Tools of an Integrated Software Environment for the Architectural Design Process
- Concepts, Technologies and Added Value

Sevil Sariyildiz
Mathias Schwenck
TU Delft
The Netherlands

The technological developments in every field of science have an influence on the society and therefore on the design and design process itself. We are forced by the rapid developments in the field of ICT (Information and Communication Technology) to think fundamentally about changes in existing design process as consequence of the influence of this new technology. What will be the way and the method to integrate the new tools in a design process to increase its efficiency and to reach better design results?
In this paper we will focus on the three main aspects of using computer tools in an architectural design process. By means of examples we will illustrate our vision concerning the future tools for design developments and their integration into integrated design support systems. We will provide a survey of related problems of the design process and deal with aspects of related disciplines that have to be integrated into the design process.

Key words: *ICT design tools, architectural design, materialisation, tool integration, integrated design support systems*

TOOLS OF AN INTEGRATED SOFTWARE ENVIRONMENT FOR ARCHITECTURAL DESIGN

INTRODUCTION

If we look at the history, every technical invention and development has resulted in advantages and disadvantages for the well-being and prosperity of mankind. In the building sector and built environment, the discovery of new materials and techniques has always led to fresh challenges and changes. Developments in other fields of science, such as mathematics, materials science, mechanical and aerospace engineering have always influenced building and architecture. Buildings like the Eiffel Tower, skyscrapers as well as the Munich Olympic Stadium could never be built without the development of the new techniques.

In our time, besides the inventions on the field of CAAD, AI techniques and other multi-media tools for engineers and architects, the communication technology plays an important role. If we look at the middle ages, the monasteries were the central point of the scientific developments and practice. By the discovery of the book print technology by J.Gutenberg in 1455, the scientists found each other and could communicate with each other even if it was very limited. Now with the ongoing developments of internet technology the world is getting smaller and smaller.

This technology will have influences and bring innovations and changes for the building sector. The way how we handle the design and its process and the use of tools will be different than the traditional ones. The exchange of knowledge by means of this technology will bring new stream of world architecture and inventions in the field of building technology.

Independent from the communication technology, whatever it will be, the developments concerning the building design will focus on these three main subjects. Therefore it is necessary to prepare tools for these areas in an integrated way [SaSc96]. As illustrated in figure 1 these tools are basically:

- architectural design related tools
- building techniques related tools
- building process related tools.

In this paper we will focus on these points and will give some examples of our developments.

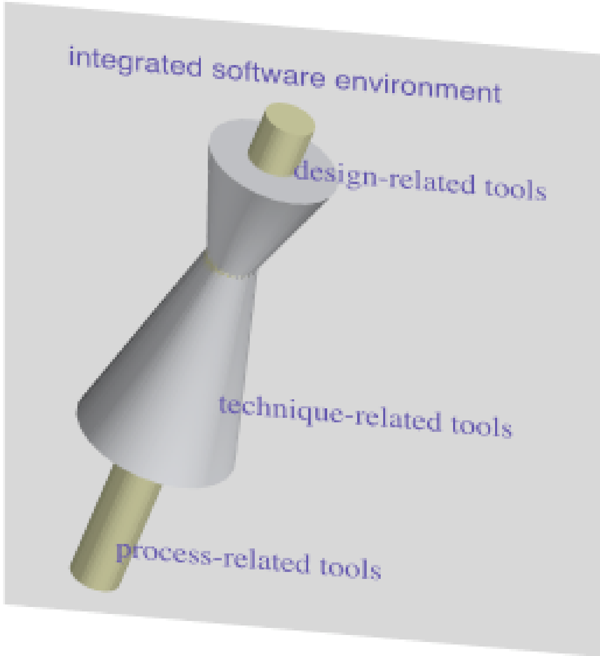

Figure 1

ARCHITECTURAL DESIGN RELATED TOOLS

It is very hard to define exactly what a design is and how architects design, because every single design is as unique as the designer himself. There are no general, unanimous rules applicable to each process and each designer. The starting point is always different, although there are certain questions every designer will have to face.

Irrespective of whether it is a bridge, part of a machine or a building, every design will start with a programme of requirements, after which a concept is developed. After this phase the various design processes will divert.

