lifecycle cost was used (as one of the criteria) to determine the economical most advantageous proposal. Different "fit for purpose" approaches were submitted for LCC tenders.

Year of construction – 2007 to 2012

Gross internal floor area (GIFA) – N/A



Aims and objectives of LCC analysis

The role played by civil service has evolved from a 'builder' to that of a 'director' as not only building work is being tendered but design and maintenance work as well. The interaction between contract parties is changing and LCC information needs to be included.

Lack of transparency, an undesirable bargaining position and a tender process with increasingly stiff competition between contractors led to a requirement for a more detailed specification of the desired structure and an exact description of the desired result.

Under the previous approach, contractors were not enticed to be inventive or innovative in realising cheaper or less time consuming solutions. Furthermore, any mistakes or diversion from the contract or building process were leading to expensive contract changes.

Changing policy with regards to the role of the civil service is another reason for development of alternative ways of specifying and tendering contracts and including LCC. The political trends to decrease civil service and transfer of responsibility to the private sector have been important stimuli. All of this has had a major influence on the development and application of new forms of contracts, contract specifications, tender process and inclusion of LCC.

LCC process Objective

The main objective was to use and test tenders and contracts with economically optimised structural solutions on the basis of life cycle cost. Tenders consisted of initial design cost + initial building costs (and possibly maintenance costs), but the lowest tender was determined by the initial costs plus the Net Present Value (NPV) of the maintenance prognosis.

Preliminary identification of parameters and analysis requirements

The Ministry of Transport, Public Works and Water Management (RWS) carries out a significant proportion of building work, which are tendered with a ten to fifteen year period of maintenance. This period is determined on the basis of the life cycle cost analysis of pavement/surfacing. Many other components or structures of a highway/motorway have a significantly higher life expectancy and therefore longer term maintenance risks are insufficiently covered in this period.

Maintenance is generally the result of choices made during design. A key feature of civil engineering projects is the fact that the first significant maintenance activity typically takes place many years after the initial build has been completed. In the tenders for the A4 Burgerveen – Leiden on the basis of life cycle cost, long term cost forecasts were taken in account, even though these costs would never be the responsibility of the contractor. Assessment of the NPV of the maintenance forecast was used to compare the different tenders.

The Dutch government currently specifies a general discount rate of 4 %. For large scale projects or high risk projects this rate may be readjusted to, in some cases, a more conservative rate of 3%.

The environmental performance is not a strong decision criterion.

Risk and sensitivity analyses are not part of the requirements for LCC driven tenders although focus is on quality.

Confirmation of project and facility requirements

A difficult aspect with applying life cycle cost criteria is determining the most likely life cycle period or lifespan. Choices made during the design determine the technical lifespan of a structure and in most cases the actual lifespan is determined by functional demands (such as changing road widths or permitted axle-loads). Data collected on demolished bridges (viaducts) from the last 20 years shows that the life expectancy of such structures is approximately 80 years.

In most cases, the functional purposes of a structure would still apply at the end of a technical life. Costs for demolition and replacement should therefore be taken in to account, assuming replacement by a structurally similar solution.

Applying an exact lifespan in a life cycle cost analysis is arbitrary because comparing different alternatives may be confused by the selected combination of a lifespan and applied discount rate. Applying an infinite time horizon may be more informative, especially when uncertainties in lifespan are taken into account in probabilistic models. The assumption is that structures will be demolished and replaced with an average interval (repetitive life cycle). The functionality of a demolished structure remains and will be fulfilled by a new structure. This assumption has only a limited impact on life cycle cost results (compared to a set time frame) because costs generated in the distant future contribute little to the lifecycle cost total due to the effects of discounting.

Assembly of cost and performance data

The comparison of tenders was carried out using a software tool, recently developed by Rijkswaterstaat a 'Cost Analysis Lifecycle Model (CALM)', a prototype tool to facilitate a tender process on the basis of life cycle costs. CALM contains a small database with a variety of mainstream structure-types, their correlated components and their standardised maintenance strategies (referred to earlier) most commonly used in and over highways in the Netherlands. Each of these structure-types and components is provided with a predetermined 'costs per unit' for future maintenance. These 'costs' are made up of averages, based partly on theoretically determined deterioration behaviour and partly on deterioration experience. These costs per unit are then converted to a Net Present Value (NPV) per unit.

Concerning an overall structure-type all costs are "All-inclusive". This means that not only 'out of pocket' costs are negotiated but V.A.T (taxes) and company/civil service costs are included in the cost per unit. Costs per unit for components consisting merely of 'out of pocket' costs are multiplied with an 'overhead factor' in order to determine 'All-in costs'. This factor determined for each structure type.

CALM distinguishes design costs (all costs related to the design process (V.A.T. included)) and realisation costs (all costs related to the actual building process (i.e. labour and materials etc.) (V.A.T. included)).

CALM also allows for exploitation costs - the total of costs expected to maintain (newly) acquired functions on a required level and within the required (legal) boundaries, this means all activities to keep a function 'running', including maintenance. A structure is maintained solely in order to fulfil and thus maintain a function. These costs are not included in the contract sum.

These costs can be divided into (i) costs for replacing complete structure-for each structure type the average lifespan is determined. On the basis of this interval costs for replacement are set out infinitely; (ii) costs for Inspection - the average yearly costs made for a diversity of inspection types performed on each particular structure type ; (iii) costs for Routine Maintenance - the average yearly costs made for routine maintenance performed on each particular structure type and (iv) costs for Gross Maintenance - the major

cost bearing components are determined for each structure type. A subscribing contractor enters his choice for a particular component (type) in the adjacent column. On the basis of a quantity determined by the contractor, the NPV for expected maintenance costs is calculated. These costs are multiplied with the relevant overhead factor. If additional traffic (diversion) measures are needed (predetermined) then these costs are also converted to NPV and added to the expected costs for maintenance.

