FINAL REPORT

Task Group 4 : Life Cycle Costs in Construction

Version 29 October 2003

This version has been endorsed during the 3rd Tripartite Meeting Group (Member States/Industry/Commission) on the Competitiveness of the Construction Industry.

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1 Executive Summary

1.1 Terms of reference

The terms of reference of TG 4 are to:

Draw up recommendations and guidelines on Life Cycle Costs of construction aimed at improving the sustainability of the built environment.

1.2 Background

1.2.1 In the Communication from the European Commission "The Competitiveness of the Construction Industry" dated 04.11.1997, sixty-five recommendations for action were included. At the meeting on 31.05.1999, the Tripartite Working Group (consisting of representatives of the member states, Commission and industry) agreed an abbreviated list of priorities, including "Sustainable Construction".

1.2.2 Three Task Groups (TG) were subsequently set up under the auspices of the Working Group sustainable Construction. TG1: "Environmentally Friendly Construction Materials", TG2: "Energy Efficiency on Buildings", TG3: "Construction and Demolition Waste Management". Following the completion of the individual reports of these TGs, a "General Report" on sustainable construction was also drawn up and agreed entitled "An Agenda for Sustainable Construction in Europe".

1.2.3 These reports are available on the European Commission's website: http://europa.eu.int/comm/enterprise/construction/index.htm

1.2.4 The "General Report" contains a number of recommendations, one of which proposed that a fourth TG be set up to draft a paper on Life Cycle Costs in construction and to make recommendations on how these might be integrated into European policy making. Consequently TG4 was established and this report constitutes a response to this recommendation.

1.2.5 "It has to be stated that this Report is neither an official document of the European Commission nor a document of the Member States because they were not involved officially. So TG 4 Final Report can still have the status of an expert document and does not have any official or legal status."

1.3 Headings of recommendations

1.3.1 Recommendation 1: Adopt a common European Methodology for assessing Life Cycle Costs (LCC) of construction.

1.3.2 Recommendation 2: Encourage data collection for benchmarks, to support best practice and maintenance manuals

1.3.3 Recommendation 3: Public procurement and contract award incorporating LCC

1.3.4 Recommendation 4: Life cycle cost(ing) indicators should be displayed in buildings open to public

1.3.5 Recommendation 5: Life cycle cost(ing) should be carried out at the early design stage of a project.

1.3.6 Recommendation 6: Fiscal measures to encourage the use of LCC

1.3.7 Recommendation 7: Develop Guidance and fact sheets

2 Introduction

2.1 Approach and background, distinction between Life Cycle Assessment (LCA) and Life Cycle Costs (LCC)

2.1.1 Derived from ISO 14040: In construction, environmental life cycle assessment (LCA) is for assessing the total environmental impact associated with a product's manufacture, use and disposal and with all actions in relation to the construction and use of a building or other constructed asset throughout its life cycle. LCA does not address economic or societal aspects.

2.1.2 Derived from ISO 15686:

Life cycle cost – LCC is the total cost of a building or its parts throughout its life, including the costs of planning, design, acquisition, operations, maintenance and disposal, less any residual value.

Life cycle costing – LCC is a technique which 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 costs. In particular, it is an economic assessment considering all projected relevant cost flows over a period of analysis expressed in monetary value. Where the term uses initial capital letters it can be defined as the present value of the total cost of an asset over the period of analysis.

2.1.3 Life Cycle Cost and Through Life Cost are terms used to describe the same process as Whole Life Costing (WLC). The expression “WLC” is more commonly used in UK, and essentially used to describe the Life Cycle of a building, LCC is used in UK more for the Life Cycle for a material. Internationally it appears that LCC is used for both a building and a material, so in order to avoid confusion, LCC is only used in this report.

2.1.4 Most of us use the process of LCC consciously or sub-consciously in our normal purchasing activities. When we buy a car, for example, we want to know not just the price, but the vehicle’s running costs, such as the estimated regular maintenance cost, fuel consumption, the cost and timing of replacement of time-expired parts as well as the residual value on disposal. The same principle should apply to buildings.

2.1.5 In general, products cause environmental impacts via the inflows and outflows of all processes related to their life cycles. Inflows are the use of materials and energy in their production; outflows are the resulting impacts such as air emissions, water effluents, waste materials and other releases. In addition to their impact on the external environment, buildings and constructed assets provide an internal environment for human activity. The quality of the indoor environment provided to people and the impacts upon human health, comfort, well-being and productivity are equally important though possibly more difficult to address. Such impacts should be assessed by the use of complementary methods.

2.1.6 Environmental impacts associated with building and construction activities and the built environment generally can be significant and should be addressed as far as possible at project planning stage. These impacts may occur at any or all stages of a building’s life cycle and can be local, regional or global, or a combination of all three.

2.1.7 The integration of Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) presents a powerful route to improving the sustainability of the built environment. Combining economic and environmental assessment tools to obtain "best value" solutions in both financial and environmental terms has the potential to make a significant contribution to achieving sustainable development. LCC and LCA in the construction industry have developed separately in response to economic and environmental problems, but the two have much in common.

2.1.8 The assessment of the environmental impact of design options should be carried out in parallel with a technical, as well as an economic assessment, together with an assessment of social-cultural issues which are **not considered** in this report.

2.1.9 Buildings and constructed assets have a long service life. Parts of the underlying data required for both LCA and LCC should be drawn from the product application context and from scenarios concerning technical and economic performance, as well as user-related aspects. Environmental assessments in accordance with ISO/CD 21930 can only reflect today's information or today's expectation of the future; therefore assessments deal with predicted performance, which may not give the same result as a post completion or post-life retrospective performance evaluation. The purpose of Service Life Planning[1] (SLP) is to create a realistic picture of the predicted performance and should therefore make such scenarios more accurate.

2.1.10 Presentations on LCC made by participants during meetings are described in Appendix 7.6.

2.2 Differences and similarities

2.2.1 LCC and LCA in the construction industry have been developed separately in response to economic and environmental considerations but the two tools have much in common.

2.2.2 The key similarity is that both of them utilise data on:

- Quantities and specification of materials used (mass, thickness, density and amount;
- The service life for which the materials could or should be used;
- The maintenance and operational implications of using the products (assumptions about building use)
- End of life proportions in relation to recycling (and sale value) and disposal.
- Variance of service life for the same material in different building contexts.

2.2.3 The essential differences are:

- Conventional LCC methods do not take into consideration the process of making a product; they are concerned with the market cost. LCA takes production into consideration when considering embodied energy.

2.2.4 It is important to emphasise that it was decided that this report should **not** address the issue of Life Cycle Assessment. Therefore any reference to this term in this report should be considered purely incidental.

[1] ISO 15686-6: Buildings and Constructed Assets – service life planning – part 6: procedure for considering environmental impacts is in preparation – committee draft approved in March 2002.

3 LCC Methodology

3.1 Background

3.1.1 There is no specific legislation in Europe that *requires* life cycle costs to be taken into account in procurement procedures, but in the current and proposed public procurement directives there is an *option.*

3.1.2 In the case of the UK there are a number of guidance documents aimed at government departments embarking on procuring construction and a requirement to demonstrate best value. A number of private UK client organisations have undertaken to procure construction on a whole life cost basis.

3.1.3 In Germany a Guide for Sustainable Building was implemented in March 2001 for application to all Federal buildings and cost estimations have to consider operating and maintenance costs as well as construction costs.

3.1.4 In Finland, Sweden, Ireland, Luxemburg and Netherlands, have also a policy or guidelines on LCC.

3.2 A methodology for calculating life cycle costs

3.2.1 A life cycle cost methodology is an iterative process. At each stage of the project, (inception to disposal) decision and procurement processes, the calculation of LCC should be refined to provide increasing certainty of the total LCC of the project.

3.2.2 In the early conceptual stages it will only provide a broad estimate of the costs, but when decisions are made and the design details defined, it will provide an increasingly more reliable prediction of the total cost of owning and operating the asset.

3.2.3 At the initial stage, the assessment of capital and other costs will probably be based on the use of historic costs per square metre. This is subsequently refined to incorporate actual labour, materials, components and other costs. However, irrespective of whether or not historical cost information is available, it is always preferable to estimate costs from first principles and only use historical cost and performance information as a check.

3.2.4 LCC also takes account of post-occupation costs. The aim is to arrive at a plan applicable to all stages in the acquisition and use of a constructed asset as the basis for the client's procurement decision. The original assumptions are replaced by better assessments of quantities, price and predicted performance of alternative components, materials, energy consumption and services.

3.2.5 When considering LCC, *designers should work in close collaboration with the supply team – main contractors, specialist contractors, suppliers and manufacturers.* This is the procurement route most likely to result in integrated teams[2], integrated working and best value solutions.

[2] An integrated team includes the client and those involved in the delivery process who are pivotal in providing solutions that will meet the clients requirements. Thus those involved in asset development, designing, manufacturing, assembling and constructing, proving, operating and maintaining, will have the opportunity to add maximum value by being integrated around common objectives, processes, culture, values, risk and reward. Accelerating Change – a report by the Strategic Forum for Construction, July 2002.

3.2.6 Close collaboration is particularly important because it is necessary to make predictions and estimates about the long-term performance of a facility based on the expected lives of systems and their components. In particular, values need to be ascribed to the rate of deterioration, the level of deterioration at which intervention is required and the continued rate of deterioration after repair or replacement. Manufacturers and suppliers will provide durability, maintenance and replacement information and therefore the reliability of their input is essential.

3.2.7 In order to calculate operating and maintenance costs through the life of a constructed asset or facility, *a nominal working life of the asset should be agreed with or specified by the client*. It is then possible to establish how many times short life elements and components may need to be replaced during the lifetime of the asset, the required maintenance to retain acceptable performance and the timing for interventions.

3.2.8 Consideration must be given to the need for and timing of major refurbishment or replacement during the life of the facility and the cost of end of life disposal.

3.3 Life cycle costing – the decision process

3.3.1 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

3.3.2 The decision process and elements of the facility that need to be considered are illustrated[3] in Fig. 1 and described in more detail[4] 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

[3] Based on a 3-dimensional model developed by Cranfield University.

[4] Whole Life Costing – A client's guide, Construction Clients' Forum.

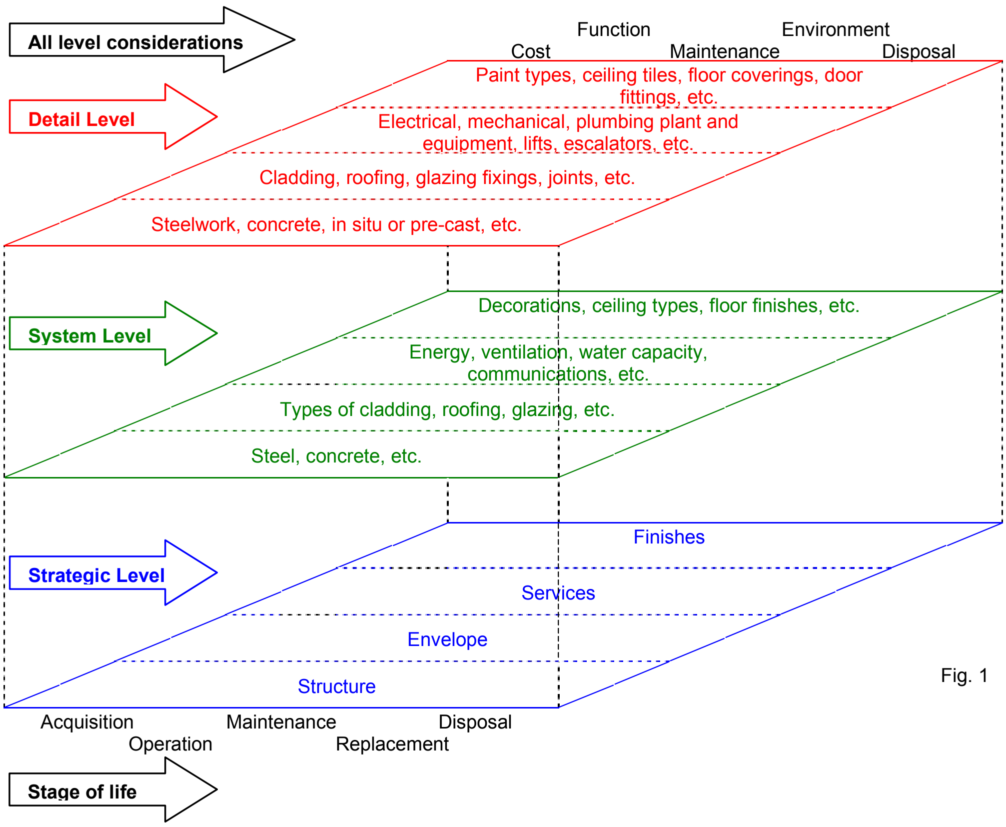

Fig. 1

3.3.3 Strategic decision level – initial appraisal (Pre- construction phase)

3.3.3.1 During the strategic decision level, options and approximate budgets are identified. The outline business case is made giving consideration to:

- Definitions of functional and performance requirements
- Client priorities such as the required rate of return on capital investment
- Design life or the period to be covered in the life cycle cost evaluation

3.3.3.2 Assumptions may be required on the following:

- The cost of alternative fuels
- Imprecise knowledge of durability such as the life of components before failure or replacement
- Imprecise performance requirements such as size, accommodation, period before the constructed facility is complete
- The choice of the discount rate to be applied
- The timing of cost flows

Guidance on these issues is included in ISO 15686 Part 1, which describes a process of planning the service life of the asset going beyond simple comparisons between alternative solutions.

3.3.4 System and detailed decision levels – design appraisal (Pre – construction phase)

3.3.4.1 During the system and the detailed decision levels, the design is developed and the LCC plan, based on the assumptions listed above, is progressively refined. The original assumptions are replaced by better assessments of quantities, price and predicted performance of alternative components, materials and services.

3.3.4.2 When considering LCC, it is recommended that the designers work in close collaboration with the supply chain, contractors, suppliers and manufacturers. Their early involvement enables decisions to be made that are based on actual or warranted durability and costs, as opposed to those based on predictions. The client, in conjunction with the designer, needs to decide which elements of the construction should be long life when supported by periodic maintenance (based on a plan, condition or reliability) and which should be short life and replaceable. Such decisions and selections are recorded and can be audited for compliance with appropriate procedures, if the client requires this. Product and materials specification should be based on these considerations, calculated on a LCC basis.

3.3.4.3 It is important that the LCC are developed concurrently with the design and that they are continuously related back to the initial investment plan to resolve any problems. Progressively, reliance on historic costs will be replaced by confidence in predicted costs for the project under review.

3.3.4.4 It is widely recognised that 80% of operation, maintenance and repair costs of a building are fixed in the first 20% of the design process. But decisions, data feedback and continual monitoring and optimisation of LCC must continue through the life of the facility. Although not included in Fig. 1, completion and post-occupation appraisals should follow ending only at the time of disposal. These continuing stages are described in the following sections.

3.3.5 Construction, operation, maintenance and replacement. (Completion and post-occupation phase)

3.3.5.1 The completed construction project or facility should be supported by manuals setting out information on operation and maintenance procedures. The LCC plan is a different and distinct document and includes:

- Durability information
- A maintenance profile which indicates whether services lives match design lives
- Anticipated life cycle costs of the components and services

3.3.5.2 The plan should include sufficient detail to allow monitoring of costs and timing of work. Monitoring the performance and costs of the completed construction will highlight:

- Deviations from the cost predictions
- Consequences of changes to the operating and maintenance regimes
- Increases in running costs which might indicate the need for refurbishment or replacement
- Over-cautious or optimistic durability or time estimates

3.3.5.3 Consideration of the need for major refurbishment or replacement will require a fresh LCC exercise, starting from an initial appraisal of the available options. The decision to undertake refurbishment should include assessment of:

- Residual service lives of elements of the construction to be retained
- Revised remaining service life of the constructed asset
- Whether the original design life assumptions remain valid when set against achieved service lives.

3.3.6 Disposal (Completion and post-occupation phase)

3.3.6.1 Disposal of the asset at the end of its service life, whether demolition, should be considered in the LCC plan. Monitoring performance and operational costs (including maintenance, energy, etc.) may identify obsolescence that cannot be rectified by refurbishment or replacement. This may mean that disposal is required earlier than originally anticipated, which will affect the profitability of the client's business.

3.3.7 Life Cycle costs to be considered

3.3.7.1 A breakdown of the costs involved at each level or stage of the LCC process stage are outlined in Table 1 below. They are also described in greater detail in Appendix 7.2.

3.3.7.2 The individual costs that comprise the total LCC included have been selected from Appendix 7.2 on the basis that they probably constitute the majority of LCC. That is, of course, a matter for individual judgement but it should be noted that predictions of future costs are imprecise, even when refined by the input of historical or current costs. It follows that there must be a level of detail beyond which the effort expended is greater than the benefit of the results – the law of diminishing returns.

Life Cycle Costs LCC

- **Non-Construction Costs**
  1. Site or asset purchase and associated fees
  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
- **Construction Costs**
  1. Design and engineering (design and build)
  2. Temporary works, site clearance or groundwork
  3. Construction, fitting out, commissioning and handover
  4. Project management and planning supervisor (CDM Regulations)
  5.
- **Operation Costs**
  1. Rates (and rent if applicable)
  2. Insurance
  3. Energy costs for heating, cooling, power and lighting, and utilities – water, sewerage
  4. Facilities management, cleaning, security
  5. Annual regulatory costs (e.g. fire, access inspections)
- **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
  5.
- **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
  2. Loss of the facility during replacement
  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.
  5.
- **Disposal Costs**
  1. Demolition
  2. Waste disposal
  3. Site clearance

Table 1

3.3.8 Converting future costs to current costs

3.3.8.1 To account for different operations taking place at different times, incremental costs can be converted to current costs using a discounted cash flow method. This is particularly important when comparing options that have different replacement cycles.

3.3.8.2 The Present Value – PV procedure reduces a series of cash flows which occur at different times in the future to a single value at one point in time, the present. The technique, which makes this transformation possible, is called discounting. This explained in more detail in Appendix 7.1.

3.3.8.3 The present value of future costs reduces rapidly over time, as illustrates in Fig 2 for different discount rates. This makes capital investment for better long-term performance unattractive to a developer in monetary terms.

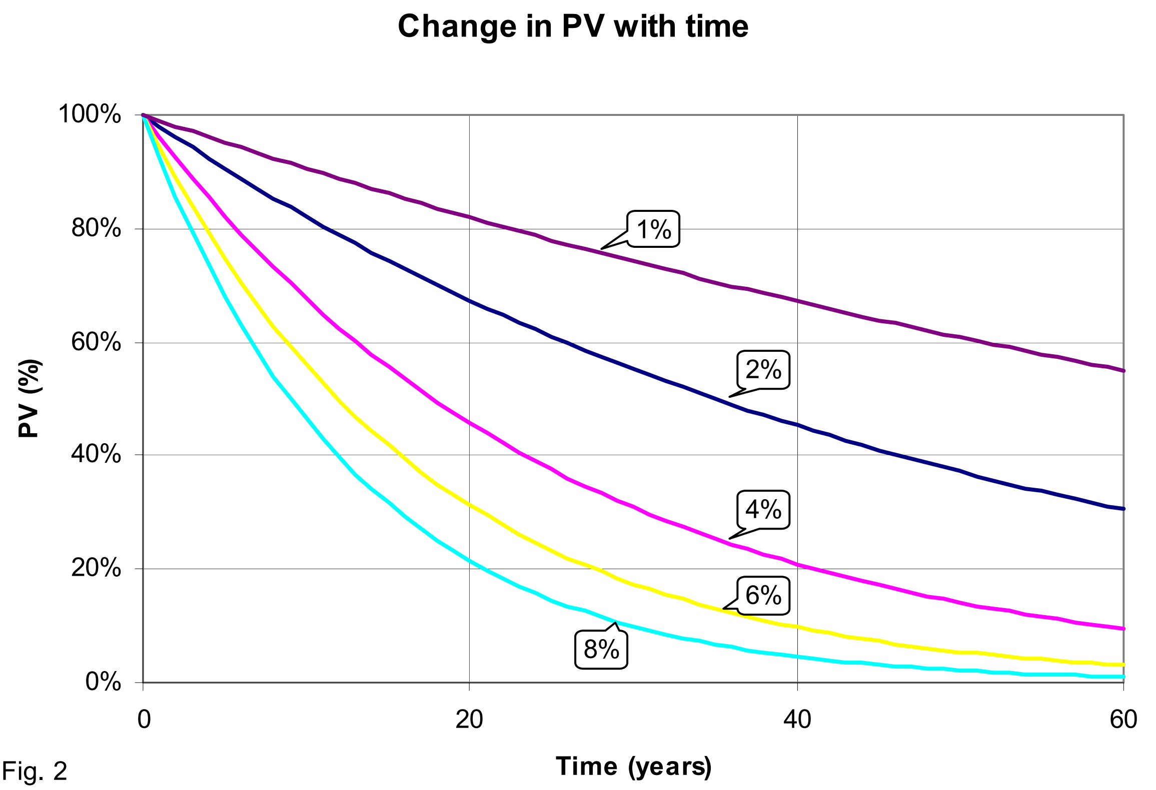

Fig. 2

Probabilistic approach

3.3.8.4 For LCC to become widely accepted, concerns about uncertainties in forecasting must be overcome. This concerns particularly the costs and performance of a building, products and systems. A related European RTD project EuroLifeForm is to advance a probabilistic approach on LCC in construction. This is explained in more detail in Appendix 7.3

3.4 Recommendation 1: Adopt a common European Methodology for assessing Life Cycle Costs LCC in construction

3.4.1 Referring to the mentioned sensitivity of LCC calculations in chapter 3.2 it is evident that transparency in the calculation method and criteria used is essential. Therefore the development of a European harmonised methodology closely referring to international standards is considered as being essential.

- A **common methodology** should be adopted for the estimation of life cycle costs of built facilities and recognised as a European methodology. Furthermore, the methodology should include a system for estimating **LCC indicators**.
- A classification of different costs at various phases of the LCC, e.g. Through the development of European Standards.
- The European Commission should support the development of a harmonised framework to facilitate the development of software tools to estimate LCC on a European basis.
- The **Methodology included in chapter 2 of this report is suitable**. This methodology may be revised when ISO 15686 Part 5 becomes available.

Explanatory note:

3.4.1.1 The standard also sets out at international level the methodology for life cycle costs.

3.4.1.2 Service life planning can be applied to new and existing structures, although in existing buildings the residual service life of the retained elements will have to be assessed.

3.4.1.3 Costing of projects should include full life cycle costs of the facility as well as more immediate construction and project costs

4 Data Collections, benchmarking and manuals

4.1 Introduction

4.1.1 For life cycle costing to become widely accepted, concerns over uncertainties in forecasting must be addressed and progressively reduced. These uncertainties must be reduced, either through the collection of more reliable information or the development of more reliable predictive models, or be accommodated within the system by enabling the level of risk to be quantified. Values need to be ascribed to the rate of deterioration, the level or stage of deterioration at which intervention is required and the continued rate of deterioration after repair or replacement. Manufacturers and suppliers should be encouraged to provide durability, maintenance and replacement information and therefore the reliability of their input is essential. Benchmarks need real data e.g. from data that has been used in submissions for technical approvals (Building Regulations e.g. for energy use).

4.1.2 Life cycle performance of buildings is affected by operational factors which are not necessarily measurable at the design stage in terms of cost, for example the quality of environment in terms of natural daylight and ventilation, access for disabled, improved flexibility of design. Research is needed to quantify the relationships and the cost benefits of these ‘softer issues’ over the life cycle.

4.1.3 This relationship (operational efficiency related to quality of environment) is measured in terms of the well being of the users, (eg patient recovery rates in hospitals, days off work due to sickness, ability to attract staff, improved income due to improved accessibility)

4.1.4 The information gained from the first phase is analysed to demonstrate the life cycle cost saving potential due to enhanced well-being of users that can be achieved in the design process. This information then forms the basis of good practice guidance to be disseminated across the European Union.

4.2 Recommendation 2 : Encourage data collection for benchmarks, to support best practice and maintenance manuals

4.2.1 Data Collection

- Public clients should make publicly available the capital cost and life cycle cost of new build and refurbished construction projects that they have commissioned. Construction costs may be presented as a cost per square metre of gross internal floor area or as cost per unit such as bed space. Life cycle costs, which will include the capital cost of construction, will need to be presented at net present value and the study period identified and may be presented in a similar way as construction costs. (Note: life cycle costs include consideration of capital costs)
- A Europe-wide forum should be established to normalise and exchange costs and durability data. Data should be recorded in an agreed format and managed and published by government sponsored agencies for each member state.
- Private clients should be encouraged to provide similar data.
- Classifications of different costs at all stages should be developed e.g. by creating EN Standards.

4.2.2 Life cycle cost benchmarks to support best practice

- Develop life cycle cost benchmarks initially at national level and ultimately at pan-European level. Benchmarks will be derived from life cycle cost data arising from this recommendation.
- Life cycle cost benchmarks should be suitable for both private and publicly funded construction. Where different criteria are used, these should be clearly identified.

4.2.3 Maintenance manuals

- Maintenance manuals developed in accordance with the Common LCC Methodology should contain estimated service lives of buildings parts, maintenance works and costs, how to repair and how to use construction waste after renovations and demolition.
- Decisions and selections are recorded and can be audited for compliance with appropriate procedures. Decisions, data feedback and continual monitoring and optimisation of LCC should continue through the life of the facility.
- The completed construction works or built facility should be supported by information on operation and maintenance manuals.

5 LCC and Public procurement

5.1 Introduction to the Economically Most Advantageous Tender (EMAT)

5.1.1 The report of the EMAT Task Group (for further informations on EMAT please refer to Appendix 7.6.2) is a recommended methodology that enables contract award to the economically most advantageous tender.

5.1.2 The group was mindful of the current Public Works Directive and the draft Directive on the co-ordination of procedures for the award of public supply contracts, public service contracts and public works contracts.

5.2 Incorporation of life cycle costs into the Economically Most Advantageous Tender (EMAT) mechanism

5.2.1 The EMAT TG Report and recommendations July 2001 states:

Life cycle [or whole life] costs are the subject of a separate action plan priority for which a working group has yet to be established. As life cycle costs are an essential part of any assessment of the economically most advantageous tender, provisional suggestions on how they might be incorporated into the award mechanism are included in this report. It is acknowledged that the suggestions may need to be modified following the recommendations of the life cycle cost task group.