A part of a machine will mainly be designed with a view to its functional and financial requirements. A bridge or a toaster, however, should also have other qualities. In this case different added values will be expected, in particular those regarding quality of form.

From a design of an architect people will expect additional value, namely the perception of space. Not only should a new building look attractive, but people should also feel at home inside the building and in its immediate surroundings. In this respect there is a fundamental distinction between architectural design and the designs in most other disciplines.

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 but a challenging task. An architect has to combine these 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 aesthetic and social aspects on the other hand.

Initially, the addition of both these qualities, form and perception of the environment, takes place conceptually. In the eventual realisation of a design various disciplines will play a role, and in the completed design, function, technique and form should be expressed as integral parts. Subsequently, these concepts are also materialised.

The architect has to evaluate his design and communicate with the others concerning the design, and therefore he has to make variants from which to choose the best. The best way of evaluating the quality of a design and to communicate with others is to simulate its future reality. The optical qualities of an object can be illustrated much more efficiently with a computer, and can be changed far more easily than in scale models and drawings. So far, only haptic (bodily tactile) qualities cannot yet be simulated.

Design engineers who make use of computers basically work with a man-machine-system, in which the machine is deployed as a means to render ideas directly into concrete forms, but the qualities are not visible they only exist in man's conscience. The question is now, how computer science can help the designer in this (initial) phase of the design process?

We do not believe in that the computers can guide the designer during the process of finding forms and concepts. It can only support the designer by offering this new medium. That is why we do not believe in the developments of artificial intelligence that the design full automatically done by computer. It can never replace the human experience and creativity. But it can support the designer where it is confronted with the exact criteria and knowledge which can be converted to a computer model.

The computer can only work on a pre-program, in accordance with the programs man has taught it, whereas man works on the basis of his education and upbringing, as well as from his imagination and creativity. In this phase one can think about knowledge-based systems or Decision Support System in order to support the architect in this phase.

Starting with this way of thinking, we develop a *pattern grammar* to use them as an underlayer during the creating of spatial forms. 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 and the urban design process. Some aspects of this research are described in [SaDP97], [Sari91] and [Sari95]. On the next two pages (figure 2-13) we show an example of a design with pattern worked out by Christian Müller [TO&I94].

BUILDING TECHNIQUES RELATED TOOLS

A design starts with a functional analysis, resulting in a well-defined programme. The concepts of quality of form and perception of the environment are then added.

Once the concept is ready and determined, after the testing of possible variants with the aid of advanced visualisation tools, this design has to be materialised. That means that the model has to be transformed into components and materials.

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. 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. Besides, these two processes never have the same starting point. Throughout the design process dozens of sub-processes constantly intermingle.

Thus; the architectural design process is a process which is the mixture of deductive and inductive processes. It is an iterative process which works the various steps across.

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.

To date, materialisation has been achieved through a time-consuming procedure, according to traditional methods, which often fails in effectiveness and consistency and does not offer all the possibilities from which to select. The development of methods by which three-dimensional materialisation can be supported by means of computer science technology is largely unexplored territory.

It is common knowledge that a computer is very appropriate to check exact criteria, but in the conceptual phase of the design process there are hardly any exact data. In the consecutive phase, the materialisation, however, data become more and more exact.

In the phase of materialisation the question arises to determine which material, element, or detail will best satisfy all the requirements regarding costs, aesthetics, physics of construction, applied mechanics, installations, dimensions of load-bearing structures and details. This we call the building techniques aspects of the architectural design or materialisation phase of a design

In this process there is a great need for applied knowledge such as mathematics, geometry in particular, applied mechanics, material science, building physics, knowledge about calculation of constructions in general and calculation of dimensions in particular.

Before the developments of information technology, this has been done merely based on our own experience and knowledge. Within the developments of this technology, many software has been written for specific problems - purely ad-hoc such as cost calculations or for building physics aspects, calculation of constructions. But still there is no software available which can integrate these various disciplines of design in one system to support the designer while taking decisions.

The greater part of the knowledge required to take these decisions is expert knowledge which can be stored and made accessible by means of an expert system.

