

# "DESIGN COLLABORATION AND TEAM WORKING"

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## ABSTRACT

One of the core problems within construction industry is knowledge exchange between the different participants during the design- and engineering process (Lechner 1991, Cross 1992, Reymen 2001, van Aken 2005). To link the parts of the knowledge-triangle practice, education and research forms the basis for possible solutions – in the context of the building design-engineering (Quanjel&Zeiler 2003). This context can be represented by the Product-Process-Organization model (Bax&Trum 2000). At the Technische Universiteit Eindhoven (TU/e) in collaboration with TNO Built Environment and Geosciences, first experiments to find a format for supporting Design Collaboration, started in 2000. Set up where training-workshops for the members of BNA/ONRI (Royal Dutch Organization of Architects / Dutch Organization of Advisory Consultants), for design- teams including participants with the same educational background. More recent, a first set up was done for design teams with participants with different educational backgrounds. These quasi-experiments (Campbell&Stanley 1971) are coupled on the basis of a concrete task from the practice and the PhD-research EURACTIVE ROOFer by E. Quanjel at the TU/e-TNO. The objective of this project is to improve the knowledge exchange between design participants of active roofs in product development as part of the total building design and its comfort-systems.

Salter and Gann (2002) found that face-to-face interaction and the use of sketching are still the most important elements for developing new ideas and solving problems. Given this aspect and the characteristics of the problem definition, a methodology to support the design team during the development of the building design is introduced. This method is based on the Methodical design methodology; a matrix orientated approach used in the mechanical engineering domain (van den Kroonenberg 1978). Within the setting of Methodical Design several design-support tools are used: the Morphological Overview and the Kesselring-method (Zwicky 1969, Kesselring 1954). These practical tools from the theoretical method are connected with the design practice, as reflexive practice, through quasi-experiments for architects and roofer-engineers (Schön 1983). The experiments will be done in a serial with feed-back; the Kesselring-method as well as the results of the quasi experiments itself. To distinguish the knowledge-exchange aspects, Bales' Interaction Process Analysis model is used (Bales 1950, Emmit&Gorse, 2007). The result of these experiments is a design decision support tool for both architects and roofer-engineers in the setting of Collaborative Design.

## KEY WORDS

Integral Approach, Collaborative Design, Practical Design Decision Tools, Workshops

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## INTRODUCTION

Gaps of knowledge between the worlds of design and engineering in the Building Industry are recognized by researchers as well as practitioners (Lechner 1991, Cross 1992, Reymen 2001, van Aken 2005, van Dinten 2006). Learning capacity is identified by several researchers as the basis of knowledge development in design teams and projects (Schön 1993, Dixon 1999, Argyris, 1999). Knowledge development in daily practice starts with effective collaboration between the participating disciplines of the design team (Kolb 1984, Nonaka&Takeuchi 1995, Paashuis 1998, Argyris 1999, Emmitt&Gorse 2007), making designing the most central activity in engineering a new product (Krick 1967, Korbijn 1999, Reymen 2001). The basis of a design process is concept generation; this is the natural habitat for designers for finding possible product solutions (Lawson 1994). Most important decisions for the product / product-life-cycle are usually made in the conceptual phase of the design – the early design phase – even though not all relevant information, knowledge and participants are available then (Wichers Hoeth&Fleuren 2001, Zeiler et.al. 2005). For solving complex design problems, creative concept generation involves multi-disciplinary approach of experts in a team-setting (Campbell 1968). Thus multi-disciplinary teams will generate a larger variation in objectives than individuals and mono-disciplinary teams (Wallace 1987) and a wider range of solutions (Ysseldyke et al. 1982). A wider range of objectives and solutions increase the possibilities of innovative designs that better suits clients needs. Concept designs can be seen as the basis of knowledge development within the design-team related to specific design solutions (Hatchuel & Weil 2003, van Aken 2005).

