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Final Report

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

Final Report

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1 Introduction

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 project: "Life cycle costing (LCC) as a contribution to sustainable construction: a common methodology" No. 30-CE-0043513/00-47, commenced in January 2006 and the work was concluded in March 2007 with the presentation to the Commission of a draft Methodology (*A common European methodology for Life Cycle Costing* – hereinafter referred to as the Methodology)and supporting material.

This report describes all the research activities leading to the development of the Methodology. It summarises the findings of the work and draws conclusions about the form and content of the Methodology and related Guidance and Case Study material which are available separately.

This Draft Final Report should be read in conjunction with all accompanying documents:

- Appendices to this Final Report (presented as a separate document), covering:
  - A – Record of Advisory Panel meetings
  - B – Content of research interviews and analysis of results
  - C – Questionnaire survey and analysis of the results
  - D – User groups and analysis of the findings
- The Literature Review
- The Methodology (*A common European methodology for Life Cycle Costing*)
- The Guidance on use of the Methodology and its application in public procurement
- The Case Studies of the application of LCC in construction (as an Annex to the Guidance document)
- A process map for the application of LCC in construction
- The Specification Framework for Software Development.

It is intended that this Draft Final Report will be finalised following the project Validation Workshop on 16 April 2007 and receipt of final comments from the Commission.

2 Background

The origins of the project lay in the Commission's Communication 'The Competitiveness of the Construction Industry' COM (97) 539 of 4.11.1997 http://europa.eu.int/comm/enterprise/construction/compcom/compcom.htm which identified the need for improvements in the competitiveness of the construction sector. More specifically, one of the key ways of improving competitiveness was considered to be the implementation of life cycle cost tools and criteria in all key phases of the construction process. By taking into account not only initial costs but all subsequent costs, clients could undertake a proper assessment of alternative ways of achieving their requirements whilst integrating environmental considerations.

This finding was supported by the recommendations of the Sustainable Construction Working Group established to help take forward key elements of the Competitiveness study. The Commission Communication COM (2004) 60 of 11.02.2004 http://europa.eu.int/eur-lex/en/com/cnc/2004/com2004_0060en01.pdf on the thematic strategy on the urban environment outlined 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. It was felt that the construction sector and its clients (and, in particular, public procuring authorities) could help improve the sector's environmental performance and realise potential cost savings by concentrating on the early integration of environmental considerations in the construction cycle.

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.

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[1] recommended the development of a common LCC methodology at European level, incorporating the overall sustainability performance of building and construction.

The Task Group recommended the development and adoption of a common European methodology for LCC in construction taking into account the work done under international standard ISO 15686. This methodology should allow for the definition of a harmonised framework to facilitate the development of software tools to estimate Life Cycle Costs on a European basis.

The scope of this study was therefore identified as providing an analysis and evaluation of the different national approaches for LCC, as well as elaborating an approach for the estimation of Life Cycle Costs and related indicators for buildings and constructed assets which could be of added value at EU level. The work was intended to focus on practical guidance on how to refine LCC estimates at each stage of construction projects, 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 to support both the public and the private sectors, although it would primarily address public 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.

3 Aims and objectives of the project

The overall aim of the project is to help improve the competitiveness of the construction sector. To help achieve this aim, the key objective is to develop a common methodology at European level for evaluating life cycle costing (LCC) that will help improve the sustainability of the built environment. .

The overall objectives of the study are:

- Improve the competitiveness of the construction industry
- Improve the industry's awareness of the influence of environmental goals on LCC

[1] *Task Group 4: Life Cycle Costs in Construction; Version 29 October 2003*, Enterprise Publications, European Commission. Endorsed during 3rd Tripartite Meeting Group (Member States/Industry/Commission) on the Competitiveness of the Construction Industry. See http://europa.eu.int/comm/enterprise/construction/suscon/tgs/tg4/lcalccintro_en.htm

- 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 complete supply chain.
- Generate comparable information without creating national barriers and also considering the most applicable international developments.

4 Outputs from the project

The following outputs were planned as a result of the research activities on this project:

- **Literature review** – as a result of a critical review of the LCC methodologies, guidelines and tools existing or under development in the EU Member States or elsewhere. The review covers a representative number of national cases in Europe, including those from the United Kingdom, Germany, the Netherlands, Sweden, Finland, Norway, Ireland, Span Greece and Czech Republic. The review explains the scope and the extent of the different approaches and assesses their methodologies as well as the robustness of models used and the relevance of results to those to whom they are addressed. It also provides an indication of the user-friendly orientation of supporting software tool, their architecture, the levels of aggregation of the information, the transparency of the assumptions and calculation methods, the compatibility with other software and the potential transferability to other national contexts.
- **The LCC methodology** – developed on the basis of the results of the Literature Review and fieldwork to establish common elements of good practice in LCC in construction in selected EU countries. The requirements of a possible EU common methodology were intended to cover, *inter alia*, simplicity of use, transparency of information about cost and indicators calculations, reliability of data and information used or generated as well as the interface with national input/data. The methodology was also intended to provide details on how all stages of the project life cycle and the basic elements of the constructed asset or facility would be dealt with at different levels of decision making or appraisal: strategic, system and detail level. It was also intended to comment on possible thresholds for the scale of projects that should be subject to LCC, in particular for the purpose of public procurement.
- **A set of six case studies** – intended to test and validate the above-mentioned EU common methodology. A cross-section of case studies from different EU Member States was targeted, and the intention was to include some 4 public procurements and 2 private projects.
- **A practical guide** on the application of the above mentioned EU methodology and its use in the context of public procurement. This document provides guidance on how LCC might be incorporated into the Economically Most Attractive Tender (EMAT) award scheme.
- **A specification framework for software development** to support the development of the online tool enabling LCC calculations and analysis to be undertaken that are consistent with the common Methodology.
- **A report from research interviews and on-line questionnaire survey** highlighting the use of LCC in different national contexts and analysing the basis of the decisions guiding the development of the Methodology.

