June 2006

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

Draft Methodology: Key issues and outline framework

Contents

Background

The main purpose of the Commission Communication COM (97) 539 http://europa.eu.int/comm/enterprise/construction/compcom/compcom.htm was to examine ways of raising the competitiveness of the construction sector. In particular, the Communication outlined the need to implement life cycle costs criteria in all the phases of the construction process and to elaborate standards for durability assessment and accurate planning of maintenance, running, replacement and disposal costs, especially for public procurement procedures. By taking into account not only the initial costs but also the subsequent costs, this would allow a proper assessment of different alternatives to achieve client's requirements whilst integrating environmental considerations.

The Commission Communication COM (2004) 60 http://europa.eu.int/eur-lex/en/com/cnc/2004/com2004_0060en01.pdf on the thematic strategy on the urban environment also outlines the need to develop a common methodology at European level for evaluating the overall sustainability performance of building and construction, including their life-cycle costing. This would incorporate among others the standardisation work which has been carried out by the European Standardisation Committee within the context of the Directive 2002/91/EC on the Energy Performance of Buildings http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_001/l_00120030104en00650071.pdf.

As a follow up to the above Communication, the Commission convened a Task Group comprising of representatives from construction industry, national administrations and research institutions with the scope of elaborating recommendations and guidelines on Life Cycle Costing (LCC) aimed at improving the sustainability of the built environment.

The report from the Task Group is available at the following address: http://europa.eu.int/comm/enterprise/construction/suscon/tgs/tg4/lcalccintro_en.htm. Among others, the Task Group recommended to adopt a common European methodology for LCC in construction taking into account the work done under international standards ISO 15686. The methodology should allow the definition of a harmonised framework to facilitate the development of software tools to estimate Life Cycle Costs on a European basis.

The work undertaken focuses on practical guidance on how to refine the estimations at each stage of the project, from the initial appraisal up to the completion and post-occupation phases, including the disposal of the asset.

An EU approach for LCC is intended for both the public and the private sectors, although it would primarily address contracting authorities. In particular, the outcome from the study would support incorporating LCC in public procurement of large scale projects when the criterion of the Economically Most Advantageous Tender (EMAT) is chosen.

1 Introduction

1.1 Objective

The overall objective of this project is to provide a specification for a standardised methodology for estimating Life Cycle Costs (LCC) while taking into account environmental factors and EU member countries' local approaches and development needs. In meeting this objective, the methodology aims at improving:

- competitiveness of the construction industry
- industry's awareness of the influence of environmental goals on LCC
- performance of the supply chain, the value offered to clients, and clients' confidence to invest through a robust and appropriate LCC approach
- long-term cost optimisation and forecast certainties
- reliability of project information, predictive methods, risk assessment and innovation in decision-making for procurement involving the whole supply chain.

It also aims to:

- generate comparable information without creating national barriers and also considering the most applicable international developments.

1.2 Developing a methodology

This paper identifies key issues in the development of an LCC methodology. It provides an outline framework for the further development and practical use of the methodology and raises issues for discussion.

Our approach is being developed around the following components:

- Guidelines specifying the **process** (and steps) necessary for the successful application of an LCC methodology and containing advice and recommendations on how to use it.
- **Techniques and tools** representing the detailed analytic and evaluation processes and guidance on how to use them throughout the entire assessment lifecycle.
- **Templates** providing reusable documents and checklists with advice and assistance in completing tasks.

A Methodology is considered as a system of principles, practices, and procedures applied to LCC with series of choices that would include:

- what information and data to gather
- how to analyse the gathered information and data
- how to interpret and use the outputs.

An important feature of any approach to LCC is its essentially **iterative** nature. Construction projects progress through key stages at each of which decisions about choices of products, components, materials and other matters need to be reviewed, refined and developed. The estimation and calculation of LCC also needs to be progressively refined and focused to provide increasing certainty of the total LCC of the project.

In practice, LCC remains a set of techniques that are not applied in a consistent manner within EU member countries, let alone across the EU as a whole. An important consideration therefore in the development of an LCC methodology is to identify a sort of '**common denominator**' (essentially a simplified basis) that can provide a recognisable framework for using LCC and also provide the basis for future development. Our approach to this is to take account of the most essential and commonly used scenarios and instances in which LCC may be applied, whilst allowing for country-specific approaches in line with local standards and guidelines.

1.3 Scope of the methodology

We believe that the methodology should be targeted at a consistent LCC approach and calculations as well as providing for consistent use of environmental data in the assessments. Of course, the methodology should not be aimed at reducing costs but at making more informed and consistent economic, financial and environmental decisions, while budgeting for, or comparing options. (**Note** that we provide definitions of LCC and its boundaries in Section 3 below).

We believe that a common LCC methodology should provide for the following:

- Allowing users to identify their:
  - Needs and constraints
  - Role in the LCC process
  - Stage in the project life-cycle at which LCC is to be deployed
- Establishing a common basis for comparison (if comparing options)
- Deciding on the level of environmental considerations and applying the relevant assessment method and tools
- Selecting the most suitable financial model, sensitivity analysis methods, risk assessment method and supporting tools
- Performing and documenting LCC estimates
- Reporting the results
- Identifying the most suitable design option or solution, including the optimum:
  - cost-driven solutions
  - technological solutions
  - environmental solutions

We are developing a methodology to be generic enough for practical use across a broad range of project and technology types as well as stages of the project life cycle. It will build on established cost accounting practices that are uniform and consistent with best pr4actice in EU member states. For completeness the methodology will also addresses data sources, supplementary analyses, reporting structures and roles and responsibilities.

1.4 Limitations

In developing a methodology we do not assert that cost savings should be the deciding criterion in determining the design or technological solution. It is recognised that regulatory compliance, low environmental impact, stakeholder concerns, reduced risk, etc. may each be equally important to the decision maker.

Direct comparisons between projects is difficult because of the number of variables involved, including differing cost accounting practices, contract types, organisational structures, IT tools and approaches, and work breakdown structures. It is outside the scope of this project to develop and disseminate a single, comprehensive standardisation policy or capability for cost estimating and accounting that considers all these independent variables.

The methodology is not intended to replace country-specific decision models and approaches.

2 Overview

2.1 Initial development work

Our initial work on the development of a common LCC methodology sought to map the 'domain' of LCC assessment. We were particularly interested in understanding – initially at a broad, conceptual level – what should be included in Life Cycle Costing (LCC) as distinct from what should be included in Life Cycle Analysis (LCA – which focuses specifically on environmental performance). Given that the development of LCA standards and methodologies is the subject of separate work at EU level, we are keen to define the boundaries of LCC as it relates to LCA.

Thus we have developed a schematic (shown in Appendix A) that attempts to identify, at a broad conceptual level, the main components of LCC and how these relate to LCA. The main components of LCC arising from this analysis are:

- LCC analysis approaches and techniques
- Data requirements and formats (including cost classification methods and systems)
- LCC estimating and calculating methods, techniques and models
- IT tools
- Risk assessment approaches and methods

We analysed and reviewed this further via:

- A literature review (we have produced a separate report on this – see our June 2006 report)
- Consultation with key country experts in a workshop environment, and also by correspondence (this is described in our Progress Report of June 2006)
- Consultation with in-house practitioners.

The analysis has resulted in the identification of initial proposals for the key elements of a common methodology, and these are outlined in the following section.

2.2 The key components of a common LCC Methodology

We see the essential components of a common LCC methodology to be as follows:

A process model – essentially a model for the practical implementation of LCC that presents a decision process, together with the necessary criteria, analysis tools and techniques that will enable the user to undertake an effective LCC evaluation. This is described more fully in Section 4 below.

An issues and decisions matrix – essentially a map of key stages in the project life cycle against the key 'levels' at which LCC evaluations need to be undertaken and decisions taken This identifies the key issues to be taken account of in LCC decisions at each stage in the project life cycle and for each level of analysis. This is described more fully in Section 5 below.

User scenarios – these are typical project scenarios that take account of different user requirements at different stages in the project life cycle. The number of possible user scenarios derived from the issues and decisions matrix is potentially large, and selecting

typical scenarios provides a means of focusing the methodology on the most likely uses. Scenarios are described further in Section 6 below.

Data requirements and Cost classification – the data required for LCC and the ways in which cost data can be classified to aid analysis and comparison are an essential part of the common methodology, although we note that it is not within the scope of this project to determine new standards for data and cost classification. These are described more fully in Section 7 below.

Economic and Financial Analytic tools – the methodology will need to incorporate a range of economic, financial and other analytic tools and techniques. These are described more fully in Section 8 below.

Other Analytic and evaluation tools – including LCA, risk analysis, sensitivity analysis, IT tools and other techniques need to be identified in the common methodology and, in so far as possible, integrated within it. These are described more fully in Section 9 below.

2.3 The way forward

We believe we have identified and described the key components of the common methodology and presented them in a way that is potentially very workable and useful. Work is now underway on how these different components can be structured and integrated, which is the next main task on the project. We believe that by combining the key elements of the process model outlined in Section 4, together with the Issues and Decisions Matrix in Section 5 and the User Scenarios at Section 6 provides the best option for integrating all these components. We would welcome the views of the Project Steering Group on how this might best be done.

