Life Cycle Costing as part of decision making - use of building information models

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ABSTRACT: Building Information Modelling (BIM) is a new approach for being able to describe and display the information required for design, construction and operation of buildings. More extended use of BIMs, with the development of Information Delivery Manuals (IDMs) for environmental assessments, energy calculations and LCC, ensuring more automatically data flow between different data bases, calculation tools and Building Information Models (BIM), will simplify the use of LCC in design. More extended use of LCC, and storing the results for future use may also improve the Facility Management. Several projects have dealt with cost information flow, as information exchange between the BIM and LCC-tool and improving cost data bases, simplifying the data access as well as storage possibilities to ease and extend the use of LCCA. This paper will present the current stage of the different project aiming at increased use of LCCA by use of BIM and IDMs.

1 INTRODUCTION

Building and construction projects may benefit by use of Life Cycle Cost Assessment at early stage of the design process, the results contributing to decision support taking both investment and operation costs into account. Qualitative good results demand good input data to the calculations, even at stages where few decisions are taken.

Building Information Modelling is a new approach for being able to describe and display the information required for the design, construction and operation of constructed facilities. It is able to bring together the different threads of information used in construction into a single operating environment thus reducing, and often eliminating, the need for the many different types of paper document currently in use.

Realistic LCCA, as a good basis for decision making, requires easy accessible data in all phases from brief to construction, where statistic information, key numbers and experience data is valuable information. A well defined classification system for the categorisation of costs and other input data is important for a successful use of LCCA. Increased use of LCCA at several stages in the decision process also requires increased data exchange and storage possibilities. Extended use of LCCA may improve the decision process towards more economic as well as environmental and energy efficient buildings.

More extended use of Building Information Models (BIM), with the development of Information Delivery manuals (IDMs) for environmental assessments, energy calculations and LCC, ensuring more automatically data flow between different data bases, calculation tools and Building Information Models (BIM), will simplify the use of LCC in design. More extended use of LCC, and storing the results for future input to Facility Management may also improve the Facility Management.

Easy access to comparable data gives the building owners’ possibilities to benchmark their buildings, with emphasis on energy use and operation cost. This will lead to more focus on operation of buildings, as well as improvement of energy efficiency.
Several projects have worked with improved cost information flow, as information exchange between the BIM and LCC-tool and improving cost data bases, both key number bases and cost data bases related to building parts, and further information flow from FM-information into cost data bases. Key numbers may be found from statistical treatment of collected data. For instance, energy use/energy costs per m², cleaning costs per m², or cost used for management or maintenance for different building categories (function and age). Key numbers may be used for benchmarking, as all users may compare their actual data with the collected data, and hence know how their use and management of the building is compare to others.

2 BUILDING INFORMATION MODELING

2.1 IFC, BIM, and buildingSmart

The development, maintenance, implementation and dissemination of Industry Foundation Classes, IFC and IFC enabled products is part of the buildingSMART initiative of the International Alliance for Interoperability, IAI, and its affiliated organizations and companies. “buildingSMART is integrated project working and value-based life cycle management using Building Information Modeling and IFCs.”

The purpose of IFC as part of the buildingSMART initiative is "enabling interoperability between AEC/FM software applications". It is embedded in a broader scope of achieving beneficial change in industry, using Building Information Modeling (BIM) and IFCs as the trigger to smarter ways of working. IFCs target both the software development community and the practitioners in the AEC/FM industry.

- Developing software that benefits from the international, single and interoperable schema of construction elements, specifications and structures is the task of software companies. Software developers have to understand the detailed structure, content, and processing of IFC.

- Applying interoperable and IFC compliant software within construction processes requires users that are knowledgeable about their processes, the exchange requirements within each process, and its relevance to the technical, commercial and legal side of the operation. Practitioners have to understand how to map general concepts or parts of the IFC to the detailed exchange requirements within their projects and how to assess and use IFC compliant software.

IFC and use of BIM will have great potential for cost reduction and utilize effects in the value chain at least in these areas:

- Focus on the customers and end-users requirements within the building process and life cycle phases.

- Re-engineering of the building process with new opportunities for new and existing actors.

- A comprehensive and common international knowledge model database with standardized ICT tools, objects and communication rules and available best practices examples.

- Cost reduction and better project economy in the supply chain, between the suppliers and the contractors.

- Improved possibilities for early stage analysis about: best practice design, construction cost, energy consumptions, environmental impacts and lifecycle cost.

