

Workshops for integral design of innovative roofs

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WORKSHOPS FOR INTEGRAL DESIGN OF INNOVATIVE ROOFS

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Keywords: *integral design, knowledge management, workshops, sustainable solutions*

Abstract

Traditionally, the installation of accessories on roofs is the domain of roofers, having the traditional knowledge and experience of successful mounting and integrating existing roof products in both new and renovated roofs. In the current roofing situation, many new products are added to the building design and building process. As a result many problems occurred, resulting in poor quality, unsafe working conditions and high repair costs. Today there is a need from the roofers for a more active role not only in the constructing process, but also in the design process; Collaborative Engineering. The active role for the roofer is therefore related to the several aspects of the context in which the roofer has to participate. The result should lead to innovative roofs, roofs that are producing sustainable energy and are active in the interaction with the thermal environment.

First experiments to find a format for supporting Design Collaboration, started in 2004 with workshops for design- teams including participants with the same educational background. In 2005, a first set up was done for design teams with participants with different educational backgrounds. These workshops are coupling a concrete task from practice and research focusing on the roofs where there is a lack of innovative designs, caused by a sub-optimal interaction between solutions and application in design practice. The process where actors from different disciplines work together to develop a (new) product is called Collaborative Engineering (CE). Workshops are used to offer a collaborative context to professionals and to determine in steps an adaptive method to analyse and improve the design collaboration related to knowledge exchange.

The project, as part of the European 6th framework research EURACTIVE ROOFer, resulted in a series of workshops for architects and roofers to develop active roofs for integral sustainable comfort (HVAC)- system design, engineering and installation. The workshops gave first insights into the knowledge exchange and knowledge development between the participants. This paper describes the methodical backgrounds, the set-up of the EURACTIVE ROOFer-workshop and first results related to the knowledge management aspects.

1. Introduction

A lack of innovative designs is observed in a specific part of the Building Industry; the traditional roof design. Innovative designs can be defined as designs that produce something like nothing done, experienced or created before by the process of making improvements. A design is defined here as; a basic scheme or graphic representation that affects and controls function or development for a subject that has to be constructed or manufactured. Professional parties indicate that this lack of innovation is caused by a sub-optimal interaction between solutions and application in design practice of traditional roof design compared to innovative roofs. There is a contradiction in influence and design-information between the designer / architect and builder / roofer, a contradiction in knowledge-flow between disciplines with different educational background (EURACTIVE ROOF-er 2005). The process where actors from different discipline work together to develop a (new) product is called Collaborative Engineering (CE).

Actors within CE have different cultural backgrounds, way of working, different motivation of collaboration and geographical conditions (Korbijn 1999, p. 18).

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A supportive process approach for a more effective collaboration between designer and builder, between architect and roofer, is therefore needed. This process knowledge through collaboration will link the needed requirements for innovative designs; the design- or object knowledge and the building- or realization knowledge (van Aken 2005). The types of knowledge as stated are communicated within the collaboration between architect and roofer, with different educational backgrounds and with large differences in competences and skills, through different kinds of representation (Brereton 1998). Object knowledge can be defined as knowledge on the characteristics and properties of artefacts and their materials as used by architects, where realization knowledge is knowledge on the various physical processes to be used to realize designed artefacts, used by for instance roofers (van Aken 2005). One of the aims of the 6th framework Pan-European EURACTIVE ROOFer project, as part of the research design of E. Quanjel, was to develop a methodology for supporting the whole design team in the early phase of the design process on integrating active roofs – as energy generating integrated building components – in relationship with the product development of the active roof itself. Workshops and a specific design method (Morphological Overviews) are used to get insight into the knowledge exchange and the knowledge development between architect and roofer.

First the methodology is described as well as the specific design method (MO) to support participants by structuring design- and realization-knowledge. The second part of the paper will give the set-up of the workshop, as one example of a range of workshops used, as the setting where the methodology is used and first results related to the use of MO related to knowledge management.

2. Integral Design Methodology

In our view an integral approach will result in synergy between rational problem solving (Cross 1989) and reflective practice (Schön 1983). However, as designers-researchers we are not primarily aiming to improve “understanding of design through scientific methods of investigation” (Cross 2001, p.53). We are focusing on research *for* design, in this specific case: ‘how can we aid its development towards the generation of more innovative roof designs?’