3 The domain of Life Cycle Costing

3.1 What is Life Cycle Costing (LCC)?

There are a great variety of different definitions of LCC – our literature review accompanying this paper provides an overview. Our working definition for our current work on the development of an LCC methodology is as follows:

> *A tool or technique that enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational and asset replacement cost.*

LCC is generally used to compare alternatives that satisfy the same functional requirements, or to assess the overall impact of producing, operating and disposing of an asset over its life cycle, primarily in financial/economic terms. Investment choices are normally made on the basis of options that offer the most attractive (to the investor/client) combination of performance and cost.

3.2 What is Life Cycle Assessment (LCA)?

In developing a common methodology for LCC, we believe it is important to distinguish clearly between LCC and LCA. This is partly because LCA is currently the subject of other work focused on the development of new standards and assessment methods (CEN/TC 350 WI 350001 (2006) *Sustainability of construction works – framework for assessment of buildings* (working document for European Standard)) and also because LCA has a particular focus on environmental aspects that can be problematic and difficult to incorporate within an LCC framework.

Again, there are a variety of definitions for LCA, and the one we have adopted as a working definition on this project is:

> *The assessment of the environmental impact of a product or service throughout its lifespan.*

LCA refers to the comprehensive examination of a product's environmental and economic aspects and potential impacts throughout its lifetime, including raw material extraction, transportation, manufacturing, use, and disposal. LCA methods deal with the complex interaction between a product and the environment. The technique is sometimes referred to as Ecobalance. LCA systematically describes and assesses all flows to and from nature, from a cradle-to-grave perspective. There are generally two steps to LCA:

- Inventory step describes which emissions will occur and which raw materials are used during the life of a project.
- Assessment step assesses what the impacts of these emissions and raw material depletions are.

The ISO 14000 series demands continuous improvement in environmental management systems. LCA, with its focus on product/process improvement can help meet this demand. However, the lack of readily-available, quality inventory data is often a barrier to manufacturers, among others, for incorporating life cycle considerations into their decision making process. While much progress has been made on standardising and improving the uniformity of the Life Cycle Assessment (LCA) methodology, less success has been achieved in increasing the availability of quality life cycle inventory data.

3.3 Integrating LCC and LCA

Integrating LCC and LCA represents a powerful route to obtain best value solutions in financial as well as environmental terms. However, a key barrier is that respective outputs from LCC and LCA are different. LCC outputs are normally expressed financially (see further below at Section 8), e.g.:

- Net Present Value (NPV) for selected options
- Cash flow statements
- Net benefits (NB) and net savings (NS) results
- Benefit-to-cost ratio (BCR) and/or savings-to-investment ratio (SIR)
- Internal and overall rates of return (IRR and ORR)

By contrast, outputs from LCA results are normally represented by an environmental performance score (e.g. eco-points) that can aid the decision process. Converting these environmental measures into financial measures can be a time-consuming task, and there is no generally available or widely accepted methodology to allow this.

Further, LCA and LCC deal with different 'components' of projects, and it may sometimes be necessary to aggregate them in order to ensure like-for-like comparisons across the two approaches. Also, LCA and LCC deal with different time periods – the focus of LCA on 'cradle-to-grave environmental performance of products can mean that LCA considers aspects that are out of the range of LCC (which takes as its starting point project initiation, rather than pre-project processes concerned with raw material extraction and production, for example).

LCC and LCA are two domains without common output, as shown in Fig. 3.1 below.

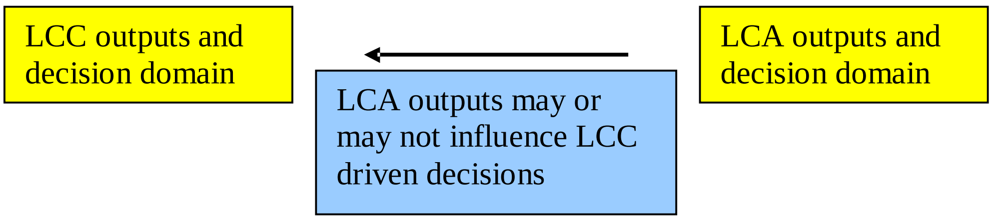


Fig. 3.1 Relationship between LCC and LCA domains

4 LCC – the process model

4.1 Process models

We have reviewed a number of LCC process models as part of the literature review that accompanies this paper. A useful model is that by Kirk and Dell'Isola (1995) which outlines an LCC implementation process. This is shown in Fig 4.1 below.

LCC Implementation model (costing procedure) (based on Kirk and Dell'Isola 1995)

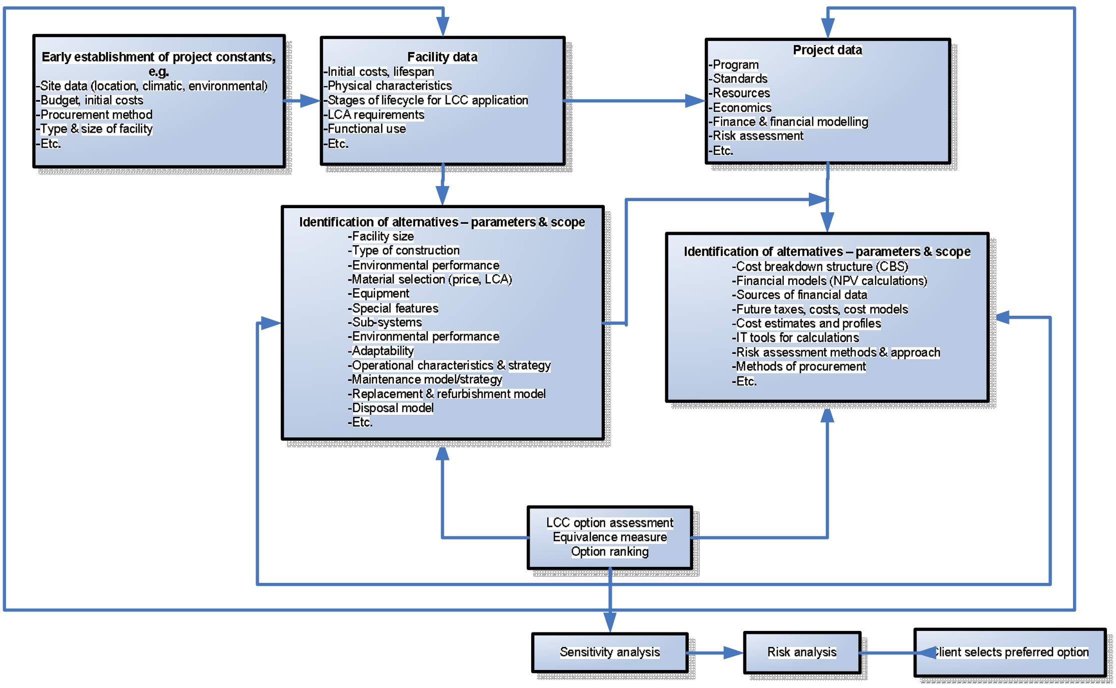


Fig. 4.1 LCC implementation model by Kirk and Dell'Isola 1995

The key elements are:

- Identification of project constraints
- Assembly of benchmark data (for the type of facility contemplated, and for the project in particular)
- Identification of alternatives (again for the type of facility contemplated, and for the project in particular)
- Options assessment, followed by Sensitivity and Risk analysis in order to identify and select the preferred option.

We find this schematic very useful in providing a basic and understandable model of the process. We have used it to develop a more detailed model as shown in Fig 4.2 overleaf. The main components of our proposed model are as follows:

1 Data collection

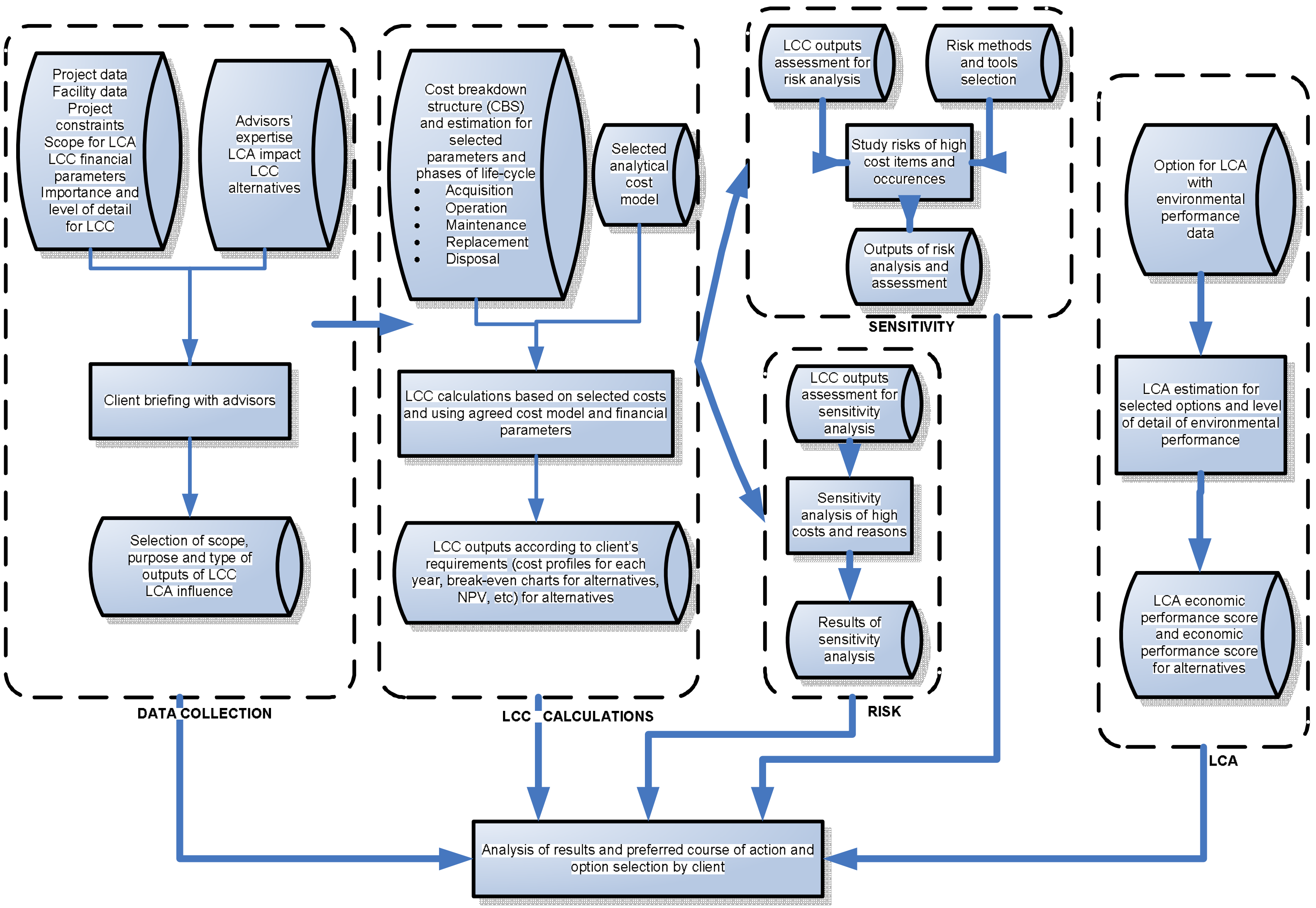
2 LCC calculations

3 Sensitivity analysis

4 Risk analysis

5 LCA

The Project Steering Group's views are invited on this approach, and the appropriateness of this Process Model.



Project data
Facility data
Project constraints
Scope for LCA
LCC financial parameters
Importance and level of detail for LCC
Advisors' expertise
LCA impact
LCC alternatives
Client briefing with advisors
Selection of scope, purpose and type of outputs of LCC
LCA influence
DATA COLLECTION
Cost breakdown structure (CBS) and estimation for selected parameters and phases of life-cycle
Acquisition
Operation
Maintenance
Replacement
Disposal
Selected analytical cost model
LCC calculations based on selected costs and using agreed cost model and financial parameters
LCC outputs according to client's requirements (cost profiles for each year, break-even charts for alternatives, NPV, etc) for alternatives
LCC CALCULATIONS
LCC outputs assessment for risk analysis
Risk methods and tools selection
Study risks of high cost items and occurences
Outputs of risk analysis and assessment
SENSITIVITY
LCC outputs assessment for sensitivity analysis
Sensitivity analysis of high costs and reasons
Results of sensitivity analysis
RISK
Option for LCA with environmental performance data
LCA estimation for selected options and level of detail of environmental performance
LCA economic performance score and economic performance score for alternatives
LCA
Analysis of results and preferred course of action and option selection by client

Fig. 4.2 LCC proposed detailed implementation model

5 Issues and decision matrix

5.1 LCC – the decision process boundaries

According to the Task Group 4 report “Life cycle costs in construction” (which is supporting the finalisation of ISO 15686 Buildings and constructed assets – Service life planning – Part 5: Life cycle costing), the time dependant stages of the life of the facility that need to be considered during the decision and procurement processes are:

- Acquisition (including pre-construction and construction)
- Operation
- Maintenance
- Replacement (or refurbishment)
- Demolition

The decision process and elements of the facility that need to be considered are illustrated in Fig. 5.1 and described in more detail later. There are three decision or appraisal levels:

- Strategic
- System
- Detail

At each level consideration must be given to the basic elements of the facility:

- Structure
- Envelope
- Services
- Finishes, fixtures and fittings

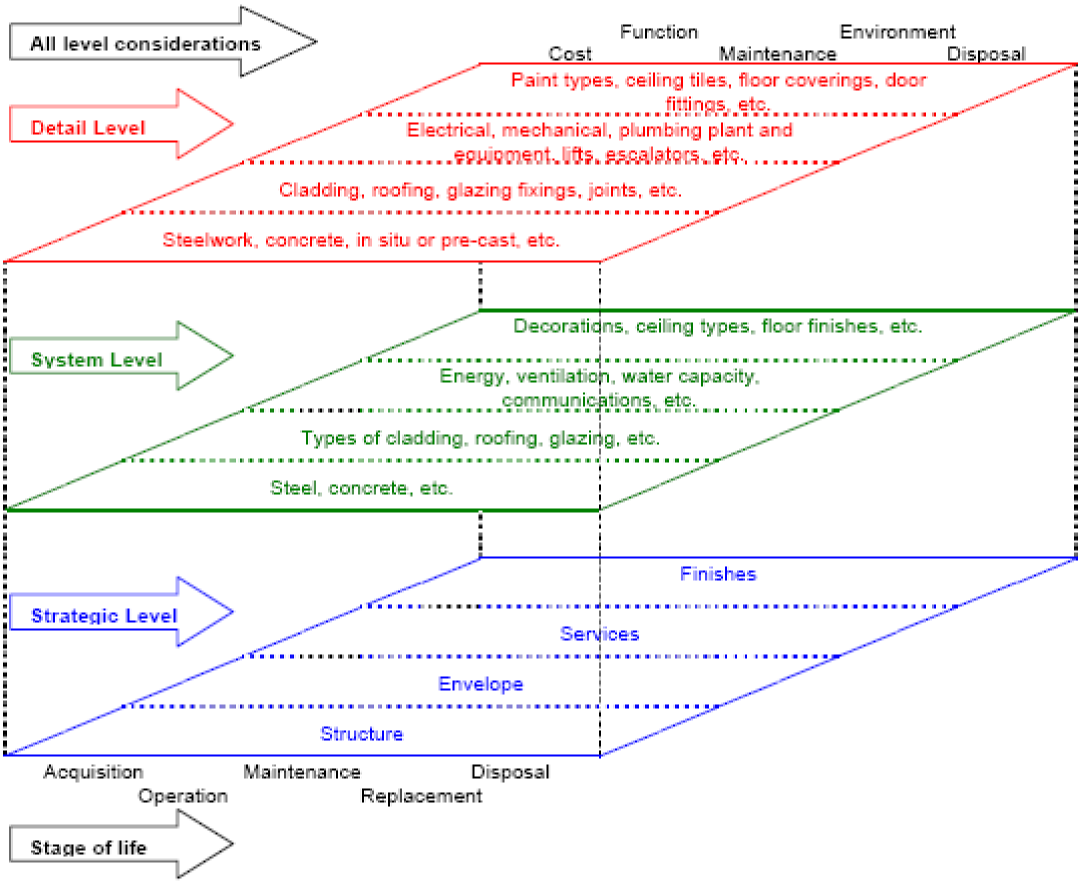


Fig. 5.1 The decision process and elements

We believe it is appropriate to adopt this broad framework the help structure the development of the methodology. We use it as a starting point for a more detailed framework that identifies the important issues to be considered and the decisions required at key stages in the life cycle of assets.

Fig. 5.2 shows our initial attempt at a matrix that identifies the key issues and decisions for each of the project stages and levels of analysis.

In theory the matrix should help guide users through the LCC process and the decisions needed. Users of the LCC methodology users could start by finding a path through the matrix that reflects their requirements according to particular stages in the asset life cycle and the level of detail they need to address.

In order to make the methodology more practically useful we are proposing to identify a set of typical scenarios (see Section 6 Fig. 6.1).

Countries – UK, Ireland, France, Germany, Netherlands, Finland, Norway, Sweden. Czech Republic, Spain & Greece

