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INTEGRAL DESIGN: THE NEW NECESSARY PROFESSIONAL SKILLS FOR ARCHITECTS AND ENGINEERS FOR THEIR ROLE IN SUSTAINABLE DEVELOPMENT

Professor Wim ZEILER
TU Eindhoven, The Netherlands

ABSTRACT
The built environment is one of the most important areas of sustainable development. New strong demands for a more sustainable built environment led to a more complex design process. To cope with this complexity architects and engineers have to operate together earlier in the conceptual building design process. As a consequence architects as well as engineers have to develop new skills. Also the architect has to learn, to not only share his ideas in the conceptual design phase, but to really open up his mind and to truly design together with the engineers. Designing becomes a team effort already in the conceptual phase of design. To support these diverse multidisciplinary building design teams a supportive design method was developed in cooperation with the Dutch professional organizations of architects and consulting engineers. The method is being used in a workshop Integral Design for master students at the Faculty of the Built Environment of the University of Technology Eindhoven. In this project students from different disciplines have to design a net Zero Energy Building within one semester. The design tool enables not only to support the design team during the conceptual design phase, but also to study the process within the design team in detail. Especially interesting is to see whether the architectural students would really work in a kind of open dialogue with the engineering students or that they would behave in a more traditional dominant role in the conceptual design phase. It proved that architects played a dominant role in defining the functions to be fulfilled by the design. Overall the attitude of architectural students and engineering students has to change to allow real integral design processes in which the disciplines have a real open mind towards each other without any dominance.

Keywords: Architecture, Engineering, Integral design, Morphology

1 INTRODUCTION

Although, sound decision making during conceptual development requires not only shape design knowledge (architect) but also technical expertise(engineers) as a consequence interaction between all relevant domains should be and is common understanding and practice in building design, this is not the true practically situation. However, in daily building design practice this is still quite problematic. The construction industry is in the early stages of a revolution to reinvent the design process that was used before the large scale application of HVAC systems (Heiselberg 2007). In contemporary building design the role of architects and traditional discipline based consulting engineers are changing. For a more sustainable future, the built environment is one of the most important areas to work on for sustainable product innovation. The built environment uses in the western world 40% of our energy for operating as well as another 8% embodied energy by the used building materials and their production process. In response to climate change and 'peak oil' architecture should encompass the environmental task of design a low carbon built environment (Chen et al. 2011). As such, architecture has an important role in directing sustainable development (Taleghani et al 2010). Within the European Community the member stated declared that all new buildings should be nearly energy neutral by 2020 and that they want to achieve an energy neural built environment by 2050. This led to the development of Zero Emission Buildings: a building which emits virtually '0 (zero)' carbon dioxide (Kang et al 2010). However this new target in building design ZEB, requires totally different approach from conventional building in terms of design, construction and operation (Ritter 2010).

These new strong demands for a more sustainable built environment lead to a more complex design process. The increased complexity of building design inevitably calls for more design collaboration (Lee and Jeong 2012). To fulfill the demand for nearly Zero Energy Buildings there is a need for synergy between the architectural and engineering domain. To cope with this complexity architects need more support from specialized engineers. The different expertise of engineers must be used more effectively especially in the conceptual design phase to reach for new solutions. This has consequences for the role of the engineers involved; they have to operate early in the conceptual building design process and act more as designers and less as traditional calculating engineers. As a consequence engineers have to develop new skills. Also the architect has to learn to not only share his ideas in the conceptual design phase but to really open up his mind and to truly design together with the engineers. It is important that the architect is no longer the one who leads the design process but that the team of architect and engineers leads the design process: Designing becomes a team effort already in the conceptual phase of design. Engineering consultants now have to do more than was traditionally expected from their engineering discipline, as stated by one of the major Dutch building consultants firms (DGMR 2011). Architect and engineer should work together from the very start of a design project and try to reach synergy by combining the different knowledge and experience of the different disciplines. One of the complicating aspects in building practice is the different cultural back-ground of architects and engineers and their different approaches to design. Still synergy between the different disciplines involved in present building design processes is necessary to reach the innovative highly sustainable designs. Trebilcock (2009) concluded that when designing sustainable energy-efficient buildings it requires that architect and engineers overlap their knowledge and skills and share the character of a designer (Brunsgaard et al 2014). King (2012) states that in order to do anything meaningful in terms of moving to low carbon society, we need a consistent framework and design method, within which we can apply knowledge embodied in a design team. The solution for improving the overall quality of building design might lay within the design team itself and letting the design team functioning as a real team. This implies equality and mutual respect between the various disciplines within the design team. However, this is not something easily achieved and design tools and methods might help the process. However, proper design tools and working methods are needed which could help architects in the design process (Kanters et al. 2014). To support these diverse multidisciplinary building design teams we developed a supportive design method in cooperation with the Dutch professional organizations of architects and consulting engineers.

