COMPREHENSIVE AND SCALEABLE METHOD FOR LCA-, COST- AND ENERGY CALCULATION.

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Introduction

Research on energy and environmental performance optimisation as well as basic research on design optimisation has shown the complex nature of the design process with incomplete knowledge, a multitude of iterations and a great number of involved actors [PAP93]. Taking into consideration sustainability objectives and the life cycle of buildings adds supplementary degrees of complexity to the design process. Existing LCA methods do not support the design process efficiently for several reasons: They generally are stand alone solutions which do not share the data with other design tools like CAAD systems. For this reason they cannot establish interactive relations showing e.g. the interdependence of energy consumption and cost. Furthermore these methods are generally adapted for one specific design situation; in most cases they are therefore either too detailed or too general. To cope with the changing degree of differentiation, different methods are used successively from checklist type tools through energy balance calculation to labels for specification. The results are a disproportional effort of repeated data input and an inconsistent framework of functional units, target values etc.

Basic requirements for LCA methods supporting the design, construction and management of buildings

The basic framework of the method should cover

- all life cycle phases (from design brief to facility management and deconstruction) ,
- the most important performance criteria like resource consumption (energy, costs,materials), impacts (on the ecosystem, on human health) and comfort .

The data should be retrieved either from a database or directly from other design tools (CAAD, element catalogues etc.). The functional units (reference units) should be adapted and adaptable to the different life cycle phases. It should be clear if data are hypotheses, design values, experience values, measured values etc.

The LCA methods should support a constraint based type of optimisation. Simple optimisation functions (like linear programming), multicriteria decision methods, rule- or case-based approaches do not allow to take into consideration the complexity and the scope of the design task. For this reason design optimisation research has moved to assisting methods with a high degree of interaction using extensive visual control. These methods try to assist comprehensive design teams in different situations, storing and retrieving simultaneously design step, contextual data and the relevant performance s.

All LCA methods more or less explicitly relate material causes (mass flows from the biosphere to the antroposphere) to effects on the ecosystem or on human health. Even if the existing physical energy and massflow approaches do not yet model all process in sufficient depth, there is no alternative to this general, system-ecological approach. The main issues are to decide where the best trade offs are and how reliable the results are as a basis for design and management decisions. There can be no doubt that all future LCA methods will be based on physical energy-massflow basis. The available computing and storage power allows to model the upstream, downstream and the building specific process in a detailed way even if only a small part of the possible results are used in the design process. The principal data issue is not LCA calculation but the description of the building. In the present professional practice (and design teaching) the geometric presentation of buildings through two-dimensional plans and sections and increasingly three-dimensional CAD models are still dominant. These representations are well suited for presentations to clients and to a lesser degree as production information. They do not allow any conceptual relation both with technical or simulation data and with historic or social context information [HAS00]. It is therefore difficult to bridge the gap between multidisciplinary scientific research and architectural practice as long as the geometric models did not have any relation to the knowledge based semantic representations of building product models.

The ongoing digitalisation of the design, management and production process and the international division of labour need some type of general, common, machine readable description of manufactured objects. The problem cannot be solved by the addition of interfaces between different applications. A product model is the attempt to model all information concerning the life cycle of a product. A product data model structures the different geometrical and semantic information and allows specific users determined presentations (views). [BJÖ92],

Efficient LCA tools which support the design, construction and management of buildings must be based on a generic framework which combines a state of the art modelling of physical mass and energy flows with a building description based on a product model which covers the life cycle of a building. This allows to continuously link the different performance aspects on a basic simulation level and to present automatically appropriated, phase- and actorspecific views. The specification of a life cycle oriented building product model [KOH97] and its implementation in software tools has been described in another contribution on the German LEGOE system. The structural components of this tool are

- a database with element and process specifications and reference buildings
- different simulation tools (energy, life cycle analysis, comfort, costs calculation, scheduling etc.)
- a tool which stores the data of a specific design stage from simulation, from the CADD system, from databases etc. The tool can retrieve a multitude of specific views from the basic data.

