

Collaborative Integral Design of Active Roofs

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SUMMARY

In the world of design and engineering, gaps of knowledge between these disciplines are recognized. The learning capacity of the building industry – as well as in other industries – is becoming a main issue, also within Architect-organizations. To link the parts of the knowledge-triangle practice, education and research forms the basis for possible solutions – within the context of the building design-engineering. This context can be represented by the Product-Process-Organization model. This integral approach is the basis for integral solutions, by structuring knowledge of design and engineering within the design team.

A model for structuring knowledge on different abstraction levels is found in Methodical Design, a system theory based on the combination of the German design school (Pahl, Beitz and others) and the Anglo-American school (Archer, Krick, Jones and others). Methodical Design is a problem oriented model based on functional hierarchy, which can be applied on several levels of abstraction and makes it possible to link these levels of abstraction with the phases in the design process itself.

This paper describes the research methodology, based on Methodical Design, as used in a doctoral design related to practice and the 6th European framework research project EURACTIVE ROOF-er. The research methodology – as quasi-experimental design – uses the structuring method of the Methodical Design to investigate how this specific design method and associated design tools can support the collaboration between designers and engineers.

INTRODUCTION AND PROBLEM DEFINITION

Roofs play a special role in buildings. Their value and impact often significantly surpass the cost ratio they represent in the total investment cost of the building. Traditionally, roofs have a protecting function and their basic design has changed little over hundreds of years. Nowadays however, they are increasingly used as preferred location for mounting additional functions such as photovoltaic systems, roof lights, ventilation devices, insulation and safety devices. The roof will contain more and more aspects which are strongly related with the comfort of the building as a whole. Looking in a wider context, the build environment is dominated by the circumstances related to energy use. As results of Global Warming become more and more prominent, it is necessary to look for new ways to save more energy and to generate more sustainable energy for the comfort in the building environment. [24, 25]. In current building design primarily the façade, as the most prominent building component, is used as integral part of these sustainable comfort systems. This integral approach is lacking for the roof, where these systems are mostly treated like add-on components to the already completed conceptual building design.

Until now the roof was not actively developed to meet the new demands. Active Roofs should change this. Active Roofs is the concept related to this change: the possibility or need to change the culture, process and or product related to the roof. Active roofs, with the described possibilities, implicate a more active role in the process for the roofer and roof-advisor. An active attitude of the total roof-culture is needed in order to design and construct innovative and better roofs. The approach needed for the development of these knowledge and skills is integral as defined by Quanjel and Zeiler [8]. Integral design is meant to overcome, during design team cooperation, the difficulties raised with the early involvement of consultants. This is achieved by providing methods to communicate the consequences of design steps between the different disciplines at early design stages. Related to the specific field of the roofer this means the direct connection of construction /user- and design-related knowledge. A domain-related methodology, therefore has a large group of different users with different backgrounds, which will influence the set up for methods and tools.

The actual state is that there is a gap exists between solutions and application in design practice of active roofs (EURACTIVE ROOF-er, 2005). Roof design and roof engineering with all its existing – traditional – and new functions and applications are most of the time handled like separate and add-on aspects. As complexity and scale of design processes in architecture and in building services engineering increase, as well as the demands on these processes with respect to costs, throughput time and quality, traditional approaches to organize and plan these processes may no longer suffice [26]. This implies defining a process methodology that acts as a “bridge” between architectural elements such as shapes and material on the one hand, and the aspects of indoor climate issues such as overheating and ventilation on the other; an integral approach where all design members have shared understanding – with their own background – on the project [27].

Offering design teams and product developers an appropriate methodology will result in decision support for integral roof-design, within the setting of the primal design. Therefore a decision supportive methodology, within the integral design approach of active roofs, is developed. This implies defining a design methodology that acts as a “bridge” between architectural elements such as shapes and material on the one hand, sustainable energy use and the aspects of indoor climate issues such as overheating and ventilation on the other.