2.1 An Integral Approach; Methodical Design Model as supportive Process Tool

An Integral Approach is combining all the aspects and disciplines involved related to the clients questions and context, is needed for the development of these knowledge and skills (Quanjel & Zeiler 2003). During design team cooperation integral design is meant to overcome the difficulties raised with the early involvement of different disciplines and cultures. 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 roofers this means the direct connection of construction/user-practical (realization) knowledge with design-related conceptual (object) knowledge. The integral design methodology must therefore support different users during the design process. These different users have completely different cultural backgrounds and different capacities to think in abstractions, which will influence the set up (design model) for the necessary tools (design methods) to support the integral design process. 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. In this research the Methodical Design Model is used as Process Tool and Morphological Overviews as Design Method.

The Methodical Design Model is based on the Methodical Design from van den Kroonenberg (Blessing 1994); used in the mechanical engineering domain. Through the use of the Methodical Design Model we introduce it into the domain of the building industry as setting for Collaborative Engineering Teams. 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. These abstraction levels can be seen as aspects and functionalities related to object- (architects) and realization-knowledge (roofers). With the Methodical Design Model the team of architects and roofers can develop a design through different iterative phases of the design process: the analyzing, synthesizing, selecting and modifying phases. By structuring the different aspects and functionalities, within each abstraction level, development of a shared understanding between architect and roofer is encouraged. From the insight in different possibilities, through a shared understanding, based on the design requirements by roofers and architects more possible – new – solutions can be generated.

Within the setting of Methodical Design Model several design-support tools are used to structure several functionalities, generate and select possible solutions. The research is focused on the added value of a specific design method, the Morphological Overview (MO). The described workshop is the framework of the Methodical Design Model (working in phases and levels) as a Collaborative Engineering setting for professional architects and roofers to introduce the design method of Morphological Overviews.



Morphological Overview for Adaptable Roofs; the red en green lines give possible combinations for possible solutions / concepts

Fig. 1. Example of a Morphological Overview; left column show the different functionalities related to adaptable roofs, the horizontal rows show probable solutions to the functionality. The red and green lines give possible combinations as possible solutions for design (configurations). The Morphological Overviews are developed in collaboration of all design-team participants in order to generate different solutions.

2.2 Morphological Overviews as supportive Design Method

As discussed, during the design process depending on the focus of the team member, aspects and functionalities exist at different levels of abstraction. Morphology provides a structure to give an overview of the aspects and functionalities considered and the alternative solutions. General Morphological analysis was developed by Fritz Zwicky (Zwicky & Wilson 1967) as a method for investigating the totality of relationships contained in multi-dimensional, usually non-quantifiable problem complexes (Ritchey 2002). Essentially, general morphological analysis is a method for identifying and investigating the total set of possible relationships or “configurations” contained in a given problem complex.

The main aim of using Morphological Overviews is to widen the search area for possible new solutions. Morphology provides a structure to give an overview of the considered functionalities and aspects and their solution alternatives. Functions are the design intentions or purposes; the results of the artefact’s behaviours; the purposes of the design being designed, i.e., its teleology (based on FBS-definition by Roseman and Gero, 1998). Functionalities are all those functions and aspects which are related to the object-, realization- and process-design. Transformation of the program of demands, by the team, into aspects and functionalities, (vertical axis figure 1.) and formulation of the different solutions and relations related to these aspects and functionalities (horizontal axis, figure 1.), leads to the construction of a Morphological Overview (figure 1.). The Morphological Overviews are developed by all participants during the design process. The different participants will use their own specific knowledge and their own interpretation of the design-task and necessary aspects and functionalities (solutions related to specific aspects and functionalities on the horizontal axis, figure 1.). During the design process they will discuss and develop together these different approaches, through different design stages (analyzing, synthesizing, selecting and modifying), to possible solutions or even innovative new solutions (red and green lines in figure 1.). Related to the focus of the research, the use of explicit object- and realization-knowledge and the influence of the design method in the collaborative setting; the Morphological Overview becomes both the tool for the design team as well as one of the instruments to actually show the used and shared knowledge

by the team to the researcher. So the workshops are used as setting for Collaborative Engineering to introduce the Morphological Overviews *and* research the knowledge management between architect and roofer.