The two principal characteristics of this method are scalability and the modelling of default values.

Scalability

Research in the field of energy simulation and to a certain degree cost planning has shown that in the design process the same questions are asked several times during the advancement of a project, but that the level of accuracy and the granularity change. Furthermore, additional specialists enter the design process later on. One of the problems is that for each stage (and specialist), new conceptual models (and their corresponding software) are used. These models have different assumptions, different system limits and different mathematical resolution techniques. One way to overcome this dilemma is to use scaleable methods where the same complex model is used from the very beginning of the design process. Very few inputs are open in the beginning, most of them being occupied by default values (average values). When the process advances and new evidence or new specialists appear in the design process, the default values are gradually replaced by resulting design or dimension values. At the end the measured values can be used allowing improvement of the model for further applications [KOH97].

The basic idea is that the common model for the life cycle of building can only be the "building as built". The "building as built" is the starting point of the life time of a building and of its induced mass, energy, work and monetary flows. All planning steps, which precede the "building as built" can be considered as a temporarily uncompleted building or as not yet instantiated structure. The design process reveals the building (it discovers and fills the underlying structure). The questions of functional units is crucial because as long as a functional unit has not been given a specific value through a planning decision, it must take a default value, which can be the average value of similar buildings. This allows to produce a large number of simulations of possible design outcomes, which are of course not exact, but which are plausible.

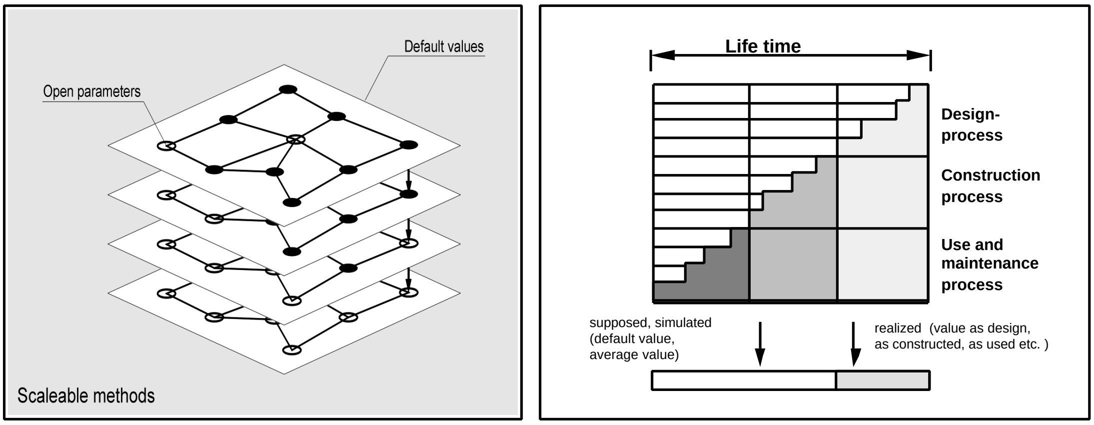

Fig. 1: Scalable methods in design

The basic assumption of this approach is that buildings of a certain function (housing, office buildings, hospitals, factory etc.) are much more similar than we generally think. Their cost and environmental impacts during their life time can already be determined during the design brief and through performance specification by associating performances and functional units. It also implies that simulation techniques can be used very extensively to verify if the performance targets are reached during the ongoing planning phase. The impacts of the building during the life cycle phases after construction (building as maintained, refurbished and demolished) can be simulated the same way, taking into account the upstream and the downstream processes. If we consider the "building as built" as the central representation, then the planning and use process of a building can be considered as the gradual replacement of average or default values by actually realised values. In the beginning a building is therefore described by 99 % of average (default) values and 1 % really planned (realised) values. This principle can be applied through the use of different (common) functional units. The advantage is that the whole building is considered and nothing is forgotten. It is therefore possible to represent buildings as combinations of planned and not planned parts, of realised and supposed parts, of real and virtual parts, of past, present and future parts.

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