

Integrated Support Systems for Architectural Design

Sevil Sariyildiz and Mathias Schwenck

Delft University of Technology
Faculty of Architecture
Section Building Technology
Chair "Technical Design & Computer Science"
Delft
The Netherlands

ABSTRACT

Many software systems are used in the field of architectural design. On the other hand, we can state that there is a significant lack of integrated systems providing a general support for the designer during the whole design process from initiative till demolition. This research project deals with the development of such an integrated design support system.

We consider a complete automation of architectural design as an unlikely proposition and undesirable for the architect. Therefore, the general objective is to give support to the architect to improve the quality and to increase the efficiency of the design process. So far there are different tools providing such functionality. Nevertheless, there are no appropriate tools for many of the sub-processes. Furthermore, the current state of available design software is characterised by a lack of integration of different tools. To overcome these two problems our research project involves the development of tools as well as it deals with the aspect of tool integration.

We will give a general description of the support that software can offer to architects during the materialisation phase of design. We conclude that many different tools are needed which have to be integrated in an open, modular, distributed, user friendly and efficient environment.

1 THE ARCHITECTURAL DESIGN PROCESS

The design process in the field of architecture can be divided into two main steps - conceptual design and materialisation.

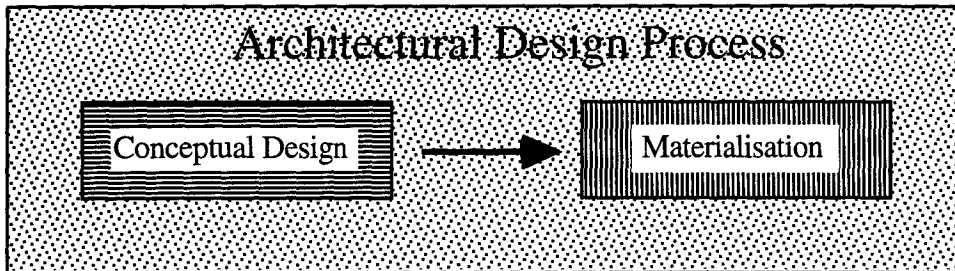


Figure 1: The Two Phases of the Architectural Design Process

We also took the following aspects into consideration in order to understand the process completely:

- the characteristic features of architectural design
- the position of the design stage in the whole building process.

1.1 Architecture and Architectural Design

Architecture is a science which is a mixture of an exact science and the art. The combination of these two important items makes architecture a difficult task. Difficult here does not indicate the task itself but the responsibility of an architect. An architect has to combine these both primary elements in the design and at the same time while

expressing the feeling of art, must take very good care of many other factors which play an important role in the building and design environment. The technical aspects on one hand, the social aspects on the other hand.

The general goal for the architect (in the eyes of some others perhaps) is to preconceive a building that fits with the needs of the programme. This programme originally is expressed in terms of functions and will be formulated in terms of space, connections and relations. Only in a next step this formulation will be materialised.

That is the reason why nearly each building engineer has the pretension he can do this at least (supported by his analytical brain !) as good as the architect.

But the architect is chosen, not because he is the only one who can realise this preconception of a building, but specially and only for the qualities he is supposed to add to the realisation of the programme : the qualities of form and space(s) - figure 2.