3. Workshops as experimental settings

Research on Integral Design in practice with professionals through the study Integral Design (an initiative from the Royal Institute of Dutch Architects (BNA), the Dutch Society for Building Services (TVVL) and Delft University of Technology (TUD)), both for development and evaluation, is ongoing from the year 2000. This research was continued in 2004 with a new research within the Knowledge Centre Buildings and Systems (KCBS), in which Eindhoven University of Technology (TU/e) and the Netherlands Organization for Applied Scientific Research (TNO) cooperate. These studies resulted in ongoing workshop series, in which already over 250 professionals from BNA and the Dutch Association of Consulting Engineers (ONRI) participated, used for development and evaluation of the specific integral design methodology Methodical Design and Morphological Overviews (Savanovic 2007).

The developed workshops appear to be effective and adaptable environments for professionals to work / design in team-settings *and* as research situation to evaluate and develop the proposed design-method of Methodical Design and Morphological Overviews. Until now the workshops were organized for design-team-members with the same educational back-ground. The workshop as proposed in the setting of EURACTIVE ROOFer focussed on the situation of Collaborative Engineering, where participants with different educational backgrounds work together. Experiences from former workshops are used in the set-up and working methods for the Workshop Innovative Roofs as well workshops held with students (TU/e 2005-2006) and a workshop-in-company with professionals (Brakel & Atmos). These workshops as well as the described Workshop Innovative Roofs are also part of the PhD-research Integral Design Methodology in the Context of Collaborative Engineering for Active Roofs by E. Quanjel and executed at the Technische Universiteit Eindhoven (TU/e) in cooperation with TNO.

The workshop as described and analysed in this paper is part of the EURACTIVE ROOFer-research and was organized by the TU/e in collaboration with TNO Delft and Het Hellend Dak, all partners of the research-project. The workshop was organized in September 2007 with professionals of the different involved disciplines (architects and roofers). To distinguish the knowledge-exchange / development aspects related to the use of the design method MO, several views are used to extract data out of design teams: by evaluation-questionnaires for all participants, video-registration / analysis of the experiments

The EURACTIVE ROOFer-research is more focused on the general decision support part of Collaborative Engineering for Active Roofs, where the PhD-research is focused on the Design Methodology and the use of Morphological Overviews as a practical design method for structuring and support knowledge exchange and knowledge development between architect and roofer. The Workshop for Innovative Roofs tried to couple these aspects, with the focus on the following aims:

- Which functionalities are used by different disciplines of roofers and architects in the setting of Collaborative Engineering for Active Roofs, how are they part of the use of MO and design solutions.
- What is the influence of the former aspects of MO on knowledge sharing between the different participants in the setting of Collaborative Engineering (roofer and architect).

Figure 2 shows the set-up for the Workshop. Teams were in the same configurations during the Workshop because the focus was for the participants to work on designing innovative roofs in a collaborative setting with different tools. Three different methods were used for analyzing the Workshop results; the explicit results by the Morphologic Overviews, the designs made by the participants and the questionnaires filled in by the participants. The third method was used as feed-back for specific information about the used representation by roofer or architect and process; video-film and photos each 10 minutes. The questionnaire for the session with the Morphological Overview was also used in previous workshops. One video-camera with microphone with a fixed position per team was used, only per 10 minutes a photo was made by one of the assistants. The Workshop was not presented as research, but as design-sessions for Innovative Roofs. Total amount of participants where: 5 Architects and 6 Roofers, all with the competences needed; member of the Professional Associations, at least 5 years professional experience with building design/engineering. Figure 2. shows the set-up for the Workshop (WS 4) for 28 September 2007, organized in Zeist / Buitenplaats Groenoord (The Netherlands).

The first part (step 1.) was done individual; 5 architects (o1-o5, figure 2.) and 6 roofers (u1-u6, figure 2.) using MO. The second part (step 2.) of the workshop was done in teams architect and roofer; groups G03 (o1-u6), G05 (o2-u5), G06 (o3-u4) and G07 (04-u3). One member of the architects and 2 of the roofers did not attend the second part. The first part the individual disciplines had to made a listing of functionalities and aspects related to the design task of sustainable innovative roofs. Where in the second part of the workshop teams of each one roofer and one architect had to work on a design task for sustainable roofs. The last part (step 3.) was done collectively as an evaluation on the workshop and the workshop-results.

