LEGOE – A COMPLEX DESIGN AND VALUATION TOOL

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INTRODUCTION

The design world of architects and engineers is changing. In addition to the still dominant investment orientation, costs arising during the whole life cycle of the building are being taken into account as well as ecological and technical requests for objects produced from building products. Therefore there is a high demand for complex tools to support design decisions. They must guarantee that previous evaluation criteria, like function, form, and economy are met and not negated by environmental and health protection aspects.
The goal of the German LEGOE project was the integration of an ecological evaluation into normal work routines and tools (CAD, specification and quantity surveying) used by architects and engineers. This integration has taken the form of complex integrated design and construction tools. In addition to usual building cost rates and performance certifications, the designers will be provided with additional information about economic data (investment and running costs), ecological data (resource consumption and environmental impact), energetic data (observance of national laws and ordinances) and health data (comfort) during the design process which will allow a direct feedback.
Unlike in conventional design tools, the whole life cycle of a planned construction ought to be represented. The usual work flow in building design will be maintained to keep the adaptation difficulties to additional problems as low as possible.

STRUCTURE AND PROCEDURE

Basic data on energy, transportation, materials, and waste elimination

The life cycle analysis of energy and mass flows of building products, building parts and buildings as a whole requires data about resource consumption and the environmental impact resulting from the preparation of final energy, transportation services, the extraction and production of materials and waste elimination. The data for the life cycle inventory and life cycle impact of building products are obtained by recording the process chains and not simply by taking data from literature. This allows for a standardisation of assumptions and a regular update of the data. In the framework of LEGOE, basic data of the Öko-Institut Darmstadt (GEMIS) [GEM95] as well as that of the ETH Zurich (ECOINVENT) [FRI95] are used.

Database for ecological and technical qualities of building products

Ecological data for building products (building materials as well as building parts, composite building parts and manufactured components) are provided for the level of life cycle inventory analysis and life cycle impact analysis. These are calculated by using uniform basic data stored in a DBMS. Since the linking of the process steps is maintained within the DBMS, an update of the data stock (due to changes in the process chains) is possible. The system limit of the data acquisition is the finished building product at the production site corresponding to the approach "from cradle to gate". Building products carry information, which can only be realistically evaluated in the final context of the building on its site. There is no continuous evaluation of the life ("from cradle to grave") on the level of building products.

Evaluation procedures of environmental impact

LEGOE is not limited to one particular evaluation method. It allows the possibility to choose between several methods. The module "evaluation procedures and evaluation data" consists of a selection of known evaluation procedures including the required basic data. Basic evaluation data are method-specific evaluation factors for single elements of life cycle inventories as well as weighting factors of aggregation methods. At present the following evaluation possibilities are available:

- mass flow

- primary energy consumption
- effect-oriented impact categories
- full aggregation (eco-indicator).

Energy prices are managed separately to allow different present and future economic evaluation methods.

Building elements and building specifications

LEGOE uses a catalogue of building elements whose attributes contain all necessary life cycle specific information. This is the basis for the analysis of the economic and ecological consequences of certain design decisions building over the entire life cycle of the building. In current practice building elements describe material and constructive solutions. They allow the estimation of the building costs and the plausibility of a solution already in early design stages. The life cycle evaluation is made possible by the introduction of energy and mass flow data, impact categories, health aspects and life cycle scenarios. Usual data like technical information and cost rates are maintained.
The building elements of this catalogue are composed of building process specifications. On the level of the building process specifications, it is possible to identify the single material processes needed and to describe them by the necessary quantities of materials used (including all auxiliary materials and waste) and of tools and machines used (including their energy consumption and their maintenance). Since the building process specifications are assigned to building elements, the basic quantities can be calculated for the building elements and then linked to the evaluation data. [BAR95]
In order to reflect the life cycle of a building element, additional information is needed about the life expectancy, maintenance and cleaning cycles, energy consumption during use, recycling behaviour and appropriate elimination paths. Through this method, the traditional construction elements for building parts and technical equipment are complemented by cleaning, maintenance and refurbishment elements with their specific set of evaluation data

Building description

The attributes of the building element catalogue can be used to describe buildings composed of building elements. However, this description is not sufficient for certain life cycle calculations. They need topological information and neighbourhood relationships which cannot be derived from the element catalogue attributes. LEGOE is based on a CAAD system using a building model which serves as an input module which is able to store, to manage and to interpret geometrical and semantic building information. The user can associate elements of the catalogue to the elements of the design in the CAAD system. By this procedure, all building element-specific data of the catalogue are available and can be used in combination with data at building level. In the case of topologically independent criteria, the quantities of different building elements and classes of elements of the design are immediately available and can be transferred into the project-specific database (PDB). The building specific topological data are used as input for calculation methods which require attribute values of the building elements as well as data derivable only from the spatial and space enclosing structures of the building. The interpretation programs use a combination of building-specific and element-specific data.