Level	1. Acquisition (pre-construction & construction)	2. Operation	3. Maintenance	4. Replacement or refurbishment	5. Demolition/ Disposal
3. Detail appraisal level • Details of steelwork, concrete, in-situ • Cladding, roofing, glazing • Electrical, mechanical, plumbing • Paints, ceilings, doors	3.1.1 Initial decisions' checklist 3.1.2 Implementation of LCC 3.1.3 Cost drivers 3.1.4 Selection of materials & components 3.1.5 Site processes 3.1.6 Resources & workmanship level 3.1.7 Data collection 3.1.8 Refined LCC plan 3.1.9 Performance Drivers	3.2.1 Initial decisions' checklist 3.2.2 Cost drivers 3.2.3 Detailed operational costs 3.2.4 Subcomponents of the risks centres & their cost options 3.2.5 Detailed cost models for waste disposal, water, telecoms, sewage, security, etc. 3.2.6 Detailed cost models for support costs (mail, transport, archiving, moving, etc.) 3.2.7 Performance drivers	3.3.1 Initial decisions' checklist 3.3.2 Cost drivers 3.3.3 Strategies for fit-out improvement 3.3.4 Subcomponents of the risks centres & their cost options 3.3.5 Detailed maintenance regimes (normal, emergency, cyclical, preventive) 3.3.6 Performance Drivers	3.4.1 Initial decisions' checklist 3.4.2 Cost drivers 3.4.3 Detailed frequency & schedule for repair & replacement of elements 3.4.4 Subcomponents of the risks centres & their cost options 3.4.5 Performance Drivers	3.5.1 Cost drivers 3.5.2 Salvage value 3.5.3 Salvage & recycling - capabilities & value 3.5.4 Mechanisms to recycle components
2. System appraisal level • Steel/concrete • Cladding • Energy, M&E • HVAC • Finishes, fixtures & fittings	2.1.1 Initial decisions' checklist 2.1.2 Implementation of LCC 2.1.3 Facility outline 2.1.4 Ease of functional reconfiguration 2.1.5 Impact on quality of life 2.1.6 Design & construction process 2.1.7 Contractual arrangements 2.1.8 Payment methods 2.1.9 Resources 2.1.10 Data collection 2.1.11 Performance Drivers	2.2.1 Initial decisions' checklist 2.2.2 Cost drivers 2.2.3 Data collection 2.2.4 Operational cost models 2.2.5 Denial-to-use costs 2.2.6 Occupancy data 2.2.7 Strategies for reconfiguration 2.2.8 Strategies for building operational costs (security, insurance, water, sewage, cleaning & waste disposal, etc.) 2.2.9 Mechanism for FM 2.2.10 Risks centres for energy & FM 2.2.11 Performance drivers	2.3.1 Initial decisions' checklist 2.3.2 Cost drivers 2.3.3 Data collection 2.3.4 Frequency & schedule for internal, external & M&E maintenance 2.3.5 Grounds maintenance 2.3.6 Mechanisms for evaluating operational termination 2.3.7 Mechanism for facilities management & project management 2.3.8 Risk centres for maintenance & finance costs 2.3.8 Performance drivers	2.4.1 Initial decisions' checklist 2.4.2 Cost drivers 2.4.3 Data collection 2.4.4 Frequency & schedule for internal, external & M&E repairs & replacements 2.4.5 Mechanism for facilities management & project management 2.4.6 Environmental impact of options 2.4.7 Performance drivers	2.5.1 Cost drivers 2.5.2 Data collection 2.5.3 Residual value (what is worth at the end of live) 2.5.4 Land & demolition cost 2.5.5 Disposal methods 2.5.6 Site & land clean-up
1. Strategic appraisal level • Structure • Envelope • Services • Finishes	1.1.1 Methodology type 1.1.2 LCC – purpose of use 1.1.3 Implementation of LCC 1.1.4 Cost drivers 1.1.5 Data needs 1.1.6 Finance – costs, budgets, spending 1.1.7 Selection of methods of procurement 1.1.8 Facility characteristics 1.1.9 Mathematical modelling for investment assessment 1.1.10 Risk management strategies, techniques, models & measures 1.1.11 Performance drivers	1.2.1 Initial decisions' checklist 1.2.2 Cost drivers 1.2.3 Operational strategies 1.2.4 Costs of economical factors (rates, taxes) 1.2.5 Operating costs 1.2.6 Occupancy modelling 1.2.7 Income 1.2.8 Risk reserves for insurance, charges & taxes 1.2.9 Selection of forecasting methods 1.2.10 Data needs 1.2.11 Performance Drivers	1.3.1 Initial decisions' checklist 1.3.2 Maintenance purpose 1.3.3 Maintenance regimes 1.3.4 Maintenance requirements selection 1.3.5 Cost drivers 1.3.6 Data needs 1.3.7 Costs 1.3.8 Risk reserves for maintenance 1.3.9 Performance Drivers	1.4.1 Initial decisions' checklist 1.4.2 Maintenance models & strategies 1.4.3 Environmental impact 1.4.4 Cost drivers 1.4.5 Costs (replacement, refurbishment & alterations) 1.4.6 Risk reserves for replacement or refurbishment 1.4.7 Data needs 1.4.8 Performance drivers	1.5.1 Cost drivers 1.5.2 End of use strategies 1.5.3 Environmental benefits 1.5.4 Salvage value 1.5.5 Reserve for waste disposal 1.5.6 Site resale or redevelopment 1.5.7 Risk reserves for end-life 1.5.8 Data needs

Fig. 5.2 LCC framework matrix

6 Typical user scenarios

The scenarios below do not limit the use of the LCC methodology. In practical terms these are the most common situations where the LCC calculations and re-calculations are most needed.

WHO	WHEN	WHAT	WHY	HOW	DATA
Public client with advisors (financial, technical (QS, M&E, FM and architects), legal, industry planners and HR)	Acquisition, pre-construction	Early cost advice (NPV) for option comparison Report from advisors	Finalise site data (location, environmental) Size up budget and initial costs Procurement method Financial profile Early feasibility assessment (size, cladding, heating, etc.) Prepare ITT Secure finance Approach consortia Decide length of contract	Check NPV for different sizes, heating, cladding, etc. and using historical data Take into account the following costs for NPV (investment, replacement, residual value, energy, operating, maintenance and repair costs)	Advisors' historical data and models Advisors' experience and databases Client's data and models Existing regulations & national standards Sources of financial data (taxes, DR, inflation)
Consortium (contractor, architect, FM, M&E) with advisors (financial and technical (QS, FF&E, specialist contractors, manufacturers))	Acquisition, pre-contract, post-contract pre-construction	Cost advice (NPV) for option comparison Residual value at the end of the contract Risk assessment report Schedule of items with cost and life expectancies	Negotiate contract details with the client Finalise more physical project characteristics Establish general impact on sustainability and environment for various options Decide FM regime Align with finance	Using results of feasibility studies decide on main options Assemble schedule of main items with costs and life expectancies for maintenance regime Align with finance (payments as fixed costs or expenditure)	Advisors databases and models Manufacturers' data Environmental data Sources of financial data (taxes, DR, inflation)
Consortium (contractor, architect, FM, M&E) with advisors (financial and technical (QS, FF&E, specialist contractors, manufacturers))	Post-contract, pre-construction and construction	Economic evaluation calculations Cost advice (NPV) for option comparison Other economic evaluation – NB/NS, BCR/SIR, IRR, PB Sensitivity analysis Risk assessment Finalised/detailed schedule of items with cost and life expectancies	Optimise choices (cost and benefits) Select the most beneficial option Appoint specialist contractors Comply with regulations and standards Consider environmental impact and balance it against costs Identify cost effective designs Identify cost effective replacement times and maintenance schedules Decide on level of operation (soft FM) Decision on lease or buy	Using design details and specification decide on main options Assemble schedule of main items with costs and life expectancies for FM Align with finance (payments as fixed costs or expenditure) Carry out economic evaluation with justification and selection Calculate environmental impact Carry out sensitivity analysis & risk assessment	Advisors databases, and models Manufactures' data Environmental data Sources of financial data (taxes, DR, inflation)
Consortium (contractor, architect, FM, M&E) with advisors (financial and technical (QS, FF&E, specialist contractors, manufacturers))	Hand-over, outset of operation, maintenance and replacement phases	Detailed cost advice (NPV) for option comparison Other economic evaluation – NB/NS, BCR/SIR, IRR, PB Sensitivity analysis Risk assessment Updated schedule of items with cost and life expectancies Environmental performance	Finalise soft and hard FM models Calculate residual value at the end of contract Compare options for component selection Budget Assess environmental performance	Using design details and specification decide on main options Assemble schedule of main items with costs and life expectancies for maintenance regime Align with finance (payments as fixed costs or expenditure) Produce environmental performance report Carry out updated risk assessment	Advisors databases, and models Manufactures' data Environmental data Sources of financial data (taxes, DR, inflation)

Fig. 6.1 Typical scenarios for methodology application

7 Data requirements and Cost classification

7.1 Cost categories

The current draft version of ISO/DIS -15686 – Part 5:2006 lists a generic cost structure which should be flexible enough to accommodate national classifications used for the LCC calculations.

Also in Figure 3 ISO/DIS -15686 – Part 5:2006 lists costs and describes their scope which has slightly different structure. In order to normalise costs definitions, allocation to the main cost groups and their scope a comparative table was produced which maps both cost categories.

Table 7.1 Mapping of cost categories within ISO/DIS -15686

Generic cost structure as in ISO/DIS -15686 – Part 5:2006	**Costs listed in Figure 3 of ISO/DIS -15686 – Part 5:2006**
Acquisition Costs (including pre-construction and construction	Non-construction costs (acquisition, finance, business) Construction costs (design, temporary works, construction, external and infrastructure costs, PM costs and FF&E)
Operation and Maintenance Costs	Operation costs (rates, insurance, regulatory costs, taxation, local charges, FM) Maintenance costs (service and maintenance) Handback costs
Major Repairs, Replacement and Adaptation Costs (including upgrades and refurbishment)	Construction costs (adaptation, refurbishment, etc.) Maintenance costs (repairs, replacement) Replacement costs (restoration, adaptation, fitting out)
Energy, CO_2 Emissions and other Environmental Costs (dealt with as part of whole LCC analysis)	Operation costs (energy)
Sunk Costs - costs of goods and services already incurred and/ or irrevocably committed are ignored in an appraisal.	
End of Life / Disposal and Decommissioning Costs	Non-construction costs (disposal)
Other Occupancy, Facility Management and Business Support Costs	Operation costs (other FM) Maintenance (downtime and business disruption) Replacement costs (downtime and business disruption, unanticipated costs)

Customer Impacts and Intangibles	
Externalities	

Further a combined table of costs was produced which listed and categorises all cost types in ISO/DIS -15686 – Part 5:2006 (Fig. 7.1 below) for the purpose of this methodology and in order to fully comply with terms, classifications and definitions of ISO/DIS -15686 – Part 5:2006 and to reconcile content of various categories.