setting WS 04

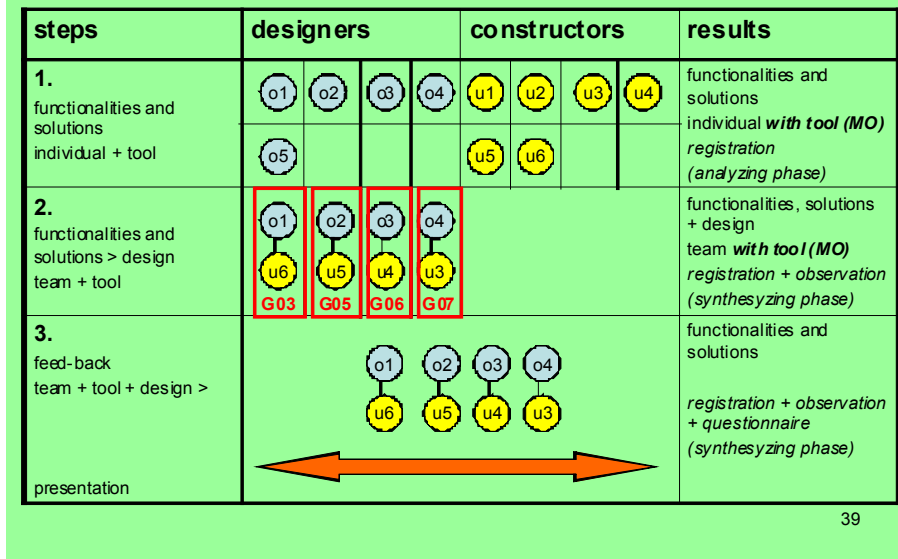


Fig. 2. Set-up of for the workshop Innovative Roofs; working individual and working collaborative between architects (o1-05) and roofers (u1-u6); individual (step 1) and in teams (step 2.) with the use of Morphological Overviews. Step 3 as evaluation of the workshop and the workshop results through the designs.

4. First results of workshop WS 4

4.1 Workshop part 1; use of Morphological Overviews individually

The workshop started with an introduction about an overview of sustainable comfort systems by a member of TNO-Bouw and practical solutions of sustainable comfort systems by the senior architect of BAER-architects. These introductions were followed by an explanation of the use, characteristics of Morphological Overviews by the PhD of the Technische Universiteit Eindhoven.

The first part was done individually through a brainstorm on a roof-design. The analysis focused on the different functionalities generated the amount of functionalities and which / how many were incorporated into the design proposal(s). The same analysis was done in the second part where architect and roofer were working together of a comparable design-task. One part of the group was using the Morphological Overviews, the other groups not. The last analysis took place in the setting which changed teams; comparable design task, with and without design-support tool. The results for the brainstorm are shown in table 1 and table 2. The second part of the Workshop was done collaboratively, with the results as shown in table 3 and 4. For this part 4 teams were formed; team G03, G05, G06 and G07. As table 1 shows there is a clear difference in amount of introduced functionalities between architects (26) and roofers (13). There is also difference in amount of functionalities used in the produced individual design drawing; 13 functionalities used by architects versus 6 functionalities used by roofers in their individual design drawing. Architects used more specific descriptions of sustainable functionalities (A4-A7, table 2.) where the roofers introduced more practical functionalities such as assembly and safety (R20, R23, table 2.), missing by the introduced functionalities of the architects. Similar used aspects where: general items about protection against rain and sun, cooling and warming of the building, energy, aesthetics, and use-functions.

Table 1. Overview of amount of functionalities and sub-functionalities generated individually; solutions related and not related to functionalities; solutions in drawing; step 1 of the workshop.

Participant	Functionality	Solution related to functionality or aspect of functionality	Solution not related to functionality	In drawing
Architects total	26	24	2	13
Roofers total	13	9	4	6