- **Minutes from two Advisory Panel sessions** – initially guiding the development of the Methodology and then further advising on refining the Methodology and support Guidance documents.
- **A report from a Methodology validation process carried out via three user groups** – one of these was undertaken face-to-face and the other two via tele-conference. A representative range of public and private stakeholders of the construction sector (at all relevant levels) were contacted, in order to capture their views of the Methodology and associated Guidance. The results of these sessions are assessed and presented in Appendix D to this report.
- **A report of a one-day evaluation and validation workshop** – this is being held on 16 April 2007 to present the draft results of the work undertaken and to consider attendees' comments and suggestions for improvement. This report will be added to the Final Report on the project.

5 Approach and understanding of the work

The development of the Methodology and the supporting Guidance as the two main outputs of this project was driven by factors established in the early stages of the research. Primarily the *status quo* of the life cycle costing processes and procedures varied significantly among all sample countries. Even within the public procurement sector LCC was often undertaken in a very fragmented manner without any underlying methodology or standards. Therefore it was established early in the project that a detailed LCC process map could provide an underpinning structure and framework for the development of the Methodology and research effort focused on developing this map, based on an analysis of practice in EU Member States and expert opinion. It was intended to be broadly independent of size and type of project, being sufficiently flexible to incorporate a range of project values and circumstances.

The LCC process map developed under this project was progressively refined via successive consultations with experts from Member States – the final version is issued as part of the Methodology and as a separate document (The Process Map) accompanying this report.

The Process Map breaks down each step/stage of the LCC process and summarises the tasks, and inputs relevant to individual process steps. Each step/stage also has a list of outcomes, outputs or decisions expected to be reached before moving to the next step or set of activities. This underpins the Methodology developed on this project.

The Guidance document was then develop to illustrate in a practical way how the methodology may be applied with reference to typical examples of how Life Cycle Costing (LCC) is used in construction. 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.

This guidance document is supported by case studies of the application 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 methodology.

6 The methodology used

6.1 Overview of the study methodology

The methodology for this research consisted of the following activities:

Analysis and evaluation stage with preliminary results

- Review of supporting documents – Desk Study 1 (background general literature review and EU supporting documentation)
- Data collection including a review of related literature in the UK and selected EU countries - Desk Study 2
- Data collection including a review of existing LCC models and approaches (via international visits, telephone interviews, online software assessment and e-mail questionnaires)
- Assessment of LCC models and approaches against selected criteria (e.g. usability, cover, appropriateness, etc.)
- Analysis of the existing supporting case studies
- Further data synthesis, compilation and analysis
- Recommendations for the development of EU-wide methodology
- Development of an initial outline of a specification for a methodology
- Initial consultation with the Advisory Group in a one-day focus group style session
- First workshop with Commission's Steering Group

Development of an approach applicable at the European level for estimation of LCC and related indicators for buildings and constructed assets.

- Development of the specification, usability and guidelines and draft guidelines report
- Consultation with private and public stakeholders (via three focus groups and interviews)
- Feasibility testing on case studies
- Second workshop with Commission's Steering Group
- Draft report containing refinement of the specification of a methodology and development of interactive functionality of the online specification
- Second consultation with the Advisory Group in a one-day group session
- Third workshop with Commission's Steering Group
- One-day evaluation and validation workshop
- Finalised project report, specification for an EU methodology, implementation guidelines supporting the methodology, framework for software development and for interactive guidance/templates for the effective use of the material developed.

6.2 Countries included in the study

The following countries were selected for study:

- UK
- Germany
- Netherlands
- Sweden
- Finland
- Norway
- Ireland

- Spain
- Greece
- Czech Republic
- Belgium
- France

7 Work undertaken against work programme

7.1 Changes to the programme

7.1.1 Progress during first four months

Our work during the first four months of the study involved:

Literature review

We undertook a systematic literature review of the available material on the topic area developed over the course of the last three years (extensive literature reviews exist for publications older than 2002-2003, and we have decided to signpost readers to these reviews rather than to include their content within the review produced on this study). Through previous work, we were already familiar with much of the European and international material on LCC.

Contact with international experts

We established an Advisory Panel composed of LCC and LCA experts draw from a range of EU Member States who helped identify the status of LCC in their respective countries and pointed us to other experts and to the relevant national standards, reports and other documents via a survey we developed for them. They also committed themselves to commenting on documents produced by the team and to participating in study workshops (the first one took place in London at Davis Langdon offices on the 19th May 2006).

Methodology development

As a result of the contacts with international experts and the panellists as well as with UK experts and Davis Langdon specialists, we were able to develop a framework for the specification for the EU methodology ahead of schedule. We found it particularly beneficial as the Advisory Panellists were given a chance to see the draft specification prior to the meeting in May 2006 and further commented and discussed it during that meeting.