The active-roof design and -engineering, as an integrated product development task, involves solving a design problem. Design problems are a special type of problems and have the following characteristics [28]:

- design problems tend to be large and complex, have both logical and creative components and are wicked
- actors search for a solutions of the design problem within a certain solution space, this solution space is undetermined and the available information is incomplete, since project specifications are never complete or without ambiguity; design problems are therefore ill defined and/or ill structured
- during the design process, actors iterate between design problem and its solution(s) to support the decision making process for these generated design/engineering solutions
- design problems are open ended; it is often not clear when actors have solved the design problem; there is also not one best solution for solving the design problem

Given these characteristics, a methodology to support the design team during the development of the building design is of great importance to clarify the problems and to structure possible solutions. To support the design of large-scale, complex design processes, such as one has in

the building industry, a method is presented based on the Methodical design methodology; a matrix orientated approach used in the mechanical engineering domain. Thesis of the research is that, through the use of the characteristics of the Methodical Design, an appropriate support tool is available for Collaborative Design Teams.

WORKING PRINCIPLE

The Methodical Design method is based on system theory and a combination of ideas of the German design school of Pahl, Beitz and others [11, 12, 13, 14, 15, 16] and the Anglo-American's, Archer, Gregory, Krick, Jones and others [17, 18]. Methodical Design combines German and Anglo-American process model approaches. Methodical Design is a problem oriented model based on functional hierarchy, which can be applied on several levels of abstraction and makes it possible to link these levels of abstraction with the phases in the design process itself [19, 20, 21, 22].

The essential element in this model is the design process [21]. The characteristics of the design process can be split up into those related to: strategies, stages and activities. Within the setting of Methodical Design several design-support tools are used: the morphological overview and the Kesselring-method [29]. These are practical tools to structure several functionalities, generate and select possible solutions and can be used for different aspects and abstraction levels.

Due to these characteristics, the methodical approach can accommodate the different subjective interpretations of the requirements, inherent to the design team approach. By structuring the requirements, within each complexity level, the development of the shared understanding in the design team is encouraged. More insight by the design-team-members of different possibilities, from the different requirements, can generate more possible solutions. Through iteration cycle of interpretation-generation steps the set of requirements is continuously refined, and with it also the design solution proposals. The research is focused on the added value of the introduced design-tools, as part of the Methodical Design, within the collaborative design team for the preliminary design-phase.

The research methodology, as quasi-experimental design, uses the structuring method of the Methodical Design. This method can be applied on several levels of abstraction and makes it possible to link these levels of abstraction with each other. By using 4 different levels of abstraction as formulated as functionalities of the problem – integral design / collaborative engineering / sustainable comfort systems / active roofs – the research has a clear framework. Within each level of abstraction - though the research is about developing a methodology for design collaboration - the approach for developing edge conditions and possible approach is the same. This is applicable as well for the research methodology as for the design methodology. For each level the approach (analyze / generate / select / modify) is similar, the development will be different.

Within the Methodic Design, the relationship of the several functionalities and steps can be shown in the scheme below (fig. 1.). In order to structure the research for each level of abstraction (integral design / collaborative engineering / sustainable comfort systems / active roofs) there will be a problem definition / working principle to develop solutions / choice of developed solutions / shape of chosen solution (blue arrow) – for all the functionalities related (vertical column / green arrow).