Life Cycle Costs

Acquisition Stage Costs

Non-Construction Costs
1. Site for construction or asset purchase/leasing including associated fees and local taxes
2. Development of client brief, procurement, cost, value and risk management, planning, regulatory and legal
3. Design and engineering (client advisors)
4. In-house resources and administration
5. Finance, interest or cost of money and wider economic impacts

Construction Costs
1. Design and engineering (design and build) – professional fees, statutory consents
2. Temporary works, site clearance or groundwork
3. Construction, fitting out, commissioning, validation and handover
4. Adaptation, refurbishment, fitting out, commissioning, validation and handover
5. External and infrastructure works
6. Project management and planning supervision (CDM Regulations)
7. Fixtures, fittings, furnishings and loose equipment

Operation Costs
1. Rates (and rent if applicable)
2. Insurance
3. Energy costs for heating, cooling, power and lighting, and utilities – water, sewerage costs
4. Facilities management, cleaning, security, H&S, waste management
5. Annual regulatory costs (e.g. fire, access inspections)
5. Others (local taxation, land charges, etc.)

Maintenance Costs
1. Repairs, routine component replacement and minor refurbishment
2. Loss of the facility during maintenance procedures
3. Reduced building service life (if appropriate) resulting from any maintenance option
4. Restoration (or replacement) of minor components (sub-elements and sub-systems) to their original aesthetic and functional performance

Replacement Costs
1. Restoration (or replacement) of the main elements or systems to their original aesthetic and functional performance at various stages of the life of the facility, including associated management costs
2. Loss of the facility during replacement, downtime and loss of business costs
3. Unanticipated costs resulting from legislation introduced subsequent to completion of the constructed asset, e.g. in relation to environmental, health and safety requirements or fiscal matters
4. Adaptation, refurbishment, fitting out, commissioning, validation and handover

Hand back costs
1. Final condition inspection and associated fees
2. Additional costs of meeting assets' contractual performance and condition criteria for hand back
3. Provision of spares and consumables

Income
1. Land sale, grants, tax allowances, etc.
2. Sale of interest in asset or sale of salvaged material for recycling
3. Third party income

Fig. 7.1 Detailed cost breakdown structure as reconciled from ISO/DIS -15686 – Part 5:2006 for the methodology

A further analysis of the above cost categories and their content was carried out for the purpose of the classification of their characteristic.

Costs items can have also physical and non-physical characteristics associated with them. Physical are:

- Volume
- Amount
- Technical spec
- Performance spec
- Installation method
- Logistics requirements, energy consumption, etc.

Non-physical are:

- Frequency of occurrence (capital, continuous, cyclic (re-occurring) and residual)
- Variability
- Embodied energy
- Source of cost item information, etc.

Depending on the source of cost information, the cost items may be calculated in different manner and can display serious discrepancies. Table in Fig. 7.2 below maps the cost attributes onto the cost categories in order to make LCC methodology user aware of potential omissions, need for normalisation if variety of sources are used and a general need for critical assessment of cost items before LCC calculations are performed.

COST CATEGORY	1. Cost item's characteristics – physical (volume/amount, technical, performance, installation method, logistics requirements, energy consumption) and non-physical (frequency of occurrence, variability, embodied energy, source of data)	2. Acquisition Cost/value/estimation
Hand back costs/Disposal/Demolition 1. Final condition inspection and associated fees 2. Additional costs of meeting assets' contractual performance and condition criteria for hand back 3. Provision for spares and consumables 4. Cost of demolition and disposal (income from salvage not included)	1. One-off cost, as per contract 2. One-off cost, towards the end of the contract, varies depending on asset's condition at the end of contract and contractual obligations 3. One-off cost 4. One off cost depending on size and type of facility –	1. Standard allowance in contract 2. Standard allowance depending on duration of contract, type of facility, etc. needs adjusting towards the end of contract 3. Standard allowance in contract 4. Standard allowance based on formula (percentage)
Replacement Costs 1. Restoration (or replacement) of the main elements or systems to their original aesthetic and functional performance at various stages of the life of the facility, including associated management costs 2. Loss of the facility during replacement, downtime and loss of business costs 3. Unanticipated costs resulting from legislation introduced subsequent to completion of the constructed asset, e.g. in relation to environmental, H&S requirements or fiscal matters 4. Adaptation, refurbishment, fitting out, commissioning, validation and handover	1. Reoccurring costs, based on selected maintenance model/schedule and probability of occurrence 2. Reoccurring costs linked to maintenance/replacement schedule, depends on facility and model of maintenance, accompanies the maintenance and replacement schedule 3. Reoccurring costs, associated with maintenance and replacement schedule 4. Reoccurring costs based on selected maintenance model/schedule, technical specifications and lifetime information for items – linked to capital costs (construction and fitting out)	1. From technical specification and structural data, depends on facility, often used as a % of restoration cost 2. Depends on type and size of facility – standard values (national tables, etc.) 3. Estimated as % of restoration costs or standard allowance 4. Based of technical specification, selected solution and manufacturers' info (price, availability, performance, etc.)
Maintenance Costs 1. Repairs, routine component replacement and minor refurbishment 2. Loss of the facility during maintenance procedures 3. Reduced building service life (if appropriate) resulting from any maintenance option 4. Restoration (or replacement) of minor components (sub-elements and sub-systems) to their original aesthetic and functional performance	1. Reoccurring costs, based on selected maintenance model/schedule and probability of occurrence 2. Reoccurring costs linked to maintenance/replacement schedule, depends on facility & model of maintenance, accompanies maintenance & replacement schedule 3. Reoccurring costs, associated with maintenance and replacement schedule 4. Reoccurring costs based on selected maintenance model/schedule, technical specifications and lifetime information for items – linked to capital costs (construction and fitting out)	1. From technical specification and structural data, depends on facility, often used as a % of restoration cost 2. Depends on type and size of facility – standard values (national tables, etc.) 3. Estimated as % of restoration costs 4. Based of technical specification, selected solution and manufacturers' info (price, availability, performance, etc.)
Operation Costs 1. Rates (and rent if applicable) 2. Insurance 3. Energy costs for heating, cooling, power and lighting, and utilities – water, sewerage costs 4. Facilities management, cleaning, security, H&S, waste management, landscape maintenance, etc. 5. Annual regulatory costs (e.g. fire, access inspections) 6. Others (local taxation, land charges, etc.)	1. Reoccurring cost based on negotiated amount/per time period 2. Reoccurring cost depending on insurance conditions 3. Reoccurring cost, results from calculations based on given HVAC solution (option study recommended) 4. Reoccurring cost, based on the FM specification and contract 5. Reoccurring cost 6. Reoccurring, assessed for local circumstances	1. Standard allowance depending on location and type or if known more detailed value 2. Standard allowance of as per insurance policy details 3. Results from formula linked to facility's characteristics and technical solution selected 4. Standard allowance or calculated from FM contract 5. Standard allowance based on facility's characteristics 6. Standard allowance unless specific circumstances
Acquisition Stage Costs - Construction Costs 1. Design and engineering – professional fees, statutory consents 2. Temporary works, site clearance or groundwork 3. Construction, fitting out, commissioning 4. Validation and handover 5. Adaptation, refurbishment, fitting out, commissioning, validation and handover 6. External and infrastructure works 7. Project management and planning supervision (CDM Regulations) 8. Fixtures, fittings, furnishings and loose equipment	1. Contract details specifying level of involvement and fees 2. Programme and specification for activities, selection of options, BoQ 3. Itemised components, BoQ, performance specifications 4. Standard allowance for services, one–off 5-6. Itemised components, BoQ, performance specifications 7. Fee as per contract 8. Itemised components, BoQ, performance specifications	1. A lump sum fee for the services – according to statutory rates or negotiations 2. Standard allowance depending on facility's characteristics, technical specification, or detailed calculations if possible 3. Based of technical specification, selected solution & manufacturers' info (price, availability, performance, etc.) 4. Standard allowance based on facility's type 5-8. Based of technical specification, selected solution & manufacturers' info (price, availability, performance, etc.)
Acquisition Stage Costs - Non-Construction Costs 1. Site for construction or asset purchase/leasing including associated fees and local taxes 2. Development of client brief, procurement, cost, value and risk management, planning, regulatory and legal 3. Design and engineering (client advisors) 4. In-house resources and administration 5. Finance, interest or cost of money and wider economic impacts	1. Purchase or lease conditions of contract - one-ff or periodic throughout operation phase 2-5. One-off cost, based on scope and client's requirements, as per provisions in contract or result of individual negotiations and past experience.	1. Based on valuation adjusted for particular circumstances (if any) 2. Based on standard rates for the services in conjunction with facility's characteristics 3. Based standard fees, can be re-negotiated depending on contract 4. Standard allowance 5. Subject to individual consideration or standard allowance

COST ATTRIBUTES

Fig. 7.2 Cost matrix for a project with cost attributes

7.2 Cost classification

There is a need to accept a standardised format for classifying construction resources to facilitate procurement activities in the construction industry. As construction projects use a broad range of products and services, there is an even greater need for using a common classification standard to ensure a consistent and structured way of information exchange and storage to improve the level of detail and consistency of LCC. A listing of numbers and titles organises information about construction resources or, more specifically, construction products and activities describing the physical aspects of construction. It presents a uniform system for classifying information relating to construction products, materials, services and machinery.