As stated by Janet Beckett, director at Carbon Saver a consultant company specialised in Low Carbon Building design and building engineering physics, there could not be a better time than now in time of global change to implement a paradigm shift within building design – we cannot continue in the same vein (Beckett 2012). Earlier dialogue and true cooperation in the project design means it is easier to build on sustainability, and add innovation and engineer integrated solutions (Beckett 2012). A new kind of architect is needed, who can accept the principles of engineering alongside the building aesthetics. A new generation of architects to be inspired by engineering and science, according to Beckett (2012), willing to listen to concepts and ideas that can be both beautiful and useful as well as sustainable. Also a new kind of engineer is needed, one who is better able to communicate about the realities of how engineering services impact on the building and not just solving problems.

2 METHODOLOGY

In the early 1960s researchers and practitioners began to investigate new design methods as a way to improve the outcome of design processes. Since then, there has been a period of expansion up to the present day (Cross 2007, Chai and Xiao 2012, Le Masson et al. 2012, Ranjan et al 2012, Gericke and Blessing 2012). In the projects designed (and built) in the early 2000s, architects started to adapt their usual design process (traditional design process) by consulting engineers in an earlier stage than normally done. In sustainable building projects designed later, many architects qualified their design process as an Integrated Design Process (IDP): the architects mentioned the early engagement of engineers in the process as a clear sign of this (Kanters et al 2012). This early collaboration with engineers was found to be crucial in order to develop and implement sustainable architecture such as solar integrated architecture. However, this collaboration in the early design phase was not always easy for the architects: engineers 'spoke another language', were often 'too specialised', and 'not willing to compromise on certain issues'. So, the building design process has become more

heterogeneous, with several diverse actors involved such as architects, engineers, contractors and clients. In effect, in order for the contemporary architect to provide a cutting edge concept for a zero energy building, he must view the engineering disciplines as de facto co-designers with integral roles within the design team. Viewing engineers as co-designers has a number of consequences worthy of note. First, the relevant engineering knowledge to work towards zero energy buildings is dispersed throughout a number of engineering sub-disciplines, which implies the need for a variety of engineering disciplines to be included in the design team, e.g. structural engineers, HVAC(Heating Ventilation and Air-Conditioning) engineers, Building Physics engineers etc. Second, to gain the maximum value from this engineering knowledge and to make the design process as efficient as possible, the engineering disciplines must be included in the earliest possible stage of the design process, which can be understood as the conceptual design stage. Third, both the architect and the engineering disciplines will have to learn new skills in order to function productively in a design team scenario. The engineers will have to operate less as traditional calculating engineers, and more as designers who contribute to a shared team concept. Conversely, the architect will have to learn to be much more inclusive in the design process and allow the engineering disciplines to actively contribute to the dynamic design process rather than rely on engineers to simply verify or optimise his own design contributions. Finally, in order to facilitate the inclusion of engineering knowledge into the design team, it is necessary to provide the design team with simple and intuitive methods and design tools that the engineering disciplines are comfortable using.
In the Netherlands methodical design is a quite familiar design method (Zeiler and Savanovic 2009). The methodical design process is a framework application-independent principle with its connection to the general system theory and has some exceptional characteristics (Blessing 1994): it is problem oriented and distinguishes, based on functional hierarchy, various abstractions or complexity levels during different design phase activities. This design method was further extended by us through the intensified use of morphological charts developed by Zwicky (1948) (Zeiler and Savanovic 2009, Savanovic 2009) and the specific use of a morphological overview derived from the morphological chart. The morphological chart is formed by decomposing the main goal of the design task as formulated in the program of demands into functions and aspects, which are than listed on the first vertical column of the chart, with related sub solutions listed on corresponding rows. The use of the morphological chart is an excellent way to record information about the solutions for the relevant functions and aid in the cognitive process of generating the system-level design solution (Wynn and Clarkson 2005, Ritchey 2010). The morphological chart (MC) to visualize sub-solution alternatives plays a central role in the integral design approach for design teams. It helps architects and engineers with their new role in the conceptual design phase as it enables to structure each perspective on the design task as well as to structure the available domain knowledge. The description of the morphological overview may read as minor implementation difference of the old morphological matrices. However based on the applied Integral Design method to structure the design process and using its design tools, the effect of using the morphological overview can be presented in analogy with the model of Badke-Schaub et al (2007), see Fig. 1 (A) and (B).