5.2.2 TG4 is the working group established to address life cycle costs and it will be necessary to revisit the EMAT TG Report referred to in section 7.6.2 and update it to correspond with the conclusions of this LCC report. This section therefore proposes the modifications and additions to the EMAT Report that will probably be required. As a result of the LCC Report the LCC section of the EMAT mechanism can be simplified.

5.2.3 It is important to note that, as illustrated in Table 1, life cycle costs are the total cost of a building or its parts throughout its life. However, for the purposes of assessing the EMAT, only those costs directly relevant to the tender bid can be included. Furthermore, the tender price, which is usually the non-construction and construction costs relevant to the bid, is separately assessed. This means that in the context of an EMAT assessment, life cycle costs will usually exclude non-construction and construction costs and consist only of post completion or post handover costs (operation, maintenance, replacement and disposal costs).

5.2.4 The ratio of construction (capital) cost to maintenance and operating costs and business operating costs for office buildings over 30 years can be 1:5:200[5]. In deciding the weightings of tender price, quality and life cycle costs it is necessary to bear this ratio in mind and allocate appropriate weightings.

5.2.5 Current practice indicates that normally only the construction price and (sometimes) quality are assessed. LCC should be a priority criterion of the EMAT mechanism and evaluated in the same way as quality and price.

5.2.6 Because an assessment of LCC is an essential element of the EMAT system, an appreciation of the basic requirements is summarised in the following sections. As the EMAT system is concerned only with the evaluation of tenders, those elements of LCC that would be considered and incurred directly by the client before or outside the tender evaluation process are excluded.

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5 Source: Royal Academy of Engineering, BAA plc.

5.2.7 An EMAT system should include an assessment of each of the previously explained appraisals, in accordance with the relevance to the particular project, which should be built into the award mechanism. Where the LCC of a particular element of the construction project under assessment are significant, such elements should be separately assessed and subsequently incorporated into the total LCC. This is particularly important when considering the energy consuming elements such as electrical, heating, air conditioning and similar systems. Such systems require maintenance during their use and their lives are generally shorter than for the construction project as a whole. Assessment of the following factors (and/or any others relevant to the particular project) should therefore be made in respect of these systems and incorporated into the EMAT award mechanism.

- The weighting to be given to life cycle costs such that the quality, price and life cycle cost weightings add up to 100% (to be determined by the client and stated in the contract notice and tender documentation). It should be noted that the weightings might not necessarily be the same for individual elements or systems where these are individually assessed.
- The operating costs of the element of the asset under assessment.
- The maintenance costs of the element of the asset under assessment.
- The replacement (or refurbishment) costs of the element of the asset under assessment.
- The disposal cost of the element of the asset under assessment.

5.2.8 Tenderers should provide the information necessary to enable LCC to be assessed and scored and incorporated into the EMAT award mechanism. LCC criteria can be incorporated into the award mechanism in alternative ways.

- Weightings are established for the selected life cycle cost criteria, which are assessed and scored in the same way as quality criteria and incorporated into the award mechanism.
- Alternatively, costs for selected life cycle cost criteria can be requested from tenderers, scored and incorporated into the award mechanism in the same way as tender price.

5.2.9 Because of the uncertainty of predicting future costs, especially those relating to energy – oil, gas, electricity and the like – consideration should be given to alternative ways of assessing and scoring the whole life cost elements of tender offers, such as operating costs. These could be based on energy consumption rather than its cost, i.e., kWh not €. Alternatively, as the concept of energy labelling is developed, relative scoring of tenders could be achieved by summation of the energy consumption scores of the individual components.

5.3 Recommendation 3: Public procurement and contract award incorporating LCC

- In the context of the public procurement directives for those tendering procedures based on the Economically Most Advantageous Tender (EMAT) rather than simply the lowest price, LCC calculations based on a recognised European methodology should form one of the bases of identifying the EMAT.
- The European Commission should develop guidelines to support public procurement procedures and to encourage contract award on the basis of a consistent recognised European EMAT methodology incorporating LCC. Such guidelines should also benefit contracting authorities in the application of the methodology.

Explanatory note:

5.3.1 Procurement policy should be concerned with the optimum combination of life cycle costs, quality and performance to meet the needs of the customer. This enables clients to specify what they need to meet their own operational and strategic objectives and achieve the best value solution or “economically most advantageous tender[6]” (EMAT[7]).

[6] Public Works Directive [93/37/EEC] and the Proposal for a Directive on the coordination of procedures for the award of public supply contracts, public service contracts and public works contracts [COM (2000) 275 final].

[7] See also the reports produced under the action plan following the adoption by the European Commission of the Communication [COM (97) 539 final] to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions on the competitiveness of the construction industry: Prevention, Detection and Elimination of Abnormally Low Tenders in the European Construction Industry, June 1999; EMAT TG Report And Recommendations July 2001.

6 Promoting sustainability through LCC

6.1 Introduction

6.1.1 The required life and environmental performance should be agreed with or specified by the client. This will be difficult and will require careful drafting if all countries are to have the same method of measurement - e.g. energy use in the north compared to the south of Europe.

6.1.2 The recent international standard that has been published also addresses these issues. ISO 15686 Buildings and Constructed Assets – Service Life Planning. Part 1 : General Principles of the standard provides an overall framework which addresses the design of a building or construction with a view to its operation through the whole of its operational life. The approach requires long-term performance and overall operating costs to be addressed early in the design stage. It enables the design to be assessed against the client's long-term needs for the service life of the building.

6.1.3 A major impetus for producing the new standard has been concern over the industry need to forecast and control the cost of ownership because a high proportion of the life cycle costs will have been set by the time it is handed over (see figure of Impact of early life cycle cost input). The standard encourages the involvement of all parties in the decision process for the selection of components and systems based on performance (durability) appropriate for the function and expected life of the asset.

6.1.4 Most importantly it focuses on the lack of data on durability and provides a methodology for assessing and recording decisions on estimating the service lives of components where there is a lack of robust scientific and certified product data.

6.1.5 Service life planning is an integral aspect of life cycle costing. The replacement cycles of sub-components that are expected to last less than the overall service life of the main component or the life of the building are very sensitive to the calculation of whole life costs. Reliable forecasting of future replacements against the functional requirements of the building will reduce the possibility and costs of disruption to the business or processes being carried out in or being supported by the building or construction project due to unexpected component failure. Service life planning assists in the identification of critical elements in the design. It can be applied to new and existing structures, although in existing buildings the residual service life of the retained elements will have to be assessed.

6.1.6 The standard also sets out at international level the methodology for life cycle costing. This will be addressed in more detail with the publication of Part 5 of ISO 15686.

6.1.7 In the Annex 1 of the Construction Products Directive (89/106/EEC) it has been stated that 'products must be suitable for construction works which (as a whole and in their separate parts) are fit for their intended use, account being taken of economy, and in this connection satisfy the six essential requirements where the works are subject to regulations containing such requirements. Such requirements must, subject to normal maintenance, be satisfied for an economically reasonable working life. The requirements generally concern actions which are foreseeable'.

6.1.8 Harmonized specifications (harmonized products standards or European technical approvals) will in near future cover most construction products. In harmonized specifications product durability information has been given according to the state of art principle. This information can be a basis for more detailed durability assessment of a works or part of the works according to ISO 15686 standards. But there are some 'gaps' between these two approaches to durability. These gaps or aspects missing between CPD and ISO 15686 are related to a different approach to testing and evaluation. ISO recommends, in general, long term exposure tests of products in their intended end use conditions, while CPD generally uses shorter testing or indirect assessment. There is work going on to over - bridge the missing aspects.

6.1.9 For life cycle costing to become widely accepted, concerns about uncertainties in forecasting must be overcome. This applies both to the methods employed and to the long-term cost and performance data that fuel the models. These uncertainties must be reduced, either through the collection of more reliable information or the development of more reliable predictive models, or must be accommodated within the system by enabling the level of risk to be quantified.

6.2 Awareness raising and benefits

6.2.1 Achieving excellence in design is essential in order for a project to deliver best value. Design is both a creative and a technical process and should include the following components, each of which must be addressed appropriately:

6.2.2 The functional design of the facility must meet the needs of its users and its operations. This should result from a detailed assessment of the needs of the users and operations and how they may change over time as well as how the facility will need to be altered to meet those changing needs.

6.2.3 Detailed design of each assembly and component whether manufactured on site or in a factory, and whether a standard product or purpose-made or adapted for the facility is key to achieving the required service life.

6.2.4 Design of the entire construction process needs to address how each component will be manufactured, transported and assembled to complete the facility. The maintenance of the facility including details of how components can be replaced and or repaired should be addressed as well as its ultimate disposal.

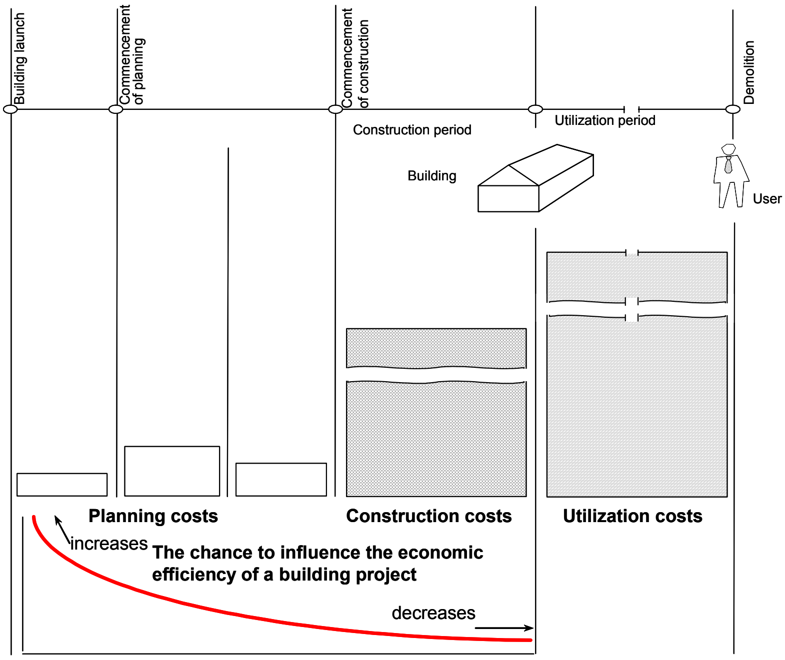
6.2.5 Costing of projects should include full life cycle costs of the facility as well as more immediate construction and project costs. The quality of both design and construction has the potential to greatly reduce life cycle costs, including costs-in-use and the eventual disposal of the built facility.

6.3 Recommendation 4: life cycle cost indicators should be displayed in buildings open to public

- LCC indicators assessed on the basis of the Common European Methodology should be clearly displayed in all new and renovated buildings exceeding 1000m2 floor area accessible by the public.

6.4 Recommendation 5: life cycle costing should be carried out at early design stage

- The opportunities for modifying the costs of a project are greatest at the beginning of the project. To a large extent, the cost-effective decisions will have been made during the definition of the programme and the initial concept phase. The earlier life cycle costs are considered in the life cycle of building procurement, the greater the opportunity for creating best whole life value.
- Therefore the planning team needs information about LCC-criteria of the applied products (durability, maintenance costs etc.) and what the cost criteria are in connection with the whole building (optimize volume, area, glazing etc.).
- This is important for those who also work with different contracts and distinguish between the contract with the architect or engineer and the contract with the construction enterprise



6.5 Recommendation 6: Fiscal measures to encourage the use of LCC

- Member states should examine their fiscal regimes in order to determine whether adjustments can be made to promote life cycle costing linked to the Common European Methodology.

6.6 Recommendation 7: Develop Guidance and fact sheets

- Develop guidelines and fact sheets to demonstrate the benefits of adopting a life cycle cost approach to procuring new and refurbishing existing buildings. These should be supported by case studies.

7 Appendices

7.1 Converting future costs to current costs

7.1.1 The determination of costs is an integral part of the construction asset management process. Life Cycle Costing is a process to determine the sum of all the costs associated with an asset or part of thereof, including acquisition, installation, operation, maintenance, refurbishment and disposal costs.

7.1.2 Since asset component costs for differing options occur at varying times throughout the asset life cycle, they can only be compared by reducing them to costs at a common base rate. This can be achieved through the process of discounting.

7.1.3 Present Value (PV) is the value of a future transaction discounted to some base date. It reflects a time value of money. The present day equivalent of a future cost, ie the present value, can be thought of as the amount of money that would need to be invested today, at an interest rate equal to discount rate, in order to have the money available to meet the future cost at the time when it was predicted to occur. The effects of inflation can also be included in these calculations.

7.1.4 LCC is calculated as a present value of the accumulated annual future costs (C) over a period of analysis time (t), eg 60 years (N), at an agreed discount rate (d), eg 2% = 0.02 pa, dependant on prevailing interest and inflation rates. PV is calculated according to the following formula.

$$PV = \sum_{t=0}^{N} \frac{C_t}{(1+d)^t}$$

7.1.5 PV can be calculated using nominal costs and discount rate based on projected actual future costs to be paid, including general inflation or deflation, and on projected actual future interest rates. Nominal costs are generally appropriate for preparing financial budgets, where the actual monetary amounts are required to ensure that actual amounts are available for payment at the time when they occur.

7.1.6 PV can be calculated also using real costs and discount rate, ie present costs (including forecast changes in efficiency and technology, but excluding general inflation or deflation) and real discount rate (dreal), which is calculated according to the following formula, where (i) = interest rate and (a) = general inflation (or deflation) rate, all in absolute values pa. e.g 2% =0.02.

$$d_{real} = \frac{1+i}{1+a} - 1$$

7.1.7 Buildings have long service lives. Because of difficulties to predict inflation in long term it is recommendable to use real costs (without inflation) and the real discount rate. Over a long period of time, the real discount rate is usually 0 - 2% pa only. At low discount rates long-term future costs and savings are immediately meaningful, as can be seen in Fig 2. Thus investment for a better future would look more rewarding.

7.1.8 If the service life of a building has been determined or predicted longer than 100 years, it may not be wise to use more than 100 years in the calculations. Disposal costs shall be taken into account in every case.

7.1.9 It may be claimed that future LCC costs may increase due to higher energy prices and new environmental and other regulatory requirements.

7.1.10 Care also needs to be taken when applying a predicted inflation rate because this needs to be linked to construction labor and material costs not to the more generally quoted 'cost of living' indices, which are often lower.

7.1.11 LCC include the capital cost, which is Ct in year 0 (C0). These costs are the total of the non-construction and construction costs actually incurred, which should be known at the time the facility is handed over.

7.1.12 The costs in subsequent years (t = 1 to N, the end of design life and year of disposal) are individually calculated on the basis of the LCC plan, and summed to predict the post constructions costs.

7.2 Life Cycle Costs to be considered

7.2.1 The following is a summary guide or checklist of life cycle costs associated with the acquisition and ownership of constructed assets or facilities classified according to the stage of life[8].

- Acquisition (Non-Construction) Costs – new, refurbishment, purchase or rental.
- Acquisition (Construction) Costs – new or refurbishment.
- Operation Costs.
- Maintenance Costs.
- Replacement Costs.
- Disposal Costs (negative or positive)

7.2.2 The sub-costs within each classification should be selected, amended or supplemented to suit the specific requirements of the facility under consideration. This report is not intended to be exhaustive or necessarily applicable to all facilities.

7.2.3 Income is excluded as this report is confined to life cycle costs.

7.2.4 Each part of a facility has its own physical and economical lifespan. Any model needs to reflect the economical lifespan of each part.

Acquisition (Non-Construction) Costs – new, refurbishment, purchase or rental[9]
Site or asset purchase and associated fees.
Development of client brief, procurement, cost, value and risk management, planning, regulatory and legal.
Design and engineering (client advisors) including: a) Health and safety assessments to ensure that the facility is safe for all phases of its life: construction; occupation; maintenance, alteration and refurbishment; disposal. a) Flexibility for upgrading the facility from time to time. a) Provision to allow those elements such as insulation and heating systems to be replaced or upgraded with more efficient and effective systems that might be developed in the future. a) Use of standardisation and pre-assembly and components that can subsequently be detached for refurbishment and improvement. b) Costs that a particular maintenance option may incur at the design stage (e.g. costs of building in access for cleaning or replacement options). c) Identification of aesthetic and functional failure as the client brief or building regulations. d) Minimisation of use of energy and fossil fuels and generation of carbon dioxide.
Commissioning.
In-house resources and administration.
Finance, interest or cost of money.
Change management and coaching.

Acquisition (Construction) Costs – new or refurbishment
Design and engineering (design and build).
Temporary works, site clearance or groundwork (depending on whether new construction or refurbishment).
Construction, fitting out, commissioning and handover.
Project management and planning supervisor (CDM Regulations).

[8] Items in RED are extracted from the BRE and draft ISO 15686-6.

Items in BLACK are from the OGC Construction Procurement Guidance No 7 Life Cycle Costs where not already included above.

[9] Depending on the procurement method, some of the above elements may be part of an integrated design and construction package.

Operation Costs
Rates (and rent if applicable).
Insurance.
Energy costs for heating, cooling, power and lighting, and utilities.
Facilities management, cleaning, security.
Annual regulatory costs (e.g. fire, access inspections).

Maintenance Costs[10]
Repairs, routine component replacement and minor refurbishment.
Loss of the facility during maintenance procedures, e.g., down time (loss of function for a period), disruption of business activity, etc.
Reduced building service life (if appropriate) resulting from any maintenance option.
Restoration (or replacement) of minor components (sub-elements and sub-systems) to their original aesthetic and functional performance.
Replacement Costs
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.
Loss of the facility during replacement, e.g., down time (loss of function for a period), disruption of business activity, etc.
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.

Disposal Costs
Demolition.
Disposal.
Site clean up.

[10] Maintenance and management costs will tend to recur on a regular cycle, while repair costs may occur only once, and may be analysed separately or as part of the capital costs

7.3 EuroLifeForm

7.3.1 For LCC to become widely accepted, concerns about uncertainties in forecasting must be overcome. This concerns particularly the costs and performance of a building or other constructed asset, products and systems. A related European RTD project EuroLifeForm is to advance a probabilistic approach on LCC in construction. The principal objective of the project is the development of a generic model for predicting life cycle costs and performance. This will be applicable initially to the design of buildings and structures to optimise the life cycle costs and latterly to optimise interventions through maintenance and repair. Here the newest theories and software are used for probability, risk, sensitivity and optimisation; @Risk 4.5 utilising Monte Carlo simulation with RiskOptimizer 1.0.

7.3.2 The project is primarily addressing technological and cost issues but other factors, such as environmental impact, are becoming increasingly important. Some of these factors are difficult to value in monetary terms, but qualitative methods of assessment are being investigated. Methods for multi-criteria decision-making are being investigated in this context using the newest software, Logical Decisions 5.1, to enable the client to optimise in relation to his own hierarchy of priorities and the weighting between them.

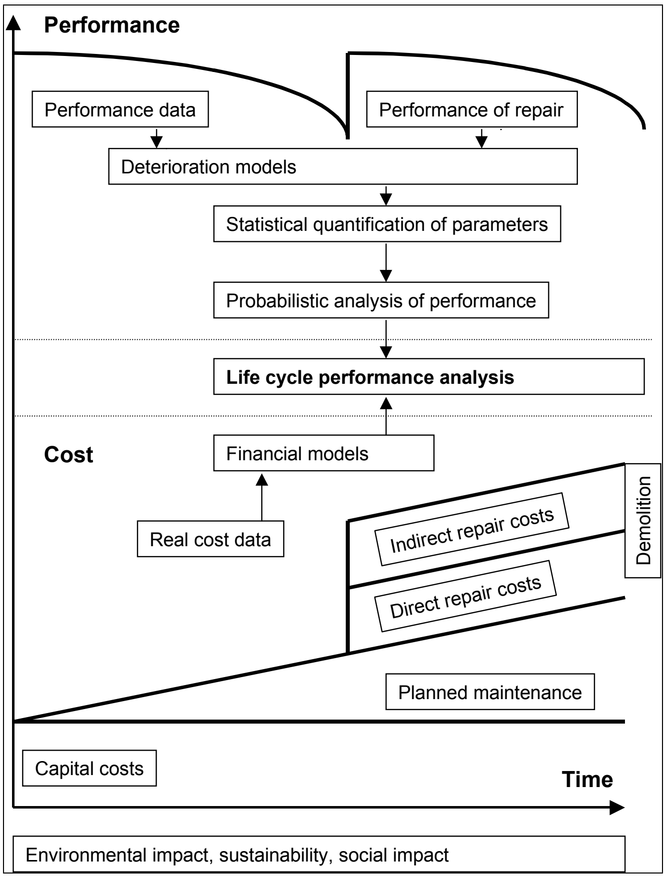


Figure 1: EuroLifeForm – main features

7.3.3 The principal benefit from this project will be improved predictability in relation to the cost and performance of an asset. Uncertainties will always exist but the intention is to enable these to be identified and quantified using a risk-based approach. By enabling more transparent and better-informed decisions at the design stage this will lead to better value and more efficient use of resources.

7.3.4 The final outcome will be a generic model for LCC and Performance - LCCP, in a software format, to replace deterministic values for costs and performance with a probabilistic approach, good for investors, developers, designers and contractors.

7.4 Definitions and extracts from ISO standard 15686

Selection of terms and definitions commonly used in service life planning and whole life costing taken from *ISO 15686-1 Buildings and* constructed assets – Service life planning AND Considerations for whole life costing as proposed by ISO 15686 Stage of building life.
Some terms and definitions are taken from *ISO 15686 Pt5 Whole Life Costing*. This is currently being circulated for comment and therefore some of the definitions may change in the final version

TERM	DEFINITION	NOTE
Acquisition cost	All costs included in acquiring an asset by purchase or construction, excluding costs during the in-use phase of the life cycle	Also known as initial capital costs
Capital cost	Up front construction costs, (and the costs of replacements where they are treated as capital expenditure)	May be identical to acquisition cost if replacement costs are not included
Condition	Level of critical properties of a building or its parts, determining its ability to perform	
Cost performance	The overall indication of value indicated by a whole life costing analysis	
Defect	Fault, or deviation from the intended level of performance of a building or its parts	
Design life	Service life intended by the designer	Eg As stated by the designer to the client to support specification decisions
Discount rate	The factor reflecting the time value of money that is used to convert cash flows occurring at different times to a common time	Eg To convert future values to present values and vice versa.
Discounted cost	The resulting cost when real cost is discounted by the real discount rate or when nominal cost is discounted by the nominal discount rate	
External costs	Costs associated with the asset which are not necessarily reflected in the transaction costs between provider and consumer	These may be taken into account in a whole life cost analysis but should be explicitly identified as such
Externality	The cost or benefits that occur when the actions of firms and individuals have an effect on people other than themselves	They are positive externalities if the effects are benefits to other people and negative or external costs, if the external effects are costs on other people. There may be external costs and benefits from both production and consumption. If the externality is added to the private cost/benefit we get the total social cost or benefit
Inflation/deflation	A sustained increase/decrease in the general price level	It can be measured monthly, quarterly or annually against a known index
Life cycle	The period of time between a selected date and the cut-off year or last year, over which the criteria (e.g. Costs)	This period may be determined by the client for the analysis (e.g. to match the period of

TERM	DEFINITION	NOTE
	relating to a decision or alternative under study is assessed	ownership) or on the basis of the probable physical life cycle of the asset itself
Life cycle cost	Total cost of a building or its parts throughout its life, including the costs of planning, design, acquisition, operations, maintenance and disposal, less any residual value	From *ISO 15686 Pt1General principles*. This definition is likely to be superseded by the term Whole Life Cost - see below
Maintenance	Combination of all technical and associated administrative actions during the service life to retain a building or its Parts in a state in which it can perform its required functions	
Maintenance cost	The total of necessarily incurred labour, material and other related costs incurred in conducting corrective and preventative maintenance and repair on constructed assets, or their parts, to allow them to be used for their intended purposes	
Maintenance, Operating and Management costs (MOM)	The expenses incurred during the normal operation of a building or structure, or a system or component including labour, materials, utilities, and other related costs over the life cycle	
Net present value	The sum of the discounted future cash flows.	It is often the standard criterion for deciding whether a programme can be justified on economic principles but other techniques are used and may be preferred
Nominal discount rate	A rate used to relate present and future money values in comparable terms, taking into account the general inflation rate	
Present value	Monies accruing in the future that have been discounted to account for the fact that they are worth less today	
Period of analysis	The length of time over which an investment is analysed, which may be shorter than the life cycle of the asset	
Private clients	Are all clients NOT subjected to the provision of Public Procurement	
Predicted service life	Service life predicted from recorded performance over time	Eg As found in service life models or ageing tests
Refurbishment	Modification and improvements to an existing building or its parts to bring it up to an acceptable condition	
Repair	Return of a building or its parts to an acceptable condition by the renewal, replacement or mending of worn, damaged or degraded parts	
Residual service life	Service life remaining at a certain moment of consideration	
Real cost	The cost expressed in values of the	

TERM	DEFINITION	NOTE
	base date, including estimated changes in price due to forecast changes in efficiency and technology, but excluding general price inflation or deflation	
Real discount rate	A rate used to relate present and future money values in comparable terms, not taking into account inflation (whether general or specific to a particular asset under consideration)	
Service life	Service life that a building or parts of a building would be expected to have (or is predicted to have) in a certain set (reference set) of in-use conditions. Period of time after installation during which a building or its parts meets or exceeds the performance requirements	
Sensitivity analysis	A test of the outcome of an analysis by altering one or more parameters from initial value(s)	These should be ignored in an appraisal. However the opportunity costs of continuing to tie up capital should be included in the analysis
Service life planning	Preparation of the brief and design for the building and its parts to achieve the desired design life,	Eg In order to reduce the costs of building ownership and facilitate maintenance and refurbishment
Time value of money	Measurement of the difference between future monies and the present day value of money	
Uncertainty	Lack of certain, deterministic values for the variable inputs used in a LCC analysis of a structure, building, component etc	It is implicit that the projected costs are to achieve defined levels of performance, including reliability, safety and availability
Whole life cost	An economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value	

7.5 Case studies

7.5.1 Case study 1 in UK (Barrack Accommodation for Ministry of Defence)

Comparative Life Cycle Costs – client compliant bid versus energy efficient design

For the exercise, key building elements were selected in consultation with the client and the design team. The overall project value is in the order £4.0 million.