It is recommended that Unified Classification for the Construction Industry (UniClass), should be used a preliminary checklist for facility's elements and potential further assessments. UniClass was published in 1997 in UK by National Building Specification (NBS). UniClass is a classification scheme for the construction industry (architecture and engineering). It defines in 15 tables codes for a multi-level international classification of building and civil engineering elements, spaces, documents, phases, materials etc. European Product Information Co-operation (EPIC) is basically compatible with UniClass and will potentially be absorbed by it.

UniClass Tables are as follows:

- Table A (Form of Information)
- Table B (Subject disciplines)
- Table C (Management)
- Table D (Facilities)
- Table E (Construction Entities)
- Table F (Spaces)
- Table G (Elements for buildings)
- Table H (Elements for civil engineering works)
- Table J (Work Sections for buildings)
- Table K (Work Sections for Civil Engineering Works)
- Table L (Construction products)
- Table M (Construction aids)
- Table N (Properties and characteristics)
- Table P (Materials)
- Table Q (Universal Decimal Classification)

When costing, depending on the level of available detail and the purpose of the LCC calculations the above table could be refined according to requirements. As shown in Fig.7.2 all the elements have a selection of attributers, which need addressing. Table in Fig. 7.3 below shows the proposed matrix for elements of attributes for costing purposes using part of Table H.

UniClass - Table H – Elements for Buildings	Physical characteristics (volume, amount, technical data, performance data, installation method, logistics requirements, energy consumption (if applicable))	Non-physical characteristics (use, frequency of occurrence, variability, embodied energy, source of data (if applicable))	Cost data of options (cost, value, estimations)	Maintenance & repair cost schedule/cycle/ frequency (time, cost, variability (obsolescence))	Replacement & refurbishment cost - schedule/cycle/ frequency – lifetime period, cost	Residual income & disposal cost – period, cost/income
G1 - Site preparation (Option 1) (Option 2, etc.) G11 - Site clearance G12 - Ground contouring G13 - Stabilisation G2 - Fabric: complete elements G21 - Foundations G22 - Floors G23 - Stairs G24 - Roofs G25 - Walls G26 - Frame/isolated structural members G3 - Fabric: parts of elements G31 - Carcass/structure/ fabric G32 - Openings G33 - Internal Finishes G34 - Other parts of fabric elements ETC.						

Fig. 7.3 Example of proposed costing matrix for part of the UniClass – Table H

For the costing purposes there is often no requirement to fill in the cost item data, however carrying out a mental process of assessment of all the attributes for building items will identify potential costs not taken into account or assessed in a different manner, potentially leading to incomparable results.

7.3 Cost indicators and benchmarking

Unit-cost indicators can be used to benchmark options or level of effectiveness and create an information system and database that ties into the final LCC.

This section is under development subject to feedback from subsequent consultations.

8 Economic and Financial Analytic tools

8.1 Plan development for LCC with boundaries' establishment

The Life Cycle Costing process begins with development of a plan, which addresses the purpose, and scope of the analysis. The plan should:

- Define the analysis objectives in terms of outputs required.
- Define the scope of the analysis in terms of the project/asset(s), the time period (life cycle phases) to be considered, the use environment and the operating and maintenance support scenario to be employed.
- Identify any underlying conditions, assumptions, limitations and constraints (such as minimum asset performance, availability requirements or maximum capital cost limitations) that might restrict the range of acceptable options to be evaluated.
- Identify alternative courses of action to be evaluated. The list of proposed alternatives may be refined as new options are identified or as existing options are found to violate the problem constraints.
- Provide an estimate of resources required and a reporting schedule for the analysis to ensure that the LCC results will be available to support the decision-making processes for which they are required.

The plan should be documented at the beginning of the Life Cycle Costing process to provide a focus for the rest of the work. Intended users of the analysis results should review the plan to ensure their needs have been correctly interpreted and clearly addressed.

Figure 8.1 below shows an "awareness" map of the aspects and boundaries which should be considered

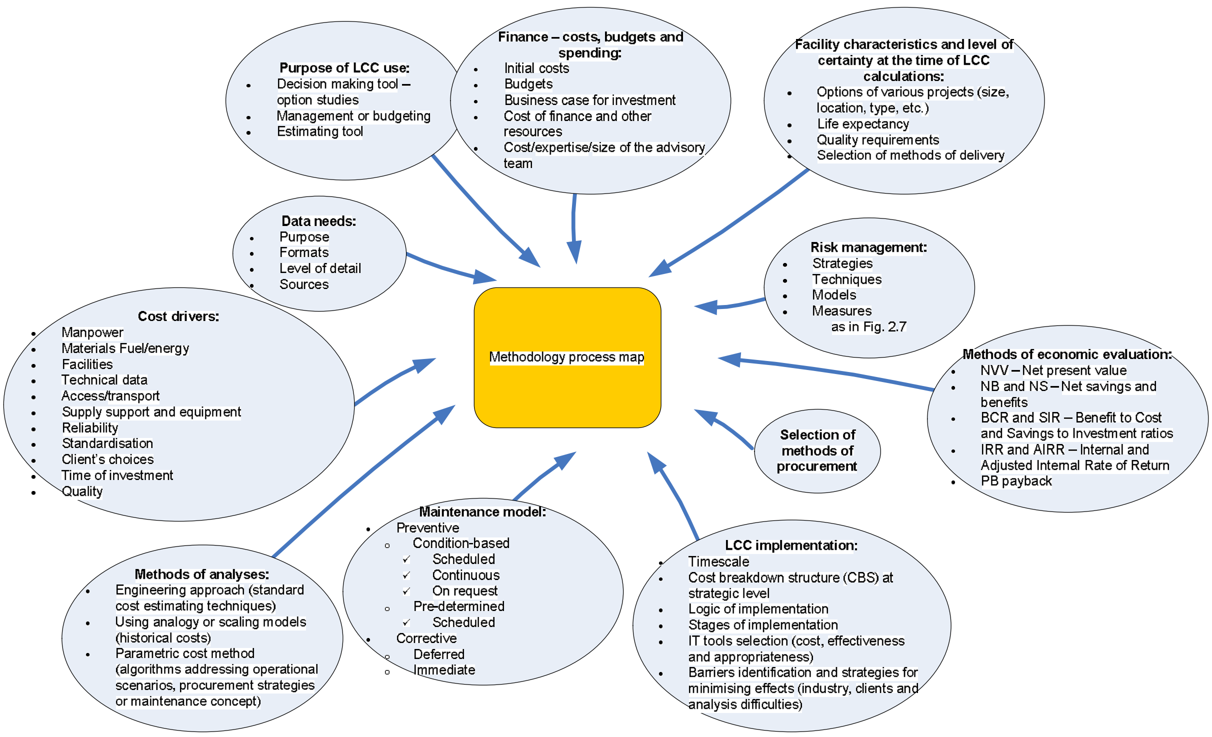


Fig. 8.1 Methods of analyses and

8.2 Financial approach

8.2.1 Cost model

The cost model is designed to measure the consequences of LCC for businesses. The selected cost model has been chosen as the one which provides a simplified, consistent method for estimating the costs in LCC. It takes a pragmatic approach to measurement and provides estimates that are consistent across all areas.

The cost model does not focus on the policy objectives or regulations. As such, the measurement focuses only on the costs that must be undertaken in order to comply with the content of the model and not whether the regulation itself is reasonable or not.

A key strength of the cost model is that it is uses a high degree of detail in the measurement of the administrative costs, in particular going down to the level of individual activities.

Almost all models found in the literature employ the NPV approach. However, different nomenclature and/or cost breakdown structure are used to describe principal components of LCC. The American Society for Testing and Materials (ASTM 1983) published the following model:

$$NPV = C - S + \sum_{i=1}^{T} (R + A + M + E(+W + O)) \quad (8.1)$$

C – investment costs

R – replacement costs

S – the resale value at end of study period (residual costs)

A – Annually recurring operating, maintenance and repair costs

M- Non-annually recurring operating maintenance and repair cost

E – energy costs

W – (often isolated)– water costs

O – other costs (e.g. costs of contract)

The unique feature of this model is the separation of energy costs, and hence different discount rates can be employed to reflect different inflation rates.

The ASTM LCC model distinguishes between energy and other running costs which is useful in adopting different discount rates for these two cost items.

8.2.2 Methods of economic evaluation

Table 8.1 Summary of methods for economic evaluation

Method	**Application**	**Comments**
Present Value LCC - LCC in present value currency of a building or system, including all costs (costs included depend on	To building decisions for which determining factor is cost effectiveness. For deciding whether to accept or reject a given	LCC is used to determine if an investment in a given system or modification is worthwhile.

purpose of evaluation and model selected)	investment by identifying cost-effective components, systems, O&M models, etc.	
Net benefits (NB) and net savings (NS) – NB = time-adjusted (benefits minus costs) NS = time adjusted (savings – costs) when no benefits but reduction in future cost	For finding the economically efficient choice among building alternatives. For budget allocation decisions.	It additionally accounts for variations in benefits as well as costs among alternatives. Not currency measurable benefits or savings not accounted for. NB or NS should be positive for accepting the investment decisions.
Benefit-to-Cost-Ratio (BCR) and Savings-to-Investment-Ratio (SIR) – numerical ratios whose size indicates the economic performance of an investment	Used to determine if project is acceptable on economic grounds. Particularly applicable when investment's advantage is lower costs.	SIR is to BCR as is NS to NB A ration less than 1 indicated uneconomic investment. If computed based on incremental rather than total benefits and costs, can be used to design or size projects.
Internal Rate of Return (IRR) and minimum acceptable rate of return (MARR) – IRR is compared against the investor's MARR. IRR = value of discount rate which will result of NB or NS = 0 when used to discount benefits or costs.	Should be used with caution. Should be only used for deciding whether accept or reject a given project.	MARR is based on the opportunity cost of capital and = discount rate. IRR has 3 shortcomings – may overstate profitability, cause selection of less productive alternative and possibility of non-unique solution.
Overall Rate-of-Return (ORR) – annual yield from a project over the study period taking into account reinvestments of interim receipts.	Used for comparing projects , will indicate project with greater NB. Use ORR for the same applications as BCR and SIR. Can be used to decide whether accept or reject projects, to combine interdependent projects and to allocate funding among competing uses.	ORR developed to overcome shortcomings of IRR. When the reinvestment rate is made explicit, all investment costs are expressed as time-equivalent initial outlay and all non-investment cash flows as a time equivalent terminal amount.