Although the learning capacity of the total Building Industry is insufficient (Wichers Hoeth&Fleuren 2001, Noorderhaven et al. 2006), a lack of innovative designs is observed in a specific part of the Building Industry; traditional roof design. Professional parties indicate that this lack of innovation might be caused by a sub-optimal interaction between solutions and application in design practice of traditional roof design compared to innovative – active – roofs. There is a contradiction in influence and design-information between the designer / architect and engineer / roofer, a contradiction in knowledge-flow between disciplines with different educational background (EURACTIVE ROOF-er, 2005). For centuries the roof has been the part of the total building design which has basic functions of physical protection (wind-rain-snow) and is now used more and more for storage of comfort-technology (HVAC etc.). Roof design / engineering with all its existing – traditional – and new functions and applications related to the comfort-aspects of the total building, are usually handled as separate and add-on aspects in design as well as in practice. Traditional process-approaches might no longer suffice, because complexity and scale of design processes continuously increase through time and quality (Dorst 1997, van Loon 1998, van Aken 2005).

In practice, the often heard reaction to this situation is a call for a ‘forward integration’. Forward integration assumes that most problems could be avoided if during early design phase knowledge of disciplines which are usually later introduced in building (design) process would be available. However, even though we assume that a multi-discipline design team instead of a mono-disciplinary view on design is the way to pursue building (design) integration (Savanović 2006), simply adding new stakeholders into preliminary design phase could even increase problems. Training participants, students as well as professionals, in design collaboration and team working could be one of the effective methods to start with in education and practice. Monitoring these training-meetings could give valuable data and

insight into major aspects of the needed knowledge exchange between participants and how to improve it.

The 'Integral Design' project (Quanjel & Zeiler 2003), conducted by the Dutch Society for Building Services (TVVL), BNA and Delft University of Technology (TUD), which involved mainly architects and building services consultants, initiated research related to (forward) integration. Main focus of 'Integral Design' project was to raise awareness of different disciplines about each other's positions and problems in relation to building design. The project concluded with a call for 'Integral Approach': "a broad view on the world around us that continuously needs to be adapted and developed from sound and documented experiences that emerge out of interaction between practice, research and education. This integral approach can eventually lead to integral process, team and method – all the required conditions for design of the end product." (Quanjel & Zeiler 2003).

Based on the above considerations, and in contrast to the traditional sequential building design approach, we propose that the design team should start working on a design task from the very beginning of the design phase. Related to the problem of the knowledge gap between design- and engineering/construction-knowledge such a building design team should consist out of an architect, a structural engineer, a building physics and – related to the roof – additional a roof-construction specialist. These 'specialists have specific knowledge about the object and the process how to construct it. The defined design team's disciplines have 'object- as well as 'construction-knowledge. 'Object knowledge is knowledge on the characteristics and properties of artefacts and materials; 'realization knowledge is knowledge which makes it possible – necessary – to construct and build the designed object (van Aken 2005). Van Aken's distinction between object, realization and process design knowledge is very effective in explaining what is – in our view – necessary in design collaboration and team working; to integrate *explicit-based* 'object- and realization design knowledge' through implementation of 'process design knowledge'.

## OBJECTIVE

What is necessary to examine in order to come to effective design support-tools:

- *how* the knowledge exchange / development between designer / architect, engineer / roofer of innovative roofs – as part of the total building design and its comfort-systems and within the context of the Dutch building construction industry – is realised in the early design phase
- *what* is the influence of a supportive knowledge exchange tool – as part of a specific design model – on the knowledge exchange / development in the former setting

We add as hypothesis: using a specific structuring method for designing (the Integral Design Methodology), will improve the possibilities of the necessary knowledge exchange and knowledge development as stated above.

## RESEARCH SETTING: STRUCTURING PRINCIPLE

Many studies related to team collaboration have been conducted, focused on a variety of topics related to knowledge exchange / development. Beside the more general studies about knowledge development (Schön 1993, Dixon 1999, Argyris 1999), there are studies that examine team designing (Tang&Leifer 1988, Cross&Cross 1995; Goldschmidt 1995-1996, Stempfle&Badke-Schaub 2002) concerning face-to-face collaboration. Other important research studied the effects of different media on collaborative design but focused mainly on communication. (Majumder 1994, Eastman 1996, Gabriel&Maher 1999, Ahmed et al. 1999, Boujut&Laureillard 2002, den Otter 2005, Emmit&Gorse 2007). Related studies where done on shared understanding, representation and tools (Olson&Olson 2000, Salter&Gann 2002,

den Otter 2005) and knowledge transfer in collaborative settings (Court et al. 1996, Badke-Schaub & Frankenberger 1999). Olson and Olson (2000), after reviewing over ten years of co-located and non co-located synchronous collaboration both in the field and laboratory settings, concluded that distance still matters. In the case study of innovation in engineering design, Salter and Gann (2002) found that despite modern information and communication technologies, face-to-face interaction and the immediacy of sketching are still the most important elements for developing new ideas and solving problems. Though, if we would like to research the knowledge exchange between designer / architect and engineer / roofer most effectively we should focus on the explicit knowledge exchange / development in the most basic way in the design-setting of face-to-face interaction.