7.1.2 Proposed changes and justification

Our initial discussions with Advisory Panel members in the selected countries suggested that the application of LCC was not as widespread across Europe as we had expected, and there was a limited degree of LCC expertise among many practitioners in EU member countries. While there was a considerable degree of academic-led research activity underway during the initial period of this project, the practical applications of LCC on real projects was not extensive, although there was a lot of government support in many countries.

Furthermore, we used our discussions with Advisory Panel members to supplement our literature review and to inform our early thinking on the broad outline of a possible common

methodology. In this regard we made more progress than anticipated on the development of the basis for the specification for a common EU methodology.

This led us to review our forward programme of activities, in particular our planned interview and questionnaire activities that were intended initially to test provisional findings on the factors influencing he use of different LCC approaches. Given the advice of our Panel on the limited extent of practical application within different countries, and the progress we made on the development a framework for a common methodology, we felt that the proposed interviews and questionnaire survey could be used more effectively to test the outline methodology framework, rather than solely to identify practice in the different Member States studied.

Accordingly, we prepared an early draft of the specification for the EU methodology prior to the panel meeting on the 19 May 2006 for initial discussions at that meeting. Our draft of the specification for a common European methodology benefited from experts' comments in the early stages of its development. The identification of initial issues and opinions, additional sources of data and suggestions for improvement were invaluable during the progressive development of the final Methodology.

Following contributions from the Advisory Panel members on the first draft of the outline Methodology, a draft framework for the Common Methodology was produced and submitted for further scrutiny to the members of the Monitoring and Steering Group (MSG) assembled by the Commission for this project. This was reviewed and discussed at the MSG meeting on 26 June 2006.

At the MSG meeting in June 2006, we also set out our proposals for a revision to the overall work programme to take account of the fact that we had found it more helpful to develop an outline framework for the Methodology early in the study and subsequently to use the planned fieldwork to test and refine this framework in addition to building a clearer picture of LCC approaches and practices in the countries selected for study. When contacts in target countries were approached later in the process rather than earlier, all the visits and interviews resulted in more in-depth outcomes. During the interviews we covered all issues specified in our proposal and, in addition, received very helpful comments on the draft specification of the common Methodology.

Overall, the scope of the project was not changed by these revisions to the work programme, which principally involved either postponing or bringing forward key activities on the time schedule.

7.2 Extension of time for the final deadline

In December 2007 we informed the Commission that, due to circumstances beyond our control, it was very unlikely that we were able to meet the deadline for completion of the draft methodology prior to the planned Monitoring and Steering Group meeting on the 12 January 2007. Therefore we applied to the Commission for deferral of the January meeting and extension of the project programme.

The delays we were experiencing were due to a number of factors:

- Delays in identifying key experts for participation in our interview survey. We made extensive enquiries to identify key experts in different countries. While some of these experts were known to us, others were referred by third parties some of whom, following

lengthy discussions, eventually either declined to participate in the study or referred us on to yet other experts. The time required to draw up an acceptable interview list was considerably longer than we had anticipated.

- Delays in finalising interviews due to the availability of experts. In many cases experts were not always available for interview, due to their other commitments, and some meetings were arranged and then postponed to a later date at the request of the interviewee. Despite having started the process of arranging interviews in August 2006, the bulk of the interviews were not complete until well into November, and by the end of the year there were still a small number to finalise. This is not to imply any criticism of those interviewed on this study – to whom we are very grateful for giving up their time to contribute their knowledge and expertise to the study – but simply to note that these experts all had other commitments and, for some, this study was not a priority.
- Delays caused by the need to monitor updates to ISO 15686 Part 5. This standard is very important to our study in that it provides definitions for Life Cycle Costing (LCC) that have the authority of an ISO standard. It was anticipated that this standard should have been finalised and agreed during 2006, but it has been the subject of much debate and dispute at Committee level and which, at the time of writing this report, has not yet been resolved. The crucial issue concerns the definition of LCC itself; this came to the fore in our discussions with the Finnish representatives during our interview survey. We spent a lot more time tracking this activity – and meeting key people involved – than we had anticipated, and a lot of thinking time exploring ways of resolving the impasse. The Methodology developed on this study is based on the terminology defined in the Draft ISO 15686 Part 5.
- Delay caused by the need to reschedule the next meeting of our Advisory Panel, at the request of some key members. We had hoped to hold the next meeting of the Advisory Panel in December 2006; however we had to re-arrange this for January.

The cumulative effect of these delays – which we estimated to be of the order of some eight weeks – meant that we did not make as much progress as we had planned with the development of the outline methodology. Accordingly we requested an extension of time of some eight weeks to enable us to finalise the specification for the methodology so that we could capture the views of key experts via the proposed questionnaire survey and user groups prior to finalising it for submission to the Commission and the MSG. This extension was granted by the Commission.

8 The characteristics of the work

8.1 Progress and outputs at mid-term (to June 2006)

At the time of the mid-term meeting with the commission and the Monitoring and Steering Group meeting we had undertaken the following activities and produced the following outputs:

- Draft literature review – continuously under refinement and development with more sources emerging from the member countries while additional LCC experts are contacted.
- Advisory Panel meeting on 19th May 2006 in Davis Langdon offices in London - the agenda and minutes are enclosed in Appendix A.
- An outline of the methodology – this was developed in order to make most use of the proposed consultations with key stakeholders. It also helped to identify key issues in the

further development of a new common LCC methodology, as well as providing an outline framework for the further development and practical use of the Methodology. The approach was initially introduced at the Advisory Panel meeting and subsequently discussed with the Commission prior to the June MSG meeting.