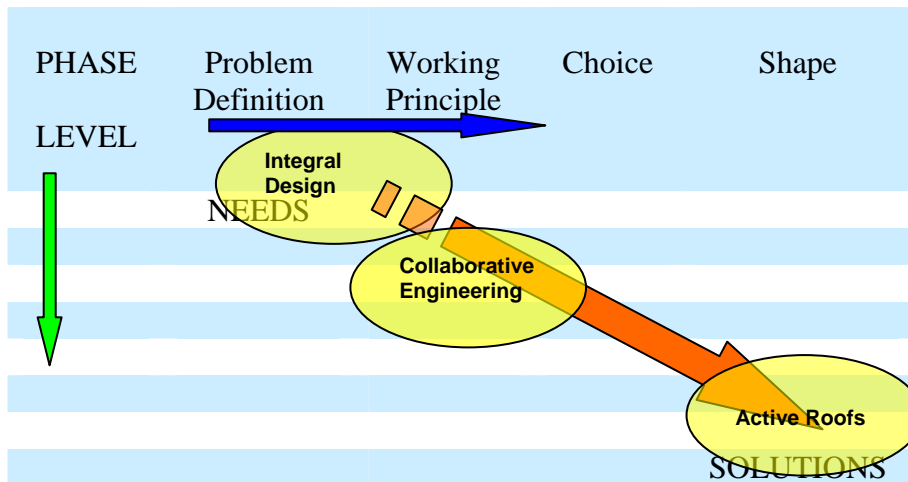


Figure 1. The modular system of hierarchical abstraction as basis of the research methodology

As shown in figure 1, the problem definition generates the working principle for the research methodology. For each level of abstraction within the defined research topic, the several stages and their specific functionalities / needs have to be taken into account. These stages will be described in this paragraph.

The integral approach of the research methodology means different viewpoints on the same topic [8]. For this research the two main viewpoints are that of the designer – the architect – and the engineer – the roofer. By using different typologies of quasi experiments – case studies, scenario's and design task workshops – comparing, verifying and clarifying these experiments, also on research level the different viewpoints are used. By using quasi-experiments, step by step a next – more concrete abstraction level – will be analyzed and verified in order to get a clear view on the influence of the several functionalities / needs related to the specific abstraction level (Integral Design / Collaborative Engineering / Sustainable Comfort Systems / Active Roofs).

Before investigating solutions of 'bridging the gap between architects and roofers, the research will start with investigating the needs and knowledge which causes this gap of design solutions and application engineering.

Therefore the following analysis is made:

- needs in primal design phase for designers / architects
- supply / knowledge from engineers / roofers
- analysis of the differences and similarities between needs and skills of both disciplines

By analyzing all these aspects, an overview of which functionalities are necessary for possible design decision tools to support the participants (architect and roofer) in the setting of collaborative engineering, will be generated.(fig. 2)

Through this first step a further analysis of the roof engineering / installer industry is possible, to develop a model of competence profiles. This model will show which steps are necessary, as a path to success, for creation of appreciation for this specific industry on different levels in the context of collaborative engineering: organization / process / product-level. To have a

reference with practice the competence profile of the façade engineering / installer industry, as a successful path-to-success, is used.

Next step is to set up functionalities related to design- and engineering aspects and generate them in a database useful for both architects and roofers. Related to the different users, two different menus are developed to search and combine the knowledge needed, to design and/or engineer an active roof. The database will be developed in a web-based-setting to facilitate the different users with the needed knowledge, related to design and engineering active roofs.

From the practice, case studies are used to show which kind of problems are there in the traditional design process for roofs and facades, as part of the total building design, in relationship with engineering aspects.

Three different projects will be analyzed (to prove the assumption of the problem);

- comparison of traditional process and collaborative process-approach
- SWOT-analysis with focus on communication and information sharing
- in relationship with architectural concept product/system requirements and technical facilities
- determine criteria of specialist interaction aspects of collaborative design and engineering
- feed-back for aspects of a competence-model and aspects engineering knowledge supply for roofers in the design process

The designed competence profile will be used to set up several, process-based scenarios, used for testing and modifying the data-base-structure as part of Methodical Design methodology. The experiments for testing will redefine the data-base-structure and give a more precise view on the influential and important aspects and functionalities of the knowledge needed in the primal design/engineering phase. Through these steps more precise aspects which are necessary for using more optimal the Methodical Design Tools and Database, can be developed. (fig. 3)