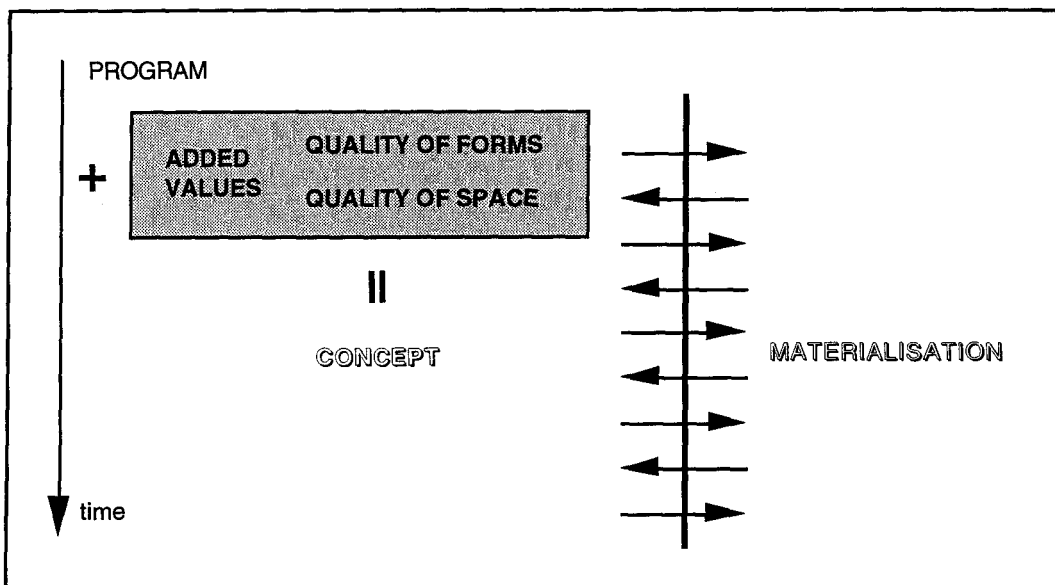


Figure 2: The Architectural Design Process

The preconceived building has a lot in common with the future reality. The preconceived building has the same geometry and the same morphology as the future reality ; both make it possible that sciences understand the plans of an architect, can imagine the reality aided by their senses. But senses cannot realise the perception of the totality, because senses cannot make a perception of the qualities. Qualities are not visible. Qualities only exist in man's consciousness.

As the architects role is to give qualities, it's normal that he will try to give information about these qualities, he will simulate them.

1.2 Architectural Design as a Part of the Whole Building Process

An analysis of the architectural design process has to deal with the position of architectural design within the whole building process from initiative till demolition. Architectural design has many relations with earlier and later phases of the building process.

Figure 3 following on the next page illustrates the life cycle of a building:

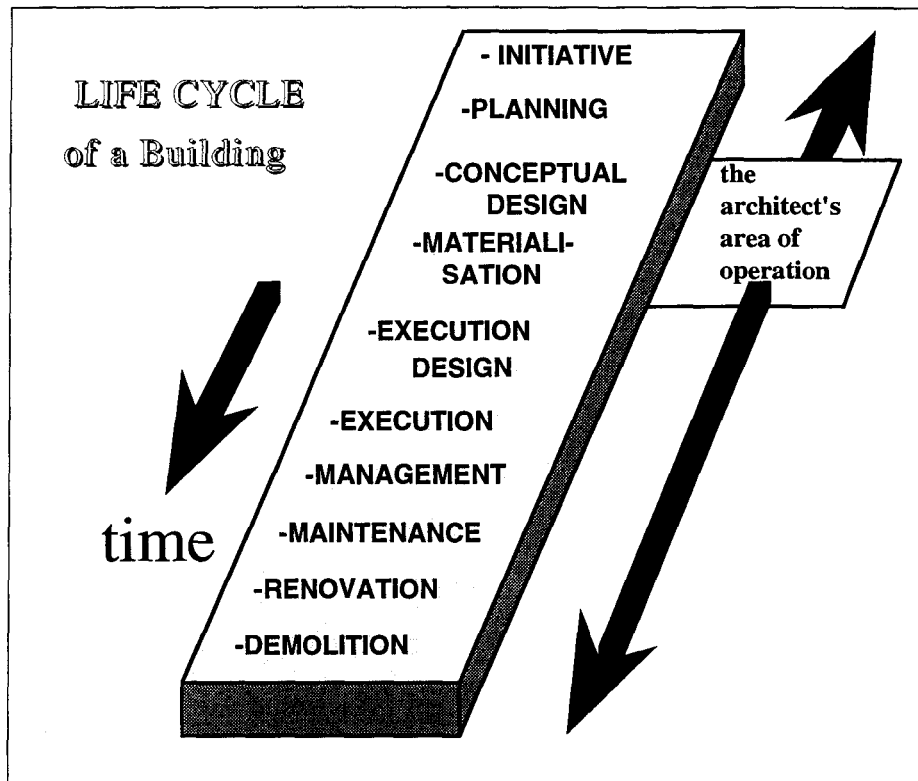


Figure 3: The Life Cycle of a Building

1.3 Design Methodologies

[MaLo86] describes design methodologies in a very general way as the science of methods of design. Over the years, a range of specific methodologies have been developed. These techniques are sets of rules, tasks and procedures for organising and guiding the design process.

They have been developed to meet the following needs:

- (a) Organisation of design
- (b) Teaching of design
- (c) Design aids by providing a more structured approach
- (d) Automation of design

The first aspect has significant importance. For increasingly complex design problems brought about by the rapid technological advancement in the twentieth century new technologies, production methods and expanding markets have increased the scale and complexity of the design process creating a need for a form of design management.

2 THE RESEARCH PROJECT

Our research project mainly comprises the following two subjects: Conceptual design and its materialisation by means of computer tools. The partial output of these developments is the computing instruction material for the building sector and, of course, for its students.

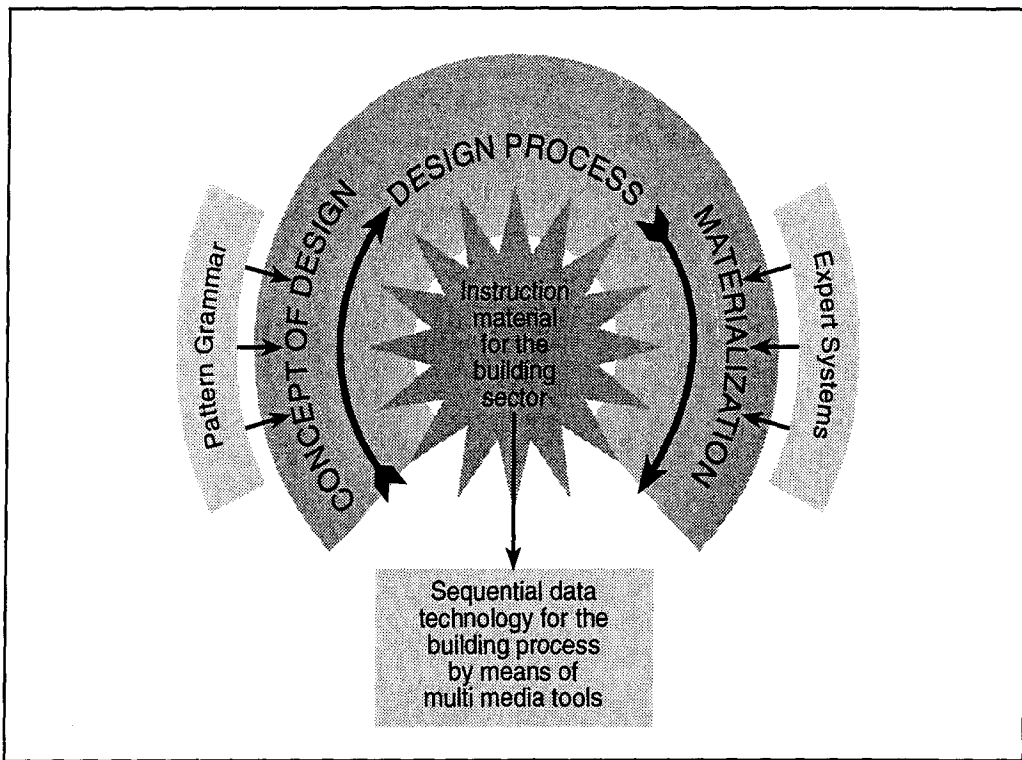


Figure 4: Global objectives of the research project

2.1. Conceptual Design

How can computer science help the designer in the conceptual phase of the design process?