- Consultation with other UK experts outside the Advisory Panel members – LCC tools were continuously being researched and developed by BRE (Building Research Establishment) and a number of cost consulting companies had developed in-house models for LCC. We carried out additional interviews with these organisations as well as with own in-house experts and gained their comments and views which were incorporated into the outline methodology.
- Assembling a portfolio of contacts – in the course of enlisting the Advisory Panel members and the literature review we contacted many authorities, LCC experts and practitioners and briefed them initially about the project. At that point they were keen to support the development of a new Methodology and, while in some cases it proved difficult to elicit their support within the original time-frame of the project (see also 7.2 above), most of them eventually contributed to the project.
- Assembling potential sources of case studies from Sweden, Netherlands and UK – while building up a network of contacts we approached organisations with potential case studies of their involvement in LCC. We also identified projects internally at Davis Langdon, which had been subject to detailed LCC assessments. Some of these projects were ongoing and it would be necessary at some point to update LCC estimates and to undertake performance reviews – hence it was felt that these projects could provide a potentially useful testing ground for the new Methodology.
- Review of the in-house LCC tool at Davis Langdon – we also sought comments from users on this tool and these highlighted a number of issues which we fell needed attention in developing the framework for the proposed software. The principle issues identified included flexibility and general compatibility with the organisation's expertise, security and data access. Secondary points included the need for auditing, increased reporting and compatibility with external data sources and the general need to update and adopt new software techniques.

8.2 Progress and outputs during the second half of the project (to February 2007)

At the time of the final meeting with the Commission and the Monitoring and Steering Group on 13 March we had carried out the following activities and produced the following outputs:

- Further development of the specification for the Methodology – this was progressively developed and refined through a series of iterations following:
  - The MSG meeting in June 2006
  - Further review by the Davis Langdon project team during July and August 2006
  - Completion of country visits and face-to-face interviews up to December 2006
  - The online questionnaire survey in January 2007
  - The Advisory Panel meeting in January 2007
  - The first user group session in early March 2007
- International visits and interviews - in order to test the proposed methodology outline and further investigate the factors influencing the use of the range of different LCC approaches and their effectiveness, we undertook a series of telephone and face-to-face

interviews with a wide group of LCC experts and practitioners. We contacted at least 2-4 experts or practitioners knowledgeable about the LCC in each of the 11 countries selected for participation in the study.

- Second consultation with the Advisory Panel in a one-day group session in order to further validate the proposed Methodology and Guidance. The agenda and minutes are enclosed in Appendix A (in a separate document – Appendices to the Final Report).
- Questionnaire survey (essentially requesting respondents' opinions on the appropriateness, completeness and potential usability of the outline Methodology, as well as seeking to capture key and national preferences and practices).
- User group sessions - we have held three user-group sessions towards the end of the project. One user group session was carried out prior to the meeting with the Commission and the MSG in March 2007. The other two took place at the end of March 2007 in the form of a teleconference. Experts who could not participate sent their comments by e-mail which were then circulated among others and further commented on prior to incorporation in the development of the Methodology.
- Development of a framework for software specification – the framework for the specification of software is presented in a separate document under three key headings:
  - Summary of function and operation
  - Specific functionality and scope
  - Framework for technical specifications.
- Case studies testing the Methodology – in order to test and validate the feasibility of the specification for the common European Methodology, as well as the usability and relevance of the public procurement guidelines, we invited a selection of organisations to identify real-project case studies of the application of LCC in construction, on which the new Methodology could be tested. We secured 5 public procurement projects and 1 private sector project from different countries (UK, Sweden, Norway, France, Netherlands and Finland).
- Final meeting with the Monitoring and Steering Group and a meeting with the Commission on 13 March 2007.
- Post project verification meeting with EU

8.3 Progress and outputs since the final MSG in March 2007

Following our meeting with the Commission and the MSG on 13 March, we undertook to make a series of changes to the Methodology document, Guidance document and the Case Studies. This involved:

- Incorporation of comments and outcomes of the discussion during the MSG meeting into the Methodology, and further revisions to improve readability and accessibility
- Further development of the Guidance to simplify the presentation and improve the signposting to the Methodology
- Further develop of the Case Studies to present key data in a more consistent and accessible format.

All these activities have now been completed and final versions of the Methodology, Guidance and Case Study documents have been submitted to the Commission in advance of the evaluation and validation workshop on 16 April. Thereafter, these documents and this draft report will be finalised for submission to the Commission as the final outputs of the work undertaken on this project.

8.4 Aggregated comments on the characteristics of 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 developed a schematic (shown in Appendix A) that attempted 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 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.

8.5 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.

Common uses of LCC - these are typical project examples that take account of different user requirements at different stages in the project life cycle. The number of possible user examples derived from the issues and decisions matrix is potentially large, and selecting **typical** common uses provides a means of focusing the methodology on the most likely applications.

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 have realised that it is practical, feasible and acceptable to determine new standards for data and cost classification.

Economic and Financial Analytic tools – the methodology has incorporated a range of economic, financial and other analytic tools and techniques. The selection of these tools and methods was guided by common uses and real-life applications.

Other Analytic and evaluation tools – including sustainability assessments, risk analysis, sensitivity analysis, IT tools and other techniques had to be identified and positioned in the common methodology and, in so far as possible, integrated within it.

Applicability to public procurement – the methodology has incorporated the variety of approaches of public procurers, as identified in the sample countries. The methodology can also be used in the selection of tenders govern by EMAT.