The results of the analysis show that an initial additional capital spending of £72,648.76 on the Energy Efficient Option will produce a Life Cycle Cost saving of over £236,945.74 (discounted at 6%) at current prices. The additional costs mainly covered re-designing the building to reduce air exfiltration (leakage) to international best practice standards and to likewise increase wall and roof insulation and building mass. Savings were made to the heating system by adopting a heat recovery approach, taking advantage of occupancy patterns and realising the passive environmental control from utilising building mass and the effect of increased insulation.

The following graph demonstrates the 'payback' period of the selected elements, which will occur in year 5.

7.5.1.1.1.1.1 Metrics	Compliant Option	Energy Efficient Option	Saving/extra
Initial Capital Cost of elements analysed	1,623199.49	1,695,848.25	**- £72,648.76**
Whole Life Cost (WLC) over 60 years	4,272,398.85	2,870,913.77	**£1,401,485.08**
Net Present Value (NPV) of Whole Life Cost over 60 years	2,608,191.65	2,371,245.91	**£236,945.74**

Note: the Net Present Value (NPV) calculation used the Treasury rate of 6%.

4.2 Energy / Utility costs

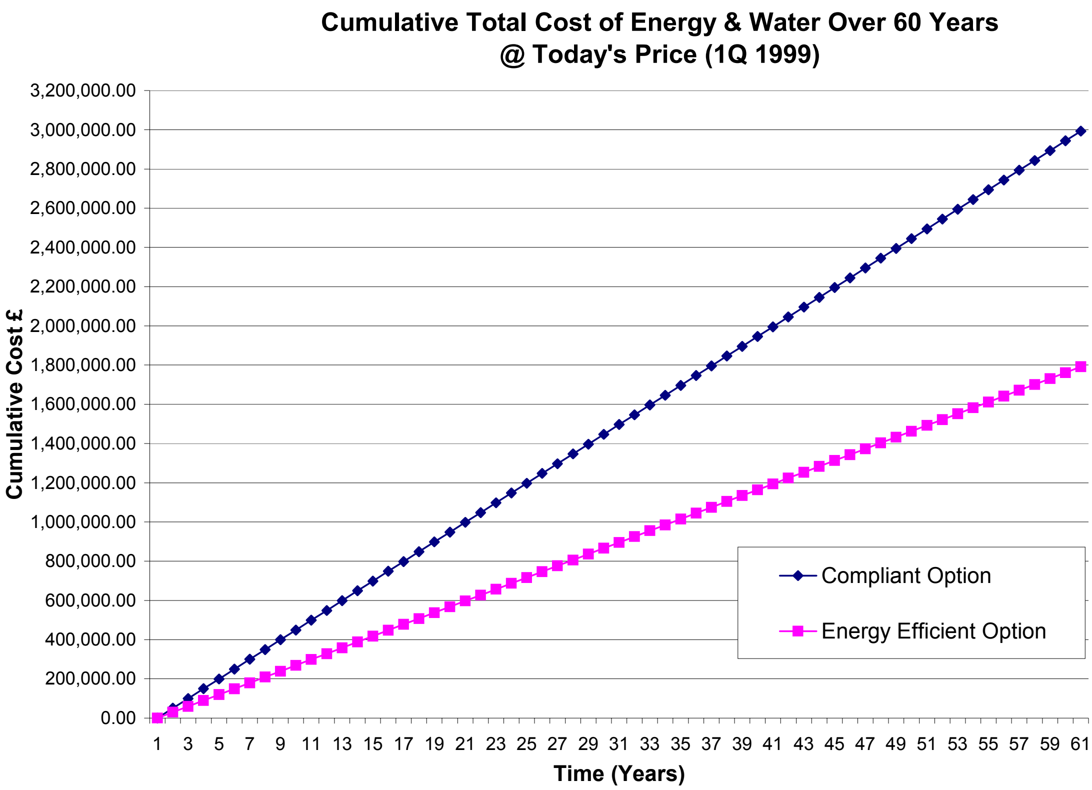
The following costs have been estimated using 'CYMAP', which is an industry recognised energy use computer software. All energy and water consumption figures are based on calculations carried out by the design team services engineer. The costs are based on local rates provided by the utility providers.

Yearly Costs	Compliant Option	Energy Efficient Option	Saving
Gas	19,252.00	7,280.00	11,972.00
Electricity	23,332.00	18,004.00	5,328.00
Water	7,304.04	4,562.47	2,741.53
Total	**£49,888.04**	**£29,846.47**	**£20,41.57**

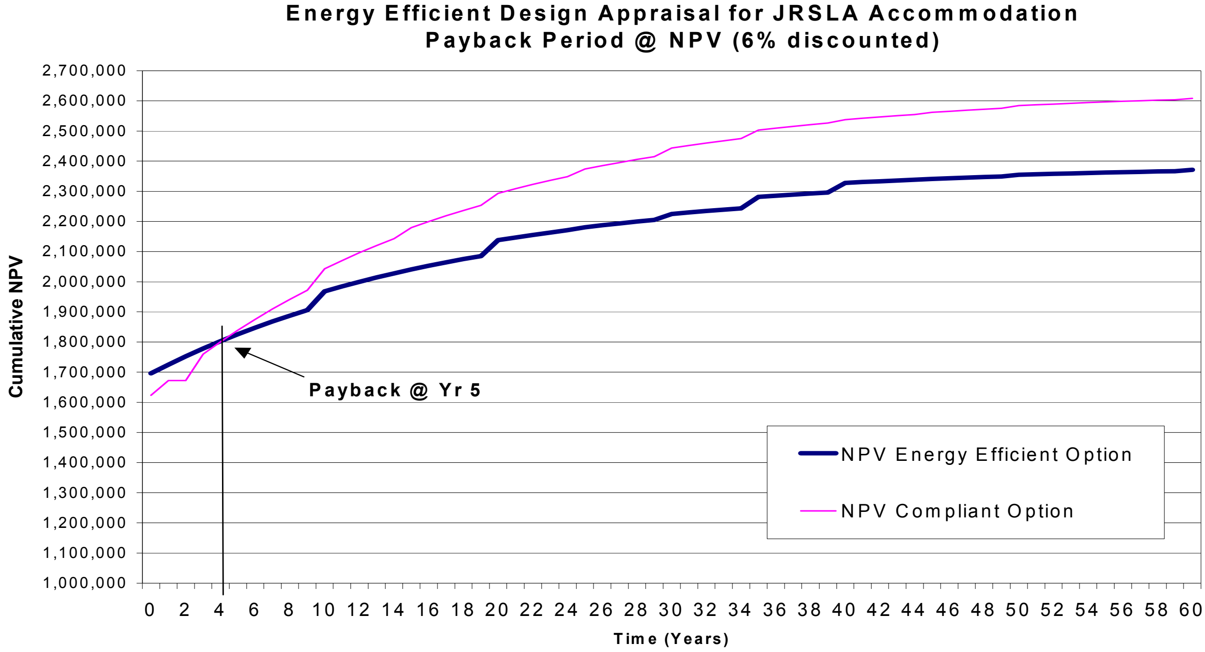
The gas cost takes account for an estimated additional £1000 pa saving in hot water heating cost through using low water flow showers.

Total Energy / Utility Cost (non discounted over 60 years

	Compliant Option	Energy Efficient Option	Saving
Gas	1,155,120.00	436,800.00	718,320.00
Electricity	1,399,920.00	1,098,244.00	301,676.00
Water	438,242.40	273,748.20	164,493.80
Total	**£2,993,282.40**	**£1,808,792.20**	**£1,184,489.80**



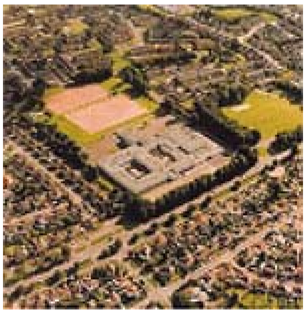
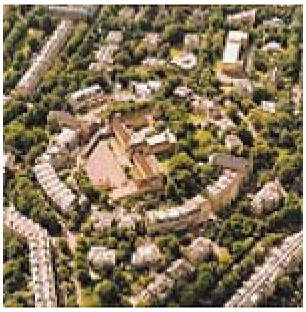
These figures are illustrated in the following graphs.



7.5.2 Case study 2 in UK (Schools in Scotland)

The application of the techniques described above has been evident on a currently running Schools PFI scheme in Scotland. This and other case study overviews are presented on the following pages. Designing for Life – Building Performance Group (Article first published in PFM Magazine)

The £1.2bn deal to renovate 29 secondary schools in Glasgow has demonstrated that consideration of whole life performance at all stages of the design and construction process can produce significant savings in capital and operating costs of a building.


Three of the 29 secondary schools due for renovation

Project 2002 is the biggest single educational investment programme in the UK and is set to become the blueprint for such investment in the future. Glasgow City Council appointed 3ED (Glasgow) Limited, a consortium of Halifax Project Investments, Miller Group and Amey Ventures, to undertake the revitalisation of secondary education in Glasgow. 3ED was selected by the council as a preferred bidder on the quality and cost-effectiveness of its proposal.

Building Performance Group's role was to assist the bid team with expert advice on Whole Life Performance (WLP). Throughout the bid process BPG provided advice on component specification, maintenance planning, life cycle costing and durability for the refurbishment, extension and rebuilding of Glasgow's 29 secondary schools. They are to be rebuilt or completely upgraded and refurbished providing the city's 30,000 secondary school pupils with modern learning facilities as well as the latest computer and internet technology and ensure that every school is equipped with a technologically advanced system by 2002.

The project will see 11 new secondary schools built, eight more will have major extensions and undergo total refurbishment, and a further nine will be completely upgraded. In addition, a new primary school will be built and maintained as part of the contract. There will also be a School of Dance, a School of Sport and an International School.

Costs for the rebuilding and refurbishment works will total £220m, being spent between April 2000 and December 2003. The capital investment in IT will be a further £19m until 2012, £14m of which, will be spent over the next two years. Under the new contract Glasgow City Council will contribute a yearly fee of £40.5m commencing from 2003. This will include not only the investment and maintenance costs but also the day-to-day property costs of running the schools; cleaning costs, utilities and energy management, IT maintenance and help desk, grounds maintenance, insurance and general upkeep of the fabric. Catering services for the schools are not included.

Out of a significant life cycle fund, BPG was able to assist in achieving savings through life cycle choices and option appraisals sufficient to construct 12 new schools rather than the three originally intended by the brief.

Driven by initiatives such as PFI, PPP and Prime Contracting, investing in asset whole life performance and life cycle costs are worthwhile when procuring a new or existing building because:

- Operating and maintenance costs can be designed down if considered during the design process. (80 per cent of maintenance costs are fixed in the first 20 per cent of the design process)
- Capital costs can be reduced by avoiding over-elaborate specifications
- Service charges and rents can be both realistic and competitive
- It encourages appropriate funds to be put in place to protect its value
- Funding stream is optimised to obtain finance at the most advantageous rates
- Predictions can be made to allow optimisation and best use of Capital Allowances
- Sinking funds are accurately established A framework is established to manage change throughout its life
- Carbon tax on energy use can be reduced
- Robust and sensible predictions of WLP are insurable throughout the whole life cycle to further reduce the residual risk
- Dormant funds set aside for unexpected maintenance and repair expenditure can be utilised to support the core business needs
- The lessons learnt can be fed back into future development for continuous improvement.
- Life time savings

The Defence Estates 'Building Down Barriers' project (a pilot project for the Ministry of Defence, Defence Estates to explore the benefits of Prime Contracting using supply chain management and consideration of cost in use) demonstrated a 3 per cent increase in capital cost, but a 10 per cent saving in life cycle. It is anticipated that higher savings will be achieved in future schemes. Using the ratio of 1:5:200 for capital cost: maintenance cost: operating cost to a £10m capital value project, provides a potential saving, over the life cycle maintenance alone, of £5m.

WLP prediction is an exercise in risk management. The risks must first be identified and then managed according to their likelihood and impact. For example, a failure in an air conditioning plant may be a passing nuisance for an office but is unacceptable for a hospital, or a heat sensitive digital broadcasting unit in a television studio. WLP characteristics can be predicted to suit the business need. First, the client must establish the 'life' of the building or its components. For a house or school one could consider lives in excess of 60 years. However, for a manufacturer of computer components, it may be ten years. Shopping centres' internal finishes may be refurbished for marketing reasons on seven year cycles.

Surveying the existing condition of the individual components, and assessing how far they are through their natural life can readily establish the remaining WLP. The first opportunity to make savings and improve quality is to analyse the designs at component level.

Although the building may be unique, the constituent parts are likely to be standard components. However, the component choice is not analysed merely on its capital cost, but usually on the net present value (NPV) of the component over the whole life cycle including purchase, installation, regular maintenance, repair and replacement.

7.5.3 Case study 3 in Germany (Appartment in Berlin)

Karlsruhe University

Holger Köng, Dipl-Ing. Arch.

Sustainable Management of Housing and Real Estate

LEGOE Software GmbH

Project Description

Apartment and retail building in Gormannstrasse 24, situated in central Berlin

Client: „Bauherrengemeinschaft Gormannstrasse GmbH“ (owner-user partnership Ltd.)

Execution: 2001

Gross cubic space: 4930 m³ *Gross floor space: 1645 m²*

Fig 1: Elevation South

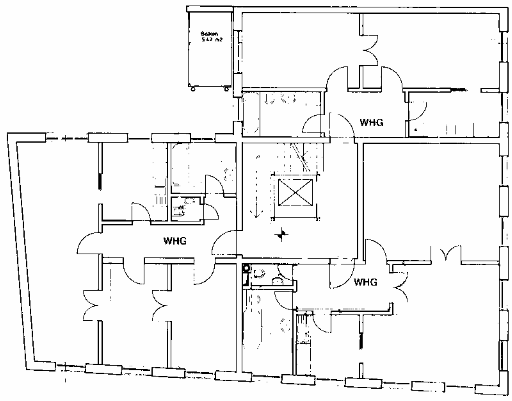


Fig 2: Floorplan Upper Level

The four-storey building was completed in 2001 on an free-standing site in central Berlin. The building comprises a parking lot in the basement, two business units on ground level and on the upper levels 7 two-bedroom and 5 three-bedroom apartments.

Construction

The cellar is made of reinforced concrete, the perimeter walls are of monolithic clay-bricks and plastered, the windows are of wood, thermally insulated glass and iron-claded shutters, the ceilings are of brick-elements with floating floor screed and underfloor heating, the attic-walls in post and beam construction, the landscaped roof of wood rafters, and cellulose insulation, the inner walls of sand-lime brick, clay-bricks and prefabricated gypsum boards, the balconies of galvanized steel with glass-bricks, the stair-way of concrete and stone slabs, the lift of glass. On the property the path-ways are paved and the flower-beds landscaped. It includes a play-ground and parking area for bicycles.

Method and results

For this project the costs were extrapolated from results derived from LEGOE® - a LCA and LCC software application. Construction cost calculations in Germany are usually ordered in cost groups defined in the German industrial standards DIN 276 "costs in construction" and the DIN 18960 "costs during building use". For comparability the cost data is structured according to the cost structure recommended by TG4 Whole Life Costs [WLC] in Construction.

In the case study the WLC method was used to set up a complete capital and cost budget for the whole life cycle of a building over a period of 80 years. Figure 3 presents the capital costs in C_0 (total of the non-construction and construction costs actually incurred until the facility is handed) are presented. In figure 4 the annual recurring operating, maintenance and replacement costs are depicted. Figure 5 shows solely the disposal cost after demolition in year 80.

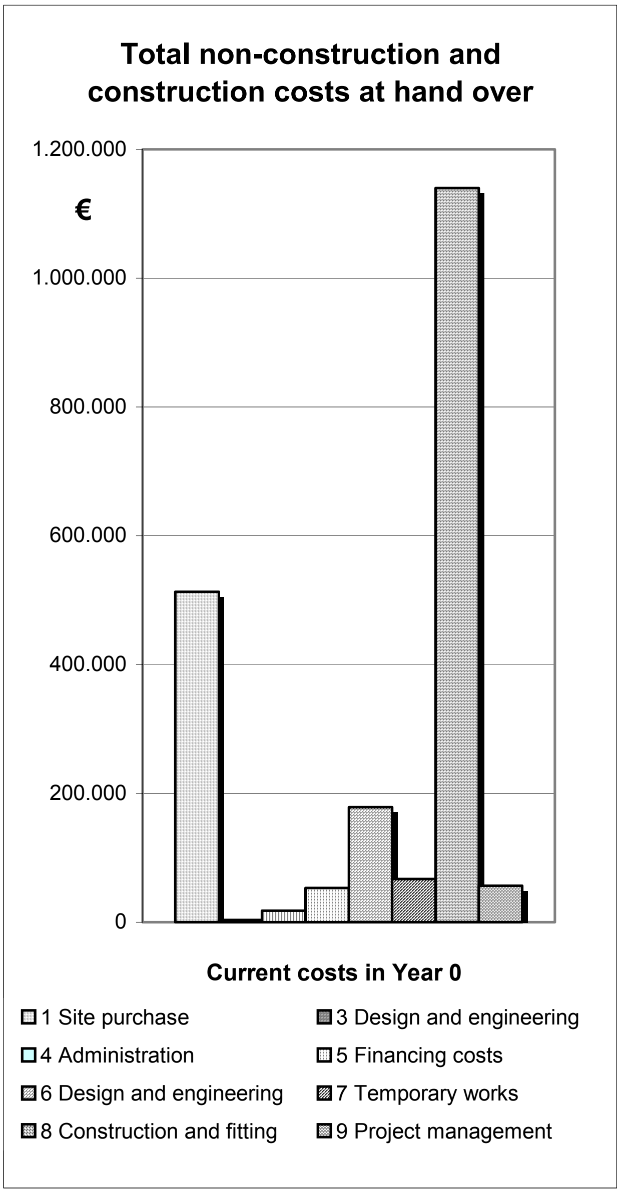


Figure 3

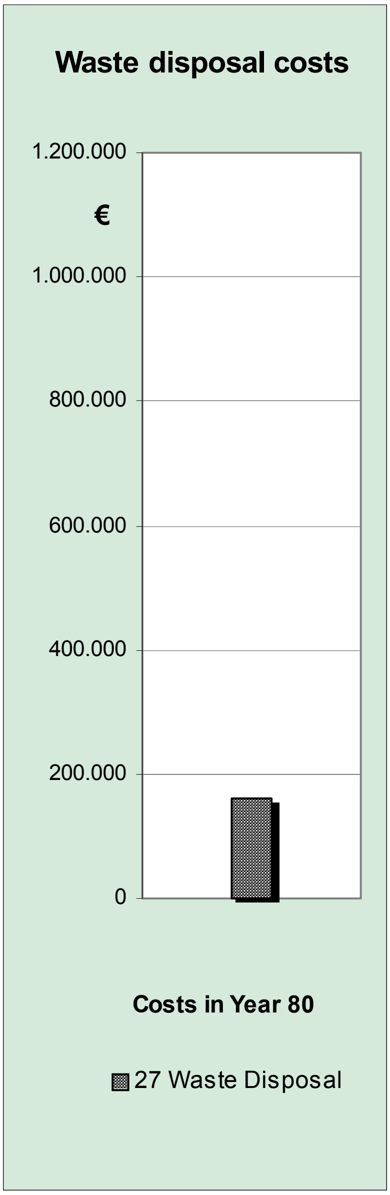


Figure 5

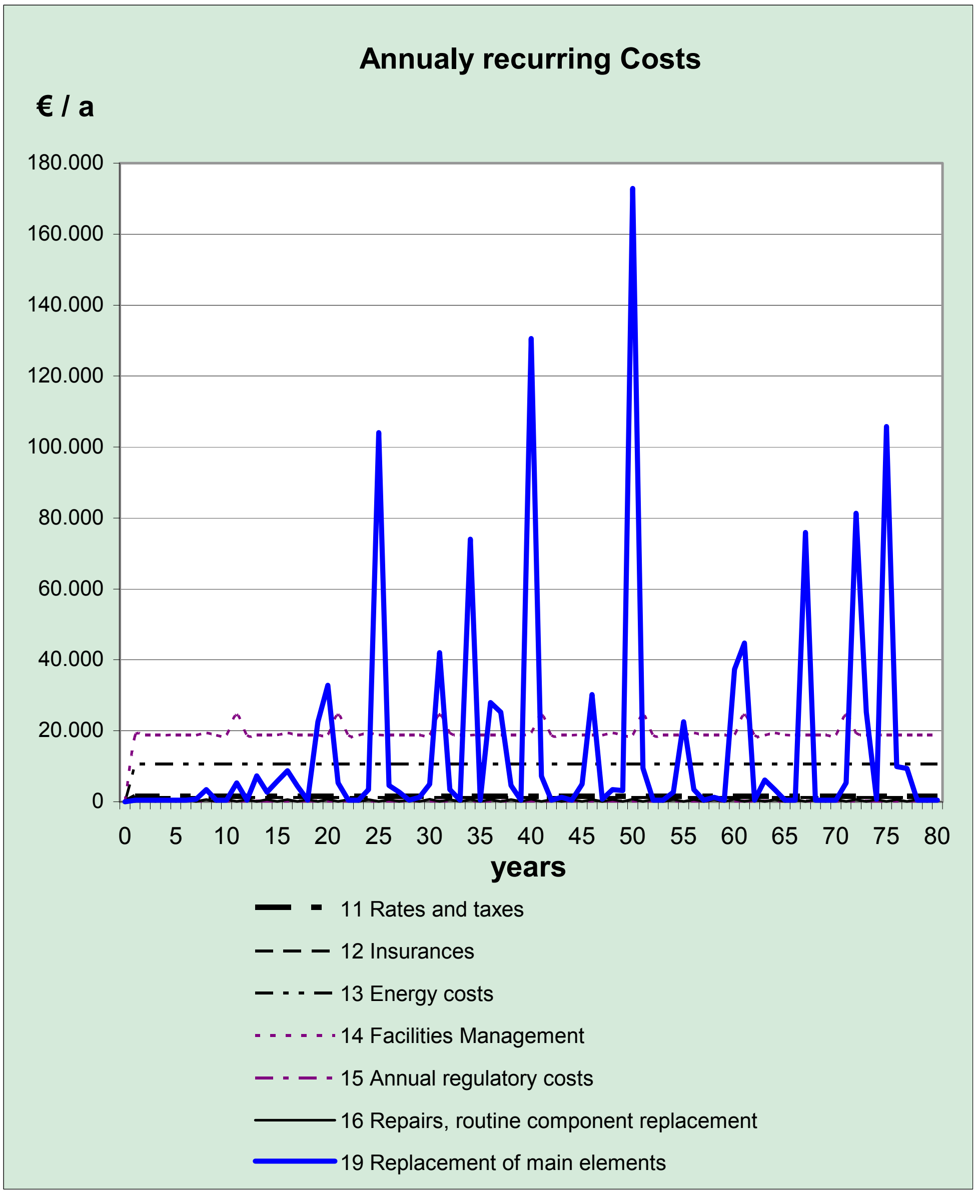

Annualy recurring Costs
€ / a
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
years
11 Rates and taxes
12 Insurances
13 Energy costs
14 Facilities Management
15 Annual regulatory costs
16 Repairs, routine component replacement
19 Replacement of main elements

Figure 4

7.6 Presentations made by participants of TG4

7.6.1 Summary of March 2002 presentation to TG4 given by Christopher Watson of Building Performance Group

BPG is a multi-disciplinary commercial organisation, which specialises in the provision of whole life building performance advice to organisations with a long-term interest in their buildings. Our client base is comprised of over 50 PFI consortia, housing associations and other owners or procurers of building stock portfolios. Our broad practical experience enables us to offer a unique insight into the issues that arise through whole life costing considerations in the design, build, operate and fund construction process.

BPG provide a technical audit service to support long-term defects and premature failure insurance. To support our audit, insurance and whole life services, BPG established a durability database, which initially comprised information on the durability of more than 500 extensively researched components. All published results are regularly reviewed in the light of claims' feedback and readers' comments. We have actively participated in the development of ISO 15686 parts 1 and 3.

Whole life costs and strategic thinking

The decision to build is usually based on the lowest capital cost even though the ratio of capital cost to maintenance cost to operating cost has been assessed at 1:5:200. With repairs and maintenance costs accounting for 49 per cent of all UK construction output, it is somewhat surprising that there is little consideration given to the much greater costs of building management and maintenance, factors which have a much greater effect on the long-term sustainability of a business.

In the UK the drivers for change were the Latham report and the Egan Agenda, which contained principles used by the Government in laying down guidelines on building procurement. These principles were further supported by OGC Note 7, which required all government procured buildings to have Life Cycle costs by April 2002. Private Finance Initiatives and Public Private Partnerships are established under Design Build Operate and Fund forms of contract where the contractor is responsible for maintenance and sometimes also the operation of the facility. The Whole Life Cost Client's Guide (2000) describes all the costs involved (income and expenditure) from initial site acquisition through to demolition.

Establishing whole life costs

There are two ways to establish a life cycle cost. Firstly, to review historic costs based on cost per square metre for similar buildings types, and secondly to build more robust and accurate predictive costs based on predicting the durability and hence repair, maintenance, and replacement of components together with cost of energy use. The latter method allows optimisation of capital and operating costs and 'what if' scenarios

Life cycle economics can be demonstrated by comparing a timber and aluminium window, where the initial cost of the timber window is low, but the cost of painting on 5 year cycles and the cost of replacement after 20 years (ignoring the disruptive effect of removing and replacing windows in occupied spaces) far exceed the cost of purchasing and maintaining an aluminium window over the same period.

Procurement and its role in the whole life cost process

The main obstacle to whole life costing is the traditional, fragmented procurement approach. Typically, the designer has no way of knowing how his buildings perform over time and the contractor is not aware of the client's business requirements so builds to lowest capital cost. This leaves the operator, the one person best placed to know how buildings perform over time, to manage what they have been given with little or no input into the design and construction process.