Within the entire field of computer-aided designing there are hardly any developments which provide full support to the designer right from the beginning.

The most important steps in conceptual design are dealt with as "shape grammar", "pattern grammar" and "structural grammar".

One of the alternatives we are developing for this phase is a grammar of pattern.

As it is in every language, architecture has also a grammar. The basic set-up and objective of a pattern grammar is as follows: geometrical patterns recurring throughout the history of architecture and art creates its starting point. These patterns have not been used only to decorate buildings, but also to arrange load-bearing structures.

Patterns are not only man-made but they are also found in nature, for instance in honeycombs of a bees, crystals, spider webs etc.

The art of designing patterns is clearly very old and well developed, but in contrast, the science of patterns, (study of their mathematical properties) is comparatively recent. The only and the most extensive work in such regard has been made by Grünbaum and Shephard .

In the development of this grammar, patterns are treated as three-dimensional polytopes and polyhedrons so as to use them as an underlayer in the different phases of the architectural design process.

A comprehensive survey about the possibilities of using pattern grammars for conceptual design is given in [Sari91].

2.2 Materialisation

Once a concept has been determined, it must be materialised. That means that the geometrical model has to be transformed into components and materials. Thus the question arises: what material, element, or detail will best satisfy all the requirements regarding costs, aesthetics, physics of construction, applied mechanics, installations, dimensions of load-bearing structures, details, etc.

Many architects have seen this materialisation as a purely top-down occurrence, others consider it a bottom-up process. In reality it is a mixture of both, with a purely top-down procedure in some fields, and an absolutely bottom-up development in others. It contains a number of steps, wherein some elements on a relatively low geometrical level but bearing a lot of symbolic value, are placed by geometrical more defined elements that contain less symbolic value. Throughout the design process dozens of sub-processes constantly intermingle.

It is impossible to define a specific course in advance. The one and only design process with a unique development does not exist. Not one design process has ever been like the other. However, on the other hand it is certainly possible to define each step in the process of materialisation.

Each step is aimed at further defining one specific object, which has not been completely defined yet as to geometry and morphology, adding certain geometrical elements and indicating certain morphological data. Each step amounts to defining a specific element, which was already wholly or partly known from a symbolic point of view, more explicitly. The amount of symbolic indication decreases, whereas the amount of geometrical and morphological indication increases. Each step is a complete or partial replacement of symbolic data by geometrical and morphological data.

2.2.1. *The Delft Model as a Description of the Materialisation Phase*

The Delft model as published in [Wild88] and [Sari91] can be considered as a description of the materialisation phase. Generally, five sub-processes are extracted within this substitution process. They will be shortly described now.

The input for the first step is the element that should be materialised. It is described by an “attribute”.

Step 1: “Knowledge System”

Based on knowledge and experience of the architect the attribute is completed with local, national or international norms, rules and laws, which are relevant. The work of the designer depends on his knowledge and experience inside the large field of provisions mentioned. The result is called a set of attributes or a character.

Step 2: “Generative Typology”

A set of forms is composed by using a generative method. The forms have to fulfil the requirements of the character.

Step 3: “Dimensioning”

When an adequate form was chosen, the dimensions of this form have to be calculated. To overcome the traditionally trial-and-error method a one step dimensioning system can be used to compute the dimensions. The differences between the dimensioning processes depending on the attribute are the main problem.

Step 4: "Knowledge Engineering"

In this step the forms including their dimensions were composed to a structure representing the object to be designed. It is quite vague and is often made on the basis of general trends, experience or examples. All components have been dimensioned before. When the composing is finished, the structure has to be checked as a whole against the conditions of the character. The term "Knowledge Engineering" has been chosen because re-operation of basic knowledge available about building techniques, building physics, materials science etc. is required in order to determine the structure.