It could be stated that an effective supportive design-method should have the characteristic that is could be used in the real – face-to-face – situation of design-team collaboration. A second characteristic, related to the different educational background of the design-team participants, should be that the method should be easy to adapt, could be used without sophisticated knowledge about technique or equipment. Related to the broad field of knowledge – object- and realization-knowledge – needed for designing, the third qualification should be; useful in the several stages of the design (analyzing, synthesise, selection and modifying) and the different levels of abstraction (e.g. urban to detail).

The proposed design model, the Methodical Design (Van den Kroonenberg & Siers 1992), as part of the Integral Approach, has the characteristics as described above and can be used as a basis for structured introduction of discipline based ‘object- and realization-knowledge’. Methodical Design is based on a combination of the Anglo-American school and the German design school (Van den Kronenberg 1978). This framework proved its potential within the (mechanical) engineering-domain (Blessing 1994) and makes it possible to explicitly think and act on a specific abstraction-level. An important design-method used within the model of Methodical Design is the Morphological Overview (Zwicky 1969) which can structure problems on functional hierarchy, various abstractions and / or complexity levels during different design phase activities – both for the overall design stages as for separate design activities (Zeiler 2007) (Figure 1).

Figure. 1 Example of the possible use of the structuring design method of morphology in designing (Beauty and Waste - Herzog & De Meuron)



## METHODOLOGY: WORKING PRINCIPLE OF ANALYZING/ SYNTHESIZE / SELECTION / MODIFYING KNOWLEDGE

Besides of assessing and structuring the different kinds of knowledge, to use it in the setting of team working the different members/ disciplines have to be able to use it for designing. This brings us to the characteristics of designing in relationship to knowledge exchange and knowledge development between the different team members. To come to an insight into this objectives we use the working principle of analyzing / synthesize / selection and modifying.

About this coupling of design-characteristics and knowledge exchange / development we looked for a more theoretical foundation that could be part of the Integral Design-methodology and incorporate the needed characteristics for structuring object, realization and process-knowledge of the Methodical Design methodology (Savanović & Zeiler 2007). This theoretical background is found on how design knowledge could be transformed into integral design concepts is found in the 'C-K theory' by Hatchuel and Weil (2003). C-K stands for concept-knowledge relation. This theory defines design as a process generation co-expansion of two spaces; the space of Concepts (C) and the space of Knowledge (K). A design Concept is a proposition that can not be logically valued in K; Concepts are candidates to be transformed finally into propositions of K, until then they are not elements of K. Properties of Knowledge can however be incorporated into Concepts. In our view there are two ways of knowledge exchange / development (Figure 2). Existing Knowledge is *transferred* into *more optimal* Knowledge or existing knowledge is *transformed* into *evaluated* Knowledge which is Knowledge creation and leads to Concepts. Concepts have the potential to contain innovative solutions; solutions which are necessary for new and faster changing situations. In other words, with application of 'ID-methodology' we are interested in how to stimulate design teams to produce, for themselves new, integral concepts. The 'newness' of these concepts can be measured by assuming design teams' explicit initial object design knowledge *and* realization knowledge; all there is in space K. Design within our integral approach represents realisation of potential for creation of new object/ realization design knowledge through integration of discipline based explicit object / realization design knowledge into integral design concepts.

If we have to come to an effective way to 'structure and organize the link between all the aspects for designing integral design concepts for the setting of collaborative design, we propose the use of face-to-face design meetings working with the Methodical-Design methodology and Morphological Overviews as design method (Synthesize Phase).

In order to identify whether the knowledge exchange within the Collaborative Design Team is Knowledge Combination or Knowledge Creation – the Selection Phase – we use the structuring design method of the Morphological Overview which we introduce in the Collaborative Design-setting. The characteristics of the Morphological Overview enables us to examine who of the participants introduces which kind of knowledge and if – in the specific team-setting – this leads to Redesign (RE), combination of Knowledge (K), or Concepts, creation of Knowledge (ID) (Figure 3). We are especially interested in the role of the Roofer, as a specialist with specific Realization Knowledge, in the knowledge exchange / development within the Collaborative Design (Selection Phase).