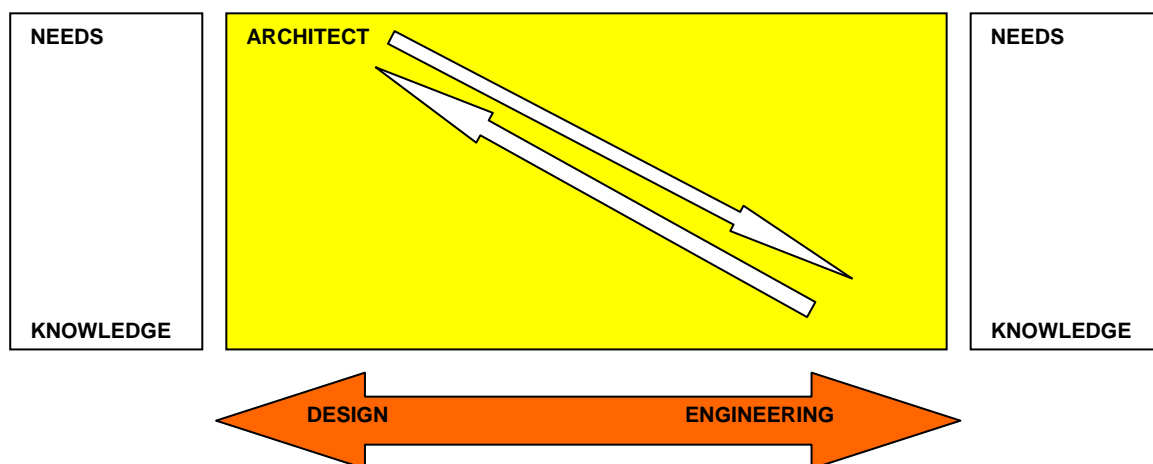


Figure 2. Relationship of needs and knowledge of architect and roofer, from engineering to design

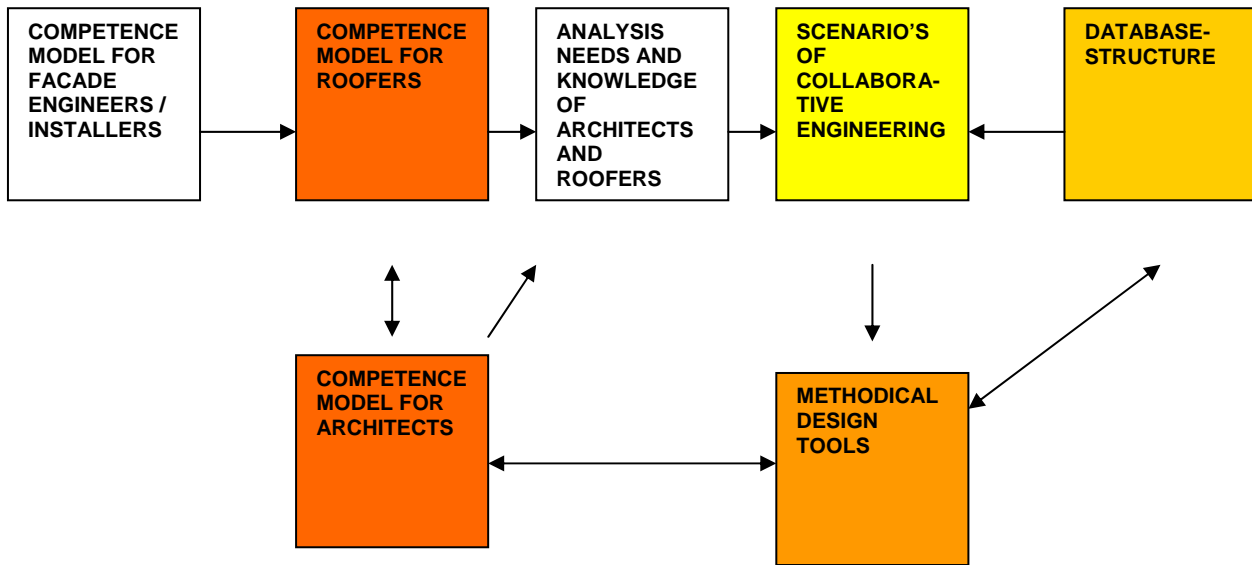


Figure 3. Process scheme for designing / engineering active roofs

Crucial point by using the experiments, in relationship to the ‘theoretical model of the Methodical Design, is the connection to a ‘realistic model which is part of the design-practice. For constructive implementation / exchange of knowledge within the design process there are 3 main different possibilities of knowledge exchange / generation:

- reflection in action [30]: which connects the design situation in interaction with a framework for the several disciplines
- shared knowledge – heterogeneous engineering [31, 32, 33]: a process of aligning cognitive and social-political elements to create and realize a good design
- ‘bricolage’ [33, 34, 35]: the use of situational resources tendering with the resources at hand.