Step 5: "Detailing"

To create a complex it is necessary to design the details connecting the components of the structure. A potential design tool can significantly improve the traditional way of detailing that is based on a permanent correction of standard details or details of former applications.

The following figure summarizes the sub-processes and illustrates the data involved.

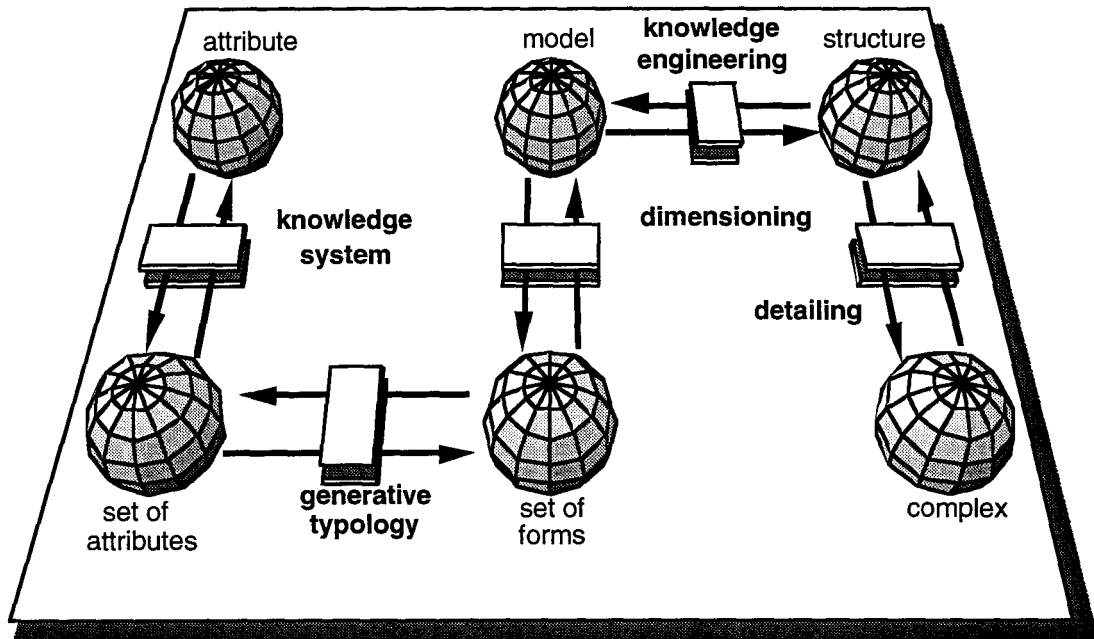


Figure 5: The Delft Model

What can be said over the sequence in which the different processes have to be executed? First of all, it has to be noted that there is no linear sequence of one sub-process behind the other. The sequence of the processes depends on the kind of the attribute as well as on the execution itself. If an error is recognised in a later step it can be required to repeat former processes. Furthermore, the materialisation process is a mixture of purely top-down procedures in some fields and absolutely bottom-up development in others. In general this issue is not defined very precisely up to now.

The cumulative aspect has to be taken into account as well. Within the materialisation of every element new sub-elements may occur that has to be materialised afterwards. This leads towards a hierarchy of materialised elements at the end of the phase. The complete complex is thus more than only a hierarchical grouping of sub-objects. Aside the geometrical relations it also presents time based dependencies, that explains the building method.

2.3 Software Support for Architectural Design

Because conceptual design depends significantly on the individual style of the architect, the possibilities for software support are limited.

In contrast to the conceptual design phase many possibilities for support could be found in the materialisation which integrate the use of computers. Therefore we take mainly into account this step. We also consider earlier and later phases of the design and building process respectively, to achieve compatibility to other software systems.

