LifeCycle Benchmarking – Methods and tools for Operation, Maintenance and planning sustainable buildings

Extended Abstract

FORSCHUNGSINITIATIVE ZukunftBAU 2013
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INTRODUCTION

The Building lifecycle approach is a new paradigm in design and construction. But this approach exists until today predominantly in theory, is not yet completely elaborated – and simply unknown in normal practice. It is actually not yet established in the usual work of architects and engineers.
The management of sustainability in building and operating needs new methods and tools for planning, the construction process and the process of monitoring in the first years of operating. For this purpose methods and tools have been developed in an ongoing research.
Source: H. Balck - "Lifecycle Benchmarking", in 2013 finished German research project of Forschungsinitiative ZukunftBAU - Research partner are Fraport, AUDI, Universitätsklinikum Freiburg)

CORE PROBLEMS OF THE BUILDING LIFECYCLE APPROACH

Building design and the building process passes a paradigm shift – from the traditional standard, realizing works of craft and industry "free from defects" - to a long-term responsibility in sustainability. A result is a prolonged time horizon – from years to decades. A methodical consequence is the focus on the lifetime of those objects, which constitute buildings: parts as subsystems, technical equipments and components. This focus is connected with extended planning contents, as physical lifecycles of materials and market related lifecycles of products and of course with improvements of construction and design due to climate change. In this context cycles of renovation and recycling have to be analyzed. But this well known demand in public discussion is nevertheless very often ignored in normal planning. To reach a practiced normality in the lifecycle approach, obviously it will take more than a quick change. On the way of transforming market-patterns some fundamental problems have to be solved:

Core-Problem 1 – unpredictable cost in long term horizons

The demand to add on costs along all phases of lifecycles evokes a problem of inconsistence between estimating costs of investments and estimating follow-up-costs. Investment costs are only predictable with high uncertainty in the early phases and less uncertainty at the end of planning. Follow-up-costs are predictable to some extent in a range of years, but hardly in a range of decades. The problem even escalates – unavoidable in the lifecycle approach – when estimating costs of investments in the early design phase have to be matched with corresponding follow-up-costs. This potentiated uncertainty of estimations of lifecycle costs can be indeed reduced at the end of planning within tendering and contracting – but will remain in a considerable degree. Investments are definite at the end of projects. But follow-up-costs in the whole lifecycle nobody knows for certain in the following decades of operation, maintenance and renovations. This uncertainty-problem is in principle unsolvable – and in best case only reducible. This is a methodological consequence of the extension of time horizons in lifetimes of constructions, technical equipments and components.

Core-Problem 2 – Established procedures of purchase resist the lifecycle approach

The central point of redefinition the planning process in lifecycle modalities is procurement. Planners and owners have to decide which industrial products may fit to the requirements of sustainability. But actually many data, needed for decision-making, are missing. Especially lifecycle benchmarks in the ecological, economical and technical aspects are rare. Complicating are traditional market patterns. The experience of the author in the last years within competition and tender procedures has shown that manufacturers and bidders are overtaxed in lifecycle methods. The lifecycle approach of procurement is no longer – as in the usual standard - fixed only on prices. The new focus is a combination of prices and predicted costs of operating, maintenance und renewal. Furthermore, qualities of sustainability need to be included. But this extension of contents of planning cannot be matched within the traditional procedures of procurement. Today typical market actors have not the knowledge about lifecycle related product information. Therefore the basics of decision-making have to get much wider as before. Lifecycle cost and lifecycle qualities are now and in future criterias of sustainability – and will determine all phases of planning, especially the early design process.

Within the markets a border has to be crossed: The traditional separation between purchasing construction works and purchasing services has to be redefined. Necessary is their combination. In other words: The choice of products in building projects have to be connected with the purchasing of those follow-up-services, which are related to properties of these products, such as operating, maintenance and renewals. For example the choice of an automatic door system should be proved in both aspects: price / quality of door systems and price / quality of facility-services for the selected door products.