Eighty per cent of whole life costs are fixed in the first 20 per cent of the design process, with the opportunity for change decreasing and the cost of change increasing as the design process continues. It is therefore crucial to include whole life thinking as part of the process from day one. Ideally the process to achieve the best whole life cost should start at concept stage, as there are many factors that can have a substantial effect on whole life costs. For instance is the site exposed or sheltered, remote from existing infrastructure or close by. Is the building to be two or four storeys? Are the extra costs of running lifts and window cleaning equipment recoverable elsewhere?

Workmanship and component durability

Materials and components should be costed and compared on a whole life basis. Spending more initially may produce a more sustainable solution, which is more cost effective over time. All durability data for each material or component then has to be factored to reflect the environment, the use, design and detailing, construction technique and workmanship. From this a model of repair and replacement cycles and their costs is built up for the entire building. This model is ragged and needs to be fine-tuned and 'smoothed' to co-ordinate repairs into sensible work packages, and meet the funding profile of the works.

This whole life cost model makes assumptions about quality of design workmanship and maintenance and these need to be verified as the life cycle progresses. Insurance claims (both in the UK and Belgium) show that approximately 40 per cent of defects arise as a result of design detailing, 40 per cent as a result of workmanship and 20 per cent as a result of component selection. These can be substantially reduced by a carefully structured third party technical review as described in ISO 15686. Also, the whole life cost model should be reviewed and adjusted throughout the Life Cycle to reflect actual on-site performance.

Achieving optimisation

The obstacles we have experienced in trying to achieve a whole life approach are largely cultural. Profit centres within a company can engender a competitive approach, which undermines the collaborative spirit required to achieve optimum whole life cost solutions. In order to achieve optimisation, a company must take a long-term approach to whole life costing but unfortunately a large number of organisations are still concerned with achieving a quick return on investment. However, this is certainly not the case with Government funded projects. The competitive nature of the building industry means that information about long-term performance and feedback is not shared leading to limited sources of reliable durability data and very few companies with the required range of skills to carry out the work.

The current sources of durability data are: HAPM Component

HAPM Component Life Manual

BPG/BLP Fabric and Services Life Manuals

CIBSE Guide to ownership, operation and maintenance of building services

Swedish Building Research Council - The longevity of building services installations

'The Dutch translation' - Lifespans of building products in practice

Kirk and Dell'Isola - Life cycle costing for design professionals

PSA - Costs-in-use tables

Software currently available is limited. BPG use two bespoke products Cactus and e-statepro.

7.6.2 Summary of the presentation to TG4 given by John R. HARROWER 15 Februray 2002

Report and Recommendations of the EMAT Task Group – A proposed methodology that permits contract award to the Economically Most Advantageous Tender

- Introduction

The report of the EMAT Task Group is a recommended methodology that enables contract award to the economically most advantageous tender.

The group was mindful of the current Public Works Directive and the draft Directive on the co-ordination of procedures for the award of public supply contracts, public service contracts and public works contracts.

It is probable that the wording will be:

"… the criteria on which the contracting authority shall base the award of contracts shall be:

(a) the lowest price only;

(b) [or] where the award is made to the most economically advantageous tender, for the awarding authorities various criteria directly linked to the subject of the contract: for example, quality, price, technical merit, aesthetic and functional characteristics, environmental characteristics, running costs, profitability, after-sales service and technical assistance, delivery date or period for completion."

The following wording is also likely to be added to the Directive as a direct result of the recommendations made by the ALT working group.

"In the case provided for [in (b) above] the contracting authority shall specify the relative weighting that it confers on each chosen criterion to determine the economically most advantageous tender."

The recommendation for the elimination of ALTs in the working group's final report, published in June 1999, was:

"Contracts should be awarded to the EMAT (economically most advantageous tender). If tenderers are aware that such examination will be a matter of routine the effect will be to prevent ALTs in the first place."

- Aims of the EMAT task group

In addition to addressing the problems caused by abnormally low tenders, the aims of the EMAT Task Group also included the following.

1. To promote fair competition, competitiveness and beneficial change, not only in the culture of clients but also in the culture of the industry.
2. To produce a rigorous methodology that provides greater transparency and auditability in the process of evaluating tenders on a best value basis.
3. To help clients devise the principal quality criteria and the relative weightings between the different quality criteria appropriate to their particular needs.
4. To help clients establish the relationship between the quality criteria and price that best reflects the optimum combination of life cycle costs and quality.

- Research

The group started its research by trying to obtain information from Member States on how they currently apply the Directive. It was said that the provision to award to the EMAT is used but, apart from the UK, Member States did not provide examples of its use in practice. It became clear that any application is erratic and inconsistent and that lowest price remains the safest and most widely used option.

An EMAT system is incomplete if it only considers initial construction costs. The total costs over the whole life of the construction must be considered because they will be significantly affected by decisions made well before any on-site work commences. For example, mechanical and electrical installations account for as much as 60% of the initial cost of a project but when life cycle costs are taken into account they will be many times more than the construction costs.

In addition, energy use accounts for between 40% and 50% of emissions of carbon dioxide. As part of any strategy for sustainable construction, there must be a commitment to eco-efficient design to reduce energy use and this should be assessed as a part of the contract award process.

As life cycle costs are an essential part of any assessment of the EMAT, provisional suggestions on how they might be incorporated into the award mechanism are included in the report. It is acknowledged that these may need to be modified following the recommendations of the whole life cost working group, which will need to not only consider life cycle costs as a part of sustainable construction but also in the context of contract award.

- Award process

An EMAT system therefore must be an ***award process*** that provides a fair, transparent and accountable method for evaluating tender submissions by balancing quality and life cycle costs with the tender price. The essentials of the ***award process*** are:

- the ***criteria***;
- the ***mechanism*** against which tenders are evaluated;
- the ***procedure*** which underpins the whole process.

Once the ***criteria*** have been established and assessed the evaluation of tenders using the ***award mechanism***, so far as it is possible, should be an arithmetic exercise.

Let us consider each of the three elements of the ***award process*** – the ***criteria***, the ***mechanism*** and the ***procedure***.

- Award criteria

In considering the ***award criteria***, the following must be decided at the outset of the design:

- the appropriate relationships or ratios between the principal criteria of ***quality***, ***life cycle costs*** and [tender] ***price***;
- the individual ***quality*** and ***life cycle cost sub-criteria*** appropriate to the project;
- the ***weightings*** that will be applied to the selected sub-criteria;
- ***mandatory criteria*** and ***quality thresholds***.

- The relationship between quality, life cycle costs and price

The relationship between the principal criteria of ***quality***, ***life cycle costs*** and ***price*** is a decision based on the relative importance of each in the context of the project expressed in terms of weightings that total 100%.The weighting of quality will increase in proportion to the contractor input and complexity of the project. For example, it is suggested that for straightforward projects the ratio of quality and price should be between 10/90 and 25/75; for complex projects the ratio should be between 15/85 and 35/65.

Further research is needed to incorporate life cycle costs.

- Deciding the appropriate quality criteria

Quality criteria can be broken down into three sets reflecting the level of contractor input: this will be low when the project is fully specified – *build to a detailed design (BDD),* greater when working to an outline specification – *build to a preliminary design (BPD),* and highest when the project is based on *design and build (DB).*

The EMAT Report suggests criteria that may be chosen, amended or supplemented to suit the particular requirements of the project.

- Deciding the weightings that will be applied to the selected quality criteria

Once the individual quality criteria have been chosen, the relative importance of each must be determined and a percentage weighting allocated so that all the weightings total 100%. This is the same procedure used for determining the relationship between quality, life cycle costs and price, but applied to the selected quality criteria.

- Mandatory criteria and quality thresholds

It is also necessary to determine which criteria are mandatory and the threshold for each.

- ***Mandatory criteria*** must be complied with for the bid to be considered further.
- ***Quality thresholds*** are the minimum scores required for the bid to be considered further.

- Award mechanism

The ***award mechanism*** consolidates quality, life cycle costs and price to identify the economically most advantageous tender. It must also include a method to measure and score each of these factors.

- Measurement of compliance with the chosen quality criteria

Measuring compliance of the tenders under assessment with each quality criterion should remove subjectivity as much as possible. A suitable method is illustrated in Section 3.9 of the Report using matrix toolkits and is reproduced at Appendix 1.

- Quality, life cycle costs and price scoring

The final piece of an EMAT ***award mechanism*** is an objective and auditable method of *scoring* to establish the extent to which each tender meets the chosen quality criteria, combined with scoring of the price and life cycle costs.

Two draft models are included in the Report. The first is based on ***prior overall weighting*** which the case studies have shown is applied successfully in practice. The second model is based on ***price discounting***, which one group member said is used but evidence and more rigorous development of this model has not been forthcoming. For the purpose of this presentation, discussion will be confined to the ***prior overall weighting*** model as this has been tested in practice and modified to incorporate life cycle costs. A worked example is included at Appendix 2.

- Quality scoring

To calculate the ***quality score***, the matrix measurement process is carried out for each quality criterion. The scores against each are checked for compliance with mandatory criteria and thresholds. If compliant, the individual scores are multiplied by their respective weightings and added together to give a total quality score.

- Price scoring

Price scoring is carried out only when ***quality scoring*** has been completed and it has been established that all tenders under assessment have scored more than the individual and overall thresholds and all mandatory criteria have been complied with. The mean price of the lowest three compliant tenders is calculated and given 50 points. To calculate the price score, one point is deducted from the score of each tenderer for each percentage point above the mean and one point is added for each percentage point below.

- Life cycle cost assessment and scoring

When the life cycle costs of a particular element of the construction are significant, those elements should be separately assessed. This is particularly important when considering energy consuming systems such as electrical, heating, air conditioning and similar building services.

Life cycle cost scores are incorporated using a method similar to ***price scoring*** that includes:

- Total project life.
- Life of the element of the project under assessment and the associated costs of

operation,
maintenance,
replacement,
and disposal.

- Combining quality, life cycle cost and price scores

The final step is to combine the ***quality***, ***life cycle cost*** and ***price scores*** to obtain an ***overall score*** for each tender. The recommended model includes all the factors already mentioned.

- The quality, price and life cycle cost ratios.
- The overall quality threshold.
- The individual quality criteria, thresholds and weightings.
- The total quality score.
- The total price score.
- The total life cycle cost score.
- The overall score.

The ***overall score*** is calculated using the ***quality***, ***price*** and ***life cycle scores*** multiplied by their respective weightings determined by the quality/price/life cycle cost ratio. The contract is then awarded to the tenderer that has achieved the highest overall score.

- Award procedure

The recommended ***award procedure*** is adapted from an existing Commission Manual of Instructions. It underpins the whole process and takes account of composition and procedures for the assessment committee.

- EMAT TASK GROUP RECOMMENDATION

Attention must be drawn to Section 3.1.3 of the EMAT Report in which the Task group recommends that:

"the proposed EMAT contract award procedure and mechanism is adopted by the European Commission as guidance and an interpretive communication to the final Directive on the coordination of procedures for the award of public supply contracts, public service contracts and public works contracts".

The Tripartite Group endorsed that recommendation.

Appendix 1

Matrix to assess quality of **supply chain management**.

INDICATOR	PROMPT FOR JUDGEMENT			
	UNACCEPTABLE (0)	**ACCEPTABLE (1)**	**GOOD (2)**	**HIGH STANDARD (3)**
Trading relationships	Selection of subcontractors/suppliers on lowest price basis only (0)	Subcontractors/suppliers selected on basis of ability and quality of service as well as price (1)	Regular use of small numbers of preferred subcontractors/suppliers in each trade/category (2)	Partnering/alliancing style arrangements in place. Subcontractors/suppliers give contractor priority when taking work (3)
Record on contracts and payment	Use of punitive subcontracts, including 'pay when paid' clauses (0)	Use recognised forms of contract, where available. Payments made in accordance with contract (1)	Payments made promptly within short timescales, change payments agreed on reasonable basis (2)	Declared policy for fair dealing, acknowledged in practice by business partners (3)
Competitive sourcing	No indication of ability to offer better value alternatives to items specified (0)	Example in previous two years of offering lower cost alternatives (1)	Several examples in previous two years of offering lower cost alternatives (2)	Consistent record of collaborating with suppliers/subcontractors in generating better value options (3)
Additional indicators				
OVERALL ASSESSMENT	**SUM OF ALL QUALITY CRITERION SUB-CRITERIA ASSESSMENTS**			

Please note
This matrix is designed to be a guide to an informed judgement. It should not be used as a simple scoresheet.
In all cases, indicators and prompts should be reviewed against the requirements of the project concerned, and amplified, modified or discarded to suit.

Appendix 2

Project title:	*A construction project*	**Project element:**	*A project element*
Element quality weighting (QW):	***30*** (QW+PW+LW=100)		
Element price weighting (PW):	***35***		
Element life cycle cost weighting (LW):	***35***		
Overall quality threshold (QT):	***40***		
Total project life (TPL):	***40*** years		

QUALITY SCORES

Quality criteria	Quality Threshold (individual)	Criteria Weight %	Organisation A QT reached	Organisation A Quality Score	Organisation A Weighted Score	Organisation B QT reached	Organisation B Quality Score	Organisation B Weighted Score	Organisation C QT reached	Organisation C Quality Score	Organisation C Weighted Score
Criteria 1	*40*	*15*	*yes*	*40*	*6.00*	*yes*	*40*	*6.00*	*yes*	*55*	*8.25*
Criteria 2	*35*	*15*	*yes*	*35*	*5.25*	*yes*	*50*	*7.50*	*yes*	*65*	*9.75*
Criteria 3	*25*	*20*	*yes*	*30*	*6.00*	*yes*	*30*	*6.00*	*yes*	*40*	*8.00*
Criteria 4	*30*	*20*	*yes*	*30*	*6.00*	*yes*	*60*	*12.00*	*yes*	*50*	*10.00*
Criteria 5	*60*	*30*	*yes*	*65*	*19.50*	*yes*	*70*	*21.00*	*yes*	*75*	*22.50*
Quality Score		100			**42.75**			**52.50**			**58.50**
Is overall quality threshold (QT) reached?					*yes*			*yes*			*yes*

PRICE SCORES

		Organisation A	Organisation B	Organisation C
Tender Price (TP)		***€ 193,567***	***€ 210,739***	***€ 203,453***
Price Mean (PM) =	***€ 202,586***			
% Variation from Price Mean		*4.45*	*-4.02*	*-0.43*
Price Score		***54.45***	***45.98***	***49.57***

LIFE CYCLE COST SCORES

		Organisation A	Organisation B	Organisation C
Project Element Life (PEL)		*18*	*22*	*21*
Operating Costs for PEL (OCE)		*€ 63,000*	*€ 61,600*	*€ 65,100*
Operating Costs for TPL (OCT)	40 years	*€ 140,000*	*€ 112,000*	*€ 124,000*
Maintenance Costs for PEL (MCE)		*€ 7,200*	*€ 5,500*	*€ 6,090*
Maintenance Costs for TPL (MCT)	40 years	*€ 16,000*	*€ 10,000*	*€ 11,600*
Replacement Costs for TPL (RCT)	40 years	*€ 430,149*	*€ 383,162*	*€ 387,530*
Disposal Costs for PEL (DCE)		*€ 19,000*	*€ 16,000*	*€ 17,000*
Disposal Costs for TPL (DCT)	40 years	*€ 42,222*	*€ 29,091*	*€ 32,381*
Life Cycle Cost Totals (LC)		*€ 628,371*	*€ 534,253*	*€ 555,510*
LC Mean (LM) =	*€ 572,711*			
% Variation from Life Cycle Cost Mean		*-9.72*	*6.72*	*3.00*
Life Cycle Cost Score (LS)		***40.28***	***56.72***	***53.00***

OVERALL SCORES

	Organisation A	Organisation B	Organisation C
Element quality weighting x quality score	*12.83*	*15.75*	*17.55*
Element price weighting x price score	*19.06*	*16.09*	*17.35*
Element life cycle cost weighting x LCC score	*14.10*	*19.85*	*18.55*
OVERALL SCORE	**45.98**	**51.69**	**53.45**
ORDER OF TENDERERS	***3***	***2***	***1***

Award mechanism worked example – prior overall weighting model

7.6.3 Summary of the presentation to TG4 given by J.G. VOGTLANDER (TU DELFT)

From 'COSTS' (LCC) towards 'ECO-COSTS' (LCA) by means of the EVR model

At the Delft University of Technology a method has been developed to link the LCA environmental aspects with LCC aspects. The basic idea of the EVR (Eco-costs/Value Ratio) model is to combine the 'value chain' (Porter, 1985) with the ecological 'product chain'.

In the value chain, the added value (in terms of money) and the added costs are determined for each step of the product "from cradle to grave".
Similarly, the ecological impact of each step in the product chain is expressed in terms of money, the 'eco-costs'. See Figure 1.

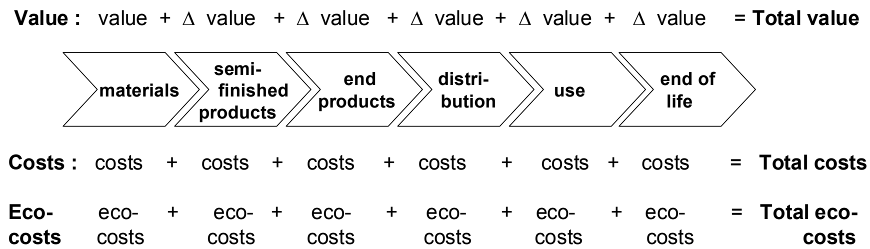


Fig. 1: The basic idea of combining the economic and ecological chain: "the EVR chain".

The eco-costs are 'virtual' costs: these costs are related to measures which have to be taken to make (and recycle) a product "*in line with earth's estimated carrying capacity".* These costs have been estimated on the basis of technical measures to *prevent* pollution and resource depletion to a level which is sufficient to make our society sustainable.

Since our society is yet far from sustainable, the eco-costs are 'virtual': they have been estimated on a 'what if' basis. They are not yet fully integrated in the current costs of the product chain (the current LCC). The ratio of the eco-cost and the market value, the so called Eco-costs / Value Ratio, EVR, is defined in each step in the chain as:

EVR = eco-costs / value

For one step in the production + distribution chain, the eco-costs, the costs and the value are depicted in Figure 2.

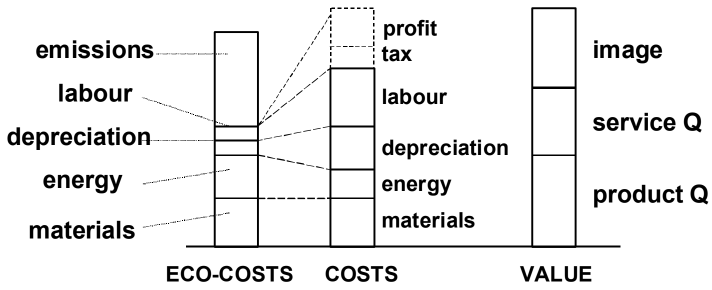


Fig. 2: The decomposition of virtual eco-costs, costs and value of a product

The five components of the eco-costs have been defined as 3 'direct' components plus 2 'indirect' components:

- virtual pollution prevention costs, being the costs required to reduce the *emissions* of the production processes to a sustainable level
- eco-costs of *energy*, being the price for renewable energy sources
- *materials* depletion costs, being (costs of raw materials)x(1-α), where α is the recycled fraction
- eco-costs of *depreciation*, being the eco-costs related to the use of equipment, buildings, etc.

- eco-costs of *labour*, being the eco-costs related to labour, such as commuting and the use of the office (building, heating, lighting, electricity for computers, paper, office products, etc.).

Based on a detailed cost-structure of the product, the eco-costs can be calculated by multiplying each cost element with its specific Eco-costs / Value Ratio, the EVR. These specific EVRs have been calculated on the bases of LCAs. Tables are provided for materials, energy and industrial activities.

The importance of the EVR model is that it adds some practical solutions to unresolved problems in the existing LCA calculation standards (ISO):

a. Calculations on services (such as maintenance), and calculations on the 'indirect' pollution (such as the partial use of equipment for construction), by providing a consistent 'allocation' method
b. Calculations of the LCA in complex cases of system boundaries, such as:
   - re-use
   - renovate
   - rebuild (re-use foundation)
   - extension of life time
c. Calculations on the 'cascade' recycle systems, where materials are recycled into *other* product systems (e.g. concrete in buildings > concrete aggregate > road construction)
d. Integration of the LCA in early stages of the (architectural) design process

Point a. through c. makes the EVR model attractive to apply the building industry, since the complexity of the business structure, and since the importance of recycling in this industry (analysing the environmental effects of recycling sytems is a necessity to select the best environmental option).

Point d. is an important issue, since architects seem to be rather reluctant in applying the conventional LCA method, so far.
See for this issue: De Jonge, T.; Why building design practice is still struggling with the sustainability Issue; World Congress on Housing: Housing Process & Product, June 23-27, 2003, Montreal, Canada (congresses organised by IAHS, International Association for Housing Science, USA).

The most important issue in relation to the work of TG4 is the fact that the EVR method can easily convert "costs" from the LCC, into "eco-costs" of LCA.
Comparison of the Tables of Figure 3 and 4 (both Tables describe the same building) reveals the difference between the classical LCA model and the EVR model: without going in any detail, it is clear that the calculation system of Figure 4 is more transparent and much more simple to apply.
Calculation of the eco-costs as such is rather complex, because of the complexity of the LCA method. The application of the EVR model is so simple, however, since eco-costs are readily available in databases for a variety of materials and building components (per kg as well as per €).

	greenhouse kg CO2 equ	acidification kg SO4 equ	eutroph. kg PO4 eq	hv. metals kg Pb equ	carcin kg B(a)P eq	s. smog kg VOC eq	w.smog kg SPM eq	Eco-costs '99 (Euro)
Concrete, reinforced, 551200kg	59629	484.6	51.07	0.46	0.015	54	6490	96921
Fe360, 51000kg	58271	708.1	63.65	1.05	0.035	79	427	32879
steel sheet, 22000kg	38585	214.4	12.09	0.12	0.021	670	176	16486
PS, 40kg	164	0.2	0.04	0	0	1	0	24
PS foaming, 40kg	222	3.3	0.07	0	0.001	2	0	58
steel transforming, 22000kg	1449	9.6	0.44	0.01	0.001	1	7	320
steel transforming, 51000kg	3475	22.3	1.03	0.03	0.002	2	17	770
Eco-costs of contractors and suppliers (guestimate)								72000
Total in kg equivalent:	161798	1442.9	128.39	1..67	0.075	809	7117	
Eco-costs '99 (Euro)								219458

Fig. 3: The output of a classical LCA of a warehouse building.

7.6.3.1.1.1.1.1.1	Value Euro / m2	EVR	Eco-costs Euro / m2	Ecokosten Euro / 900 m2
floor , reinforced concrete, 300 mm thick	140	0.8	112	100473
steel structure	80	0.7	56	50114
foundation of steel structure	15	0.8	12	11127
roof, steel+thermal insulation	75	0.4	30	26836
Cladding+ insulation (surface.=1.3xfloor area)	95	0.4	38	34036
Lighting, heating, sprinklers, etc.	45	0.3	14	12027
Total	**450**	**0.58**	**261**	234614

Fig. 4: An EVR calculation of a warehouse building (the same building as the builing of Fig. 3).

The EVR model might be based on marginal prevention costs as well as "external costs" of damage to our society (see: *Holland, M.; Watkiss, P; Benefits Table database: Estimates of the marginal external costs of air pollution in Europe, Created for European Commission DG Environment by netcen, 2002).*
However it is strongly recommended to base the eco-costs on the marginal prevention costs (as it is the case in the Tables), since the marginal prevention costs are related to the Best Available Techniques of the IPPC-Directive and to future Tradable Emission Rights. The eco-costs can link then the EU policy with business strategies.
Another argument to avoid the "external costs" of damage as a "single indicator" in LCA, is that the combination of the theory of external costs and the LCA method result in some theoretical flaws.

In the EVR model, the "costs" of LCC are strictly separated from the "eco-cost" of LCA. Therefore, TG4 decided in the meeting on the 15 February 02 to only focus on LCC.

Literature:
Vogtländer, J.G.; Hendriks, Ch.F.; The eco-costs/value ratio (EVR), materials and ecological engineering, analysing the sustainability of products and services by means of a LCA based model; Aeneas Technical Publishers, Boxtel, The Netherlands, 2002
See also Vogtländer et.al. in:
Int. J. LCA, 5 (2), pp.113-124, 2000; Int. J. LCA, 6 (3), pp.157-166, 2001;
Int. J. LCA 6 (6), pp. 344-355, 2001; J. of Sustainable Product Design 1, pp.103-116, 2001;
J. Of Cleaner Production 10, pp.57-67, 2002
and:
De Jonge, T.; Cost effectiveness and sustainability; World Congress on Housing: Housing Construction,September 9-13, 2002, Coimbra, Portugal

7.6.4 Summary of the presentation to TG4 given by Mike CLIFT (BRE)

About BRE

BRE is a world-leading centre of expertise for construction and fire, providing research, consultancy and information services to customers worldwide. It employs 650 staff and has an annual turnover of £36M. BRE provides integrated 'one-stop' solutions for the whole life cycle of a structure covering:

- design
- construction
- management and use
- demolition and re-use

For over 75 years, BRE has provided authoritative advice to Government, underpinning policy, building regulations, codes and standards. Our client base also includes leading property developers, building owners and users, contractors, consultants and manufacturers - the whole supply chain.

BRE's centres of expertise in the four main Divisions cover:

Construction

building fabric
concrete
codes and standards
ground engineering and remediation
heritage, stone and masonry
structures
timber
waste and recycling
whole life performance and costs

Fire and risk sciences

cable fires
fire and security risk assessment
fire and security testing
fire safety engineering
fire safety in transport
FRS Asia
reaction to fire
risk sciences

Environment

acoustics
air pollution
environmental engineering
productive workplace
safety, health and environment
sustainable construction
water

Energy and communications

BRECSU (Energy efficiency best practice)
communications
housing
energy technology

BRE purchased the Loss Prevention Council in April 2000 from ABI and Lloyds and the services of LPC including research, testing and approvals for the fire, security and insurance sectors are incorporated into BRE.