The current situation with respect to the use of computer systems in architectural design could be characterised as follows:

- Architectural design is suitable for the application of different computer programs. There is a wide range of possibilities to increase the efficiency of processes, to avoid errors or to get better results by using computers.
- Design and engineering firms are making random use of existing software during the materialisation phase of a design. However, the use of advanced computer science technology does not play an important role within this field.
- Architectural design in 3D has a lot of advantages comparing to traditional two-dimensional techniques but requires computer support.
- There is no software with a fundamental, integrated approach to the architectural design process in a 3-D graphic CAAD environment; from its concept to the construction drawings.
- Traditionally there is an exaggerated sense of fear about new technologies within the building sector.

Consequences regarding the availability of support software are:

- The amount and the quality of tools available for the different steps of the materialisation phase are inadequate. For some tasks there is absolutely no tool available.
- There is no integrated environment for the work with these (partly non-existing) tools.

The remarks so far lead to the conclusion that there are two main tasks:

- It is necessary to develop appropriate tools.
- The development of an integrated environment is necessary.

Our research project “The Development of an Integrated Software Environment for the Architectural Design Process” deals with both aspects.

It should be noted that up to now there has been no software system which, within an integrated and coherent whole of complete three-dimensional data exchange, can deal with and process the materialisation phase of a design and the conceptual design stage of the building process. Therefore it may certainly be considered a scientific innovation.

3 An Computer Integrated Support Environment

We consider a complete automation of architectural design as an unlikely proposition and undesirable for the architect. Therefore, the general objective is to give support to the architect to improve the quality and to increase the efficiency of the design process.

“Support” includes the following functions:

- to support the process by tools that can be used for the different tasks
- to overcome the isolation of these tools and the lack of integration by providing an integrated software environment
- to support the exchange of information between different partners participating in the building process
- to free the architect of routine tasks (for example tasks related to the management of the data)
- to reduce the error proneness of the design process, to avoid faulty actions and to detect errors as early as possible
- to extend the knowledge of the architect in some fields related to the design process
- to support the architect in his creativity by increasing the amount of available information.

Despite of the characteristic as support system mentioned already some other features are important:

- Architectural design is characterised by teamwork between architects, designers and experts for special fields like building physics, construction, material science or installation. This has to be considered in the system.
- The results of architectural design processes have to fulfil different requirements:
 - (1) the functional and economical requirements of the customer
 - (2) technical norms or laws
 - (3) the quality of forms and space
 - (4) the social aspects of architectural design

All these aspects should be taken into account by the system development.

- The system has to support the working method of the architect (if possible no limitations because of inadequate computer science technology).
- To achieve a high level of acceptance the aspect of user friendliness is very important.
- The aspect of reusability of design results has to be considered.
- The integrated software environment should contain some functionality for the development of new tools.

Based on the system characteristics the functional requirements for an integrated software environment for the architectural design process have been compiled:

(1) Provide facilities for the persistent storing of design data

Functions for the persistent storage of data are needed.

(2) Support multiple users performing in parallel multiple design tasks on multiple design projects (local distribution, multi-user and multi-tasking support)

The environment has to realise the possibility of logical distribution of design data and design activities as well as to guarantee consistency under concurrent operations.

(3) Guarantee consistency and integrity of design information

The process of data change has to be managed by the system to ensure the integrity and correctness of data.

(4) Access control

Authorisation facilities have to be taken into account. A certain user may not have the permission to execute some operations or to access certain data.

(5) Support evolutionary design

Design is an iterative process. Multiple versions of design elements must be allowed to exist at the same time. The management of different versions has to be maintained.

(6) Support hierarchical view multi-view design

Typically a design is described hierarchically at multiple levels of abstraction.

(7) Design flow management

The environment has to give support for the correct sequence of tool using.

(8) Facilitate tool integration

The environment must allow convenient and efficient incorporation of design tools.

An important condition is the demand that the introduction of these facilities should cause no significant performance degradation for the tools operating in the environment. However, we have to handle large amounts of data of different granularities in a distributed network environment. Performance is thus a very critical issue and has to be considered especially in the field of data management.