9 Collaboration during the project

The project was met with enormous interest from the LCC community in all sample countries. The following individuals and organisation were contacted during the course of the research and took part in the variety of meetings, interviews, telephone conversations or were respondents to the questionnaire.

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10 Summary of conclusions

10.1 Conclusions from the review of methodologies, guidelines and tools

The literature review identified issues which the project team was attempted to resolve throughout the duration of the project.

The literature review concentrated on the existing body of knowledge in Europe. There has been a considerable research and development carried out in the field of LCC in the US, Canada and Australia. However, because the ultimate aim was to develop a methodology for the EU member countries, the literature from non-EU countries was only reviewed when it brought into light relevant issues.

The literature on life cycle costing is mostly conceptual in nature and there is relatively little evidence about the applications of LCC approaches or about the extent of its use in different Member States. Instead, the potential benefits of LCC and the technical issues regarding applying the approach receive most of the attention in the literature. In general, this tends to focus on LCC calculation methods. Corresponding cost models and cost data are often considered as commercially sensitive and are not, in the main, widely reported.

There is a considerable body of literature relating sustainability assessments on a life cycle basis (and, in particular, to one of the main assessment methods – Life Cycle Assessment, or LCA). Some of this (particularly the academic literature) concentrated on the development and refinement of various assessment models of high levels of technical complexity, albeit that many such models do not generally penetrate into practical use in construction. Experts in both LCC and LCA fields tend to agree, however, that it is not generally feasible to try to merge the available economic tools (LCC) with LCA methods.

Generally, following our investigation of existing practices and case studies across the countries selected for study, as well as obtaining contributions from key experts via the Advisory Panel, the MSG and other sources, it appears that the practical application of LCC is generally at a lower level of detail and analysis than applied in the largely theoretical literature.

Methods of financial evaluation commonly used concentrate on calculating and analysing Net Present Value/Present Value (NPV/PV), simple payback (PB), Savings to Investment Ration (SIR). All these methods are fully explained in the separate Methodology document.

Additionally, only relatively basic sensitivity analysis are undertaken, and typically risk analysis tends to be mainly quantitative, supported by risk registers.

The selection and use of appropriate rates of discount is extensively covered in the literature, and the influence of different choices of discount rate on the outcome of the LCC calculations is also widely covered. However in practice clients and other users of LCC appear to adopt more generalised approaches. Public sector procurers tend to favour much lower levels of discount than their private sector counterparts – in some countries the appropriate public financing authorities (Government Departments of Finance or Treasury) recommend rates that are typically between 2% and 5% net of inflation – ie real discount rates). In the private sector discount rates adopted tend to be more akin to investment hurdle rates (and vary between some 2-14% 'real').

Cost and time-based data (ie data relating to material/component durability, maintenance and operating needs and repair and replacement frequencies) is an ongoing area for research. There is relatively little published data – and much dispute – on the key life cycle cost characteristics of constructed assets, and the durability and performance of related systems and components. What data is available is very fragmented and provided by variety of organisations. It is often incomplete and presented in a variety of incomparable formats. Government research organisations and others supporting the development and application of LCC in construction tend to develop own databases for their particular purposes in their countries. These databases are sometimes made publicly available for use by others. In general, however, such data that is collected by the private sector tends to be freely available only at an aggregated level that it is insufficient for detailed life cycle costing. Commercial databases are available at a price but again they are not compatible between differenet countries or even between different sectors of construction/building (eg health and education sectors) within the same country.

In order for the methodology to provide comparable results and outputs a significant amount of work is needed to normalise data in existing sources across EU member countries. It also needs to be continuously updated. However there is little interest in committing the resources to development of such common database of LCC data. There is however some work underway on the normalisation of construction cost data. The Code of Measurement for Cost Planning produced by a CEEC working group creates a co-ordinated overall framework, enabling exchange of data at high level, while still permitting differing national approaches and new innovative local developments. The CEEC-Code provides a standard basis for the sub-division of costs and for measurement of basic quantities of buildings for pan-European budgeting, comparison and analysis at management level. The structure proposed is organised to permit the use of existing national classifications at a more detailed level of information.

Risk evaluation has been researched and analysed in great detail, and within the literature there is a clear division of methods into qualitative (risk registers, matrices, etc.) and quantitative (mathematical modelling of risks with assigned probabilities using mainly Monte Carlo Simulation) to provide powerful tools. In practice in construction, however,

clients tend to use mainly sensitivity analysis – involving calculations using the likelihood/probability of projected values of key parameters occurring within pre-determined ranges. Additionally, motive scenarios and analysis of a range of service lives is usually considered as the most informative and useful.

Data for LCA and sustainability assessment is widely available and quite extensive. Clients however are mainly concerned with climate change impacts – for which CO_2 emissions and energy use are the two main environmental indicators. Some clients are interested in the monetisation of environmental impacts (sometimes referred to as "environmental costs") though the underlying methodologies remain superficial and are hotly disputed by environmental experts and practitioners of LCA in particular. It was identified that a separate set of considerations governs LCA and therefore no attempts should be made to incorporate LCA into the new LCC Common Methodology.

10.2 Conclusions from investigation and development of the methodology

The literature review has marked the extent of the boundaries of the body of knowledge relating to LCC and sustainable construction. However the field research, involving capturing the views of LCC practitioners across EU Member States, analysing LCC models for existing projects and gaining practical knowledge has mainly shaped the proposed new Common Methodology.