Scenarios and rules of calculation

The resource consumption and resulting environmental pollution due to the production of materials and the construction process can be considered as an accomplished process which is "reviewed". The appreciation of the life cycle can only take the form of a simulation of use, maintenance, refurbishment and waste elimination cycles. It is a "forecast" using scenarios and assumptions concerning the future.
Within LEGOE, a set of scenarios is available for the user. In addition, specific assumptions can be formulated. In modelling the assumed life cycle, the following criteria must be established: utilisation including a standard-use-scenario, considered time period, trends in cost development, levels of equipment, cycles of cleaning and maintenance, cycles of refurbishment and waste elimination.
In order to determine the energy and mass flow due to utilisation, life cycle inventory analysis and life cycle impact analysis is necessary, corresponding to the evaluation of the construction phases. It is necessary to provide rules of calculation for the determination of the present consumption of heating, lighting, air conditioning as well as service and maintenance. Whereas the determination of the running energy consumption of room heating and hot water can be performed according to national standards or internationally acknowledged methods of calculation, new procedures had to be found for service, maintenance,

and the use of auxiliary energy.

Building simulation

Specific calculation programs are developed or extended to simulate the life cycle of a building with regard to costs, energy, comfort and environmental impact. The life cycle calculations require the mentioned specific description of a building related to rules of calculation and pre-configured scenarios. The calculation programs require this description of the building, extracted from the building model of the CAAD system, as well as the data from the building element catalogue as input data. For each calculation program, the required data are prepared from the building model data and stored in the central data repository PDB. The element-specific data are available for each calculation program through the specific labelling of the building elements.
In detail, the following calculations depending on the chosen scenarios for the life cycle phases of new construction, utilisation, refurbishment and demolition are executed:

- costs according to DIN 276 (investment costs) and DIN 18960 (use costs)
- ecological indicators (mass flow, primary energy consumption, effect-oriented impact categories, etc.)
- heating energy according to different, partially standardised methods of calculation
- energy consumptions for room heating and hot-water
- electric energy consumption
- water consumption

The data generated by the different calculation programs are stored in the PDB and are available to the other modules.

Room simulation

The ecological construction approach (estimation and evaluation of energy and mass flow during the lifetime) is completed by an assessment of the comfort conditions of the users. The estimation of the energy and mass flow can be done for the building as a whole. The assessment of the thermal comfort or, for example, the room acoustics can only be realised for specific rooms. In the present version of LEGOE, the thermal comfort in winter is evaluated on the basis of the average value of the internal temperatures and the temperatures of the bounding surfaces. The evaluation of the summer comfort condition is realised by calculating the probable number of days of utilisation with undesirable high internal temperatures. The evaluation of the acoustical qualities of rooms is based on the reverberation-time T60.

Evaluation and interpretation

For evaluation, interpretation and, if necessary, modification, a comparison of calculated data and target values is performed. The different modules offer the possibility to define target in the form of legally fixed values as well as values taken on reference by literature, and to compare them visually to the calculated results. In order to create an overview of the calculated data, another module serves exclusively to produce the graphical representation of a subset of these data. This subset includes all aspects (costs, heat requirements, energy requirements, water consumption and ecological indicators) during the entire life cycle of the building.

Production of documents

One task in the design process is the preparation of documents for communication or authorisation (forms, certificates, etc.). Such documents are still frequently prepared manually or in some automatic way not connected to a building model (stand alone solutions).
The approach of LEGOE incorporates the coupling of the production of documents like object descriptions, evaluation of resource consumption and the resulting environmental pollution and energy certificate into the evaluation and interpretation. Based on a central object and data administration, information can be generated, evaluated and assigned to the necessary documents afterwards. In this respect, the documents can be generated by the planner during the design process "just in time". The achievement of pre-determined target values can not only be checked with LEGOE, but also be fully documented for the relevant phase of decision making.

CONCLUSIONS

In the R&D project LEGOE, the calculation of costs, energy requirements and ecological evaluation is integrated into the design process. The entire life cycle of a planned building is taken into consideration.
The extension and development of design tools is based on their integration in the current cost breakdown of the DIN 276 standard and on related current design practice. This is the reason why it was possible to develop relatively rapidly these new tools and to have a good chance in their professional acceptance. A first complete application of the LEGOE concept based on the catalogue of building elements and integrated tools for selection of building elements, calculation and interpretation of costs, energy and LCA without using a CAAD system will be developed this year.

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