Figure. 2 Transfer / combination of knowledge versus transformation / creation of knowledge; the Integral Design-methodology design model (Savanović & Zeiler 2007)

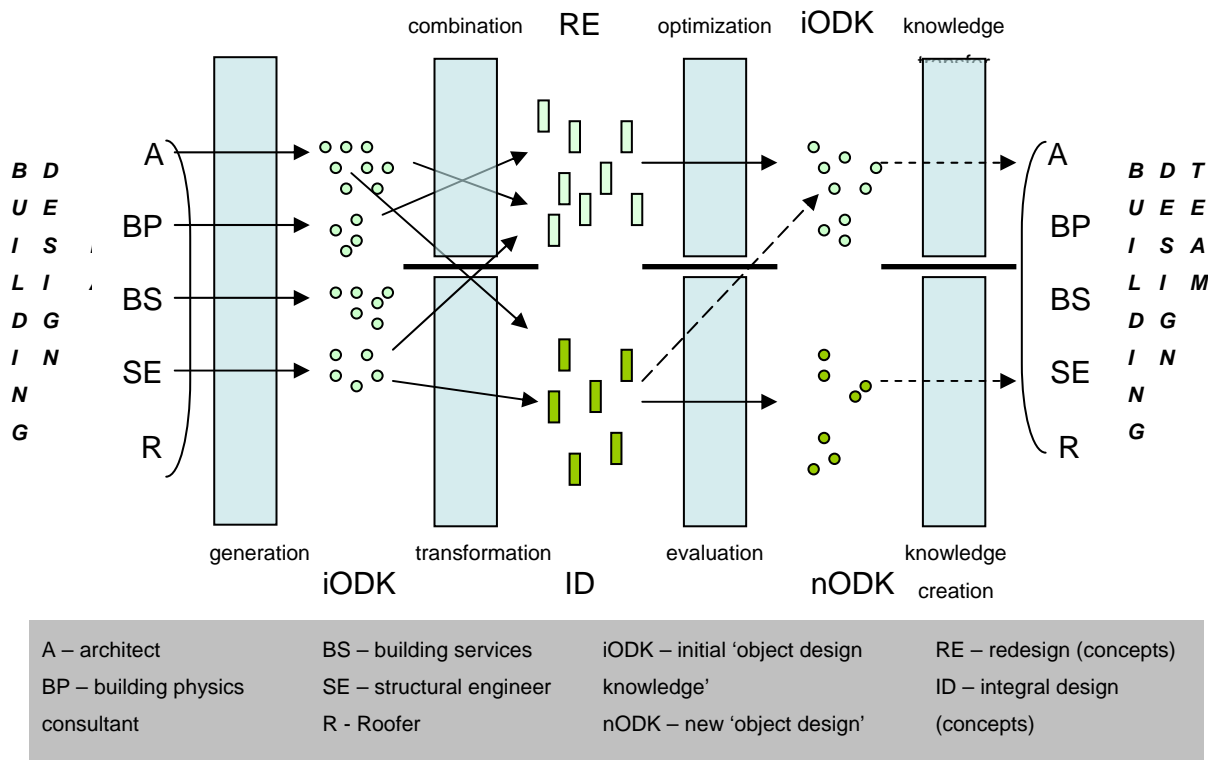
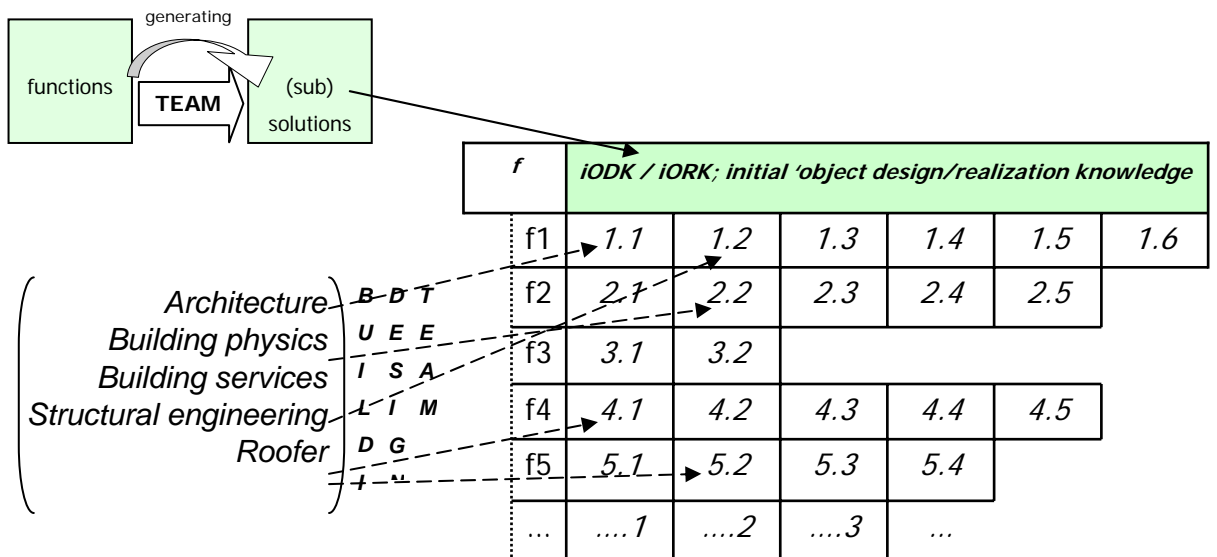