The presentations

BRE gave two presentations to TG4

The first was on the basic principles and introduction to whole life costing and the drivers for its use in the United Kingdom. It included a number of case studies based on projects carried out by BRE. One illustrated the payback period of investing in improved insulation and air tightness of a proposed army barrack accommodation against the energy saved. The second case study demonstrated the cost effectiveness of rebuilding a decayed housing estate over continued and expensive repairs and maintenance. The final example illustrated the link between the whole life costs and life cycle assessments of different window types, where low whole life costs also matched a low environmental impact. The presentation also made reference to some related European funded initiatives that BRE is involved in, including EuroLifeForm and Performance Based Building (PeBBu). A brief explanation of the BRE web based whole life cost tool - *LCCcomparator* was included.

The second presentation covered the progress of ISO 15686 Service Life Planning Part 5 Whole Life Costing and Part 6 Environmental impacts. Both parts are at committee draft, approved in March 2002. Final publication is likely by mid 2004.

Part 5 will provide a comparative assessment of the cost performance of buildings and constructed assets and their parts over an agreed period of time. This assessment takes account of all relevant incomes, expenditures and externalities arising from acquisition through to disposal. Where buildings or systems being compared have different potential revenues, these must be considered in a broader financial evaluation process.

Part 6 will describe how to address and assess environmental impacts of alternative service life designs. It identifies the interface between environmental Life Cycle Assessment and service life planning.

7.6.5 Summary of the presentation to TG4 given by Mr ABENIACAR (DRAGADOS)

DESIGN OF INFRASTRUCTURES IN TRANSPORT CONCESSIONS. THE SPONSORS APPROACH.

Whole Life Costs, applied to infrastructure concessions, comprise both the construction and the operation & maintenance costs, although the concept is mainly referred to the latter. The analysis of the design of infrastructures towards the optimisation of the long-term costs (O&M) has gained great importance during the last decade from a theoretical point of view.

However, and with the exception of the construction costs, the overall importance of the Whole Life Costs during the whole concession period is quite low in comparison with the financial costs and taxes, and the benefits derived from the minimization of costs would be even lower. Therefore, among some other reasons exposed in this article, the concentration of time and resources in the optimisation of the design of infrastructures beyond those based on experience lacks of economical interest from a managerial view.

A theoretical design of infrastructure based on a LCC analysis would start from the definition of the different levels of detail to be analysed. For example, the design of a bridge could be divided in: Allocation and main dimensions, typology, structure design and, finally, superstructure design.

Once defined the level of detail, the next step would be defining the different alternatives of design, and evaluate the expected value of the costs associated to each one of them. A simple example is the design of the road surface: asphalt vs. concrete. Based on empirical data, it would be feasible, but not easy, to obtain a relative probability distribution of the net present value of the costs associated to each alternative surface. The selected design would be that with the lower NPV for a certain degree of certainty.

This process, applied to each unit of the infrastructure or at least to the most important ones, implies a great complexity and, what is more relevant, a huge expenditure of time and resources for a company. Then, the question should be: Is it worth it?

Grupo Dragados has a long experience as sponsor of infrastructure concessions, participating in 45 concessions worldwide, including motorways, airports and railways, which confers us the leadership of the sector. We certainly believe that, in a practical approach, a design based on Whole Life Cost Analysis does not create significant value to the sponsors of the concessionaire companies. Of course, we do not mean that LCC should not be considered as a major variable that should be subject to a careful analysis when evaluating a project.

These are the reasons that support our point of view:

- Most of the infrastructure design decisions in concession contracts are previously made by the Concedent. Actually, most of the tender documents include a project developed by the Client, that should be a reference for any alternative design proposed by the sponsors.

- In terms of optimising the economic forecast of the concessionaire, LCC (excluding construction costs) only represent 15 to 25% of the total expenses, whilst debt service accounts up to 60-75% of total expenses. An optimisation of the LCC based on the analysis of different alternatives of design might outreach a design based on experience in a low percentage.

In contrast, adopting a design based on LCC would increase the preliminary costs for the sponsor due to the need to transfer resources (human and technical) to the complex analysis. Companies have a permanent shortage of resources, and thus they should be distributed towards maximizing the probabilities of winning a project, lowering the financial costs and controlling the costs during the concession period.

Besides, one of the objectives of the sponsor's management is to reduce the preliminary costs, whilst an increase of the concession costs can be easily diluted among the income statement of the concessionaire.

- In terms of mitigating the risks, we have to take into account that the risks associated to LCC (construction and O&M risks) are not the most relevant among the other potential risk of the concessionaire: Market, Financial, Political, Force Majeure, Legal and Environmental. Even more considering that the construction risk is commonly mitigated by means of a Turnkey Contract.

A design based on LCC might lower the O & M risk exposure of the concessionaire but, once again, in our opinion, the gain is not worth the effort, and an efficient management of the concessions should be enough to control the risk.

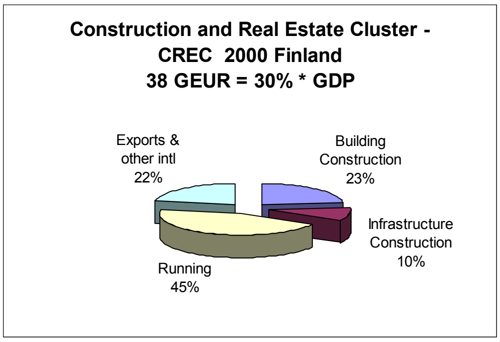
7.6.6 Summary of the presentation to TG4 given by Mr O. TUPAMÄKI (Villa Real – Future Construct)

This is a partly updated summary of my written and oral presentations made during the TG4 work.

1 Construction and CREC

In advanced European vocabulary "construction" is considered to cover the entire value chain of develop/own, design, manufacture, construct, recycle a building, infrastructure or other constructed assets. In the EU this represents 11% of GDP.

Today in Finland and elsewhere, a new expression Construction and Real Estate Cluster - CREC has been taken to use to cover all activities directly related to construction and real estate (buildings, infrastructure and other facilities = 60-70% of the national wealth). Compared to the above, CREC covers the whole life of a building, hence additional activities concern running the building, which more often is done by facilities management. In the EU this represents nearly 30% of GDP.



A reason to this approach is the fact that major contractors are moving from plain construction towards taking care of the building/facility for its whole life. Also public-private partnership projects (BOOT, PFI; toll roads & bridges, schools, prisons etc) require this approach. Also investors and property developers want this. And any **sustainable construction consideration requires CREC!**

What is Sustainable Development?

"Sustainable development is a matter of satisfying the needs of present generations without compromising the ability of future generations to fulfil their own needs" [Brundtland report, "Our Common Future", 1987]

Sustainable development means sustainability not only ecologically (= environmentally) and economically but also socially and culturally.

Lately in the EU and UN, an expression "the three pillars of sustainable development" is often used; the pillars are said to concern economic, environmental and social development. For not to forget cultural aspects, they should read **economic**, **environmental** and **societal** (= social, cultural, ethical etc) development.

Without of a culture (language, history, religion, arts, common habits, culture general) a nation cannot have any sustainable future! This is **human-diversity** to be preserved just like bio-diversity in general. Globally, according to UNESCO statistics, a half of the spoken languages, ie some 3,000 languages, are facing death. Many of those also in Europe.

As per Rio 1992, countries should prepare national strategies on sustainable development in 2002 latest. Only few countries have provided something meaningful (EU: SE, DK, DE, AT, GB) with proper objectives (what, when) and action plan (how, who, financials, monitoring).

As per Johannesburg 2002, no definitive objectives were set.

2 What is Sustainable Construction?

After Kibert's definition 1994, CIB W82 (OT a member) proposed the following definition 1998: **"The creation and responsible management of a healthy built environment based on resource-**

efficient and ecological principles". A later programme document "Agenda 21 on Sustainable Construction" (CIB Report Publication 237, 1999) repeats this definition with additional explanations.

This definition is not satisfactory, as it leaves out economic and societal issues completely!

Buildings consume 40% of total energy and account for 30% of CO2 emissions, and construction is the "hamster" of raw materials ⇨ environmentally alone, **CREC's sustainability is most important for whole society!**

3 What could be Sustainable Construction?

The ways in which built structures are procured and erected, used and operated, maintained and repaired, modernised and rehabilitated, and finally dismantled (and reused) or demolished (and recycled), constitute the complete cycle of sustainable construction activities.

The high quality of the living and working **indoor environment** (health, comfort, productivity, safety, security) as well as a healthy and aesthetically pleasing **outdoor environment**.

Minimise the use of **materials**, **energy** and **water** and **mobility**. (factor 4/10; NL: factor 20)

Building products should, as far as possible, be **reusable** and materials **recyclable**. Design for **long service life** (and durability) is superior to design for reusability. Reusability is superior to recycling, and recycling is superior to waste disposal.

In sustainable construction, reusability and ease of **changeability** are necessary product properties, in particular for modular products and systems with different service lives.

4 Competitiveness of the Construction Industry - Sustainable Construction

In 1997, the EC DG Enterprise published a document "Competitiveness of the Construction Industry". Since that time several working groups have been actively carrying forward studies on various important topics. They are usually tripartite groups with participants from the Commission, member states and industries.

The most important one is the working group for Sustainable Construction (OT a member). In June 2001 this industry-led (European Construction Industry Federation – FIEC) working group published a report titled ***"An Agenda for Sustainable Construction in Europe"***. This report (a "non-paper") has been sent to the member states. (total report, see www.fiec.org.) The report's recommendations include the following:

- All member states and accession countries to draw up and publish programmes for "sustainable construction". Within the EU, Finland, Germany, Ireland, Luxembourg, the Netherlands and the UK have (earlier) produced such papers of various qualities.
- Carry out a feasibility study to examine the extent to which eco-efficiency can be increased with the perspective of raising it by a factor of 4 or, over a much longer time frame, by 10.
- Establish guidelines that will lead to LCA and LCC becoming normal standard procedures, and make such assessments mandatory for public works valued above a given threshold.

5 What are LCA and LCC?

Derived from ISO 14040: In construction, **environmental life cycle assessment - LCA** is for assessing the total environmental impact associated with a product's manufacture, use and disposal and with all actions in relation to the construction and use of a building or other constructed facility. LCA does not address economic or societal aspects!

Derived from ISO 15686: **Life cycle costing - LCC** is a technique which 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 costs.

> *Originally the TG4 was "…to draft a paper on Life Cycle Costs in construction…", yet BRE Digest 452 distributed in the first meeting made the TG to change LCC to WLC, which is for no good; see my separate paper on ISO/DIS 15686-5 Buildings and constructed assets – Service life planning – Part 5 Life cycle costing (LCC) or Whole life costing (WLC).*
>
> *It is my proposal to go back to use LCC in the TG4. Thus the terms of reference should read:* ***"Draw up recommendations and guidelines on the Life Cycle Costing of construction aimed at improving the sustainability of the built environment"***

6 Can LCC and LCA be put together?

LCC is calculated as NPV = Net Present Value of the accumulated future costs (C) over a certain period of time (t), eg 30 years (N), at an agreed discount rate(s), eg 6% pa (i), dependant on prevailing interest and inflation rates. LCC

NPV is calculated according to the following formula, and can be done with MS Excel (up to 29 years easily...).

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+i)^t}$$

LCC gives you figures in money for any present and future costs as required.

LCA may be used to create regulatory requirements, offer incentives and determine rating/scoring systems to help decision-making. LCA does not give you any figure in money.

Eg, in the case of tenders, considering construction cost as usual plus LCC calculations together with LCA scoring, **you should be able to calculate LCC + LCA ie a total = money + points! No existing related software gives you any proper consistent solution to this equation.**

Thus, my initial conclusion is no, LCC and LCA cannot be put together.

In the following table some software tools, mainly for LCA assessment, are listed.

Name of software	Country of origin
BREEAM	UK
ENVEST	UK
ECO-QUANTUM	NL
GREENCALC	NL
ECO-PRO	DE
LEGOE	DE
EQUER	FR
OGIP	CH
Økoprofil	NO
BEAT 2000	DK
Ekoarvio	FI
LEED	US
BEES	US
ATHENA	CA
GBTool	(24 X NN)

It is my intention to further study the above equation on a case study project in Finland (Intentia HQ, Keilaranta 5, 02150 Espoo, a newly completed office building for adaptable rental use, 10,000 m2 floor area) using the newest software: LCA software GPTool 1.82 + generic multi-criteria decision making software Logical Decisions 5.1.

It is also worthwhile to notice that the forthcoming Public Procurement Directive, the hottest topic for the whole CREC this very moment, needs multi-criteria decision IT Techniques! The European Commission says there is no applicable software available yet, so it must be developed.

7 Total LCC

To overcome this LCC+LCA problem, I try to look at it purely mathematically and introduce a fresh approach, which I call Total LCC (see book *"Construction Can", ISBN 951-97676-1-4, 1998*):

Total LCC =

1 Acquisition (a total of all initial capital costs + related environmental and societal costs) +
2 NPV = Net Present Value of the future costs of ...
2.1 **Building** (operating + maintenance + repair + refurbishment + disposal - residual value) +
2.2 **Occupation** (occupational LCA factors) +
2.3 **Mobility** (locational LCA factors) +
2.4 **Environment** (environmental LCA factors) +
2.5 **Society** (societal LCA factors)

NPV = Net Present Value of the accumulated future costs and revenues over a certain period of time, as described earlier. Period or life cycle is determined as per the planned/ongoing activity and can be whatever.

Building (operating + maintenance + repair + refurbishment + disposal - residual value) refers to the future costs of all the different operating and administrative activities necessary to run the building or other constructed facility.

The above-mentioned principal activities are as defined in ISO 15686. In the NPV formula, there are costs caused by these activities. This is also true for other factors below, of course.

Occupational factors refer to health, comfort, productivity, safety and security of the building (eg office). It is here important to realise the relationship of different accumulated costs for an office building with eg 30-year ownership:

1 : 5 : 200
1 = acquisition
5 = building operating and maintenance (see 2.1 above)
200 = business operating costs ⇨ here the biggest benefits are easiest to achieve through better comfort and productivity ⇨ good indoor environment/climate/air

Mobility, hence locational factors refer to the location of a (industrial, commercial, office, school etc) building. We should calculate LCC not for the building alone but also its location in relation to incoming material and outgoing product flows as well as to employees' commuting or school children's daily transport.

Environmental factors refer to different environmental impacts that various materials and actions have; environmental profiles. Environmental factors are, however, hard to come by and need a lot of RTD at European and international levels to define their features and properties and to give them generally accepted values. Here LCA studies give a good starting point.

Societal factors finally need to be taken into account. This area is very little covered so far. Yet, for the CREC industries, cultural and other societal phenomena are necessary every-day considerations (eg concerning a new road through a village).

In the first meeting of TG4 this approach was actually approved. Yet, later it was seen too challenging, and a conventional approach was selected with a limited scope including economic and environmental considerations only and leaving out societal (social, cultural, ethical…) factors.

Today, the rate of return available through LCC considerations is lower than that offered by alternative long-term investment: as annual return; stock market 25% (-90% for dot.coms <= risk), 15% business ROI/ROC (risk), 6% bonds, 3% bank account. However, it may be claimed that future LCC costs will be increasing due to higher energy prices and new environmental and other regulatory requirements. This development will raise the calculated return and may enable **market-driven LCC considerations**.

8 Towards probabilistic approach

For LCC to become widely accepted, concerns about uncertainties in forecasting must be overcome: particularly the costs and performance of building, products and systems. A related European RTD project **EuroLifeForm** is to advance a probabilistic approach on LCC in construction. Here I was the originator and my company Villa Real is a major partner. The coordinator is Taylor Woodrow Construction GB. Here the newest theories and software is used for probability, risk, sensitivity and optimisation; @Risk 4.5 with RiskOptimizer utilising Monte Carlo simulation. The final outcome will be a generic model for LCC and Performance - LCCP, in a software format, **to replace deterministic values for costs and performance with a probabilistic approach**, good for investors, developers, contractors and designers.

Encls 1 ISO/DIS 15686-5 Buildings and constructed assets – Service life planning – Part 5 Life cycle costing (LCC) or Whole life costing (WLC) - MY COMMENT ON LCC vs WLC, dated 19 May 2003 (2p)

7.6.7 Summary of the presentation to TG4 given by Chiel Boonstra about international study LC Test

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The development of LCA and LCC tools in the building area aims in many cases on the needs of architects, designers or research institutions. In Finland a different approach has been chosen, giving special attention to the needs of building developers and housing corporations in the public, private and commercial area.

The LC Test project is conducted in 2001 and 2002 by the Polytechnic College of Kuopio, Finland under the auspicious of major players in the Finish building society. The project is part of the Finnish governmental program BUILDEN and jointly financed by the Ministry of Trade and Industry, Ministry of Environment, the Technology development centre TEKES and the energy information centre MOTIVA. DHV from the Netherlands has been brought into the project for transfer of international experience.

Although most LC tools are only applicable in the country for which they are developed, Finland aims at the development of a LC tool which is using a common language and can be understood in an international context.

In the first phase of LC Test international LCA and LCC tools are selected and tested on Finnish reference buildings. Parallel with the software test, interviews are conducted with different clients groups in order to gain insight in customer needs. On a regular basis seminars are held allowing participation of other interest groups (construction industry, software developers, a.o.). Based on the experience of the projects the practicability of the tools have been be evaluated and recommendations are made.

Inventory of the existing tools and acquiring the tools for testing

Software tools to be tested in LC-Test were searched in the Internet and with the help of the connections of DHV. Also past international studies that had included inventory of LC software tools were examined.

LCA tools for buildings were limitedly available. Nevertheless a reasonable amount of tools was gathered. Finding LCC tools proved to be even more difficult. The research group states a few reasons for this small supply on the market:

Commercial LCC services are often provided as consultancy based on the consults own closed databases.

A lot of information on maintenance and renovation costs exists at companies that prepare and perform maintenance works (mainly SME's) and organizations that own large real estate stocks. However these organizations do not provide publicly available tools for calculating.

Contrary to LCA, LCC is not a government driven approach. LCA tools in most cases origin from government or semi-government driven R&D programs or are related to green building policies.

LCC is not a common constraint, whereas market parties in most countries still focus on initial investment costs.

All acquired tools (or demo versions) were tested preliminary and their features were examined. The following tools were studied in all:

LCA tools: BEAT 2000 (Denmark), Eco-Quantum (the Netherlands), Envest (Great Britain), GreenCalc (the Netherlands), Økoprofil (Norway)

combined tools (LCA&LCC): LEGOE (Germany), OGIP (Switzerland), Ekoarvio (Finland), TAKE (Finland)

LCC tools: Kiinteistötieto (Finland), Kostenreferentiemodel (the Netherlands), Årskostnadsanalyse (Norway)

THE RESULTS OF THE PROJECT

Review on the situation of life cycle calculations

Controlling of the value and profit of real estate and the contribution of environment friendly and healthy housing require life cycle planning. This is emphasized in national and international politics of sustainable building and construction. In the Central Europe specialized tools have been developed to support these politics but there are no Finnish tools especially designed for life cycle calculations of buildings available.

According to interviews of building stock owners and constructors, life cycle tools are desired to be introduced in Finland although the strategic use of tools and the potential for competitive advantage and use for communication are yet not appreciated. Among the interviewed companies there was no earlier experiences of utilizing LCA and LCC calculation tools, apart from some pilot projects.

There is no particular interest in either LCC or LCA tools, but implementing LCC is considered to require fewer efforts. The interviewees are however gradually willing to take also LCA in use.

Most of the interviewees were more interested in life cycle cost calculations than ecological life cycle assessments. LCC tools were among other things considered to require fewer efforts in implement than LCA tools. However it was found out that the number of LCC tools in the European market is small. Following features where wanted from the life cycle tool:

Suitable for design process steering

Supports the decision making

Easy to use, resource demand as low as possible

Merges in to building practice with ease

Estimation of the ecology of real estate comes along with economy report.

Present life cycle tools used in Europe are developed to answer the needs of origin countries. Especially the LCA tools are not easily transferable to other countries, because they involve so much of national detailed data and calculation methods. The national calculation models are used also in the energy calculations, often as external calculation module. Because used calculation methods and the result information that the tools give are diverse, the results of different tools are not comparable.

LCA and LCC tools are not advanced in terms of software architecture. Compatibility with other design tools is poor and user interfaces are often complicated and not self-explaining. The calculation methods and assumptions used in the tools are not transparent to the user. Workload of the tools proved to be high, which is a problem in the fast paced building design processes.

None of the tools tested in LC-Test was directly suitable for the use in the Finnish construction and real estate maintenance planning. Every tool has its advantages and disadvantages. The combination of all positive features forms a good basis for Finland to develop an own tool.

The measures to be taken before the tool development

Because there is an interest for a useful life cycle tool in Finland, one should be developed. First however the calculation methods, selected indicators and form of energy calculations must be solved. Not to forget to discuss about the national building material database, that the tool needs. This definition work should involve wide range of actors in the real estate and building trade. International orientation can help to achieve fast results.

In Finland there is no common method for life cycle calculation. Such should be implemented. Yet it is also unclear, what kind of indicators of life cycle economy and environmental effects have to be examined in the analyses. Common international indicators should be introduced to make the result information of different tools more standardized.

LCC and LCA calculation is best to be combined in to the same tool, because the goal is to find good balance between ecology and economy. Also the energy calculations should be tightly bound up on life cycle calculations of buildings, either built in the tool or as an external module. An integrated life cycle and energy calculation tool could give the building material influence to heat transfer as a synergy advantage. It is needed to participate in to collaborative European development of the both life cycle and energy calculation methods.

Life cycle calculation software tools use the information of their databases as base material in the calculations. These databases consist of profiles of national building products. A concept for collecting material data from the numerous product manufacturers is needed. Material performance profile should include at least environmental loads, heat transfer coefficient, service life and price. Same database maintained by e.g. an independent administrator could thereby be used in energy, LCC and LCA calculations. For this, the Finnish RT environmental profile files are a good start.

TOOL DEVELOPMENT

A life cycle tool particularly for the use of Finnish builders and real estate owners should be designed. The tool should be developed to be accordant with Finnish TALO nomenclature but not forgetting the apparent international marketing potential.

Developed tool should be usable in the early design phase, when the most important decisions of building design are made. On the other hand, it is significant that the tool can be used also to examine restoration projects. Life cycle tool should be embedded among the common building design tools. Data transfer between tools should happen easily or even automatically along the different phases of building project.

The results of the environmental effect estimation should be preferably presented in SI units than e.g. ecopoints. The tool should report also the material flow results obtained in the first stage of life cycle assessment, in the inventory analysis. Tool should include sensitivity analysis, which is a feature for estimating the effect of certain calculation component to the total effects of the building and for comparing different methods of building implementation.

Shaping an existing tool for Finnish building trade could be an alternative for developing a new tool. In that case the strong expertise of the tool developer could be taken advantage of. However also in this case the preparing actions for tool development presented in the previous chapter must be made.

Achieving the objectives of the project

A good view to the needs of Finnish builders and real estate owners for life cycle calculations and tools was obtained in LC-Test. The criteria for tested software tools were composed according to interviews.

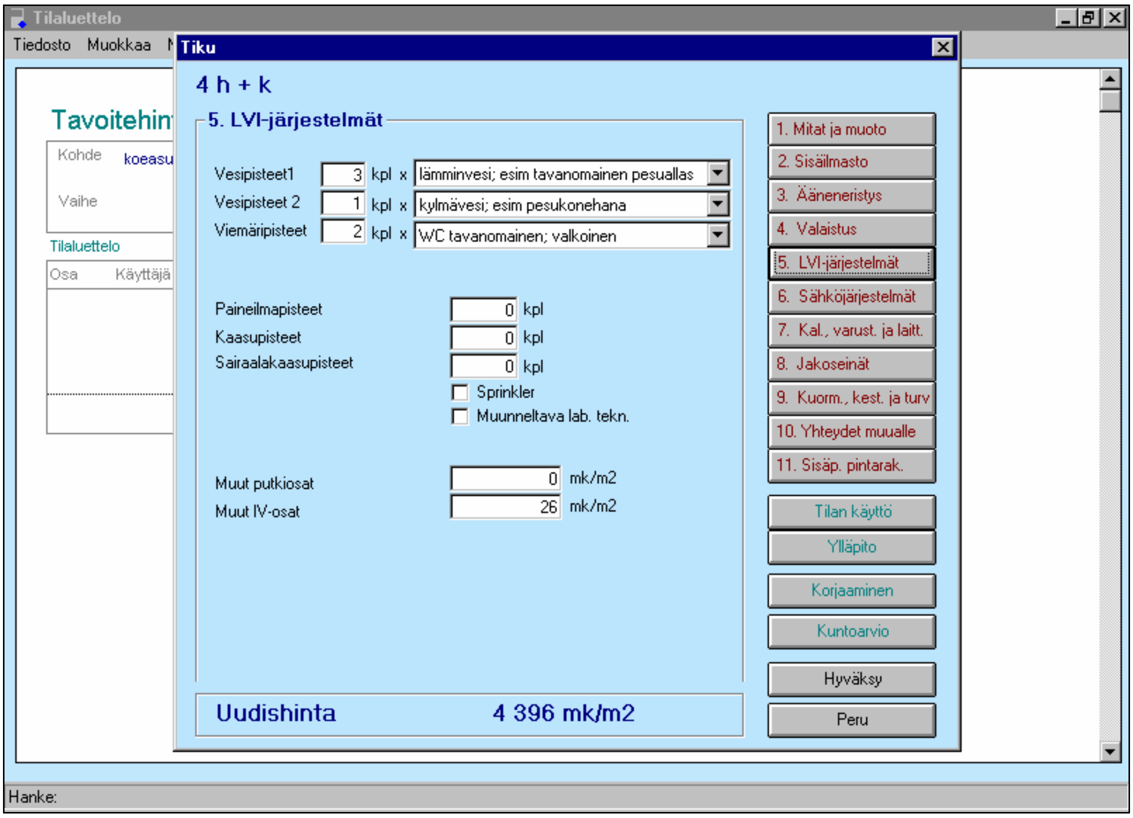
By examining and testing European tools it was also detected, what kind of features and deficiencies they contain from the perspective of Finnish building. None of the tested tools could be recommended as directly suitable for Finland. Neither could specific calculation procedure for government supported building projects be presented.