		ORR needs to re-computed if the discount rate (reinvestment rate) is changed.
Payback (PB) – measures how long it takes to recover investment costs. Simple Payback (SPB) ignores time value of money and Discounted Payback (DPB) does not.	Should be used as a supplementary measure of economic performance. (if used alone – results can be misleading).	DPB is a form of breakdown analysis when project's life is uncertain.

Table 8.2 Summary of variables for economic evaluation

Variables, models & formulas	**Source**	**Comments**
Discount rate – d (equal to investor's MARR)	UK – HM Treasury – currently 3.5%	Discounting process essential for comparing future and present amounts on a consistent basis.
Models for cash flows Simplified models (discrete and continuous) and compounding Variables – the effective annual interest rate (actual yield) and the quoted annual interest rate (without regard for compounding)	Calculations based on given and expected interest rates	Helpful to support the calculations with early cash-flow diagrams.
Single compound amount (SCA) discount factor	Most engineering economics and financial textbooks from official sources (e.g. HM Treasury, ASTM, etc.)	Variable for adjusting cash-flows to make them time-equivalent – time equivalence formulas
Single Present Value (SPV) discount factor	Most engineering economics and financial textbooks from official sources (e.g. HM Treasury, ASTM, etc.)	Variable for adjusting cash-flows to make them time-equivalent – time equivalence formulas
Uniform Present Value (UPV) discount factor	Most engineering economics and financial textbooks from official sources (e.g. HM Treasury, ASTM, etc.)	Variable for adjusting cash-flows to make them time-equivalent – time equivalence formulas
Uniform Capital Recovery	Most engineering	Variable for adjusting

(UCR) discount factor	economics and financial textbooks from official sources (e.g. HM Treasury, ASTM, etc.)	cash-flows to make them time-equivalent – time equivalence formulas

9 Other analytic and evaluation tools

9.1 Sustainability impact on LCC

LCA depends on the early decision to what extend to take into account the environmental impact and the balance between different environmental and non-environmental solutions.

Life Cycle Analysis is an important tool for both analysing processes to find ways to improve them, and assessing materials and products. LCA consists of two components: inventory analysis and impact analysis.

Inventory analysis involves summarising the material and energy flows for a defined system. The 'system' is the combination of processes and activities that manufacture a product or achieve an outcome. This typically includes all of the processes associated with:

- the mining of resources
- supply of energy
- manufacture of the product
- use of the product and
- disposal and recycle.

The resultant inventory is a list of the resources consumed and the emissions associated with the system. Impact assessment involves interpreting the significance of the resource consumption and emissions determined in the inventory stage. In life cycle assessment, these are restricted to environmental impacts. This aspect of LCA still requires further development before it is widely-accepted.

There are numerous approaches currently in use, ranging from simplified methods based on a limited number of parameters, to complex systems covering a wide range of parameters that achieve single valued effect scores, but at some point all methodologies require subjective value judgments. Energy and carbon dioxide emissions are just two most commonly addresses indicators for impact assessment.

Other include:

- Wastes generated during production;
- Energy consumed during production and the use of the product;
- Fresh water consumption during production; and
- The amount of recycling possible with the product.

In addition to energy, a comprehensive LCA will include a range of other environmental impacts such as greenhouse gas emissions and solid waste. Because a less than comprehensive LCA model can give misleading results, for every product analysed, a large number of calculation steps are necessary for a meaningful answer. Allowing all parameters to vary is, however, a laborious and costly process. To keep the amount of labour in the project manageable, the number of variable parameters should be limited to a few. This gives a few alternatives to be compared with regard to LCC and environmental impact. Environmental impact can be obtained from an LCA, which can usually be limited to the operating phase. Experience from other similar calculations naturally provides good guidance on what the most important factors are and what does not need to be analysed in greater depth.

It is appropriate to include a reference building in the parameter study that has normal glazing, climate control system, etc. The design premises of the project are applied to this reference building, i.e. geometry, internal loads, etc. This gives a comparison value for LCC and for environmental impact and indicates where in the range of parameters a particular selection of choices positions the solution.

This work should be carried out in cooperation between the client, architect, FF&E suppliers (if appropriate) and M&E designers with installation engineering expertise and documented knowledge and experience of similar calculations. Limiting the number of variables makes the LCC/LCA manageable and one of the factors the architect can use for final building design.

9.2 LCA application procedure

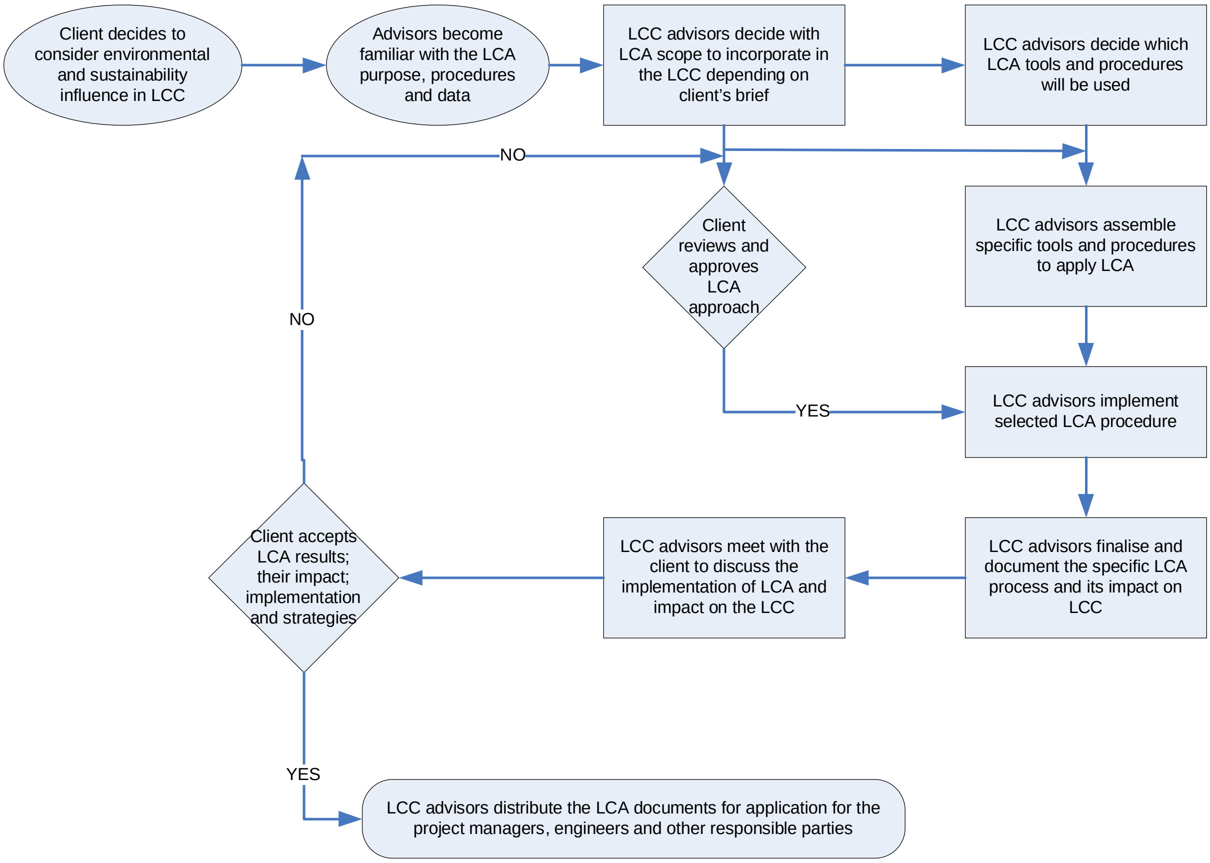


Fig. 9.1 LCA application procedure

9.3 Sensitivity analysis

In general, sensitivity analysis involves the perturbation of model variables over predetermined bounds to determine their relative effect on model outcome. Through this process, analysts can:

- identify some subset of model variables that exert significant influence on model results and (or)
- determine break-even points that alter the ranking of considered options.

Each of these goals provides important insight to decision makers who are rightly sceptical of fixed values and attendant results. Sensitivity analysis, then, is a direct admission that uncertainty often afflicts even the most careful and judicious deterministic analyses. Information employed in sensitivity analyses must be based on some sense of likely maximum and minimum values. For example, in a LCC exercise an analyst may draw on expert engineering judgement to estimate the upper and lower bounds corresponding to certain costing variables. To ensure the bounds established are consistent across model variables, the analyst should encourage the engineer to estimate minimum and maximum values based on, for instance, a confidence interval of 95%.