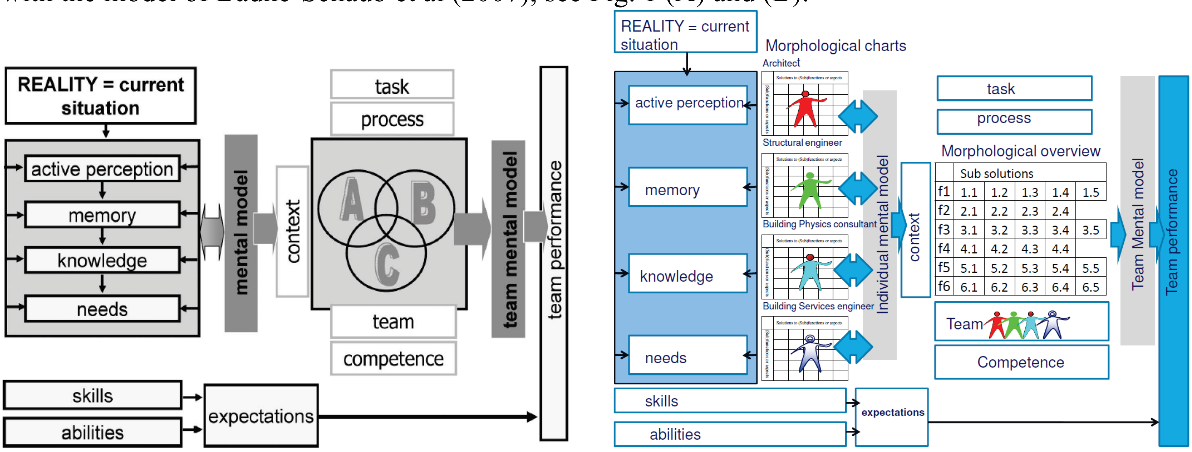

Figure 1 (A) Mental model concept (Badke-Schaub et al 2007) and (B) Design Team mental model Morphological Overview in analogy with the model by Badke-Schaub

Based on the given design task, each design team member perceives reality due to his/her active perception, memory, knowledge and needs. The morphological charts represent the individual interpretation of reality, leading to active perception, stimulation of memory, activation of knowledge and defining of needs, see Fig. 1. Within the morphological overview these individual stimuli can be combined to those of the whole design team. As such the morphologic overview can be used by the designers to reflect on the results during the different design process stages. This illustrates how the mental models in teams develop. It shows that the morphological charts and morphological overview of the Integral Design method can be used to make transparent parts of the Team's Mental Model. The individual morphological charts of each individual designer represent their active perception, their activate part of their memory, their individual knowledge used as well as their interpretation of the design needs. These individual morphological charts can be combined by the design team to one morphological overview, see Fig. 2. This morphological overview is than the representation of the design team's interpretation/perception and activated memory/knowledge.

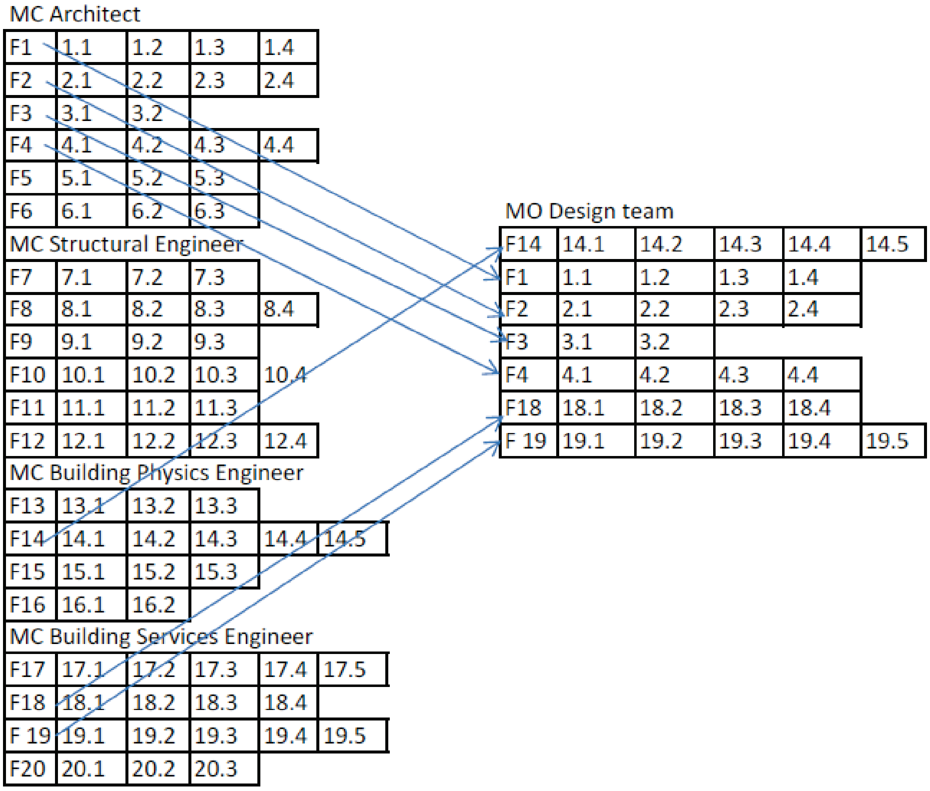

Figure 2. The transformation from the individual morphological charts towards the design team's morphological overview