The system which has to be developed should integrate the various disciplines of design during the design process and should give continuous feedback to the graphic part within an advanced environment of visualisation. That means that the various expert system tools should also integrate in this environment besides the CAAD tools. For instance, in a climatic partition wall in a building it is not its insulation value at a certain section that is of great importance, but rather the successive layers and their connection with the angles, also at the point where three walls will meet. And so, it goes beyond mere computerisation of check calculations and the results should be as graphical information.

Figure 2 - 7

figure 8 - 13

BUILDING PROCESS RELATED TOOLS

A major area in which computer science may support the architect is exchanging and processing data. This requires building up a reliable data model. Not only will such a data model of a building be of good use in the design process, but these data are also of vital importance in the life-span of a building.

Nowadays building has become much more complex. Not only in their functionality, but also in the way they are put together: infrastructure, building with support and external covering, technical equipment, communication techniques etc. Many partners are involved in the process, and a major part of the activities during building consists of collecting, processing and transferring data among the various participants, such as the architect, the engineer, the contractor, the electrician, the physician, the constructor, government institutions, and the users.

This data will have to be ordered and processed very efficiently, but the problem is how to order this data so that it can be easily processed.

The data concerning a building of relative importance are so extensive that one single person cannot possibly know and control all this information. It is absolutely necessary to order this information, so that any person involved will be able to obtain the information he needs.

This type of ordering in fact consists of a hierarchic built-up of the information. Re-ordering actually implies restoring the hierarchy.

In this hierarchic structure it is desirable for an architect to have insight in some fields, discernment in others, and in the first place an overall picture. This hierarchy must be not only vertical and horizontal hierarchy but a three-dimensional hierarchy.

That means that each part of the technical information which is put together like the electricity, plumbing etc. and imagine that when the electrician wants to know everything that pertains him in relation to the rest of the building, he must be able to call only that part of the object on scale, for instance, 1/200. He must be then able to receive the plan with, for instance, all the supply and safety installations on a scale of lets say 1/20. He will be able to see where all the lamps and interrupters are situated as well as their relationship to the rest of the building's layout.

The information must be selected according to the questioner. The architect and the building engineer do not need the same information about the details. The building engineer does not need the information about furniture for example. He needs the information about the structure of the building.

While this information is selected, it also must be usable so that when it is returned back to an architect from the building engineer, the architect should not have to draw all over everything again. The changes must be easily processed. Therefore it is necessary to built up an object in different levels in horizontal and vertical hierarchy.

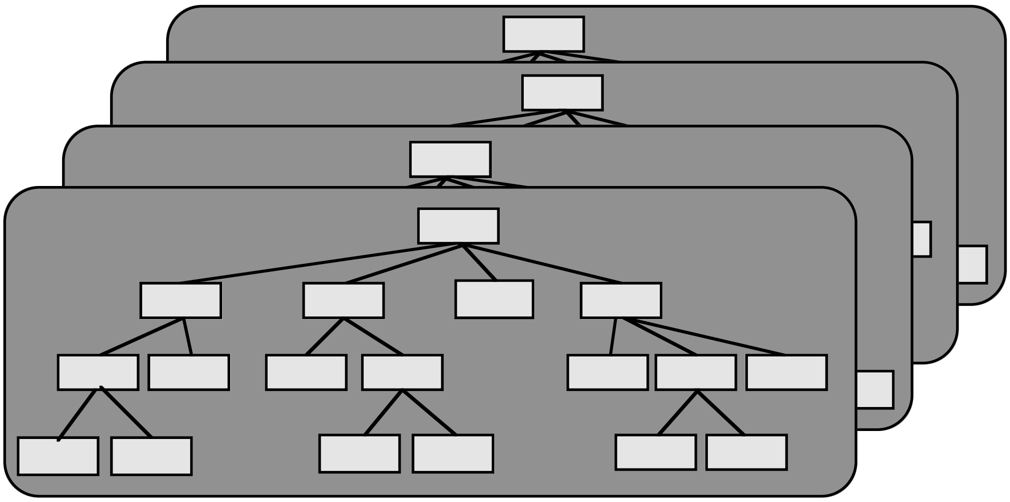

Figure 14: The three dimensional ordering of the information as object-oriented data

Each design is part of a process, and consequently part of the building process. In process technology one of the primary rules is that each step must be clearly related to the final goal, and must be tested and evaluated to this purpose.