Core-Problem 3 – buildings as configurations of products

Buildings are not only the result of the design process of architects and engineers – and not only formed out of material. Buildings of our time have generally to be seen as systems - composed of elements. Buildings are configurations of building parts and products. To realize sustainable buildings the selection of efficient products must be ruled by critical factors, for example:

- Follow-up-costs depending on the characteristics of products (e. g. cleaning, maintenance, reliability)
- Emissions in the environment, as emissions of CO_2 during operating times
- Follow-up-costs of building parts and products at the end of their lifetime

These aspects are well known topics in building research. But generally unnoticed is the difference between products with high follow-up-costs and products with less or no follow-up-costs. Especially products and systems of building services generate high follow-up-costs for maintenance and energy supply. In contrast components of constructions, like walls and ceilings can be used under normal conditions without considerable operating costs. Those differences between construction products and technical products are of high interest in the range of relevance concerning sustainability.

Redefining the classical goal system – goals for lifecycle

The organizational introduction of Facility Management – since the early 90ties in Germany – opens a new approach to planning and project management. The progress in the development and use of FM-software (CAFM) opens new ways for the analysis of data in using, operating, maintenance and energy supply – with feedbacks to planning. The impact of facilities information in the planning of new buildings or in refurbishment projects has redefined the classical goal system for projects: The magic triangle of "cost – quality – time" was doubled (figure 1).

- The analysis and the forecast of costs has been divided into costs of investment and follow-up costs – combined to Life Cycle Costs
- The definition of quality has divided into the definition of qualities, checked at the end of a project and long-term qualities, checked during the process of use and operating (qualities of sustainability) – combined as lifecycle qualities
- In addition to the time goal "completion" further time aspects are widening the context, as warranty periods, servicelevel and availability

Lifecycle-oriented goal system in construction projects

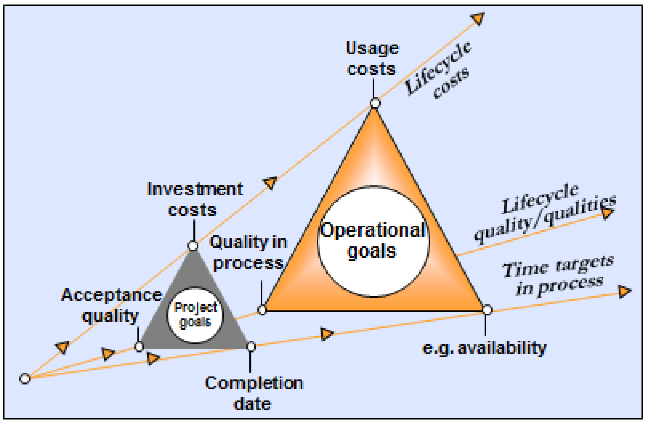

Figure 1 - The magic triangle "cost – quality – time" is doubled in the lifecycle approach © H.Balck

Rising complexity of planning and Management

Traditional projects goals of investments are reached as "spot landings". The duplication of the goal system brings with it an extension of planning contents in all levels of the building object hierarchy. But the resulting rise of planning-complexity can be reduced by distinguishing "strategic cost groups" and "non-strategic cost groups" – corresponding to "strategic components" and "non-strategic components" – with needs and rules for data mining:

- Building parts and components of buildings with high-relevance to sustainability can be identified by benchmarks. But to use them efficiently specific software with LCC-modules is needed in the organization of operation and maintenance, with possibilities of analysis and research. Actually our research teams are working on IT-specifications, because existing CAFM-Tools are inadequate
- Selection and design of constructions and technical concepts and selections of building components cannot simply be done in the lifecycle approach. The question is, how to concentrate on those building parts and components, which have the highest impacts in sustainability, especially in climate change.