2.2 Planning and construction process

Planning and design of buildings and constructions are phases in a process with many actors and an intensive process of sharing and/or repeating information. Figure 1 shows the information flows between the different actors in a construction process, both a traditional process and by use of Building Information Models.
When all actors have access to the same information, and the possibility to transfer information from the model to the different calculation and analysis tools, all decision making can be based on up to date analysis of the interesting aspects. More analysis may be done in an early phase of the project, while it is still possible to make changes. Analysis may also be done on different alternatives.

Life cycle costs analysis or assessment may throughout all stages be done by use of information in the BIM, information from different cost databases, and with application that is ifc compatible ensuring a seamless data transfer. Results from the analysis are then fed back to the BIM for use in other analysis, decision making or for later use in facility management in the operation phase.

3 LIFE CYCLE COSTING ASSESSMENT

3.1 Life cycle costing used in decision making

Life cycle costing assessment should benefit that the perspective of decisions is moved from investment costs to the total costs for the whole life cycle of the building or constructed work. Life cycle costing should not be used with the intention of decreasing the costs, but for ensuring the lowest cost over the life cycle when still fulfilling the performance requirements (functional and technical requirements). The assessment should also be used to show the estimated yearly costs before investments are done.

Using LCC as part of decision making requires good accessibility to reliable input data to the analysis at all stages of the planning and design process, starting with generic information (statistic, key numbers) to more and more specific information. Reliable statistic and generic information can be produced by collecting actual costs from management of buildings, using specified and standardized cost classification. The Norwegian Standard NS3454 Life cycle costs for building and civil engineering work – Principles and classification (NS, 1997) does, as also similar German and Austrian standards, give a cost classification system. The Norwegian database owned by Network for benchmarking yearly collect actual costs from their members’ buildings, then providing a database with costs to be used for benchmarking and input to LCC calculations. Table 1 shows the main categories in a proposition to a new common Nordic standard.

<table>
<thead>
<tr>
<th>No.</th>
<th>Main Item</th>
<th>Definition</th>
<th>Sub-categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Capital</td>
<td>All investments towards completion including</td>
<td>11 Project costs 19 Remaining costs</td>
</tr>
</tbody>
</table>
| 2 | Administration | Activities for administration, required payments and insurance costs | 21 Taxes and fees  
22 External costs  
23 Administration and management  
24 Insurance  
29 Various |
| --- | --- | --- | --- |
| 3 | Operation | Include daily, weekly and monthly activities that are repetitive within a one year period for building and technical installation systems that shall satisfy given functional demands and requirements | 31 Operation and inspection executed by own employees  
32 Operation and inspection executed by external companies  
37 Outdoor operation and inspection executed by own employees  
38 Outdoor operation and inspection executed by external companies  
39 Various |
| 4 | Maintenance | Include all activities and efforts put forward in a period of more than one year. For example, planned maintenance, replacement and emergency repairs, so that the building and technical systems satisfies the original level of quality and functional requirements. | 41 Periodical maintenance of exterior of the building  
42 Periodical maintenance of internal of the building  
43 Replacement of exterior  
44 Replacement of interior  
45 Emergency repair work for exterior  
46 Emergency interior repair  
49 Outdoor |
| 5 | Developing | Includes activities as a result from change in demand from core activities, the authorities, total refurbishment, or all activities to raise the construction standards in relation to the original level | 51 Development and upgrading of exterior of the building  
52 Development and upgrading of internal of the building  
59 Development and upgrading outdoor |
| 6 | Consumption | Consumption includes resources in terms of energy, water, and waste handling | 61 Energy  
62 Water and Drainage  
63 Waste Handling  
69 Various |
| 7 | Cleaning | All activities inside and outside for satisfactorily meeting cleaning demands | 71 Daily/Periodic  
72 Main cleaning  
73 Special cleaning  
74 Window cleaning  
75 Façade cleaning  
79 Outdoor cleaning |
| 8 | Service | All non-building related activities in support of the core activity | 81 Security and safety  
82 Reception/switchboard  
83 Mail  
84 IT service  
85 Moving  
86 Catering  
87 Accessories/copying  
88 Administrative support  
89 Furniture and inventories |

Life cycle costing can be presented as Net Present Values or Net Present costs, while other options are available, as Annual Cost or Annual Equivalent Value, or Payback. Definition of cost categories and calculation rules are given for example in ISO/DIS 15686-5 “Buildings and constructed assets – Service life planning. Part 5 – Life cycle costing” (ISO, 2006).