The objective is to achieve a practical and fully integrated 3-D software environment to be applied in the process of both conceptual design and materialisation in architecture - figure 6.

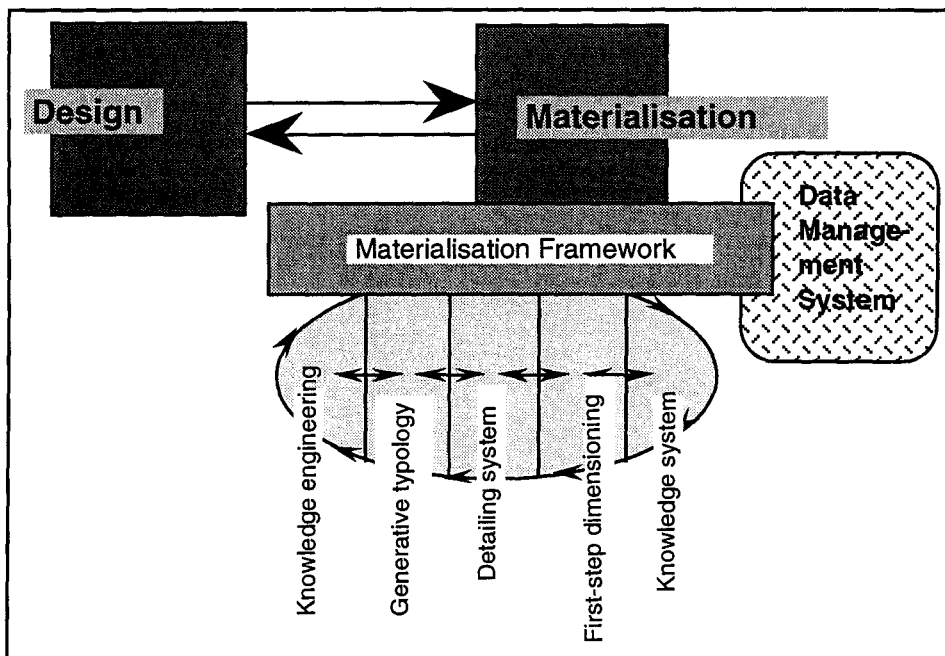


Figure 6: The Integrated Support Environment

As shown in figure 6 the system generally consists of three main parts:

- For the module "Data Management System" we will use an object-oriented database management system which is specifically adapted to the requirements of engineering applications. It is developed under leading of Prof. W. Gerhardt (TUD-Faculty of Mathematics and Computer Science).

- The materialisation framework realises the co-operation between the different tools. It enables the tools to access to the data stored in the data management system. Furthermore it offers many facilities for data and design management.

- Within the integrated environment different tools can be used. Some of them are described in the figure above. They correspond to the different steps of the materialisation process as described in the Delft model. The module "Knowledge

system” handles norms and regulations. Functions for the generation of spatial structures and the dimensioning are included in the modules “Generative typology” and “First-step dimensioning”. The “Detailing system” is directed to the use of 3D-graphical databases of building components. In the module “Knowledge engineering” facilities for the use of available basic knowledge of area as building physics, installations, materials and the environmental issues are implemented.

4 SUMMARY AND CONCLUSIONS

By means of an integrated software environment as described in this paper significant improvements of the architectural design process can be achieved.

This development is entirely new: so far, engineering and design firms have not had a practical system with direct coupling to a graphic three-dimensional design environment, which deals with the conceptual design and its materialisation as one whole. Furthermore, better decisions than before can be made in the assessment of materialisation and the execution of buildings. This will not only save time and money but also energy.

Scientifically, the developments mentioned will lead to innovations in the design process enabling an integrated approach of the design process. In addition, the support of design and materialisation aspects by means of software may lead to new, scientific views on building and the building process.

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