Annex: LCC tools

- **Finland: Kiinteistötieto v2001.01.47**

Kiinteistötieto is a tool for building stock management, rent management, annual budgeting and project programming. In addition to common data management features, tool can be used to determine investment and present values of the building and to estimate level of rent according to space types and the use. It can also be used for budgeting the construction, renovation and restoration projects and continual building maintenance.

It is possible to measure the life cycle costs of the building with easy-to-use operation costs calculation method. With the rent function the whole chain of external and internal renting can be dealt with. Functions include e.g. rent level estimation and making pre-filled tenancy agreements.



Picture 1. The input sheet of HVAC systems, Kiinteistötieto.

Kiinteistötieto tool needs to be installed on workstation of each user. The database can be located in the network drive.

Kiinteistötieto is developed by Finnish Haahtela-kehitys Oy. Company produces software tools and publications for building trade and also arranges training in the areas of construction, cost management and real estate management.

Clear graphical user interface clarifies the processing of space attributes. It is possible to input plan drawings in to the tool for the use of e.g. maintenance staff. Generally the tool works logically and the usage is easy.

Kiinteistötieto does not demand a great number of input information. If calculated object is a completed building, only floor plan and construction year are needed. Buildings that are in design phase are defined by estimated floor plan and use of space. The tool comprises lot of default information about space properties and demand of transport and technical spaces. Therefore Kiinteistötieto is well suitable for a design tool in the early design phase.

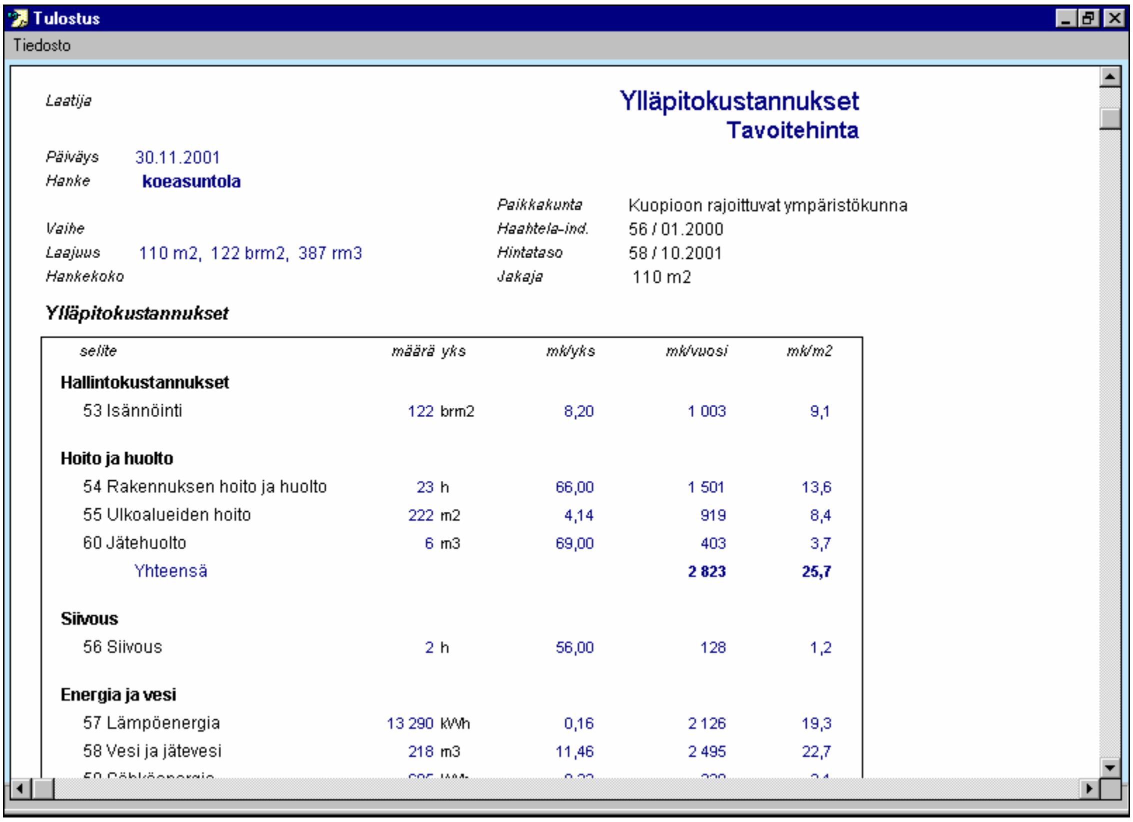
The tool has the sections of Property, Programming, Calculations, Annual Budgeting and Renting. Each section is provided with extensive report functions.

There are a couple of dozens of licensed Kiinteistötieto users in Finland. Main users are cities, municipalities and government organizations. Impediment for accretion of use of the tool is expensiveness of the license, which is about 5 000 €. Also the maintenance fees are high.

Results

With Kiinteistötieto the operating costs of building can be measured according to the Finnish norms. The tool is beneficial all the way from early design phase to demolition phase of the building.

With the tool it is possible to measure all the maintenance costs, present value of real estate, budgets of construction and renovation projects, investment program, annual restoration work, rental agreements and rent events, rent accounts and invoicing (including bar code bills).



Tulostus

Tiedosto

Laatija

Ylläpitokustannukset
Tavoitehinta

Päiväys 30.11.2001
Hanke **koeasuntola**

Paikkakunta Kuopioon rajoittuvat ympäristökunna
Vaihe
Haahtela-ind. 56 / 01.2000
Laajuus 110 m2, 122 brm2, 387 rm3
Hintataso 58 / 10.2001
Hankekoko
Jakaja 110 m2

Ylläpitokustannukset

selite	määrä yks	mk/yks	mk/vuosi	mk/m2
Hallintokustannukset				
53 Isännöinti	122 brm2	8,20	1 003	9,1
Hoito ja huolto				
54 Rakennuksen hoito ja huolto	23 h	66,00	1 501	13,6
55 Ulkoalueiden hoito	222 m2	4,14	919	8,4
60 Jätehuolto	6 m3	69,00	403	3,7
Yhteensä			**2 823**	**25,7**
Siivous				
56 Siivous	2 h	56,00	128	1,2
Energia ja vesi				
57 Lämpöenergia	13 290 kWh	0,16	2 126	19,3
58 Vesi ja jätevesi	218 m3	11,46	2 495	22,7

Picture 2. Calculation results: maintenance costs, Kiinteistötieto.

Conclusions

Kiinteistötieto can deal with any building type. One of the advantages of the tool is that it doesn't need lot a of detailed input information. Tool is made to fit in to the Finnish environment and standards and therefore the reliability of the calculation results is good.

- **<u>Netherlands: Kostenreferentiemodel Woningbouw v1.35</u>**

Kostenreferentiemodel Woningbouw is an LCC tool based on the Dutch construction methods and standards. A Dutch company Stichting Bouwresearch that makes development work in the fields of environmental friendly construction and computer software tools has developed Kostenreferentiemodel. The language of the tool is Dutch.

Kostenreferentiemodel is made for calculating the life cycle costs of all kinds of residential buildings. The investment and operating costs of new one-family, semi-detached, row and apartment houses can be calculated but the tool is not suitable for renovation projects.

The calculation model of the tool is based on the Dutch calculation standards that actually are based on the current value method in which all the costs are discounted by a fixed rate of interest to show the current value of the total costs. The calculation methods and formulas are hidden and not even commented in the manual. The costs due to consume of energy and water are calculated by the given input information but the tool does not report the calculated consumptions.

There are some limitations of what costs are included in the life cycle costs in the tool. Kostenreferentiemodel cannot calculate the costs of renovation, demolition and final disposal.

The tool can be used already in the beginning of the building project. No accurate information of measures and materials is needed to make a rough estimation and the user can give only verbal definitions. The calculation can be specified when the plans get more detailed and more information is available.

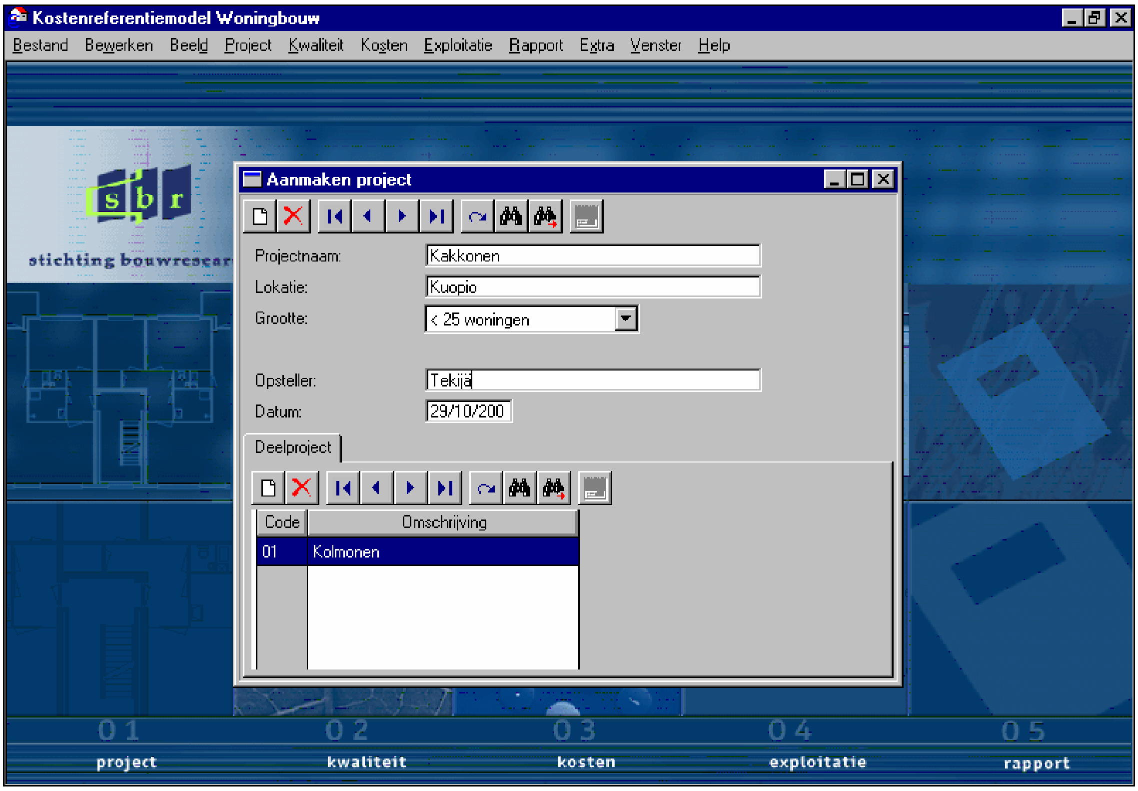
Using of Kostenreferentiemodel is made easy. It requires no specific knowledge; ability to interpret the blueprint is enough. In building project the tool could be used by the building developer, head designer and the owner. The tool is best suitable for comparing different size, shape and quality alternatives of buildings.

Because the tool is made for Dutch needs it is not suitable for use in Finland as such. The database should first be updated for Finnish circumstances and the user interface and the user manual translated to Finnish. Also the Finnish climate conditions should be taken into account.

<u>Using of the tool</u>

The structure of Kostenreferentiemodel Woningbouw is very logical; it proceeds clearly step by step. First the identification data of the building project is entered and then the information of size, shape, costs and consumptions. Finally the user can print the chosen reports. No cost factor can be skipped or forgotten because all the inquired information has to be given before getting to next stage.

There are two ways to use Kostenreferentiemodel; by giving accurate information of construction and measures or on more general level. Using the general level means that all definitions are made verbally using a three step scale. For example energy saving, water consumption and convertibility of the building are evaluated by a scale small-normal-large. In the more accurate inspection more detailed information about the constructions and materials has to be given. In both ways a big part of the information is to be chosen from the given alternatives.



Picture 3. The building identification data, Kostenreferentiemodel Woningbouw.

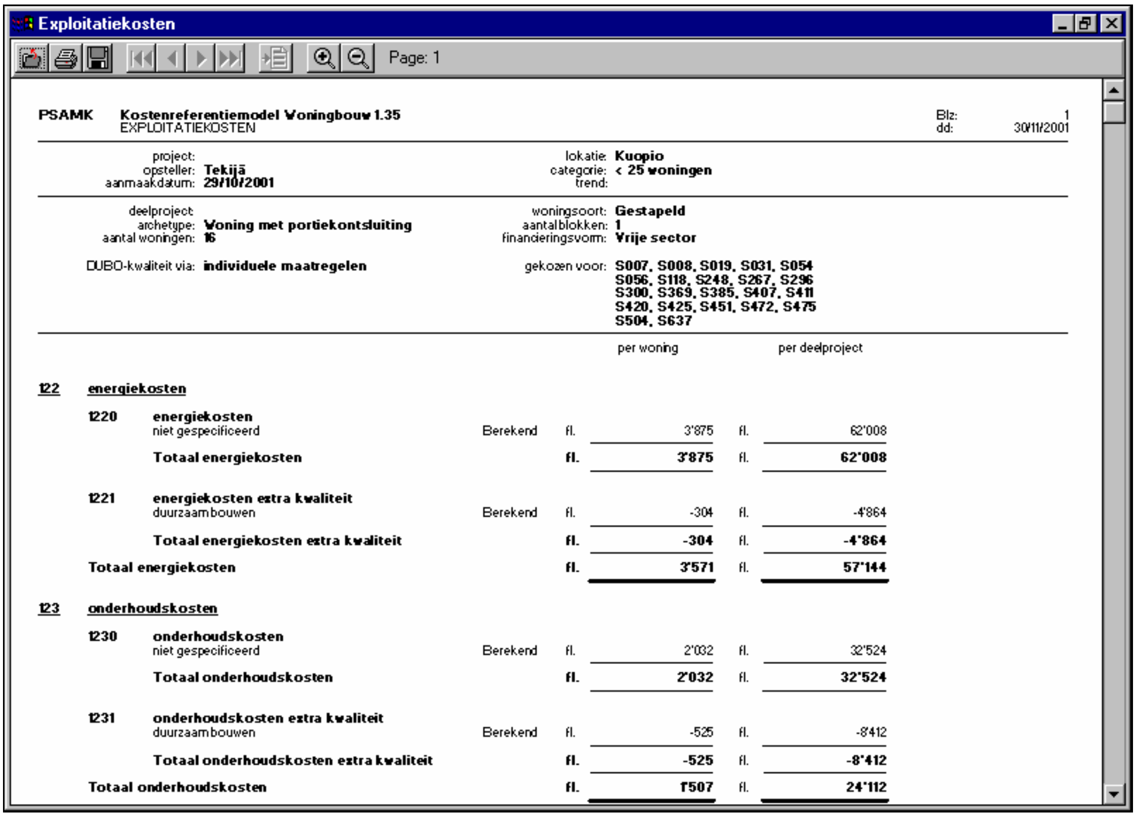
In addition to the common life cycle calculation parts Kostenreferentiemodel also has a feature to define the rent of an apartment. The user enters the planned rent and the tool calculates if it covers the costs of the apartment.

Results

In Kostenreferentiemodel Woningbouw the results are divided in to investing and operating costs. The investing costs include the costs of designing, site, construction and managing. The operating costs are composed of the energy and maintenance costs. All results are presented in Dutch guldens as costs per an apartment and per the whole building. Costs per square meter or cubic meter are not presented.

The tool presents the results as table; they are not visualized in any way. The result tables can be saved as MS Word documents. Although there are no pictures or diagrams, the results are explicit due to the clear table. Also all default values of costs, such as the costs of designing and constructing, are presented in the table.

Kostenreferentiemodel Woningbouw is made for the Netherlands, which naturally weakens the reliability of the results in Finland. At least the costs of energy consumption seem note-worthily small, which is understandable since the tool is designed for the Netherlands. Also the lack of the ability to enter the exact values degrades the accuracy of the results.



Exploitatiekosten

Page: 1

PSAMK Kostenreferentiemodel Woningbouw 1.35
EXPLOITATIEKOSTEN
Blz: 1
dd: 30/11/2001

project:
opsteller: Tekijä
aanmaakdatum: 29/10/2001
lokatie: Kuopio
categorie: < 25 woningen
trend:

deelproject:
archetype: Woning met portiekontsluiting
aantal woningen: 16
woningsoort: Gestapeld
aantal blokken: 1
financieringsvorm: Vrije sector

DUBO-kwaliteit via: individuele maatregelen
gekozen voor: S007, S008, S019, S031, S054, S056, S118, S248, S267, S296, S300, S369, S385, S407, S411, S420, S425, S451, S472, S475, S504, S637

				per woning		per deelproject
122	**energiekosten**					
1220	**energiekosten** niet gespecificeerd	Berekend	fl.	3'875	fl.	62'008
	Totaal energiekosten		fl.	3'875	fl.	62'008
1221	**energiekosten extra kwaliteit** duurzaam bouwen	Berekend	fl.	-304	fl.	-4'864
	Totaal energiekosten extra kwaliteit		fl.	-304	fl.	-4'864
	Totaal energiekosten		fl.	3'571	fl.	57'144
123	**onderhoudskosten**					
1230	**onderhoudskosten** niet gespecificeerd	Berekend	fl.	2'032	fl.	32'524
	Totaal onderhoudskosten		fl.	2'032	fl.	32'524
1231	**onderhoudskosten extra kwaliteit** duurzaam bouwen	Berekend	fl.	-525	fl.	-8'412
	Totaal onderhoudskosten extra kwaliteit		fl.	-525	fl.	-8'412
	Totaal onderhoudskosten		fl.	1'507	fl.	24'112

Picture 4. The report of the results, Kostenreferentiemodel Woningbouw.

Conclusions

Kostenreferentiemodel Woningbouw is, overall, a very usable tool. The explicit structure, reasonable amount of input information and big amount of default values enable a quick estimation of life cycle costs in the early phase of a building project. The use of the tool is not, however, limited in the early phase of the project, it can be exploited also later, even in the operating phase.

The tool is best suitable for comparing the different alternatives of size, shape, quality and consumptions of a building. For real estate business, e.g. managing the real estate and monitoring the currency flows, the tool is not suitable because of its simplified structure.

The idea in the tool of making the input phase easier by giving only a limited amount of alternatives actually made the input more complicated, since the alternatives were strictly based on Dutch construction methods and regulations. In the Netherlands the tool probably is well usable in the early design phase of the building project.

There are only a few things that should be changed if Kostenreferentiemodel Woningbouw was introduced in Finland. Naturally it should be translated in Finnish and the database should be changed to equate the Finnish circumstances. Also the Finnish weather conditions should be taken into account in the energy consumption calculation part. The given alternatives in the tool should maybe be thought over, because constructing is not as strictly regulation based in Finland as it is in the Netherlands.

- **Norway: Årskostnadsanalyse v2.0**

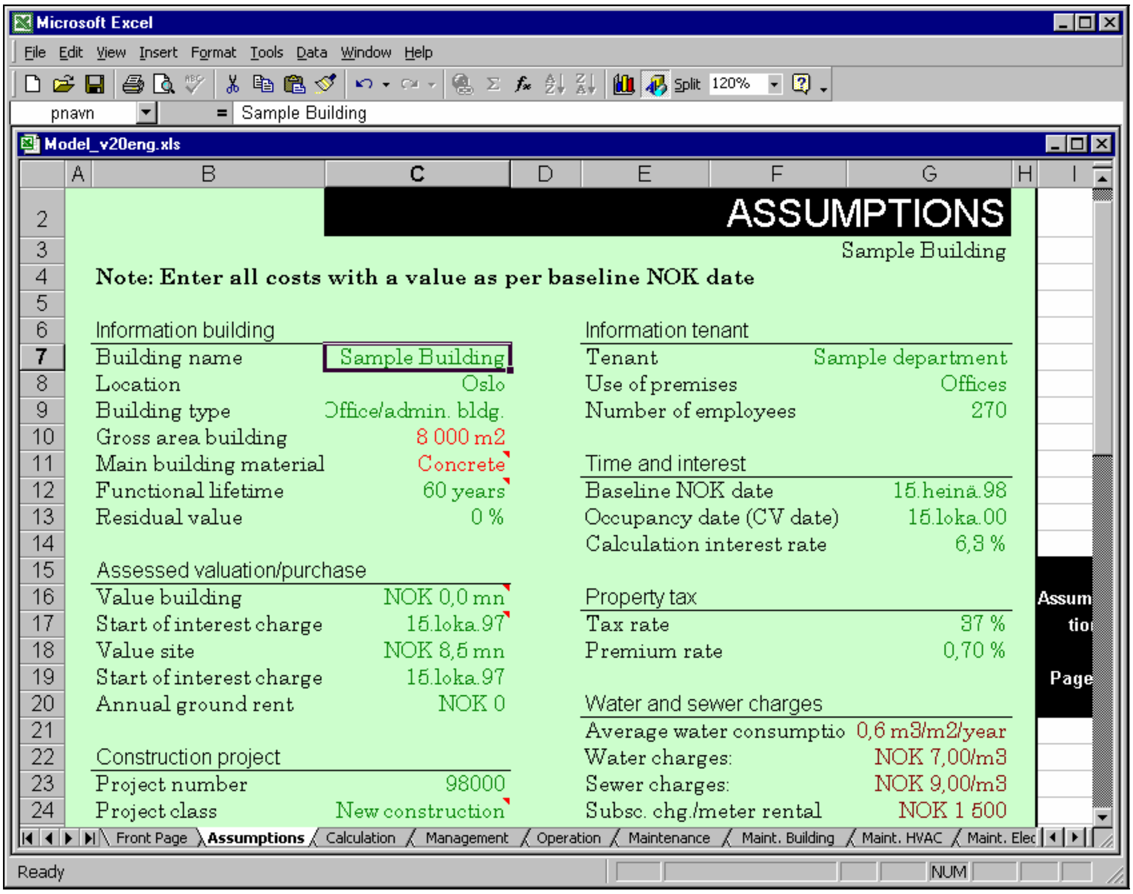
Årskostnadsanalyse is a spreadsheet (MS Excel) based on a Norwegian calculation standard NS 3454 for life cycle costs. The producer of the tool is Statsbygg, working under the Government of Norway, making building trade development and constructing and contracting in the building projects of the government. The Årskostnadsanalyse calculation or equivalent is a requisite part of government financed building projects in Norway. The tool is available for free on the web site of Statsbygg.

Årskostnadsanalyse is a tool for estimating the life cycle costs of buildings. Although, according the manual, the tool is suitable for all kinds of buildings, it is best suitable for new office buildings.

The tool is transparent. All calculation formulas are given in the manual, in tool they can be adapted according to the preferences and needs of the user. The user is provided with the password securing the structure of the tool, to enable the modifications.

Energy and water consume and their prices have to be entered; Årskostnadsanalyse does not calculate the consumptions. The total costs of energy and water are calculated by the information of consume, area of the building and the number of users.

Årskostnadsanalyse is not suitable for use in the early phase of the building project. That is because it demands accurate information of areas, materials, building services and prices. Establishing and finding the input information is quite toilsome and requires knowledge of building trade and constructing. The best suitable the tool is for head designer or the building developer.



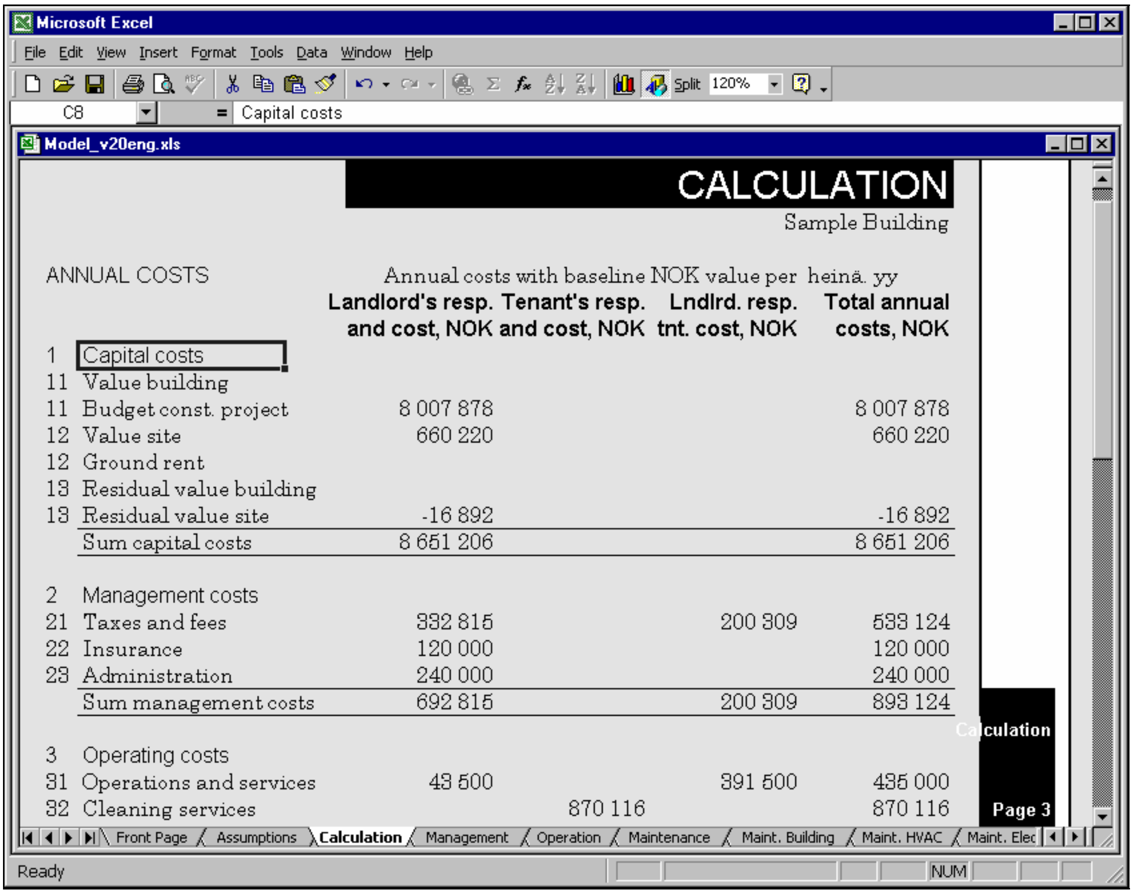
Picture 5. The input screen, Årskostnadsanalyse.