The setting which is chosen is that of ‘the reflexive practice [32, 36]. This setting has characteristics which makes it, comparing to the other two possibilities, a realistic setting which we can use to verify and validate our theoretical model of Methodical Design. It is a setting which inhabits characteristics to, as in a design-process, have a rational feed-back on the former design-steps and design-decisions and to support the next design-steps and – decisions in a realistic setting with several disciplines.

Mostly the verification of a new methodological concept is done by experiments with student groups (novices) [37] or with design groups within one company [38]. The relevance of the research methodology for practical use in a realistic setting is improved by using experienced designers and participants (professionals), as there is a major difference in approach between novice and experienced designers [39, 40].

CHOICE / SELECTION PHASE

With the found functionalities from the Working Principle – in relationship to the use of the Database-structure and Methodical Design – the scenarios for a serial of quasi experiments

will be set up and modified. This is a set up for a prescriptive method to develop appliances for supporting the collaborative design- and engineering-process in combination with engineering knowledge supply.

The quasi experiments will have the focus on the following aspects:

- communication between the design- and engineering solutions for active roofs
- generation of more possible design / engineering solutions for active roofs
- the use of the support decision tool to generate these design / engineering solutions

The same format, related to the Methodical Design, will be used for the set up of the quasi experiments as well for the verification and clarification.

The quasi experiments will be build up in a step by step format with alterations on the group setting (collaborative engineering), group tasks (use of sustainable comfort systems, design /engineering active roofs). The experiments will have the format of design task workshops and/or master classes related to design tasks. The same methodology used on the level of research as a whole is also used on the other abstraction levels within the research; in this case the quasi experiments and the verification of these quasi experiments. (fig. 5.) As example, related to the setting of Collaborative Design and the use of the Database and / or Methodical Design tools we can define the following functionalities / needs related to these quasi experiments:

- situation of the design-team without the use of database or methodical design tools
- situation of design team by using database or methodical design tools, without training
- situation of design team by using database or methodical design tools, with training

The experiments will be done in a serial with feed-back; comparison / selection of the type of experiments as the use of several verification methods as well as the results of the quasi experiments itself. The specific functionalities and results of the experiments will be verified with the use of different verification-methods.

SHAPING PHASE AND DISCUSSION

By using the Kesselring-method a comparison of the different abstraction-levels can be made, finally through the quasi experiments to optimize the experiment and the introduced tools for communication / knowledge exchange. Realization and functioning of the most successful generated tools can be improved. Based on the found and verified functionalities / needs for each abstraction lever an overview of the most successful support tools and scenario's can be generated as part of the developed methodology. Further improvement and research topics for 'how to get there can be evaluated. Through this iteration process more insight in the knowledge exchange of architect and roofers is generated and requirements for the support tools will become clear and can be modified when the circumstances change – the modifying phase. Within a wider range of the EURACTIVE ROofer project this iteration process can be used for developing the use of the Database structure and the Methodical Design Tools training-set up by the several Collaborative Design team-members for the Active Roof Design [41].

The actual phase of the described research methodology is the selection-phase for defining and applying the case-studies and quasi-experiments. Final results of the research methodology are:

- insight into the needed knowledge / skills of designers (architects) and engineers (roofers) in designing Active Roofs, as part of the total building design

- development of design-decision tool(s), within the setting of Collaborative Design teams, which can structure the needed knowledge from the different design-team members in order to design/engineer these Active Roofs

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