The simple summation of founding costs and exploitation costs may be used to determine the most economical offer, while each individual design can be rated by transparent and unified criteria.

Rijkswaterstaat 's current maintenance policy states that maintenance to viaducts and other structures in and over Dutch highways will be executed together with road surface works as much as possible. If components have an average maintenance interval greater then 10 years it is safe to assume, insuring an adequate regime for inspection, that they can be maintained or replaced during road surface works.

Maintenance costs may be increased by higher intensity use and incidents. Otherwise maintenance costs are usually relatively low, mainly consisting of costs for routine maintenance and incidents (i.e. collision damage) repairs. The volume of routine maintenance costs is dependant on choices made during design.

Sensitivity and risk analyses are not typically carried out as a separate exercise supporting the tender.

The financial parameters are typically applied uniformly to the cost groups. The duration of the life cycle varies up to 60 years.

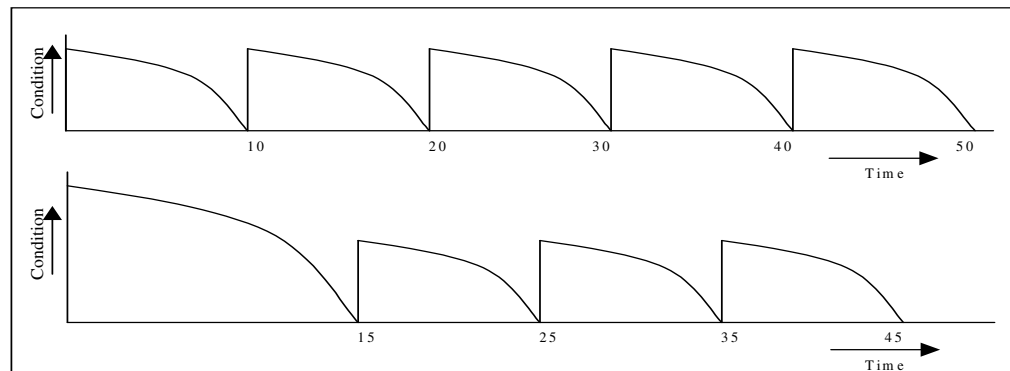
Risk and sensitivity analyses are not typically prepared within the LCC based tenders. The sensitivity and risk analyses are not aspects for LCC in the EMAT-procedure described in the tender formats, since the LCC-procedure is no more than a uniform rewarding system. However, before the rewarding system is used in contracts, a sensitivity analysis should be carried out.

Results included the outputs from the Excel based LCC tool, providing the following information: tables of costs, parameters of the analysis, annual expenditure and detailed cost profile. The formal report contains all the information which can be easy to adjust to follow to the headings in ISO 15686 – Part 5.

**LCC analysis and results
Auxiliary analyses (risk and sensitivity)**

Interpretation and reporting

Reference estimate (top) versus the contractor's solution with a longer warranty



Data entry screen in CALM as used for A4 Burgerveen - Leiden

Category	Sub-category	Amount	Unit	NPV per unit	NPV traffic cost	
Founding costs	Realization costs	€ 1.500.000				
	Design cost	€ 500.000				
	Founding cost (subtotal)	€ 2.000.000				
Exploitation costs	Inspection cost	€ 16.233,33	stuk	€ 16.233,33	€ 16.233,33	
	Routine maintenance	€ 44.000,00	stuk	€ 44.000,00	€ 44.000,00	
	Replacement cost	€ 3.888,02	m	€ 3.888,02	€ 194.401,13	
	Pavement, traffic class 1-3	1000	m2	€ 0,95	€ 0,00	€ 112.570,18
	Main span	1500	m2	€ 1,54	€ 0,00	€ 3.213,84
	End bearings	2	paarsel/indiv	€ 3.523,57	€ 0,00	€ 27.887,54
	Midspan bearings	3	paarsel/strip	€ 15.436,67	€ 121.954,04	€ 233.900,34
Joints	40	m	€ 6.646,00	€ 118.252,31	€ 533.929,89	
Guardrail structure	100	m	€ 103,31	€ 0,00	€ 14.360,32	
Exploitation cost (subtotal)					€ 1.180.197,12	
Lifecycle-cost (total)					€ 3.180.197	

Results (continued)

The LCC-criteria should be related more thoroughly to other requirements and specifications in the contract to avoid negative unforeseen effects. Expansion joints give a good example that illustrates the unforeseen effects of conflicting requirements, as they can make up 20 to 30% of maintenance costs for viaducts.

Conclusions and benefits

Life cycle costs were incorporated as a criterion for determining the (economically) most profitable bid in the tender of functionally specified contracts. By considering life cycle costs in a tender process, contractors were encouraged to design, develop and offer solutions that are profitable and beneficial on a longer term. This is not only in the interest of the procurer but also offers contractors a better opportunity to distinguish themselves in terms of quality and service. In addition, parties may gain from design optimisation for maintenance.

The LCC-tender for A4 Burgerveen - Leiden was successful in a sense that the expected maintenance costs were reduced considerably, without having a considerable effect on the construction cost. Contractors were given the opportunity to distinguish themselves by offering a balanced life cycle design and development of innovations that imply savings on life cycle cost.

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