3.2 LCC in different project stages

The standard exchange requirements published in IDM are identified against project stages defined within the Generic Process Protocol (GPP) (Michail Kagioglou et al, 2000). These are
identified below with their stage number as used in the exchange requirements documents, description and definition from the GPP. Stage 10 (disposal) is a modification to the standard GPP list to handle the final stage of a project lifecycle. These are shown in Table 2

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Portfolio requirements</td>
<td>Establish the need for a project to satisfy the clients business requirement</td>
</tr>
<tr>
<td>1</td>
<td>Conception of need</td>
<td>Identify potential solutions to the need and plan for feasibility</td>
</tr>
<tr>
<td>2</td>
<td>Outline feasibility</td>
<td>Examine the feasibility of options presented in phase 1 and decide which of these should be considered for substantive feasibility</td>
</tr>
<tr>
<td>3</td>
<td>Substantive feasibility</td>
<td>Gain financial approval</td>
</tr>
<tr>
<td>4</td>
<td>Outline conceptual design</td>
<td>Identify major design elements based on the options presented</td>
</tr>
<tr>
<td>5</td>
<td>Full conceptual design</td>
<td>Conceptual design and all deliverables ready for detailed planning approval</td>
</tr>
<tr>
<td>6</td>
<td>Coordinated design (and procurement)</td>
<td>Fix all major design elements to allow the project to proceed. Gain full financial approval for the project</td>
</tr>
<tr>
<td>7</td>
<td>Production Information</td>
<td>Finalise all major deliverables and proceed to construction.</td>
</tr>
<tr>
<td>8</td>
<td>Construction</td>
<td>Produce a product that satisfies all client requirements. Handover the building as planned.</td>
</tr>
<tr>
<td>9</td>
<td>Operation and maintenance</td>
<td>Operate and maintain the product effectively and efficiently.</td>
</tr>
<tr>
<td>10</td>
<td>Disposal</td>
<td>Decommission, dismantle and dispose of the components of the project and the project itself according to environmental and health/safety rules</td>
</tr>
</tbody>
</table>

3.3 Geometric and spatial structure

A spatial project structure might define as many levels of decomposition as necessary for the building project. The costs might be added to any element. Elements within the geometric and spatial project structure are:
- site as IfcSite
- building as IfcBuilding
- storey as IfcBuildingStorey
- space as IfcSpace
- building elements as IfcBuildingElement
- components as IfcBuildingElementComponent
- products as IfcProducts

The structure from site, building, elements, components, and products is further used as cost levels.

3.4 Performance requirements

Before doing the life cycle cost assessment it is important to have the performance requirements for the facilities to study. The BIM makes it possible to start the process by having a performance requirement model, which later will be used as part of the checking systems, analyzing which requirements that are fulfilled. The performance requirement model will then be further developed and improved throughout the planning stage. The alternatives compared should always fulfill the performance requirements.
3.5 *Intangible costs – extra value*

Intangible costs is usually not included in LCC, but if possible, value might be given and used as an additional part of the decision process. There might also be given values to extra functions or performances, for instance based on experience, but these values should also only be used as an additional part of the decision process.

3.6 *Examples of LCC in different stages*

LCC in pre-project stages is used for studying the consequences of the performance requirements, before any decisions are made. In the early stage of a project, LCC forecasting may use ‘benchmark costs’ based on historical costs of previous projects. As design evolves and more detailed information becomes available, benchmarks should be substituted with first principle project-specific estimated costs. Often (but not always) life cycle costing will include a single lump sum which represents all the acquisition costs (e.g. the purchase cost) and may also take account of residual value/disposal costs. The analysis in pre-project stages are aiming at assign different alternatives, where continuing as to day may be one option.

One example is increasing school capacity, where the alternatives may be as follows:
- Continuing as today – some pupils sent to other schools
- Extension of existing school, with or without refurbishment of existing building
- New school in addition to existing school – different location
- New school with higher capacity instead of existing building

Comparing the different alternatives it is important to include differences in costs for running the core business (school), not only the building related costs. This may be included in category 8 costs. Table 3 shows examples of sources for information at this stage, number of m2 may be statistic information based on number of pupils. At this stage the comparison is on main alternatives, not design, construction, or installations. The main cost differences may be in category 8, the decision at this stage might not be building related, but taking into account the differences in costs for the core business. Almost all costs are statistic or historic information, updated for extra m2. All costs as on building or site level.