In any process each next step further elaborates the results of the previous one. This further elaboration includes more than just assuming geometrical data developed at an earlier stage. It also concerns decisions on actions, information flow, quality etc.

It is very important to consider designing as an essential part of the building process. In current building practice, however, the architectural design frequently is no part of the building process in the sense described above. The architect restricts himself to supplying forms, after which the building contractor starts the whole process all over again. With the current state of affairs the architectural design is too far removed from the process-technology of building.

Integrated Software Environments

In addition to the problems mentioned so far, the current state of available design software is characterised by a lack of integration of different tools. The different tools have to be integrated in an open, modular, distributed, user friendly and efficient environment. Situations where limitations occur because of incompatible file formats, incompatible communication protocols or because of user interfaces that are not suited for the people working in the field of architectural design have to be avoided. Integrated design environments can provide this by realising integration in the following three dimensions [ScBr93]:

- Data (Information)
- Control (Communication)
- User Interface (Presentation).

The *data integration* aspect of tools determines the degree to which data generated by one tool is made accessible and is understood by other tools.

The *control integration* aspect of a tool determines its communicational ability, i.e. the degree to which it communicates its findings and actions to other tools and the degree to which it provides means to other tools to communicate with it.

The *user interface integration* aspect is the degree to which different tools present a similar external look-and-feel and behave in a similar way in similar situations.

Instead of only developing design tools, integrated system are also addressing the problem of the operating environment of these tools. This can be considered the principal advantage of integrated design systems and provide the added value. [Wolf93] concludes that the additional effort that has to be taken to realise an integrated support environment will be more than compensated by the advantages of these solution.

In figure 15 on the next page we illustrate the three mentioned categories of tools to be integrated. For each of them one example is given, such as database of building components within the category “building process related tools”. During the materialisation process, expert knowledge of various field has to be integrated. For example, expert knowledge of detailing can be implemented by means of an expert system. Such tools belong to the category “building technique related tools”.

Generic functions for data and design management are not implemented in a specific tool, but in a framework offering general services for the tools.