Figure. 3 The Morphological Overview as a structuring design method for available explicit object and/or realization knowledge



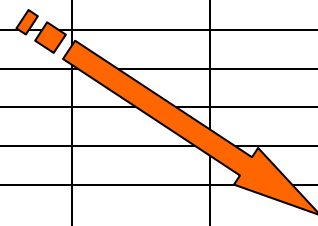
As stated above a face-to-face environment is an optimal setting for communicating – exchange knowledge between design-team-participants. Our starting point was therefore to bring those disciplines together, as equal design team members. Communication between different members of a design team is generally a notoriously difficult problem, especially at the early stages of design process (Eckert et al., 2000).

It is important to stress that in our view *the output* – both process and product – of communication in the first place needs to be transparent; not only internally for design teams themselves, but also for external participants. After all, designing is a form of service providing, meaning that design team designs for the client and not for themselves.

A suitable environment for integration of activities of a building design team is believed to be the workshop setting. Workshops are seen as a self-evident way of working for designers, that occurs both in practice as during their education. Besides full design team line-up, there are a number of other advantages of workshops with regard to standard office situations, while at the same time retaining practice-like situation as much as possible: the possibility to gather a large number of professionals in a relatively short time, repetition of the same assignment and comparison of different design teams and their results. The openness of participants for new methods is also bigger than during daily routine, something that can't be emphasized often enough. Suitability of workshops for integration of design team activities, together with suitability of morphological overviews for structuring knowledge of design team members, forms the basis for an optimum design collaboration. To examine the different aspects related to this knowledge exchange we use therefore the workshop-setting. The adaptive form of the workshop-setting gives us the opportunity to make different configurations and by the feedback-looping of evaluation – to select those aspects to improve the setting (Modifying Phase) (Figure 4).

Figure. 4 Using the methodology of Methodical Design for developing workshops for collaborative design teams; different workshop-settings with different functionalities and variations, developed through stages of analyzing / synthesizing / selection / modifying

LEVEL / PHASE	Problem definition	Working principle	Choice	Modify
Workshop 1	<b>NEED</b>			
Workshop 2				
Workshop 3				
Workshop 4				
Workshop 5				
Workshop 6				<b>SOLUTION</b>
>				



### EXPECTED RESULTS

During the last year we initiated 2 workshops with students with different educational backgrounds and 1 workshop with professionals. During 2007 we plan 4<sup>th</sup> workshop with professionals. Within these workshops we examined the right workshop settings (van Vliet 1995, Herzog 1996) to make them comparable and how to make the monitoring effective (Emmit&Gorse 2007, Bales 1950). The set-up and results of these workshops is presented in other papers (Quanjel et al. 2007a, Quanjel et al 2007b). With the 4<sup>th</sup> workshop we have a modified model to get insight of knowledge-flows between designers / architects to engineers / roofers and visa versa *and* to identify the influence from the specific method and its tools – Methodical Design – on the knowledge development between designers / architects and engineers / roofers.

### ACKNOWLEDGEMENTS

This research is supported by KCBS, PIT and the 6<sup>th</sup> European framework program EUR-ACTIVE ROOFer.

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