<table>
<thead>
<tr>
<th>Cat.</th>
<th>Alt 0</th>
<th>Alt 1a – 1b, 2, 3, and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No investments</td>
<td>Generic information – investment costs pr m2 for new buildings and refurbishment</td>
</tr>
<tr>
<td>2</td>
<td>Existing costs</td>
<td>Existing costs – corrected for number of m2 or key number for costs per m2 or per pupil</td>
</tr>
<tr>
<td>3</td>
<td>Existing costs – higher costs in future?</td>
<td>Key number for school buildings, per m2, for building from same time period – and new buildings</td>
</tr>
<tr>
<td>4</td>
<td>Existing costs – higher costs in future?</td>
<td>Key number for school buildings, per m2, for building from same time period and main materials – and new buildings</td>
</tr>
<tr>
<td>5</td>
<td>No costs</td>
<td>Upgrading of existing building – key numbers for upgrading buildings from the same period</td>
</tr>
<tr>
<td>6</td>
<td>Existing costs</td>
<td>Existing costs and key numbers, energy use as in regulations</td>
</tr>
<tr>
<td>7</td>
<td>Existing costs</td>
<td>Key number for school buildings, per m2, for building from same time period and main materials – and new buildings</td>
</tr>
<tr>
<td>8</td>
<td>Existing costs</td>
<td>Existing costs</td>
</tr>
<tr>
<td></td>
<td>Transport costs pupils to other schools</td>
<td>Changes in use of staff compared to Alt 0, need for more teachers, need for more administrative staff if 2 schools etc.</td>
</tr>
<tr>
<td></td>
<td>Costs for pupils at other schools</td>
<td></td>
</tr>
</tbody>
</table>

The calculated life cycle costs are used for choosing alternative – more than one if more detailed comparison is necessary to decide – and to get financial approval. If the costs for all alternatives are too high, this is also the stage for redefining the requirements.

As alternatives it is possible to add extra requirements to the alternatives, for instance a swimming pool. Results from alternatives with or without swimming pool should then not be
directly compared, but results used for deciding whether the value of the gain swimming pool exceeds the costs.

### 3.7 Life cycle costing in conceptual and design stage

With a database for facility management costs from existing buildings, where building information as age, main construction systems and materials, types of ventilation etc are given, statistic cost information can be tagged with those technical and functional descriptions.

When comparing different designs and technical installations, where the performance requirements always are fulfilled, many calculations still can be based on statistic information. Cost information might still be used as input on building levels, adding some specific information on system or building part level. Examples of relevant input costs, sources and level where they are to be used are shown in Table 4.

Table 4 Examples of relevant costs and level to be used in LCC in design stage

<table>
<thead>
<tr>
<th>Cost category</th>
<th>Site/building</th>
<th>Room</th>
<th>Element</th>
<th>Component</th>
<th>Product (usually not selected at this stage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>Investments aggregated from element. Demolition costs</td>
<td>X</td>
<td>Cost data bases</td>
<td>(X) Cost data bases</td>
<td>Cost data bases</td>
</tr>
<tr>
<td>Administration</td>
<td>X</td>
<td>Key numbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>X</td>
<td>Key numbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>Key numbers, &quot;corrected&quot; for statistic information from certain systems and installations</td>
<td>X</td>
<td>Statistic information/experience</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>Developing</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>X</td>
<td>Regulations or energy calculations for different designs</td>
<td>(X) Separate calculation for certain rooms/functions?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning</td>
<td>X</td>
<td>aggregated from room, key numbers</td>
<td>(X) Key numbers or experience for different levels of cleanliness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Information about elements, areas, numbers, etc will at this stage be extracted from the design model(s). As the table shows, statistic information on building level, where tagged information is used, will be sufficient for LCC at early stage, comparing different main alternatives. The LCC calculations will then also give for instance total and annual cost for the whole building life cycle.
Further in the design stage, as more and more information can be linked to elements, components and products, mainly investments and maintenance.

4 CONCLUSION

Using BIMs, from performance requirement models to design models, and different ifc compatible cost data bases, LCC calculations will be more useable as input data will be available and can be automatically transferred between the model, databases and applications. LCC can be done at every stage, and hence be a part of the decision making process early in the design process.

REFERENCES