These conditions of data mining need organizational integration of project-competence (owners, planners) and operational competence (Facility Management). But that means an organizational change. A way to manage the process of organizational integration is knowledge management, following the value chain of building and construction. It starts with the analysis and evaluation of products and systems along different branches and lines of products. The next step of knowledge management is the dialogue between investors, planners within project management. The third step of knowledge management takes place between operators / experts of maintenance and architects / engineers

LifeCycle Benchmarking is focused on “Strategic components”

Strategic components can be found out, when DIN 276 cost positions are related to corresponding follow-up-costs at least on the 4^{th}, better on the 5^{th} or 6^{th} level. These levels are not applied in DIN 276 and have to be defined additional, specific to the regarded buildings. The systematic comparison shows a significant range between components which causes high, middle or low costs of energy consumption, operation, maintenance or cleaning and the like. Components with a great effect on these follow-up-costs, we call “Strategic components”. In our research we have analyzed as well existing buildings and design concepts. Throughout we have found the same characteristic: Summed up investment costs of Strategic Components often have a part about 20 % of total sum of investment - and this part of investment caused about 80% of all follow-up-costs. These combined inverse Pareto-spreads (20-80 distribution) are an actual result of our studies. It is actually a hypothesis an has to be proved. Our next research task is to find out boundary conditions in which Pareto-spreads can be generalized.

LCC-Factors

We define LCC-factors as proportion of investment costs and follow-up-costs of the same object within a definite calculation period. Regarded objects are parts of buildings, especially technical equipments and strategic components. The LCC screening of a building by DIN 276 cost positions has a surprising result: within a calculation period of thirty years a small quantity of building components, such as flooring products, lamps, pumps, fans have LCC-factors up to 20 – that is to say the 20-fold of the original costs of purchasing. In contrast large quantities of construction components, such as external and internal walls, ceilings, roofs, have LCC-factors about 0 to 2 in the same calculation period of thirty years. So 20 % of the total investment includes parts with high LCC-factors and about 80 % of the investment includes parts with low LCC-factors. LCC-factors are the methodological core of LifeCycle Benchmarking. They shed light on spectra of cost-elements with dual cost-information: Investment cost and follow up cost of each element. Buildings – existing or designed - can completely be decomposed in such elements – and can be composed inversely. In our research we considered the EU Ökodesign regulation for energy using products (EuP) / energy related products (ErP). Those products are generally strategic components, which can evaluated by LCC-factors. Some EuP products we compared have very different LCC-factors concerning energy consumption or maintenance. Of greatest interest are products which combine highest rates in energy and maintenance costs (figure 2) – for example lamps, pumps, fans.

Focused on single plants / equipments

LCC-factor p.a.

$$\text{Lifecycle cost factor} = \frac{\text{Follow-up costs}}{\text{Investment costs}}$$

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Figure 2 – Definition of the Life Cycle Cost factor - © Prof. H. Balck

With LCC-factors a new way of benchmarking is constituted. Different from classical FM-Benchmarking, in which follow-up-costs are related to areas (BGF/ NGF), in LCC-factors follow-up-costs are related to the original investment costs. For all cost groups of DIN 276 and down to the hierarchy levels of components (5th – 6th level of DIN 276) LCC-factors can be used to give a forecast of follow-up costs regarding the whole structure of investment costs (Figure 2) is an example of LCC-driven forecasts. The calculations are divided in 10-years-steps. The figure shows that die percentage of the costs in each step are changing. Original low-cost-groups of the investment are shrinking (construction) and others get larger (technical systems).