9.4 Risk analysis

The purpose of risk analysis is to address the shortcomings of sensitivity analysis through probabilistic comparison of considered options. In risk analysis, values assigned model variables are described by probability mass functions or frequency distributions.

Through exact or random sampling methods, the probabilistic assessment of model variables is employed within the relevant computational procedure to generate a cumulative distribution of model outcomes corresponding to each option included in the analysis. The cumulative distributions, in turn, form the basis of comparison among considered options, most generally in terms of expected values and rules of stochastic dominance.

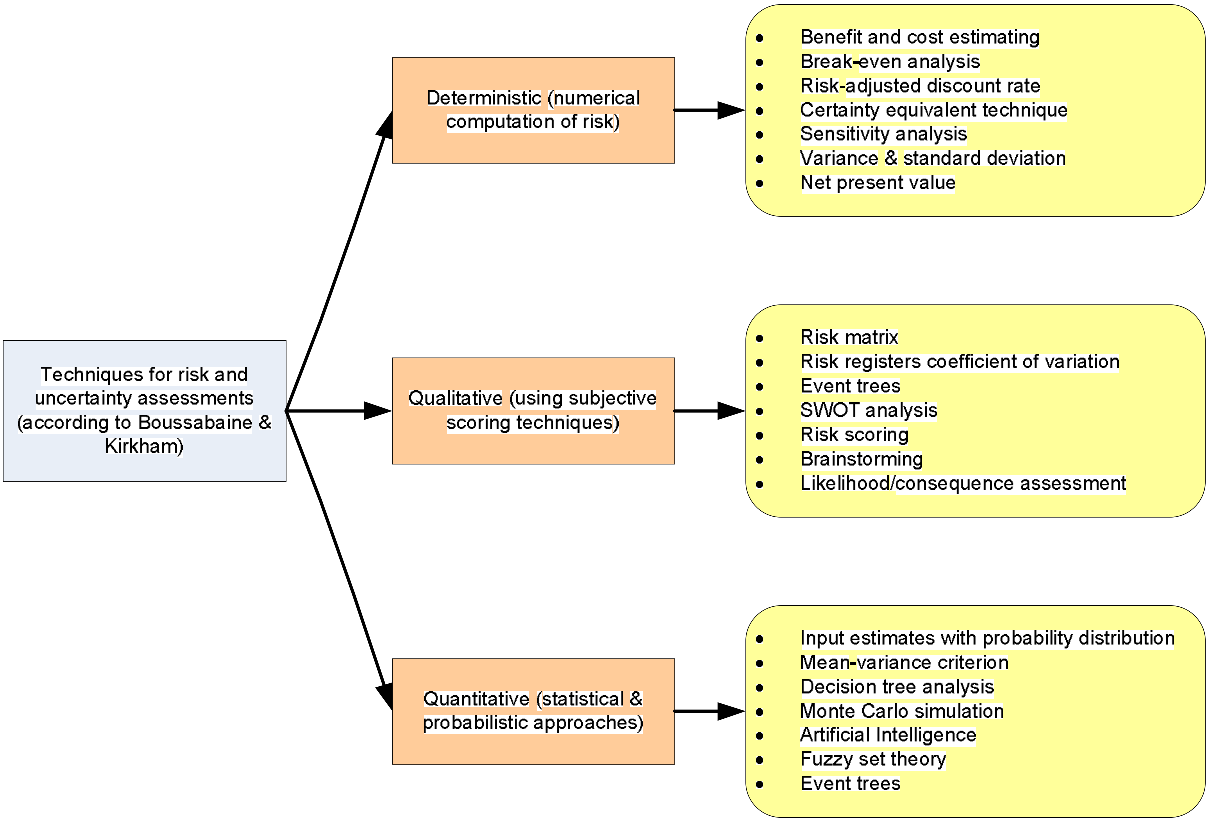


Fig. 9.2 Risk and uncertainty assessments

9.5 IT tools and techniques

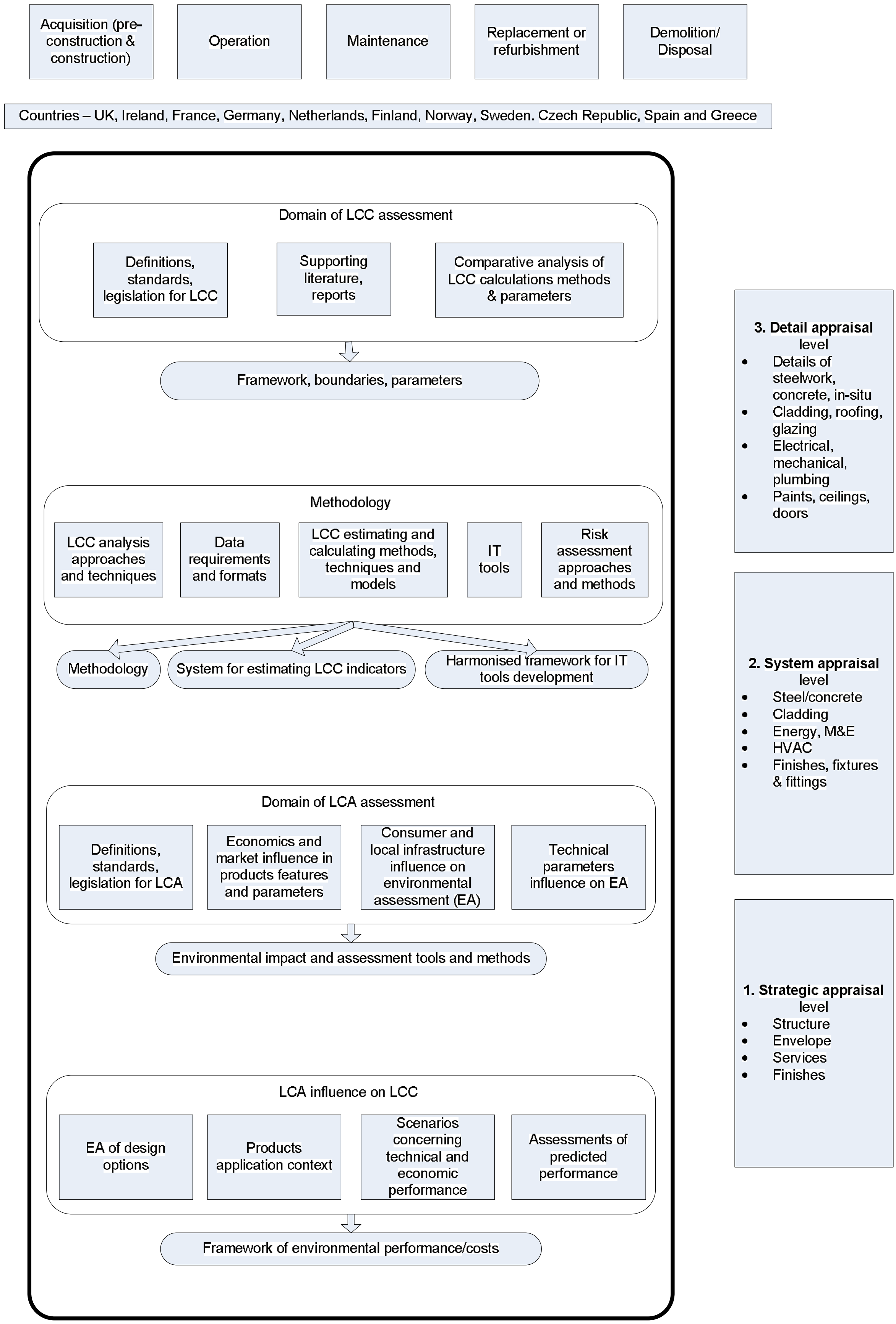
A comprehensive selection and assessment of IT tools has been assembled in the literature review document. The selection of the most appropriate tools will follow a further consultation with the stakeholders.

Glossary

For glossary of terms please refer to the literature review document.

10 Appendices

10.1 Appendix A - Conceptual level schematic


Acquisition (pre-construction & construction)
Operation
Maintenance
Replacement or refurbishment
Demolition/ Disposal
Countries – UK, Ireland, France, Germany, Netherlands, Finland, Norway, Sweden. Czech Republic, Spain and Greece
Domain of LCC assessment
Definitions, standards, legislation for LCC
Supporting literature, reports
Comparative analysis of LCC calculations methods & parameters
Framework, boundaries, parameters
Methodology
LCC analysis approaches and techniques
Data requirements and formats
LCC estimating and calculating methods, techniques and models
IT tools
Risk assessment approaches and methods
Methodology
System for estimating LCC indicators
Harmonised framework for IT tools development
Domain of LCA assessment
Definitions, standards, legislation for LCA
Economics and market influence in products features and parameters
Consumer and local infrastructure influence on environmental assessment (EA)
Technical parameters influence on EA
Environmental impact and assessment tools and methods
LCA influence on LCC
EA of design options
Products application context
Scenarios concerning technical and economic performance
Assessments of predicted performance
Framework of environmental performance/costs
3. Detail appraisal level
Details of steelwork, concrete, in-situ
Cladding, roofing, glazing
Electrical, mechanical, plumbing
Paints, ceilings, doors
2. System appraisal level
Steel/concrete
Cladding
Energy, M&E
HVAC
Finishes, fixtures & fittings
1. Strategic appraisal level
Structure
Envelope
Services
Finishes