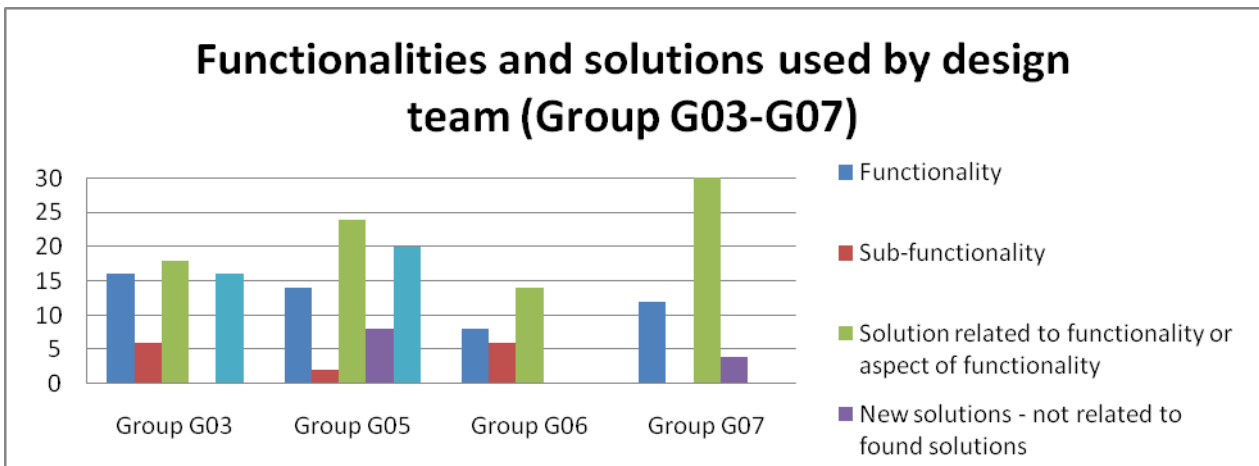
Table 2. Overview of type and amount of functionalities and number of solutions related - generated individually (step 1 workshop.); left roofers and right by architects; in red ellipse the functionalities used by roofers and missing by architects.

Roofer		Architect	
Functionality	Number of solutions	Functionality	Number of solutions
R.1 Protection against rain / weather	(4 / 2 / 4) 10	A1. Protection against rain and sun	2
R2. Cooling / warming of building	2	A2. Contribution to energy-system of the building	4
R.3 Cold battery / cooling	2	A3. Warmth battery / cold battery	4
		A4. Ventilation warm / cold	1
		A5. Heating; warmth in / cold out	1
		A6. Warmth convector / radiation	1
		A7. Active PV	2
R8. Ventilation		A8. Ventilation cold / warm	1
R9. Sun, wind, water absorption		A9. Sun , wind, water aspects	4
R10. Water, thermal, wind, fire		A10. Climate (water, wind	4
		A11. Noise protection	4
		A12. Light	4
R13. Energy	(5 / 3 / 2 / 3) 13	A13. Energy	(4 / 4) 8
R14. Aesthetics	(1 / 3) 4	A14. Aesthetics	4
R15. R15.1 Process <-> Use	(4 / 2) 6 4	A15. Use / functions	(7 / 6 / 9) 22
		A16. Water economy	1
		A17. Sun / light	2
		A18. Rain / water	2
		A19. Material / technology	7
R20. Assembly / transport / modularity	(7 / 1 / 1) 9		
R21. Sustainability	(4 / 5) 9		
R22. Adaptable to environment	3		
R23. Safety	3		

Table 3. Overview of type of functionalities and solutions; example of delivered design outcome of Group 03 roofer-architect (step 2 workshop), in the second column the functionalities used in step 1 (table 2.), in the third column new combinations by the team in drawings; red ellipse the use MO

Group	Functionalities and solutions related to 5.1.2	Functionalities and solutions new
G3	R1, R2 A1, A2, A4, A7, A17, A18	<p>Combinations of G3-5.1.2</p>

Table 4. Overview of type of functionalities and solutions used by design teams step 2 of the workshop; the light blue columns give the explicit used amount of solutions in MO (only in group G03 and G05)