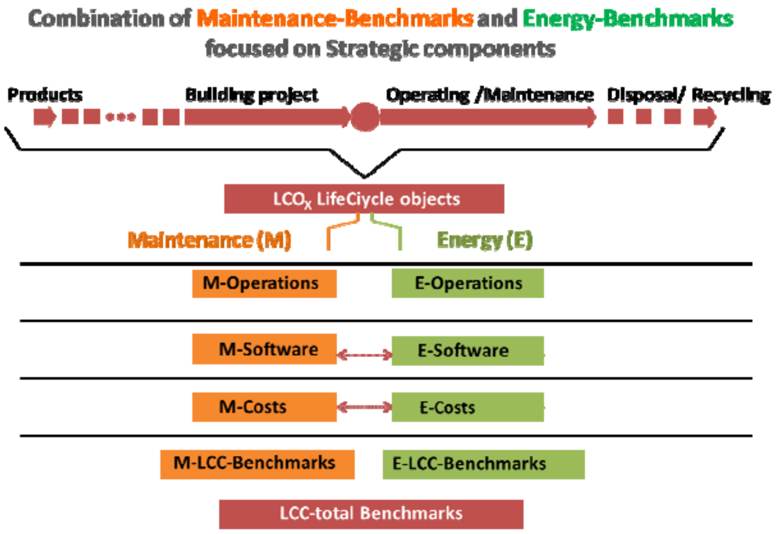

Figure 3 – Combining Benchmarks of maintenance cost and energy cost - © Prof. H. Balck

We use such patterns in early project phases to identify systems and components with high relevance in the optimization of lifecycle costs and for decision-making to select products in the phase of purchasing. The research results of the lifecycle benchmarking have made it possible to give a ranking of LCC-relevance of all typical cost groups corresponding to DIN 276. Figure 4 shows that in the Fraport ranking of maintenance cost the major group is air conditioning (430), followed by electric power supply, including lighting (440), IT and telecommunications (450) and so on.

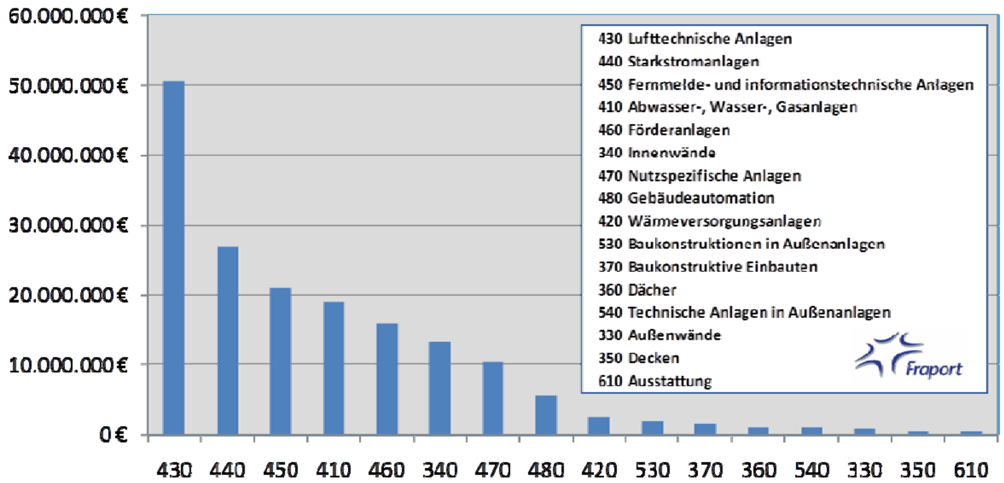

Figure 4 - Fraport ranking of maintenance cost (Total cost 3 years) © Fraport 2011

Symmetry of Project Controlling and Facility Controlling - Relevance-factors

LifeCycle Benchmarks focused on technical equipment and components establish an interaction between Project controlling (within the process of investment) and Facility controlling (within the process of operating and maintenance). In a mental experiment real costs of maintenance in Fraport buildings are compared with corresponding costs of a reference investment (High Tech Office building comparable to Fraport).The costs of maintenance in figure 4 are structured in DIN 276 cost groups. The same spectrum of cost groups we have analyzed in the reference office building – and compared the proportions between investment costs and maintenance costs. The results are of course very rough and preliminary. Air conditioning equipment requires year by year for all Fraport buildings about 30 % of all maintenance costs. In the reference object the corresponding investment-proportion is only about 5 %. The maintenance of air conditioning equipment costs in this relation about the 10-fold of the original investment costs (in this factor the energy costs are not yet included !). This kind of factors we call “Relevance factor of maintenance”. For elevators and escalators such relevance-factors are about 5. The relevance factor of external walls and facades is < 0, 1 (!).