3 EXPERIMENTS

In the last four years each time a Master Projects Integral design was held 6 teams of 4 students from different disciplines participated: architecture, structural engineering, building physics and building services. The master student's teams work together for a semester on a design task. The location and the type of building of the design brief changes every year but the goal of the design project remains the same: to design a net Zero Energy Building. The Master project starts with a workshop of two days. The design tasks during the two days were on the same level of complexity and had been used, tested and evaluated in professional workshops as well as in student workshops (Savanovic 2009). The application of morphological overviews during the setup of the design session enabled structuring of design functions/aspects and the generated (sub) solution proposals. The workshops provided a good test bench to experiment with different interventions within the design process as well as to analyse the results step by step during the design process. In this paper the analysis is limited to the results of the workshops in 2013. In total 6 multidisciplinary student teams were analyzed, with a specific focus on the interaction between the architectural student and the engineering students.

4 RESULTS

Some of the functions mentioned by the students in their own morphological chart became part of the morphological overview of the design team. This made it possible to look how many of the by students of a specific discipline mentioned functions became actually part of the morphological overview of the whole design teams. As shown in Fig. 3 A in 4 out of 6 teams the architectural students define 50% or more of the functions within the morphological overview. Furthermore, as shown in Fig 3 B. 60 % of the first mentioned functions and even 100% of the second mentioned functions came from the architectural students. Al indications for a clear dominance by the architectural students in the process of defining the functions to work on in the conceptual design phase.

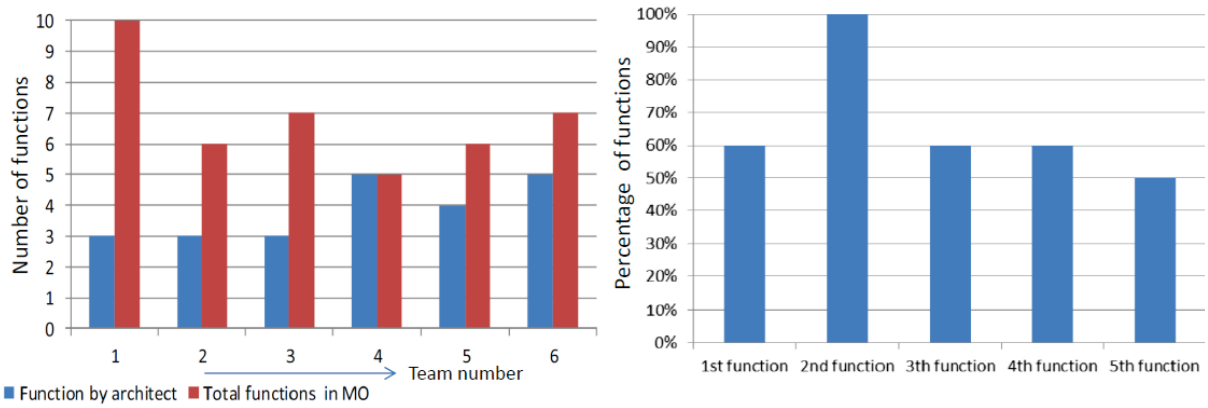

Figure 3 (A) Number of functions mentioned by the architectural students (B) Percentage of functions mentioned by the architectural students

5 DISCUSSION AND CONCLUSIONS

In the last 10 years Master Projects Integral design were held. Our design approach showed that it is possible to interactively engage engineers within the conceptual building design phase with other disciplines. Although the application of morphological charts for concept selection is common practice, however it's use to form a morphological overview based on the individual morphological charts is new. This enables to reflect on the process and to make the link towards the mental model of Badke-Schaub (2007). This is the major contribution of this research. As such everything becomes more transparent during the conceptual design phase and that was one major goal to achieve. This enables it to study specific effects. The results shown here from the 2013 workshops clearly indicate the dominance of the architectural students in defining the functions to work on in the conceptual design phase compared to the engineering students. So definitely it is necessary to develop the skills of both groups to be able to work in a more open and equal way to realize the necessary synergy for integral design.

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