Results

Capital costs, management costs, operating costs and maintenance costs are specified in the results of Årskostnadsanalyse. The results of total costs per year and annual costs per square meter are presented in tables and also in different kinds of diagrams. The representation of the results can be modified within the limits of MS Excel. Also the distribution of the operational costs per year can be viewed as chart.

The tool calculates the capital costs by the value of site and building, budget and the residual value of the site and building. The management costs are calculated by taxes, fees, insurances and water and sewer costs, operating costs by operating, cleaning and energy costs and maintenance costs by different maintenance and replacement costs.

A striking feature in the results of the test calculations was the big amount of the costs of operating phase compared to the capital costs. A big part of them was due to the maintenance and replacements of building services. This signifies that it is very important to enter the information of building services accurately, which requires expertise of their price and functioning.



CALCULATION

Sample Building

ANNUAL COSTS — Annual costs with baseline NOK value per heinä. yy

		Landlord's resp. and cost, NOK	Tenant's resp. and cost, NOK	Lndlrd. resp. tnt. cost, NOK	Total annual costs, NOK
1	Capital costs				
11	Value building				
11	Budget const. project	8 007 878			8 007 878
12	Value site	660 220			660 220
12	Ground rent				
13	Residual value building				
13	Residual value site	-16 892			-16 892
	Sum capital costs	8 651 206			8 651 206
2	Management costs				
21	Taxes and fees	332 815		200 309	533 124
22	Insurance	120 000			120 000
23	Administration	240 000			240 000
	Sum management costs	692 815		200 309	893 124
3	Operating costs				
31	Operations and services	43 500		391 500	435 000
32	Cleaning services		870 116		870 116

Picture 6. The annual costs, Årskostnadsanalyse.

All costs are first discounted for current total value and then divided to annual costs for the whole life cycle by the annuity method. The calculation procedure is presented graphically in the last sheet of the tool. Also some salary and insurance facts used in the tool are presented on the last sheet.

Conclusions

Årskostnadsanalyse is meant for nearly all kinds of buildings - residential buildings, office buildings and warehouses. Best suitable it is for the life cycle cost calculation of office and public buildings.

It is not possible to compare different scenarios for the shape or number of floors of building with Årskostnadsanalyse, because it does not inquire information about them. Comparing alternatives of size, materials and building services instead is possible and quite easy, presuming that the information is easily at hand and the user is familiar with the tool and the building project.

The biggest disadvantage in the tool is the big amount of the required information of using ages and prices. It is not overstated in the manual to recommend experts of HVAC and electricity to define the input information.

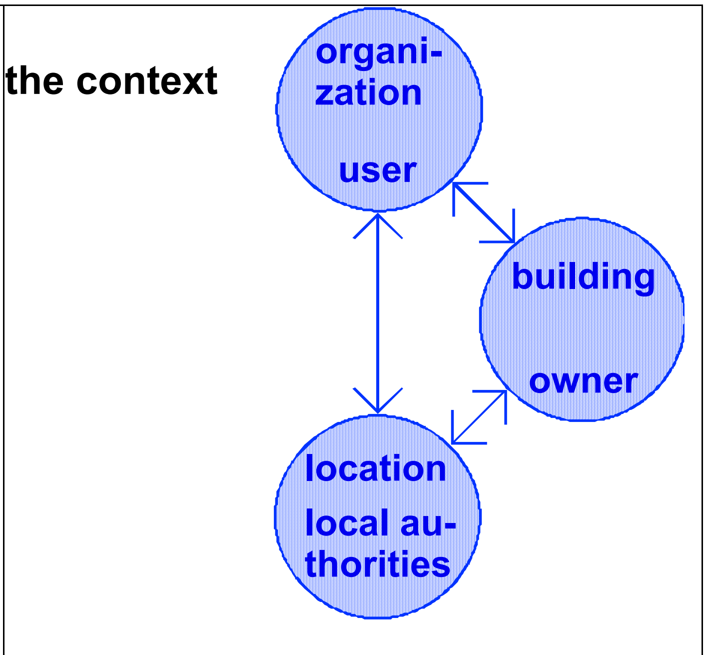
Årskostnadsanalyse is quite adjustable to Finland as such. Naturally it should be translated into Finnish, but otherwise it does not need any special localizing measures. The tool being on the Internet for free and available for everybody is embraceable. In this case, however, not even all the updates promised in the manual were fulfilled.

7.6.8 Presentation from Mr Karel VALK and Mr Axel De BOER (NL Ministry of Housing)

The group who has done all the research is called PARAP and you can visit them by www.bk.tudelft.nl/d-bmvb/parap/.

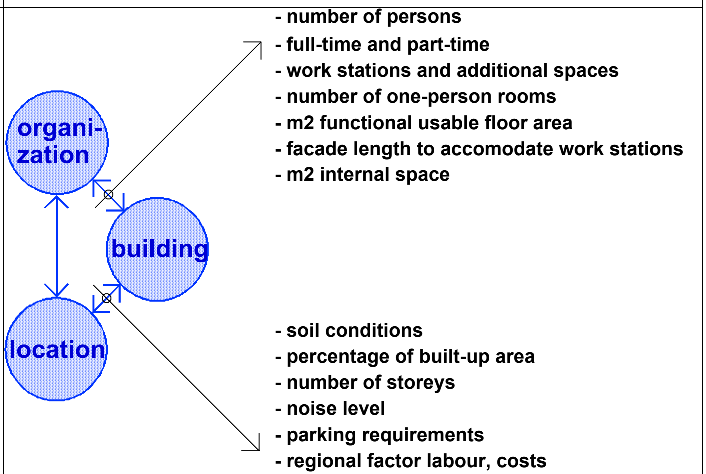
Parap is a great help in the decision making process of the facility-procurement.
In the early stage of the process the foundation of decision-making, within cost quality relationships, needs very special information. PARAP always looks at cost-quality relations after the definition of a context to avoid disharmony of consistency.
The context is triple:

2. facilitating which type of organization
3. the (type of) building
4. the location.

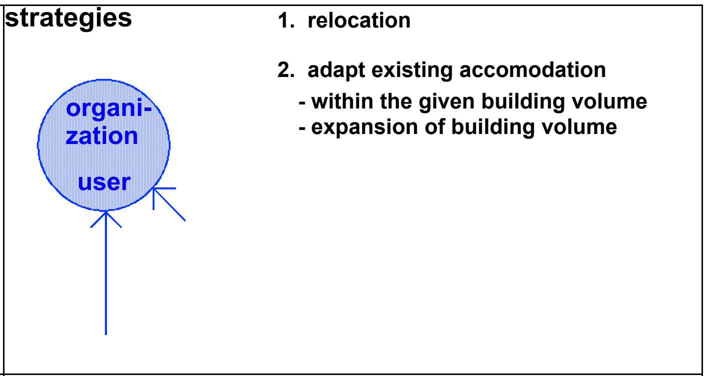


The relation organization/building shows up the aspects.

- the number of employees to be sheltered
- the relation full time/part time
- the number of workplaces and additional rooms and spaces
- the number of single rooms
- the extent of m2 functional area to be considered
- the available perimeter of the façades, with reference to daylight and view
- the m2 of space needed but allowed to be allocated inside the building if no daylight is needed (walled in)

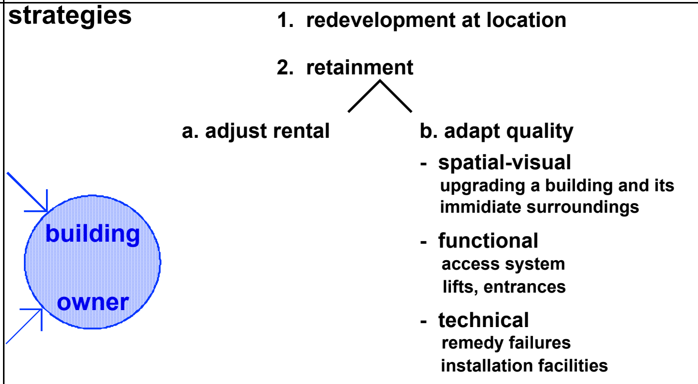


When an organization is not satisfied anymore with the facility there are different strategies to solve the problem
There are two options:
2. change (to an other building)
3. the adjustment of the accommodation within the building volume or expending or rebuilding that eventually.



If the building/accommodation is not acceptable anymore by the organization (or in general), two strategies are possible:
1. re-development;
2. maintaining, adapting, recalculated rent at a basis of improved quality of the accommodation,

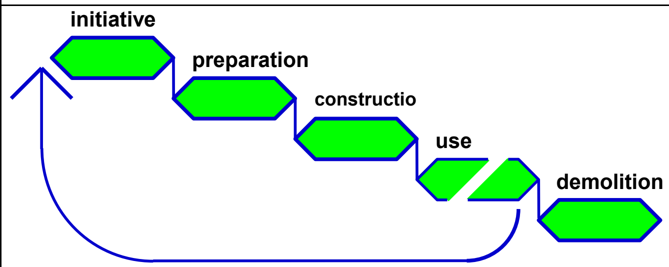
The latter concerns often the esthetical appearance of the building or/and the environment (upgrading the location). In a more functional perspective, it is possible to change or adjust entrances, lift locations and services. To conclude, a technical update of the construction, HVAC&E installations and equipment is also an option (meeting now a days standards).



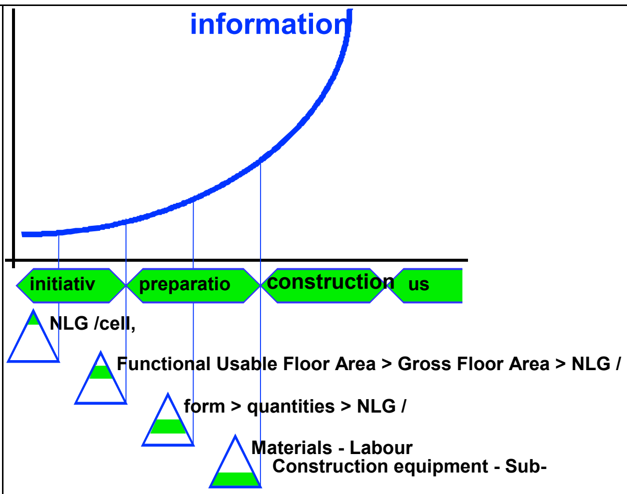
Building procurement normally shows the following stages,

- initiative
- preparing drawings, BQ's, calculations
- construction, components, building site
- use, occupation, management.

If the building does not meet the societies needs or demands anymore, it will be demolished.

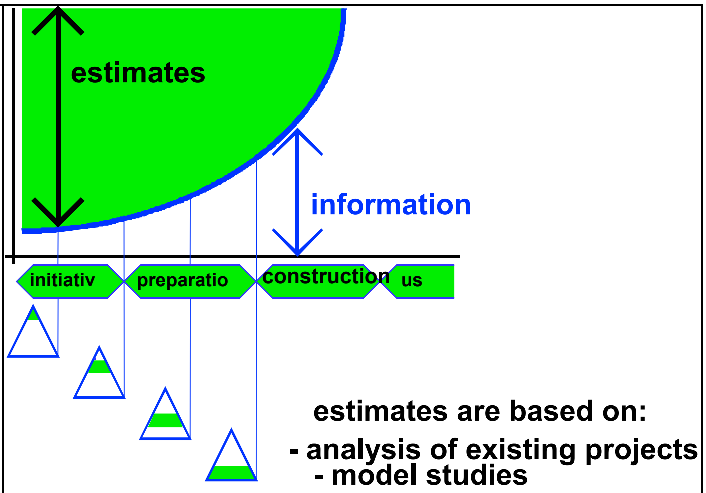
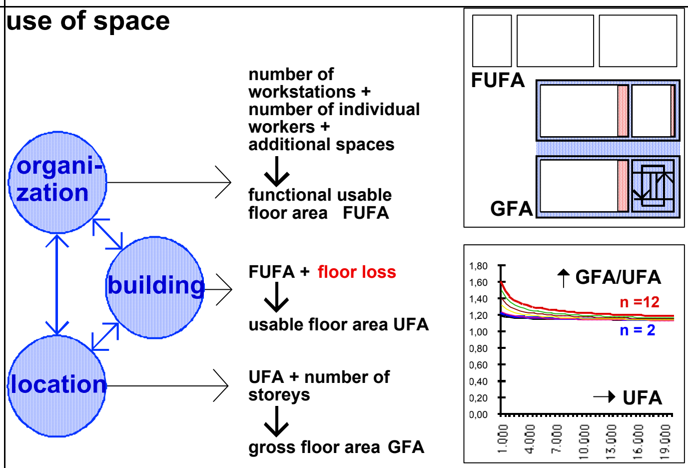


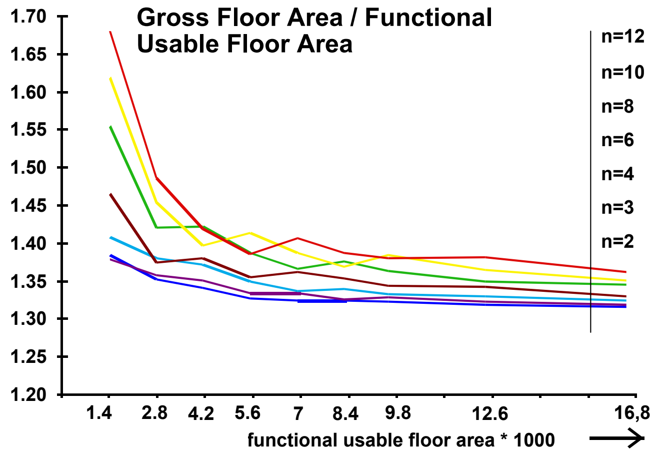
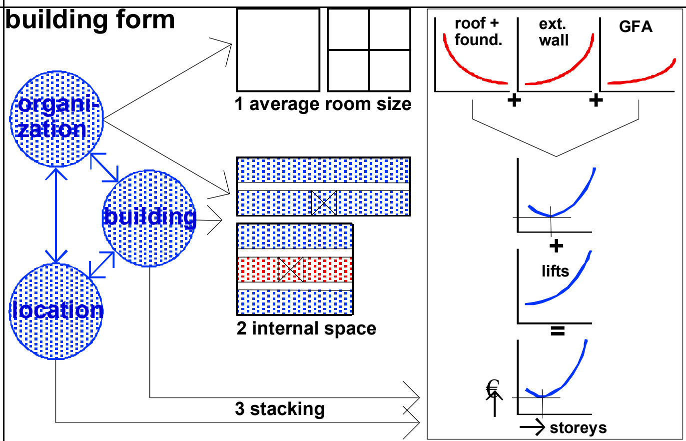
In the course of the procurement process, the extend of information on quality will grow.
Based on that information the estimating will also be more detailed and the result: more certainty about the risks.
The information in each stage of the process evaluates towards a status of complete quantities and goes from element level to BQ level, ending up in material, labor, equipment and subcontractors.



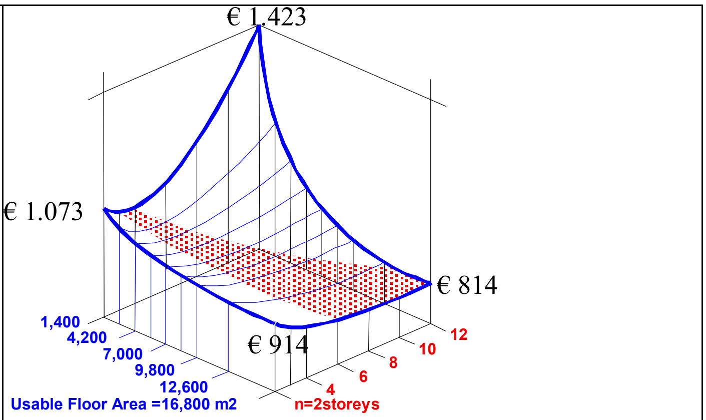
In the earliest stage of an initiative there is not even a design or, moreover, a brief.
Nevertheless one has to make decisions about new facilities (penitentiary institutes, health, education). Decisions will be made on 'functional unit costs' of the number of cells, beds, and students.
The brief stage initiates the use of cost per m2, for the size of the facility will be approximately known. The functional total m2 must be evaluated to gross floor area (gfa).
Collecting data from the existing stock and abstract them to find the key factor is indispensable: from functional m2 to....using the cost/m2........

If there exist a design, a budget can be established based on elemental cost date.
Quantities of footprint, façade, roof, separating walls and completion can be measured and elemental cost added.
Elemental costs also are compiled from databases containing historical or composed data.

Lack of information will be compensated by assumptions based on reference buildings to get a good view on cost quality developments. Estimates are founded on: • analyzing build projects • model-research, series of archetypes	
Analyses of many projects, and a considerable number of model studies have delivered know-how of items which generate cost information. These items are: 1. space, use of m2 2. building form (archetype) with important aspects as the number of floors, the 'grain size' (which is in indication of the average size of the rooms) and the amount of non-daylight rooms and rooms to be situated at the façade) 3. The extent of technical quality (to build in 'wood' or in 'gold'). These 'cost generators' are subject to a more cursory glance.	**cost generators** **use of space** **building form ---stacking** **average room size** **internal space** **technical quality**
Use of space. Organizations claim a total functional area. The number of workplaces, single rooms and additional space (meeting, archives, restaurant) are relevant in this respect. Adjusting of the m2 to a certain design structure will conclude to a certain 'design loss': The real figure of m2 functional space is more then indicated in the brief. Studies indicate this loss at 5-10%, depending on the character of the structure (archetype). The opening up system and the number of floors influences the step from functional space to gross floor area. This step needs an other 20 - 40%. *An important role plays the number of floors influences by the building*	

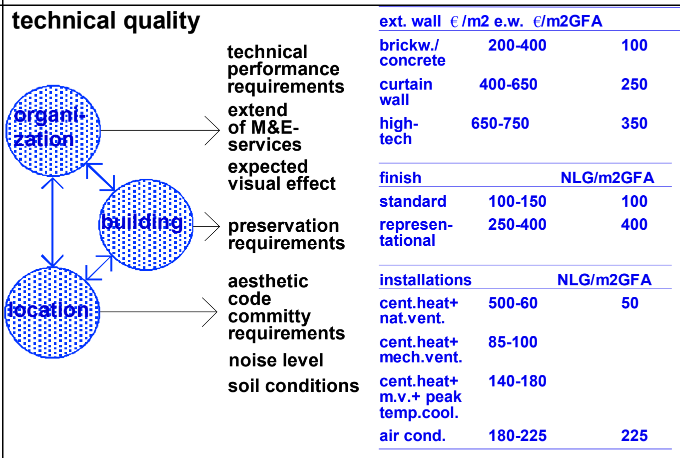
(building etc. city planning).	
Analyses of existing stock and a considerable number of model-studies by the university of Delft and the ‘Rijksgebouwendienst’ (procurement office of the central administration) did result in a deep knowledge about the impact of the number of floors. The graphic shows the relation GFA-UFA, the bandwidth is 1,3 to 2,7 within the range of 1400-16.800 m2 GFA. The values relate to 2-3-4-6-8-10 and 12 floors. More floors mean more m2 GFA resulting in excessive costs.	
The form of the building. Three aspects are important: 1. The ’grain size’. An average small-size room results in more m2 separating walls. In the brief stage of the project, the average size of the rooms has already been fixed. 2. Rooms without demand for daylight. The more these types of rooms are part of the design - options, the more possibilities to create a building with less façade. A twin-corridor layout offers the possibility to allocate non-daylight demanding rooms more easily. 3. Number of floors impact. Town building assimilation and architectural concept defines the number of floors. The impact of the number of floors can be dramatic, in respect to costs. High rise means: • less foundation and roof, • much more m2 façade. • increasing GFA, • sophisticated (= expensive) elevators. ‘Translating’ these phenomena in a mathematical way results in a minimum domain for a building form (number of floors), showing minimum cost related to defined quality.	

Model studies delivered a number of algorithms to be applied for the relationship building size-number of floors and cost of the building. The graphic shows this relationship. Cost per net functional area related to building size (from 1400 to 16.800) and number of floors (from 2 to 12). The difference (gap) between lowest and highest cost is a factor 2! The minimum domain is shown clearly.



stacking and minimum options

The extend of technical quality. Organizations will express their demand for a certain level of technical outfit in terms of quality, i.e. performance of M&E, building components and esthetics. A (protected) monumental building has its character and typical demands too. The location will impose specific solutions in terms of town building, form of the building and appearance, environment (traffic), soil conditions (pile formations) and contamination of the building site will have influence on the decision-making.



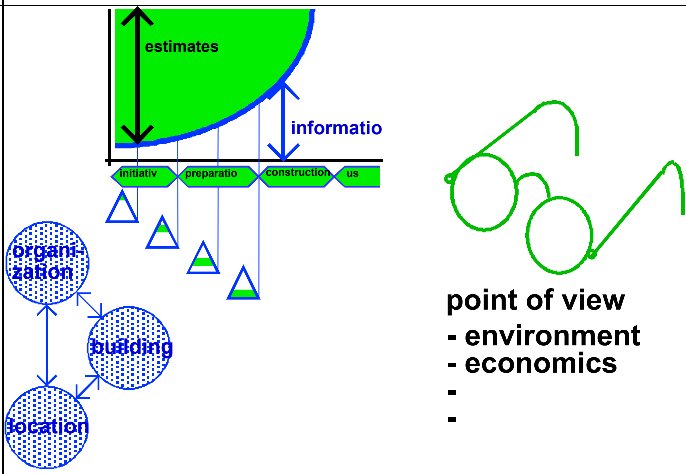
Offers an integrated approach, applying operational research much as possible, to assist decision makers in making choices or selections concerning cost/quality relations, especially in the early stage of project development.
The possibility to go for a minimum domain is part of it, whether for reference or reality.
However, this calls for a viewpoint: which domain is the objective?

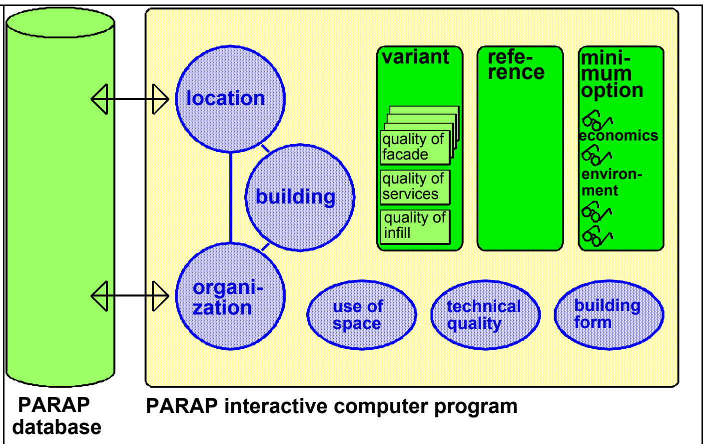
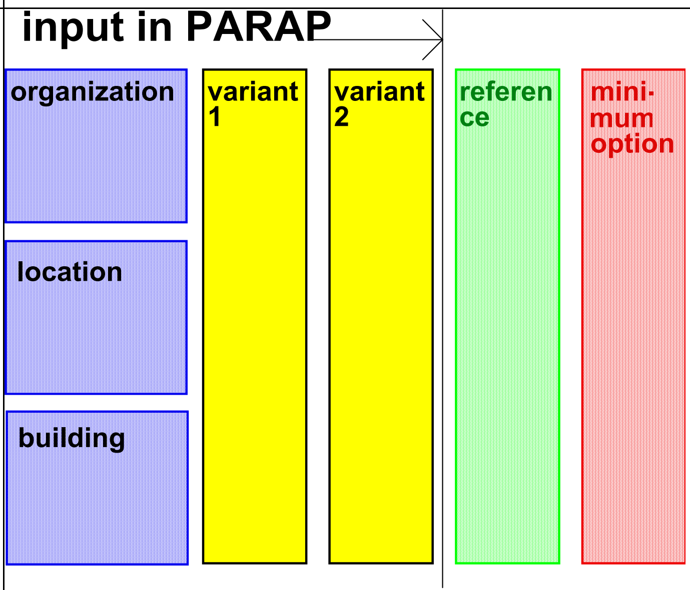
- investment, capital cost
- cost in use, occupation costs
- life cycle cost

or the 'green issues'

- energy consumption
- energy content (materials/ equipment)
- demolition (less contamination)

- all the aspects together or a selection.



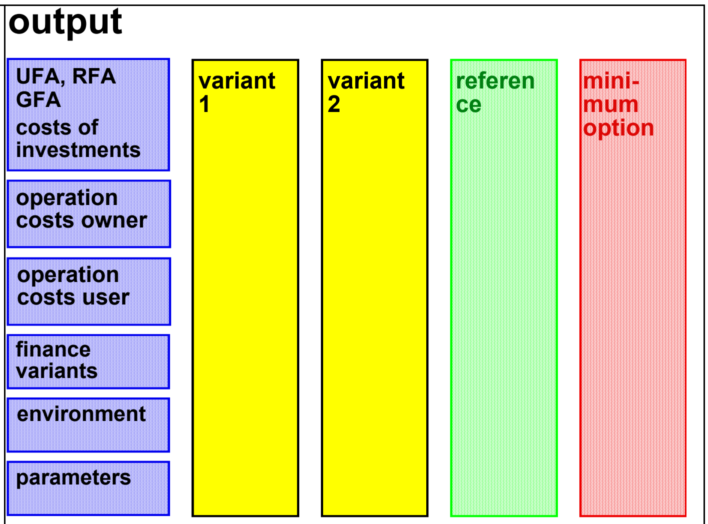
The interactive software of PARAP has two relevant parts (or fields): the database containing automatic updated cost data and a calculation facility, systemized by mathematics (MCM). The calculation facility offers possibilities to focus on alternatives, references or M.D. (minimum domain).	
PARAP's input concerns: • organization character • building archetype • location properties and handicaps Each alternative is based on the application of pre-selected variables. The software looks for (and presents) a reference building (stored in the database) and offers the MD. Depending on the kind of the decision that will be taken, it is possible to open a window, indicating organizational parameters. After completion of the input the functional net area will be calculated, and in sequence: • GFA • quantities of building elements • options in quality will be presented It is also possible, in case of an existing building, to start with the building properties and parameters. After completion, the match with the organization parameters will be made.	

The PARAP output.
Alternatives, references and minimum domains will be shown based on an elongated, oblong. building form with simple symmetry (a so called slice form).