4.1 Workshop part 2; use of Morphological Overviews in team of roofer and architect

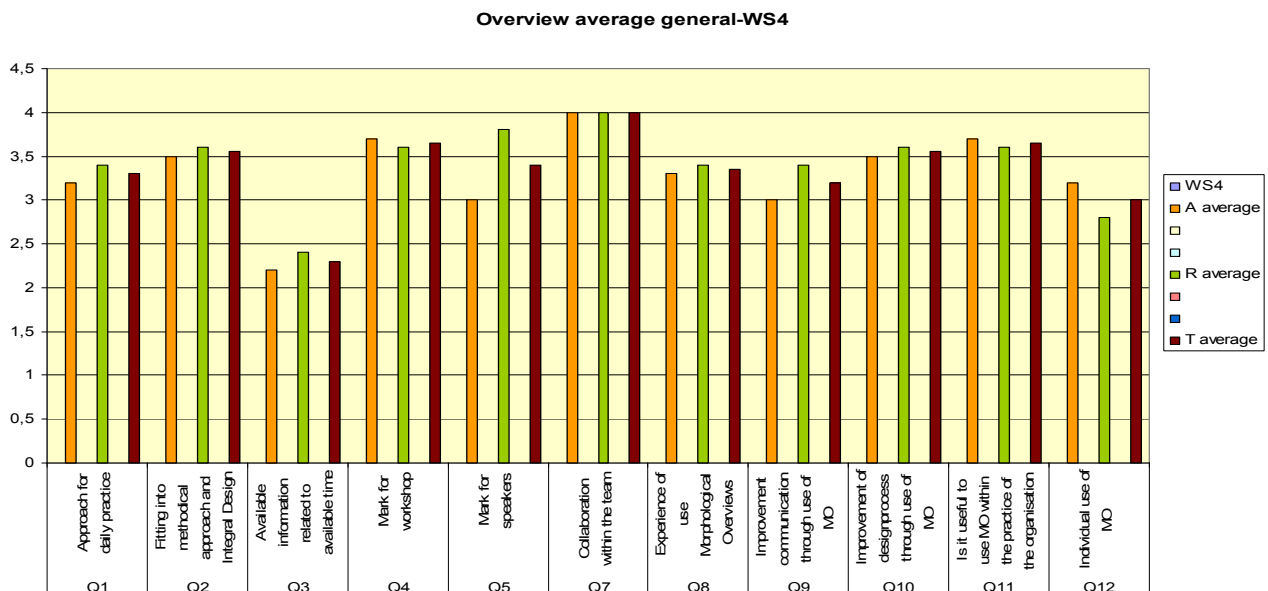
The analyze per team was done in the format as shown in table 3; first – in comparison with the functionalities used by the individuals in step 1 (table 2) – were analyzed from the produced drawings by the teams in step 2 (column 2 of table 3). Then the different and new functionalities and solutions – in comparison with step 1 – were determined (column 3 of table 3). Finally the Morphological Overviews were analyzed on the explicit notated functionalities (light blue column in table 4). Table 4 gives an overview and comparison of the found functionalities and related solutions on one hand and the new solutions (purple) and notated functionalities / solutions (light blue). As shown only few items were explicitly notated in the MO (16 for G03 and 20 for G07).

When working together the use of the MO was used mostly to determine very quickly the important aspects related to the subject, sometimes only the functionalities where notated, with some solutions. In collaboration there was more discussion in words and sketching directly on the given copies of the exciting building. In collaboration 8 (out of 14; 57%) of the functionalities introduced by roofers were used and 10 (out of 19; 52%) of the functionalities introduced by the architects. Of the similar introduced items 4 out of 5 were also used in the collaborative setting; protection against rain / weather, cooling / warming of the building, energy and different use. From the differently introduced items the use of active PV (Photo Voltaic), sun light and use of rain and water where used. From the items more related to construction and introduced by the Roofers, only assembly and sustainability were used once in the collaborative setting.

4.3 Workshop part 3; evaluation

For the overall workshop, all the designs where presented and discussed by the participating teams as well as an evaluation on the use of the Morphological Overviews and Database Structure EURACTIVE. The evaluation was also done through a questionnaire as used in all former workshops. After 6 month the same questionnaire was sent to the participants. These results are presented below in table 5.

Table 5. Average marks on questionnaire overall workshop – after 6 months



5. Conclusion and discussion

5.1 The use of the Morphological Overviews (MO)

Although the participants experience working with the MO as difficult, and in the way that they are not trained in using the MO, they generally see the MO as a positive tool to structure their individual thoughts. Architects are more positive about the use of the MO than the Roofers (Q1). In the group evaluation afterwards it appeared that the overall experience in using the MO was that 'MO is only useful / effective after brainstorming to structure in the 'second loop for design in the collaborative setting'. Training of the use of the MO could be helpful to get more insight into the possibilities and advantages in working with the MO.

5.2. The structure of the Workshop

Working together in a workshop-setting as introduced was experienced as positive by the participants (Q3). The set-up of the workshop in total was also rated positive, although a few remarks are necessary (Q4). The critics on the workshop itself can be pointed out as related to time and amount of subjects. For the participants there was too much subjects and too much new information in a short time. Because of this also a kind of tiredness can be observed in the second part of the workshop, the part where the Database was introduced and determined. The next workshop should have therefore one major theme as focus and should pay more attention to the content of the introduced tool(s). In general development of better observation-criteria and criteria for analysing the specific results are necessary.

In evaluation with TNO as well as HHD and the BNA (Royal Dutch Association of Architects) the workshop should have a follow-up in the near future. Preparations for a next workshop in March 2009 are made as well as a follow-up in longer term as part of the Permanent Education of Professionals

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