The range of LCC practitioners consulted included:

- Experienced LCC practitioners (consultants and contractors) involved in building LCC models and costing of construction projects and constructed assets/facilities
- Mangers and directors involved in high level decision making on the basis of the results of LCC analysis
- Facility managers running O&M operations and using LCC to ensure compliance/ reconciliation with O&M contracts
- Theoreticians of LCC

Their experience has helped us to identify and develop a practical and usable methodology.

The extent and variety of circumstances of uses of LCC was somewhat wider than expected, as LCC models are used for a range of purposes including to inform and encourage public bodies, to advice clients and policy makers, to support business cases, for comparison of alternative investment options, for detailed budgeting of selected options, for purchasing decisions, for assessment of economic life cycle of products, for monitoring of costs, etc.

The variety of uses of LCC in practice means that it is very difficult to specify a single approach and we have concluded that no single, prescriptive approach to LCC in the current European marketplace is feasible. Additionally, we are conscious of the need for the new Methodology not only to accommodate a variety of practice now but to be able to accommodate changing needs and requirements in the future without requiring major revision. It was also recognised that the new Methodology should contain checklists, where appropriate, to ensure that LCC practitioners consider the same range of factors.

The Methodology also needs to be applicable not only to different periods of time over the life cycle of a constructed asset, but also at various points in the life of the asset. Users may adopt an approach to LCC at the inception stage, at the design stage, at the stage of bidding

for a construction contract, at the commencement of construction, at the beginning of an O&M service contract, at the beginning of a warranty period, etc.

In practice LCC is used for a wide range of analysis periods, and the new Methodology needs to accommodate such variety which may include the life cycle (cradle to grave) from inception to disposal of a construction asset, and may also include the period of a long-term service contract (eg 25-30 years), or a pre-determined period relating to the client's/user's interest in the constructed asset under consideration. This could include periods covering design, construction and short-term operation, for example, or be restricted to periods that include only the maintenance and replacement (adaptation) of major components. It could also cover the period of Facilities Management (FM) or Public Private Partnership (PPP) contracts.

Because the term "Life Cycle Costing" tends to be broadly used and understood as describing a set of tools to help assess all relevant costs during a period of the client's interest in a constructed asset, it is applied in a variety of circumstances and to differing degrees across EU Member States. Attitudes to when to use LCC and to which processes and procedures to use in which circumstances vary widely and there are appear to be no general patterns of use except that approaches tend to be tailored to individual client requirements, depending principally on the extent (time period) of their interest in the constructed asset and their 'time value' they place on money. Differences in approaches adopted by public and private clients tends to blur in practice, and both appear to place a strong emphasis on providing value for money, albeit this is interpreted differently in different markets.

Generally (with the exception of Norway) the use of LCC in construction is unregulated and, to a large extent, public guidelines generally do not exist. Additionally, there are a variety of presentation formats and cost breakdown structures and there is not a single, prescribed or commonly used framework that would appear to fit the generality of European practice. In general, LCC assessments are undertaken at any time in the life of an asset. For these reasons a single prescriptive approach would not be appropriate to the majority of practitioners and would simply exclude them from using the proposed new Methodology; in taking these issues into consideration our focus was on developing a common and not a single methodology.

Many practitioners still carry out LCC calculations, advise clients and aid the vital investment decisions without relying on the results of risk or sensitivity analyses. It was concluded that the new Methodology needed to provide coverage of the workings and merits of risk and sensitivity analyses. Of course, depending on the particular needs of individual users and their attitudes towards risk and uncertainty, it is possible to carry out an LCC assessment without assessing risk and the sensitivity of key parameters to likely changes. While this is not recommended as good practice, it was nevertheless felt that the Methodology should include risk and sensitivity analyses as auxiliary steps within the LCC process, which may be omitted if client does not feel that that level of detail is required at a particular stage or is not prepared to finance additional analyses.

The sustainability or environmental assessments are frequently closely associated with LCC. In many countries selecting between options of varied sustainability or environmental performance is a key driver for using LCC. Quite frequently LCC calculations are driven by the requirement to justify decisions supporting the sustainability or environmental

performance of the complete assets as well as systems or components. The sustainability and environmental indicators and methods of assessment varied but LCA was identified as the most commonly encountered, though its use is by no means universal or common in construction.

Our analysis suggests that LCC is not and cannot at present be fully integrated with LCA. While the majority of LCC practitioners with whom we discussed this issue confirmed that the need to improve the sustainability performance of constructed assets underpins many of the design choices made during LCC, such sustainability issues tend to be dealt with by relevant experts and do not fall formally within the LCC framework used. In other words, LCC is used to assess the financial/economic impacts of possible design choices identified on the basis of sustainability assessments, and this assessment is generally restricted to direct cost impacts only. While some clients suggested that they would consider the 'monetisation' of environmental, social and other less tangible impacts, in general the preference was to restrict LCC to assess direct cost impacts only. In some cases, of course, LCC is undertaken without considering sustainability, but we are clear that the one of the key objectives in developing the new Common Methodology was to support improvements in the sustainability of the built environment, and consequently is approach is not reflected in the Methodology.

The main barriers preventing wider or more informed uses of LCC were identified as:

- Unavailability of reliable and adequate input data – covering both cost and time-based data (see also 10.1 above)
- Lack of uniform practices, common approaches and measures
- Difficulties in defining some of the cost factors
- Difficulties in evaluation of the effects of the changes in a product's operational conditions
- Too many factors of uncertainty
- Limited cooperation between clients and suppliers
- Poor quality of data from suppliers and lack of comprehensive data for products' performance in the operational phase
- Insufficient knowledge and lack of quality training
- A separation in public sector between the construction and O&M budgets, which are allocated to different departments and therefore the consolidation of both for the long-term LCC analysis and consequential decisions may not be feasible.