Reasons for this fundamental difference are the very different characteristics of components in technical equipment and in construction. Components of construction have a long lifetime and very little consumption of resources during the process of use. So there is not much need for maintenance. Components of air conditioning / ventilation have half the lifetime and needs intensive maintenance – and are highly suited for optimizing (figure 5).

In Reengineering-projects our teams have optimized running air conditioning systems mostly with low-investment-measures. The obtained knowledge we use as well in planning – especially to avoid oversizing – with advantages for owners, users and operators: dual cost savings (Investment cost plus Follow-up-costs) and good achievement of user demands.

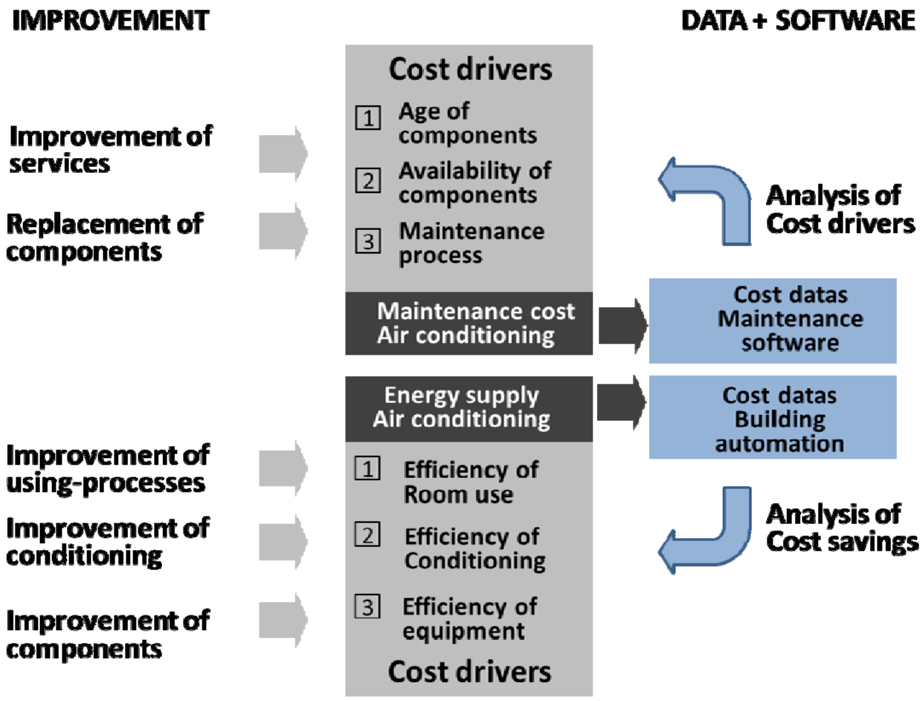

Figure 5 – Potential of optimizing of cost savings in air conditioning systems © Prof. H. Balck

Main consequences of using LifeCycle Benchmarking

When strategic components with extraordinary high follow-up-costs are identified, in general substitutes can be found, which often require additional investment costs and little payback periods. The methods of LifeCycle Benchmarking opens up abilities in planning and management to realize increasing cost efficiency – as well in all phases of building projects and all follow up phases of use and operating - with a sustain impact on ecological demands.

But all actors of Sustainable Building are involved in a high risk time competition. Obviously it will take a long time to establish the paradigm of sustainability – and meanwhile climate change is accelerating.