Cost information is selected:

- total investment
- cost in use owner
- cost in use user
- comparing financial consequences (financing models)

quality with respect to green issues.



7.6.9 <u>Presentation: A dialogue between the Swedish Government and part of the building and property sector with sights set on achieving a sustainable building and propery sector</u>.

Partnership for voluntary agreements

A dialogue between the Swedish Government and part of the building and property sector with sights set on achieving a sustainable building and propery sector.

Presentation of one of the working groups work with focus on LCC/LCA- summary

Background

Great efforts are required on the part of both national and local governments and the business community if we are to achieve the goal of sustainable development. The building and property sector has a huge impact on the environment in Sweden. How should we build, manage and live in buildings in a way that minimizes the load on the environment and satisfies our need for comfort, light, warmth and a healthy indoor environment? And how should we plan our communities?

This is the subject of the broadly-conceived dialogue called Building/Living ("Bygga/Bo" in Swedish) that has been held between the Government`s office and the private business sector, with sights set on achieving a sustainable building and property sector 25 years from now. The method being used is called "backcasting" and involves first defining a vision for the future and then discussing what strategies and measures are needed to achieve the desired goal.

The dialogue has taken place in two phases. In the first phase, 20 companies, three municipalities and the Environmental Advisory Council came up with visions, goals and strategies. In the second phase, six working groups (a report from one of the working groups dealing with LCC is presented here) with participants from companies and municipalities have pursued this dialogue in greater depth and formulated concrete proposals for measures and voluntary agreements to achieve a sustainable building and property sector.

Building structures have a relatively long lifetime and are subject to periodic alteration and renovation. The long operating period accounts for approximately 85% of the lifetime environmental impact. This makes it important to design building structures, technical systems, materials etc. with a view towards their entire life cycle and not just the initial investment phase. If more consideration is given to the whole life cycle in planning and design, environmental impact can be substantially reduced.

On behalf of the Government the Minister of the Environment and representatives for 15 companies in the construction - sector and 4 municipalities signed in May 2003 an agreement which includes seven different strategic areas.

Sustainable community planning

System selection and precurement with a life cycle perspective and a holistic view

Quality and efficiency in the building and property manament processes

Property management for a better built environment

Classification of residential and commercial premises with regard to energy, environment and health

Use of best available technology (BAT) and need for R&D for good environmental and energy solutions

Information/implementation of sustainable solutions

The main aims of the project are to enhance industry´s environmental efforts and to collect supporting data for political decisions on strategies and instruments.

<u>The prioritised themes</u> are, efficient use of energy and resources and healthy indoor climate.

The signed agreement are supposed to contribute to a sustainable building and property sector, to contribute towards fulfilment of the seven set up goals commitments for a sustainable devepment. The goals are related to the National Environmental Quality Objectives and are concerning energy, information about building materials and structures to avoid substances known as being hazardous to health or the environment, classification of buildings with regard to building-related health and environmental impacts, chemicals, waste, natural gravel. The agreement also includes evaluation and development of the dialogue.

A working group “system selection and procurement with a *life cycle perspective* and a holistic view” has come up with a number of initiatives which it proposes that the actors within the building and property sector undertake by voluntary agreement between the business community and the state. A short summary of the groups report is presented below.

A fundamental measure is that the participating companies and municipalities who select systems − design buildings and facilities and select and design technical installations − and purchase services and products lend their support to the following principles to achieve long-term sustainability:

The Working group- system selection and procurement with a life cycle perspective and a holistic view.

Proposals for commitments

Based on the problems and opportunities that have been identified the working group “System selection and procurement with a life cycle perspective and a holistic view” has arrived at the proposals for commitments:

Commitment 1: Participating companies and municipalities support the principles presented below for system selection and procurement with long-term sustainability.

Commitment 2: Participating companies and municipalities undertake to analyze functions, building structures and subsystems based on a holistic view and a life cycle perspective.

*Commitment 3:*Participating companies and municipalities undertake to regularly carry out LCC analyses when selecting systems − design of buildings, technical installations and complements. Furthermore, procurement of major building parts and components shall be done with consideration given to LCC. Where necessary, the LCC analyses shall be supplemented with LCA limited to relevant parts.

Commitment 4: Participating companies and municipalities undertake to have managerial staff undergo training in life cycle thinking, LCA and LCC, during 2003/2004. Such training shall be co-funded with the state. This training shall then be repeated at regular intervals.

Commitment 5: Participating companies and municipalities undertake to regularly prepare and use project-specific environmental programmes.

Commitment by the state:

That the state adopt similar measures with regard to its activities in the building and property sector;

That the state furthermore undertake to develop standardized data to be used in life cycle assessment (LCA).

Principles for system selection and procurement with long-term sustainability:

In system selection and procurement work, participating companies and municipalities undertake:

To comply with legislation and promote compliance with the rules of consideration of the Environmental Code,

To establish a level of ambition for own environmental work and formulate simple and clear requirements,

To prepare clear and consistent documents as a basis for tenders with regard to requirements, goals and other parameters of importance for environmental impact, To behave consistently and fairly in the evaluation of tenders against environmental requirements,

To follow up and evaluate experience from contracts and projects entered into,

To use procurement methodologies that ensure constant improvements,

To work actively for progress in the sector towards achieving long-term sustainability, for example via collaboration with suppliers and customers.

Concerned parties.

The client/property-owner is the key actor for creating a working integration between the long management period and the shorter design and construction period so that all parts of the project are implemented with a life cycle perspective and a holistic view. The client or his agent sets the tone for the collaboration and the mutual respect within and between the consultancy group and the contractor. The choice of architect and technical consultants and the formulation of conditions for their work are strategic for ensuring good quality − architectural, technical and environmental − in construction and management. *Consultants* − architects and others − work with building projects in their early phases, both new construction and alteration projects, and their work and knowledge is of great importance for the structure during its life cycle. *The contractors* execute the building projects, and it is in this phase that the intentions of the project are turned into practical action.The *material manufacturers* deliver parts and components that are used in the buildings. Selection and handling of raw materials is of importance throughout the life cycle for both sustainability and environmental impact.

In the early phase and planning, it is necessary to study reference projects and to have time for brainstorming. When architects and other consultants are selected, the reference projects and their actual performance should influence the choice. It is important that both the architect and technical consultants adopt a holistic view and a life cycle perspective in their work and have high general competence.

In property companies, the building and management units need to collaborate and exchange experience when embarking on new construction and alteration projects. If this is not done, management cannot be integrated with design and construction, which will then greatly impede the introduction of better resource management in the entire building sector. It is important that environmental management be included from the beginning,

A life cycle perspective and a holistic view of environmental impact and costs are important in the design of buildings and facilities, as well as in the selection of technical systems and procurement. Investing in and designing a building for e.g. a low energy requirement, with energy-efficient technology, longer maintenance intervals for different installations, and materials with known content and known properties, can permit considerable savings during the utilization period. This leads to both lower energy use and lower environmental impact in the end. At the same time, the construction or investing phase will account for a greater portion of the environmental impact and cost, while the operating phase accounts for a smaller portion, viewed in a life cycle perspective. When different actors are in charge of the investment and operating phases, as is common, incentives for these kinds of changes are lacking. Many real estate companies have “different pocketbooks” for construction and for operation. Unfortunately, the project manager often sees it as his most important duty to keep the investment costs down, without giving much consideration to future energy and maintenance costs or environmental impact. This obviously does not contribute to long-term sustainable development!

In office buildings, the office equipment, lighting, etc. that is in use today sometimes generates surplus heat. This requires the installation of cooling equipment or district cooling. With better products, this “unnecessary” heat output could be avoided. It is assumed that such environmentally sound, heat-efficient products will be developed. Work is being pursued internationally to design products and services so that their environmental impact on human health and the environment during their entire life cycle is reduced. This is known as Integrated Product Policy, IPP.

Current situation − how participating companies work today

There are approximately 700 million m^2 of heated buildings in Sweden, which is equivalent to about 80 m^2 per person, of which 47 m^2 is residential and 35 m^2 is commercial space, hospitals, schools, etc. There are more than 10,000 process plants for electricity, heating, water supply and waste management and 1 million km of roads, streets and utility lines. In addition there are industrial premises and unheated farm buildings.

The companies that participate in the working group together own properties with a surface area of more than $12 \cdot 10^6$ m^2. The properties are of different kinds, mainly residential, offices, hospitals and service buildings which the companies also manage.

The working group has conducted a survey of how the companies represented in the group work:

How is long-term sustainability valued?

Why don't they always comply with their own requirements?

How credible is the work in the company?

How is new knowledge disseminated in the company?

How does the client work with procurement?

How is long-term sustainability valued?

To a great extent, the companies have written documents stipulating clear goals for their own work and requirements on their cooperation partners when it comes to a life cycle perspective and a holistic view. But work methods for making choices in the early phases that contribute to sustainable development are not so well developed in all companies. More knowledge and better developed work methods are needed to shed light on the connection between different choices of systems and environmental impact. When it comes to buildings, such factors as siting, placement on the lot, compass orientation, choice and design of technical installations, and activities in the building influence the environmental impact to which the building gives rise. The siting of an activity is of importance for the transport requirement and the environmental impact of transport activities. The route chosen for a road is also of importance for the environmental impact of the vehicles that use the road.

The companies have prepared documents with questions of relevance for sustainable development in the sector. These documents are given to all actors engaged by the companies, and they are expected to comply fully with them. Some companies have also produced documents for tenants. The principle for the companies is that the total cost is crucial in the project planning and that special emphasis is given to the costs of the management phase (life cycle costs).

There are various procedures for keeping the procurement documents up to date. At one company, for example, 15 administrators have been given responsibility for maintaining the status of the documents. Each administrator is responsible for one subarea/chapter of which he has experience. The material is updated once a year to keep it in compliance with current requirements. Experience feedback obtained during the year is also incorporated.

The static building and system parts are assumed to have a long life. How other building parts and installations are valued is usually determined by technical life, but not infrequently by how long a product's market life or regulatory life is considered to be. Another important factor is how flexible a property is for different uses and tenants.

How does the client work with procurement?

The companies that are represented in the working group all have an environmental policy, and some are environmentally certified. Several of the companies have systems for tender evaluation where special consideration is given to environmental aspects. However, procurement procedures are different in the different companies, partly depending on what kinds of activities are conducted or what type of property is managed. Some of the companies in the working group have to comply with the Public Procurement Act (LOU).

Some companies have framework agreements for the provision of goods and services, and purchases are made in a highly decentralized organization by call-off under blanket purchase agreements. A central unit with specialist competencies is responsible for follow-up, experience feedback and improvements, and documentation for new agreements, as well as for information to and training of company employees.

The procurement of consultants is of central importance for the companies for both alteration and new construction projects, since the decisions made in the early phases determine the premises of the project, particularly for the energy requirement and the possibility of finding energy-efficient solutions. The results are highly dependent on the competence of the consultants.

It is common for companies to have a policy of procurement taking into account life cycle costs and a goal of selecting materials, products and methods for construction, management, operation and maintenance in a purposeful manner. This includes insisting that the contents of all materials and products that are used be known, along with the energy requirement during the whole life cycle.

Due to shorter lease periods and a high turnover of tenants, offices and other premises are altered, materials are replaced, and technical installations are modified long before they have served out their useful life. Surface layers often have a “fashion life” rather than a service life. To reduce the environmental impact of these frequent changes, the companies try to use more flexible or robust systems, for example walls that can be moved without having to change the floor covering, or ventilation ducts with some overcapacity.

The companies have somewhat different purchasing policies, but the following purposes apply:

Lower costs; products and materials with the most favourable price overall for the company, taking into account quality and life cycle costs, are chosen; flexible and simple solutions are favoured.

Higher quality; the properties of goods and services are constantly being improved, or delivery reliability is increasing.

Better environment through active and committed environmental efforts.

Uniform conduct within the organization.

It is important to adopt a holistic view, which means all requirements must be taken into consideration!

Some companies have begun to energy-declare their properties with the goal of reducing energy use. This work includes determining the status and quality of the building stock with regard to energy balance, identifying and documenting technical shortcomings, and suggesting improvements, replacements or modifications of technical equipment. This also includes performing an LCC for each proposed change. In many cases, procurement has taken into account the life cycle costs of the tenders.

Company	Stadsfas-tigheter Malmö	Svenska Bostäder, Sthlm	Vasa-kronan	National Property Board	NCC	Skanska Fastighet Sthlm	Platzer Fastigheter AB	Bengt Dahlgren AB	Locum
Type of properties	Mixed	Mixed	Com-mercial	Public	Com-mercial	Public	Commercial	-	Hospital Commercial
Managed floor area 10^3 m^2 2001	1,400	3,800	1,970	1,750	400	600 [1]	440	-	2,200
Has environmental policy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Environmentally certified ISO 14001	No	No	Yes	Yes [2]	Yes	Yes	No	In process	No
Must comply with LOU	Yes	Yes	No	Yes	No	No	No	No	Yes
Has environmentally considerate rules of procurement	Yes	Yes	Yes	Yes	Yes	Yes	To some extent	Yes	Yes
Procurement takes into account LCC	To some extent	To some extent	To some extent	To some extent	To some extent	To some extent	To some extent	To some extent	To some extent
Imposes environmental requirements on sub-suppliers	Yes	Yes	Yes	Yes	Yes	Yes	In some cases	Yes	Yes
Evaluates Projects	To some extent	Yes	To some extent	Yes	To some extent	Yes, to some extent	To some extent	Yes	Yes
Has system for integrating new environmental knowledge in rules and procedures	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[1] Total Skanska in Sweden 1,000 · 10^3 m^2 managed floor area

[2] The National Property Board (SFV) is also EMAS-registered

The above table is a compilation of the companies' types of real estate holdings and how they take into account some different factors of importance for long-term sustainability and system selection and procurement with a life cycle perspective and a holistic view.

Analysis of obstacles and opportunities

Obstacles to and opportunities for achieving long-term sustainable development in the building and property sector which the working group has identified in regard to organization, economics, knowledge, technology and structure.

The analysis shows that both obstacles and opportunities exist within all three areas that are important for long-term sustainable development − the social, the economic and the ecological area. Measures therefore need to be taken and methods etc. developed with this in mind.

The group's work has revealed that:

Figures for operating and maintenance costs in various sources used in the sector are often unreliable. The figures often come directly from accounting departments without any engineering assessment having been made of the building or its installations.

Short-term market requirements on yield can lead to problems when it comes to making long-term profitable investments.

The environmental debt of a property is not very well understood. However, the appraisers try to get information on the risks of future cleanup costs by e.g. inquiring about previous activities in the property.

Foreign companies are in the forefront when it comes to demanding environmental declarations for properties.

The results of the different methods that exist for assessing properties from an environmental standpoint are only used by real estate appraisers to a limited extent.

The real estate sector needs developed valuation models where environmental factors are included.

More contact is needed between real estate appraisers and advocates of long-term sustainable development. The appraisers need better knowledge of e.g. the relationship between investments in energy efficiency and operating costs. Course on this topic should be required for certified real estate appraisers. The property companies could contribute by providing databases with up-to-date data on operating costs etc.

The OECD’s Sustainable Building Project observes that buildings often change owners and that it is therefore difficult for the initial owners to recoup the gains of their investments unless they can incorporate a premium for this into the sales price. In theory, it is said, buildings with a longer service life and better performance should be valued by the market. In reality, it is uncertain whether this is taken into account in valuation. Future changes in such conditions as climate, energy taxes, etc., are perceived as uncertain factors.

Topics on which *certain actors* require knowledge, X, or familiarity, (X):

Requirement	Builder	Architect	Other technical consultants	Contractor	Supplier
Perform LCC/LCA			X	X	X
Relationship architectural design/geometry and energy efficiency/indoor environment	(X)	X	X	(X)	
Perform climate and energy simulations		(X)	X[1]		
Formulation of requirements early in the process and when preparing descriptions in different phases	X	X	X	X	
Environmental valuation − related to economic consequences	X	(X)	(X)	X	
Perform environmental valuation of building		(X)	X		

[1] Chiefly installation consultants (HVAC, energy and environment) when it comes to simulations etc.

Work procedure and methods in different phases.

The construction and management process consists of several phases, and it is important that a holistic view and a life cycle perspective on environmental aspects and costs should accompany the entire process, not least the initial phases. This is also vital in connection with renovations and alterations.

Current state of research

Construction-related LCA and LCC research is being conducted at the institutes of technology and at SP (the Swedish Testing and Research Institute) and IVL (the Swedish Environmental Research Institute), and funders are MISTRA (the Swedish Foundation for Strategic Environmental Research), FORMAS (the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning), and others. When it comes to the environmental impact of energy use, work is being conducted by numerous research bodies and government authorities.

Several LCA-based methods exist for assessing the environmental impact of a building structure. Research and development is under way, but there is still not any one method that is comprehensive, easy to use and sufficiently takes into account the maintenance need and its effects. Questions concerning methods for assessing the environmental load of buildings are being dealt with in the working group for “Classification of Residential and Commercial Premises − Energy, Environment and Health”. Interest in research on LCC methods for the building sector is also great.

In 1998 the OECD started the project “Sustainable Building” with the goal of providing guidance on the design of national policies for dealing with environmental impacts from the building sector. The project is aiming at reducing CO_2 emissions, waste minimization and prevention of indoor air pollution. The work was completed in 2002.

Need for measures and future work

In order to achieve long-term sustainable development, the total environmental impact of the building sector must be reduced in the future. Achieving this goal requires knowledge, awareness and a willingness to change behaviour on the part of all concerned actors. Clients in particular must be clear and impose requirements on consultants and contractors. Existing knowledge must be disseminated and used, and stipulated requirements must be enforced.

Among the measures that are needed, the following have been identified:

The first step in training is to “train” leading individuals at builders (and investors) in a life cycle perspective regarding environmental impact and costs (LCA and LCC).

In order to achieve sustainable development in the building sector, concrete guidelines must exist.

Evaluate and study methods for developing environmental indexes for proposing suitable methods. This includes how the environmental impact of electricity is to be assessed with regard to e.g. a European perspective.

Study completed evaluations of different energy and climate simulation programs and the performance of “more recent” programs.

The impact of tenants on environmental load, with a focus on energy use.

Go further with the formulation of requirements in connection with demolition, for example that an inventory shall always be performed before demolition and by competent personnel.

Requirements on the production process, where the contractor’s chief coordinator has a very important role.

More contact is needed between real estate appraisers and advocates of long-term sustainable development. The appraisers need better knowledge of e.g. the relationship between investments in energy efficiency and operating costs. Course on this topic should be required for certified real estate appraisers. The property companies could contribute by providing databases with current data on operating costs etc.

Develop and “standardize” methods for “limited” LCA, i.e. LCA for the operating phase.

Collaborate internationally, within the EU and the Nordic countries, for standardization of methods for LCC.

Use new methods where appropriate, e.g. function selling. This involves selling a function instead of a product, for example that telecom operators sell voicemail, energy companies sell a given room temperature, landlords sell access to passenger transport or food delivery, etc. Function selling does not automatically reduce environmental impacts, but by quickly making use of new technology and thereby reducing the life cycle of energy-consuming products, it can contribute towards reduced energy use; this has been done in, for example, the laundry sector. The rules in the Code of Land Laws, however, entail that all that is “affixed” to a building belongs to the building, which prevents certain types of function selling for buildings.

Examples of LCA and LCC

Example 1 − Work procedure for computer simulation

Calculation for an entire building, for example an office building

In the early phases, all parameters that are not needs or functional requirements can be allowed to vary. Such parameters include façade design, i.e. number of m^2 and orientation of windows, sun screening and glass data (U-values, direct solar transmittance, total transmitted solar energy).

Each of the different combinations provides input data for a computer simulation. The results pertain to energy need and can in turn be combined with a production cost calculation that gives the life cycle cost. In combination with data on environmental impact, the simulation also gives the results of a life cycle assessment (LCA). 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 analyzed in greater depth.

The same air conditioning system should be selected in all cases, but it may have different cooling capacities. The selected air conditioning system is a premise in the simulations. It should preferably be selected based on experience or studies of system solutions in previous projects.

Even a limited study with several parameters that vary is complex. The results influence different types of demand, such as electricity demand for lighting, heating demand, cooling demand, and electricity demand for fans.

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 can be used as an indication of where in the range the optimization has brought us.

This work should be carried out in cooperation between the programme architect, the client, and consultants with construction and 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.

This work requires that the client furnish information on which parameters should not be varied and on the standard building, data on environmental impact, and particulars on the financial assumptions for present value calculations.

Calculation for technical solutions

When choosing technical solutions and installations, the orientation and design of the building, including façade and windows, are given. In early phases, however (see above), they are parameters.

In order to get as good a solution as possible for indoor climate control, different technical solutions are studied. By means of iteration, it is possible to arrive at the capacity levels of installations for heating and cooling and the air volumes that are needed for the same indoor climate in the different alternatives. The results of the different simulations give energy costs in the form of a present value. Together with installation costs and possible building costs, the life cycle costs for the alternative solutions studied are then obtained. The annual energy needs can be used as a limited LCA.

Assessments of environmental impacts of materials and chemicals are essential in this phase, as is phase-out of hazardous substances.

Data from the client stipulating design premises are required here as well.

Comment: It is naturally possible to allow both climate system and building/façade design to be parameters, but then a multiple of the number of alternative climate control systems and building/façade designs is obtained. The costs of product determination increase, however, for which there is seldom margin in an individual project, even though it may be profitable in a life cycle perspective.

Calculation for components and individual parts

Selection of components includes taking into consideration materials and material combinations, their content of hazardous substances, etc. The standard templates included in the ENEU® concept (cf. example 3 below) can be used in assessing energy needs, as long as the proportionate distribution of energy use (e.g. between heating and electricity) does not vary widely in the different alternatives. If it does, a limited LCA is also required (cf. example 2 below).

Particulars from the client that define design premises are required here as well.

Examples of results are given below:

From LCA and LCC calculations and a comparison between these is done (Example 2)

From analyses of LCC for procurement of different building and installation parts with the aid of the ENEU® concept ("Calculate with LCC_{energy}")

Example 2 − Climate system for an office building

The example relates to a climate system for an office building, Room temperatures, operating times, internal loads, etc., have been assumed to be equal for all climate systems studied.

The example includes relevant installation costs for:

"Cooling baffle" − Refrigeration plant including piping system and cooling baffles plus air treatment plant

"CAV system" (Constant Air Volume) – Refrigeration plant including piping system and air treatment plant, no cooling baffles

"VAV system" (Variable Air Volume) – Refrigeration plant including piping system and air treatment plant and VAV terminal device, no cooling baffles

I. *Life cycle costing (LCC)*

The energy costs are calculated at their present value with a factor of SEK 7/kWh for heating and electricity, SEK 5/kWh for cooling. The costs are in SEK/m^2.

Annual investment		*Heating*	*Cooling*	*Fan electricity*	*Total*
	Cost	*Cost*	*cost*	*(SEK/m^2)*	
Cooling baffles	945	320	50	73	1388
CAV	680	475	20	153	1328
VAV	1200	368	20	121	1709

II. Limited life cycle assessment (LCA)

The examples II a and II b include energy use during one year of operation for district heating, district cooling and electricity. The CO_2 generation is calculated with a factor of 0.095 kg/kWh for district heating, a factor of 0.0033 kg/kWh for district cooling, and a factor of 0.05 kg/kWh (mean value) for electricity. The table gives CO_2 in kg per m^2.

II a The calculation is based on a mean electricity value for Sweden:

Alternative	Heating	Cooling	Fan electricity	Total
Cooling baffles	4.34	0.03	0.52	4.9
CAV	6.45	0.01	1.09	7.6
VAV	5.00	0.01	0.87	5.9

II b The calculation is based on a marginal electricity value for Europe:

The marginal value for electricity is 0.6 kg/kWh and for district cooling 0.04 kg/kWh.

Alternative	Heating	Cooling	Fan electricity	Total
Cooling baffles	4.34	0.40	9.16	13.9
CAV	6.45	0.16	13.1	19.7
VAV	5.00	0.16	10.4	15.6

*CAV is found to be slightly more advantageous than the other two systems if the calculations are only done with LCC (*not generally!)*, while cooling baffle is found to be most advantageous when LCA is applied, regardless of which input data are chosen. However, it must be borne in mind that the results of similar analyses may differ from what has been found in this particular case, which means that a critical analysis of results obtained must always be done.The present example is only intended to demonstrate one methodology that could be employed.*

Example 3 − Analyses of LCC with the aid of the ENEU® concept

The tool "Costing with LCC_{energy}. Economically sustainable procurement of energy-consuming equipment based on the ENEU® concept" has been developed by Bengt Dahlgren AB for the Association of Swedish Engineering Industries (VI). The Swedish Energy Agency (STEM) has also sponsored the project under an agreement with VI. The method was presented for the first time in 1994 in a version intended for procurement in industry (ENEU94). A first version intended for procurement in municipalities, county councils and private real estate companies (ENEU94K) also came out during 1995. A new, revised version that is partially web-based has been available since the autumn of 2001.

"Costing with LCC_{energy}" can be said to be a model for selection, evaluation and procurement of energy-consuming equipment where the life cycle cost (LCC) enters into the assessment of different investment alternatives and comparisons between tenders. The distinguishing characteristics of the method are:

Technical functional requirements or guidelines for technical systems and components are made that ensure the desired function and minimal environmental load.

The evaluation of different tenders is based on the life cycle cost.

Post-measurement is included to verify that the installation meets the stipulated requirements. The possibility of a performance bonus or penalty in the event the actual result is better or worse than the projected result is also described in the ENEU® concept.

"Costing with LCC_{energy}" includes Handbook, Legal Module, Guidelines for the different technical areas and Forms for the different technical areas. The components and major parts of technical systems that are dealt with are:

Air treatment system with fans and heat exchangers (refined calculation methodology)

Refrigeration and heat pump plants

Pumps

Air compressors

Motors and electronic frequency converters for speed control

Lighting for workshop premises, offices, healthcare premises, multi-family blocks and sports centres

Power transformers

Catering equipment, and in particular electric dishwashing equipment

General electric-powered equipment (conveyor belts, etc.)

The ENEU® concept has become a kind of de-facto standard in the building and property sector as well and is supported by most trade organizations in the installation area and related areas. It has become increasingly widespread in Sweden and beyond (the Nordic countries and the EU).

7.7 List of Participants

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