Many of the barriers identified are not easy to overcome in the near future. Attempts are being made internationally to develop product/system performance data (including durability data) and schedules are increasingly being published by a variety of commercial operators. Additionally, international fora are being established for the exchange of experience and data. However, LCC as an emerging 'discipline' or 'science' is relatively new (most work has taken place since the 1980s) and it is generally felt that a lot needs to be done to define and standardise cost and performance data, particularly as some of the benchmarking and performance data is only just beginning to be collected. It is felt that the Methodology developed on this study will provide a common, practical and acknowledged framework which at this point in time will be of considerable help in overcoming these barriers.

The circumstances of the use of LCC can be grouped around three most common uses of LCC identified as the most representative:

Early LCC assessment of a proposed asset or portfolio of assets for strategic decisions:

More and more clients (public as well as private) seek LCC as a preliminary tool to help them make strategic decisions regarding a proposed asset or assessment of the investment in the proposed/existing portfolio of assets. This type of assessment takes place mainly in two circumstances:

- The early assessment of a proposed asset applies to the life cycle (cradle to grave) and is based on many early assumptions (tested on other projects). The information sought is the life cycle cost for different strategic options regarding asset/facility size, overall configuration, specification levels, etc.
- The assessment of the portfolio (including existing ad proposed assets) is also based on preliminary, mainly historical data and the decisions clients can expect to make are also strategic and relate mainly to the composition of the portfolio (in terms of the mix of assets, overall specification levels, etc).

The example is typically applied to the complete life of an asset/portfolio (cradle to grave).

Assessment of LCC for a complete asset at design stage

This example follows the "classic" use of LCC on construction projects, when the project team is in place and the design is being progressively developed and refined. This example may also suit the circumstances which arise during construction when key design decisions need to be reviewed and assessed for overall value for money.

The application of LCC over the complete life cycle (cradle to grave) is not necessarily the only approach taken in this example, and typically other period of analysis are considered. Often clients who purchased new assets or public clients in possession of existing portfolios of assets require an LCC analysis for different periods covering their interest in the particular asset. Examples of the circumstance when this example may occur include:

- A client is interested in construction and short-term occupation of an asset before disposing of it.
- An FM company about to sign a new long-term O&M contract wishes to understand its liabilities for maintenance, repair and replacement over the period of the contract
- An asset owner requiring a renewal of asset insurance
- A portfolio owner (e.g. Housing Association) is seeking New Home Warranties for their residential property portfolio.

Assessment of LCC for a system (part of an asset) or a component for all or selected stages of its life cycle

An LCC assessment is often needed for a part of an asset only (a system, e.g. HVAC or cladding system) or even at the level of a basic component. The requirement can be to assess a system or component over its complete life cycle (if it is shorter than the remaining life of the asset of which it is a part) or the part of life cycle which corresponds to the remaining life of the asset (if the asset is expected to be disposed of before the system life expires). The circumstances of the application of this example can include the following:

- Options for the replacement of the system need to be assessed and selected based on pre-determined criteria (e.g. environmental performance, compatibility with regulations).
- Assessment of systems influencing the LCC of the complete asset need to be evaluated for insurance purposes

In this case, the influence of one system/component on others needs to be taken into account (such as energy use, change of fuel, strengthening of frame for new type of cladding).

All of these examples of use guided the development of the Methodology and supporting guidance.

11 Summary of guidelines for application of the methodology to public procurement and EMAT

11.1 Regulatory environment

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), implemented across the EU by national legislation.

The Methodology and Guidance developed on this project encourages readers to make themselves familiar with the requirements of the Works Procurement Directive in respect of:

- Bodies that are classified as 'public authorities' for the purposes of the Directive
- The contract value thresholds above which the Directive applies
- 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 are encouraged to make themselves 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.

11.2 Use of the methodology in Public Procurement

The developed methodology is highly relevant to public works procurement in a number of ways. Essentially, proper application of the methodology is expected to enable procurers and those concerned with delivering public works projects to ensure that all costs associated with the design, construction, operation and disposal of the works they are procuring are taken into consideration at an appropriate stage in the procurement process.

More specifically, public procurers have the opportunity to take LCC into account in the works contract award process. Public works contracts may be awarded on the basis of the economically most advantageous tender (EMAT). The EMAT procedure was established to avoid abnormally low tenders (ALTs) though currently there is no systematic guidance or methodology that is commonly in use across the EU on the evaluation of EMAT.

Recent work by the EMAT Task Group[2], established by the DG Enterprise Working Group on Abnormally Low Tenders, has developed a mechanism and procedure to enable contract award on the basis of the economically most advantageous tender. This work was reviewed by the Davis Langdon Team; however we understand that the legal status of this work is somewhat uncertain, and a general guideline has been developed for users of the Methodology who wish to select works tenders on an EMAT basis.

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

The key elements of this guidance are that 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 assessing life cycle costs associated with the acquisition and ownership of constructed assets or facilities.

As part of the review of the particular use of the methodology for public procurement, we considered how key parameters, in particular, the extent to which 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 Methodology has been developed to consider 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.