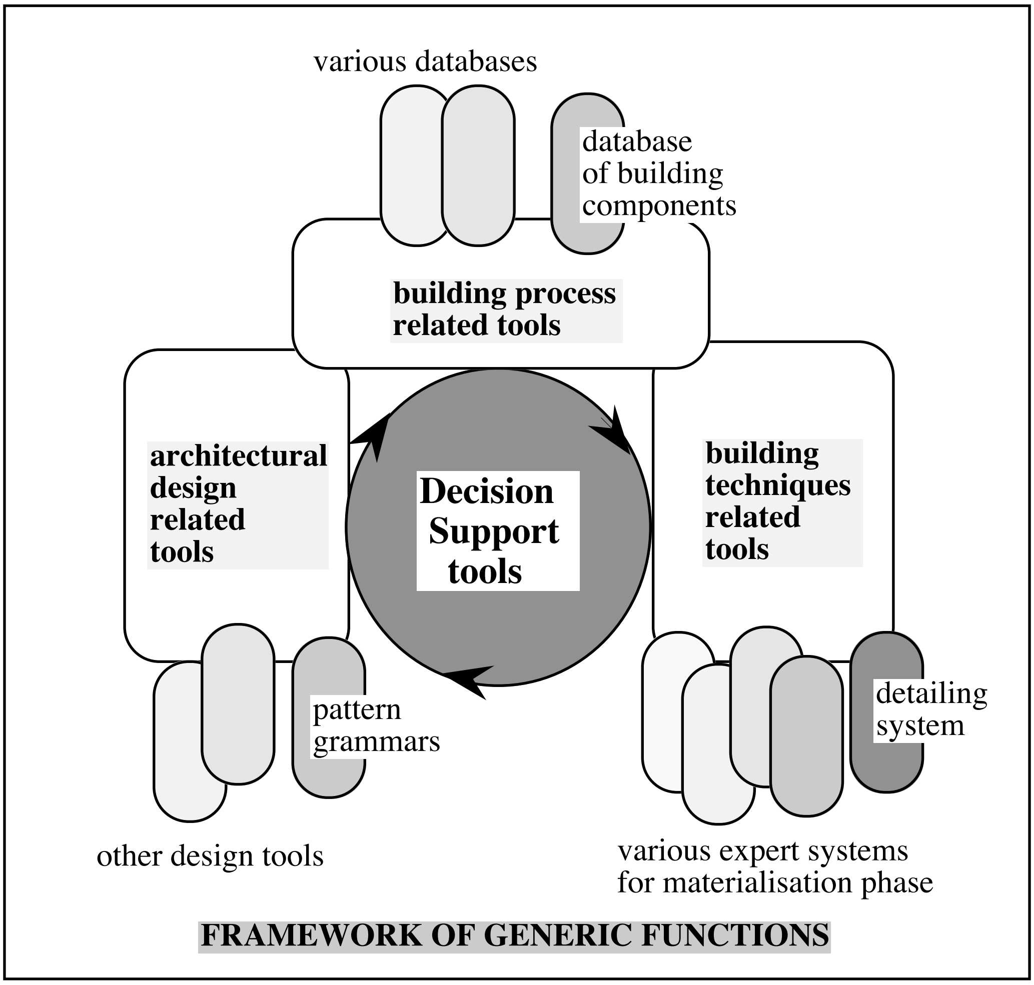

Figure 15: An integrated software environment

Consequences for the Architectural Design Process

Which changes occur in the architectural design process if we apply the new tools within an integrated software environment ?[ScVö96]

- Conceptual design and materialisation are inseparable because it is impossible to erect a building without materialisation. Knowledge about the limits and possibilities of several materials and structures as well as their combinations is available by means of software. Because of the possibility to start with a research of the “final limits” the reality of the design process will be excellent.

- The possibilities to combine materials and structures lead to a wider variation of designs. It is now possible to explore them already during the conceptual design phase.

- 3D views are vital to explore the human space limits and qualities within the materialisation limits.

- The conceptual design should be extended significantly in order to use the new possibilities. It becomes more time-consuming. The effort taken can be easily compensated by quality improvements as well as by less time demands in later phases.

- Because of the integrated way of designing it will be possible to inform the principal, the authority and the consultants on a “digital way”. The value of the calculations is as excellent as the design process.

- The documents can be generated earlier and much more complete so that every member in the design process is informed with the same quality and with the same possibilities of the building. This can take more time but the value of every document is extremely high because the tuning has been done. The definitive design needs significantly less time to be generated.

Additionally the whole design process tends to demand less time. We will illustrate this by a comparison in figure 16:

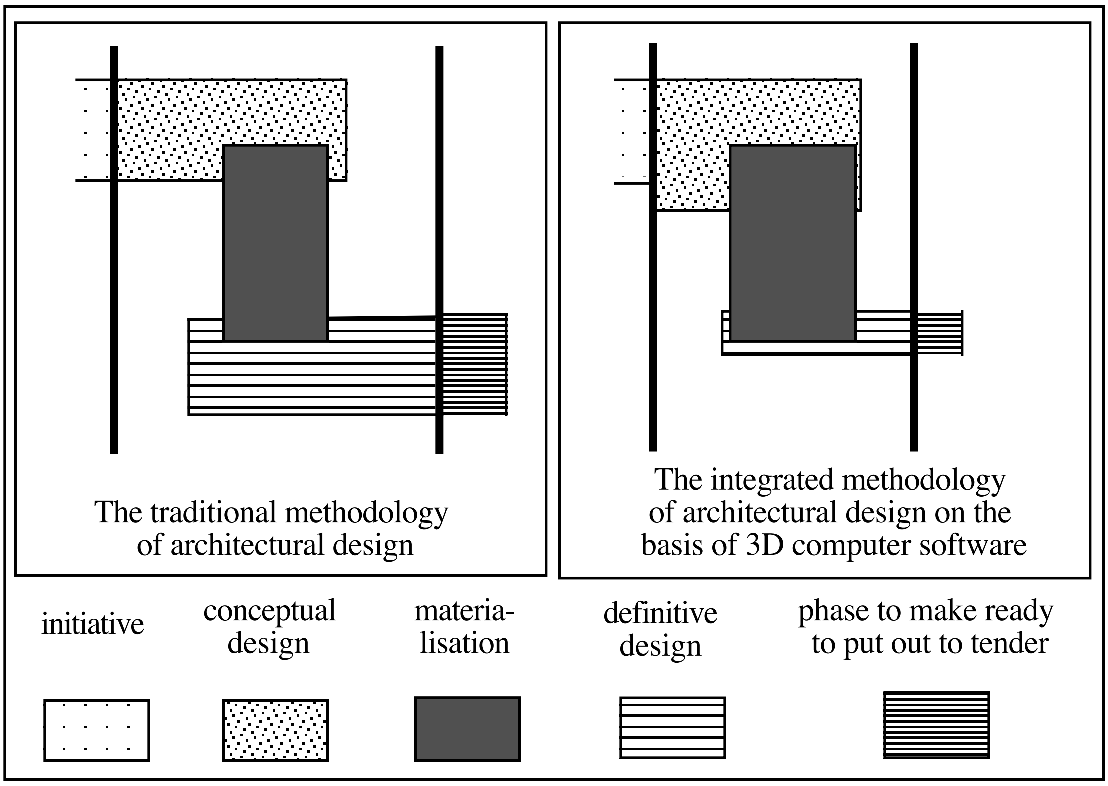

Figure 16: Expected Changes in the Architectural Design Process

SUMMARY AND CONCLUSIONS

It is almost impossible to keep pace with the incredibly rapid developments in the field of computer science. Computers are becoming cheaper and increasingly powerful. The Internet will make the world smaller and smaller, bringing scientists in very close contact with each other. Networks will enable them to communicate night and day. In the United States efforts are being made to build Electronic Super Highways and much faster internet possibilities. Today these networks, combined with fast computers, make it possible to simply exchange graphic data (drawings, photographs, films, etc.). Now, researchers may execute simulations by remote control, or hold a conference by video with colleagues abroad. In the future we will even not need a software at our disposal in our own machine but via the internet we can have access to any specific needed software on internet. The communication between the building partners will also take place by means of video conferencing that even the travel time to have meetings will bring more time to do more creative and efficient work. The emergence of new technologies will also affect our subject area, our way of living, our habits and our cities and this will create fresh challenges, fresh concepts, and new buildings in the 21st century.

The application of these new techniques, methods and tools in the building sector is a very complex problem. Contributions can be made by developing tools in the three categories that have been considered in this paper as well as by dealing with their integration.

If they are applied in such a way, these ICT developments can have significant impact on the building sector and therefore in the society. Some advantages are:

- efficient and better design and construction process
- contribution in the industrialisation of the building sector
- robotising of the construction process
- developing assembly techniques
- flexibility in the architectural design
- more variety in the architectural design
- high quality in the building and cheaper buildings
- contribution in the solving of environmental problems
- globalisation of the architecture
- because of the better communication techniques, upgrading of the knowledge of the building sector concerning the new building technology
- better communication between the partners involved in the building process.

References

[SaDP97] Sariyildiz S., Durmisevic S., Ploco J., "Pattern Grammar In Architectural Language Within A CAAD-Environment" Proceedings of the 1st AVOCAAD-Conference "Added Value of Computer Aided Architectural Design", Brussels, Belgium, 1997

[Sari91] Sariyildiz S. "Conceptual Design by Means of Islamic-Geometric-Patterns within a CAAD-Environment" PhD-thesis, TU Delft, Faculty of Architecture, 1991

[Sari95] Sariyildiz S. "X-Dimension in Building" Inaugural Speech, TU Delft, Faculty of Architecture, 1995

[SaSc96] Sariyildiz S., Schwenck M., "Integrated Support Systems for Architectural Design"

Proceedings of the 3rd Conference on “Design and Decision Support Systems in Architecture and Urban Planning”, Spa, Belgium, August 1996

[ScBr93] Schefström D., Broek G. van den, “Tool Integration - Environments and Frameworks”
John Wiley & Sons, Chichester, 1993

[ScVö96] Schwenck M., Völker H., “Modelling the Architectural Design Process - Analysis of Traditional Methodology and Approaches to the Future”
Report, TU Delft, Faculty of Architecture, 1996

[TO&I94] “Report On Research Activities”
Internal Report, Chair “TO&I”, TU Delft, Faculty of Architecture, 1994

[Wolf93] Wolf P. van der, “Architecture of an Open and Efficient CAD Framework”
PhD-thesis, TU Delft, Faculty of Electrical Engineering, 1993