In the Methodology and supporting Guidance we note that public users of the methodology may want 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
- "Cradle to grave" (life cycle) or long periods of analysis
- 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).

12 Conclusions and proposals for further research and action

12.1 Conclusions

The proposed methodology is primarily aimed at public sector construction clients in EU Member States. However, it can also be used by private sector clients, contractors and their advisors.

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. The aim of the proposed methodology was to define a common and consistent basis for undertaking LCC across Europe without replacing country-specific decision models and approaches.

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 proposed methodology must allow for such iteration and progressive development, providing increasing certainty of the total LCC of construction projects as they progress through design and construction.

The methodology and the proposed supporting documentation is based on the definitions and terminology in Draft ISO/DIS 15686:2006 Part 5, and is fully consistent with that draft standard.

It is outside the scope of this methodology to provide a single, comprehensive standard for Life Cycle Costing across Europe. Additionally, it is outside the scope to provide a standard for a unified European cost breakdown structure for construction.

In the course of the field research it was confirmed that in order for the methodology to be in line with cross-EU approaches by LCC practitioners a wide and comprehensive interpretation of the project Terms of Reference (ToR) was needed. The fundamental issue, which still remains unresolved, is the status of the draft ISO 15686 Part 5, and the definitions and principles contained therein which we have adopted in the proposed methodology. Our Project Specification is very clear, at section 4.1.3, that the methodology should be 'based on the terminology and the general principles defined in ISO 15686'. It does not refer to any other standard or emerging standard. The fact that the draft ISO has not yet been published as a formal standard is regrettable, but completely outside of our control. We have used the very latest version of the current draft standard and based the proposed methodology on its definitions.

12.2 Recommendations for further research

In order to meet its potential, the proposed methodology produced under this project needs to be published and disseminated widely. This can be done by supporting the Methodology and Guidance documents on a high profile and publicly accessible website where it might become a resource routinely consulted by both practitioners and academics wanting more information on the Life cycle costing (LCC) as a contribution to sustainable construction. This requires an ongoing commitment to its maintenance, updating and further development.

A properly maintained online resource such as this, possibly accessible from the Commission's website could be of benefit to both academe and practice in bridging the communication difficulties which lie at the heart of this field. There is a need to consider the design of the user interface and the selection of appropriate organisations to support the methodolology and its ongoing development.

Specific recommendations for further action are:

- The Commission needs to publish the methodology, its associated processes and guidance and ensure that they are widely available and easily accessible.
- The Commission should actively promote use of the methodology and its associated processes and guidance to a broad spectrum of construction clients, practitioners, researchers and other users, emphasising its potential and value in a variety of construction settings.
- Through its R&D programme, the Commission should plot a route to the further development of the Methodology and associated processes and guidance; particular areas for development include:
  - Further integration of LCC and LCA
  - The development of more prescriptive recommendations for use of the Methodology in public procurement, including its use in EMAT tender selection

- Encouraging the development of national guidelines consistent with the common European Methodology.
- Recommendations for further research

At the core of this project has been the gathering of data on existing LCC practices and supporting literature. The research data exists as a resource in itself, independent of any analysis which has been carried out and encapsulated in the guidance document, case studies, examples and records of industry consultations. The recommendations below are therefore intended as points for discussion and are drawn partly from observations on the *status quo* in the countries selected for this study, partly from the literature review and analysis, and partly from comments provided by contributors to the research.

A key area for further research is the integration of theoretical approaches to LCC and associated methodologies with the practical needs of clients and practitioners, taking account of such issues as the quality of data, the need for simplicity of calculation methods and interpretation of results. The Common Methodology produced under this project, focused clearly on clients and practitioners, is a starting point, and further work is needed particularly in the areas of:

- Cost breakdown and reporting structures, to help the comparison of life cycle costs not only between different construction projects and sectors, but from country to country across the EU
- The collection, use and dissemination of data on the cost and performance of key construction systems and components in standardised 'use' settings.
- The Member States should be encouraged to exchange experiences and information related to LCC to support the further development of the LCC methodology developed in this study
- Framework ought to be enabled for training activities and better monitoring/control of operational and maintenance expenses which also strengthens the dissemination of LCC practice in Public Procurement

Research organisations, government and the professions should aim to identify, capture, evaluate and understand the key circumstances and criteria of construction projects that respond positively the challenges of sustainability. These need to inform the further development of the LCC Methodology developed on this study.

Additionally, there is a need to investigate and develop means of measuring the performance of the built environments, particularly but not exclusively, the performance in terms of ability to meet the varied needs of users.

Recommendations for further research depend partly on the outcome of discussions now underway in relation the status of the Draft ISO/DIS 15686, Part 5 and in particular, the final status of the definitions and terminology in the document. The Methodology document in particular may need to be updated and revised in the light of these.

Every methodology/guidance document will benefit from practical and detailed application in a 'real life' setting. While the Methodology developed under this study has been tested against a small number of case studies in different countries, it is only by the continued application of the Methodology to a wider selection of international projects of various scopes and type that all aspects of the Methodology can be reviewed and refined. In the course of our research we have encountered considerable opposition to disclosing actual

costs used in LCC exercises in real-life projects. In many cases this data is considered commercially sensitive. Further work could focus on removing these barriers – perhaps by securing the participation of a group of public sector clients, for example, in a joint study wherein all data and results are shared among the participants and, if appropriate, more widely – and learning lessons from the consistent application of the methodology across a range of projects.

13 Appendices

For appendices to the final research report please refer to the separate document "Appendices to the Final Report".