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Morphology in conceptual building design

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ABSTRACT

As the effects of damage to our environment become all the more clear, there is an ongoing social transformation towards sustainability which will affect technology development and make forecasting more difficult. This calls for a holistic integrated design approach which, already at the initial conceptual design phase, requires the involvement of various design experts from different domains to form multidisciplinary design teams. In order to support these teams, a design method based on the use of morphological charts and a morphological overview was developed in cooperation with the Dutch professional organizations of architects and consulting engineers. This tool aids architects and engineers with their new role in the conceptual design phase, as it enables effective exchange of each discipline's perspective on the design task as well as structuring available domain knowledge. The method has been applied in the Master Program project “Integral Design”, at the Faculty of the Built Environment of the Technical University Eindhoven. The design support tool is part of a multidisciplinary program in which students work together with experienced professionals. The outcome shows that the design support tool facilitates a significant increase in the number of possible solutions generated by design teams, and it demonstrates that the morphological charts and morphological overview can be used as an analysis tool for evaluating the impact of different interventions during the conceptual phase of the building design process. This paper provides both a detailed discussion of the design support tool itself, and how the tool was utilized to determine the effectiveness of individual designers. The impact of various interventions is investigated, such as that of adding an experienced professional to a student's design team and the use of C-constructs based on the Concept-Knowledge theory of Hatchel and Weil, in order to further stimulate the generation of sub-solutions.

‘We cannot predict the future, but we can invent it’
- Dennis Gabor

1. Introduction

In the developed world, 40% of energy use and 36% of CO_2 emissions derive from the built environment. This makes it one of the most important areas for sustainable development (BPIE, 2014). The European Union and its Member States have a large number of on-going policy initiatives directly aimed at supporting sustainability of the built environment. Future building regulations will require nearly “Zero Energy Buildings” in Europe. The increased complexity of building design (van der Linder et al., 2016) inexorably calls for more design collaboration (Lee and Jeong, 2012; Häkkinen et al., 2015), and the early collaboration of architects and engineers can facilitate the creation of new knowledge and solutions beyond the specific scope of each individual discipline (Kovacic and Filzmoser, 2014). According to the Royal Institute of British Architects' (RIBA) president Jane Duncan, architects, engineers and builders must collaborate (CIBSE, 2016). This needed collaboration, however, might be difficult to achieve during the early stages of the design process. There is therefore the need for a *design support tool* to facilitate interaction and information exchange between the various design team members as they come up with viable alternatives to be considered by the team as a whole (Zeiler, 2016).

Section 2 presents the details of the developed design method. Section 3 describes methodology, the different interventions to improve the design process, and descriptions of the experiments for testing the method and interventions with professionals and students. Section 4 presents the results of the different experiments, while Sections 5 and 6 provide an analysis and a further discussion of these results. Finally, in Section 7, conclusions are drawn about the added value of the design method as a support and research tool, along with a discussion of the need for further research and development as concerns the morphological aspects of the design method.

2. Integral design

Due to problems resulting from the lack of quality of products and projects, in the early 1960s researchers and practitioners began to investigate new design methods as a way to improve the outcome of

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design processes (Cross, 2007). Since then, there has been a period of expansion through the 1990s right up to the present day (Chai and Xiao, 2012; Le Masson et al., 2012). However, there is still no clear picture of the essence of the design process (Horváth, 2004; Bayazit, 2004; Almefelt, 2005a, 2005b; Atkinson and Opperheimer, 2016), and many different models of this process exist (Wynn and Clarkson, 2005; Pahl et al., 2006; Howard et al., 2008; Tomiyama et al., 2009). Moreover, many of the design methodologies were developed at universities and are only rarely applied in industrial applications (Birkhofer et al., 2005; Stolterman, 2008; Gericke and Blessing, 2012; Dorst, 2016). In 1999, the professional Dutch organization for architects and consulting engineers, together with the University of Technology Delft and the Building Services Society, began research into developing an *Integral Design Method* to improve the conceptual building design process. Since 2003 this research has continued at the University of Technology Eindhoven and led to a design method based on intensive use of morphological charts. After studying different design methods, it was decided to use “Methodical Design” by van den Kroonenberg (van den Kroonenberg, 1988; Zeiler and Savanović, 2009). The outcome of this effort was evaluated in a situation as close as possible to actual practice amongst professional designers (see Section 3). The design method has the distinctive feature of a step pattern of activities (generating, synthesizing, selecting and shaping) that occurs within the design process (see Fig. 1).

This method was expanded to a multi-disciplinary design method – *Integral Design* – through the intensified use of morphological charts developed by Zwicky (Zwicky and Wilson, 1967), and more specifically by the use of a *morphological overview* constructed from the individual design team member's morphological charts.

Morphological charts were derived from General Morphological Analysis (GMA), based on the pioneering work of Zwicky (1948a). GMA was developed as a “method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes”, and its history and example applications are given by Ritchey (2011). Zwicky gives a clear description of the morphological method:

> “*The morphological method essentially is nothing more than an orderly way of looking at things. The only innovation which we propose is to carry morphological thinking to a degree of generality not commonly realized. Our aim is to achieve a schematic perspective over all of the possible solutions of a given large-scale problem. Naturally not all of the solutions which we are thus led to visualize can be carried out individually in all detail. Because of unavoidable limitations on time and means a choice must obviously be made, and preference must be given to some specific solutions. With the general perspective achieved, this choice will however be more rational and organic than it would be if one engaged haphazardly in work on this or that solution of a given problem*”. (Zwicky, 1948b, p. 121)

Morphological charts originate from the concept of the n-dimensional morphological box (Zwicky and Wilson, 1967). The two-dimensional form of the “Zwicky box” is usually referred to as a “morphological chart” (Jones, 1992, p.292). The typical individual designer's use of morphological charts requires all important design functions to be carefully defined and delineated, and possible solutions for each function to be listed, resulting in the framing of solution space. However, rather than simply being another “problem-solving method”, its main use is for the exploration of *new* concepts and *new* types of solutions.

It was Norris (1963) who first introduced the application of the morphological approach into the domain of engineering design methods. The use of morphological charts also has definite advantages for communication and for group work (Ritchey, 2004).

A morphological chart is a matrix with columns and rows which contain the aspects and functions to be fulfilled (Fig. 2, step 1), and the possible solutions coupled to them (Fig. 2, step 2). These functions and aspects are derived from a *program of demands*. In principle, overall solutions can be created by combining various sub-solutions to form a complete system solution combination (Ölvander et al., 2008). Morphological charts structure the solution space and encourage creativity. They are essentially tools for information processing, and are not confined to purely technical problems but can also be used in the development of management systems and in other fields (Pahl et al., 2006; Álvarez and Ritchey, 2015).

Design processes can be improved through improving three types of process communication (Senescu et al., 2013; Senescu and Haymaker, 2013): understanding, sharing and collaboration. The use of morphological charts and a morphological overview (see below) is an excellent way to improve the design process communication procedure. It makes it possible to record information about the solutions for the relevant functions and aids the cognitive process of understanding, sharing and collaboration.

In the first step of the integral design method, the individual designer makes a list of what he/she considers to be the most important functions that need to be fulfilled based on the design brief. This is derived from one's own specialist perspective. The morphological charts are formed as each designer translates the main goals of the design task, derived from the program of demands, into functions and aspects. This is then inserted into the first column of the morphological chart (Fig. 3, step 1_T). In the second step of the process, the designer adds the possible part-solutions to the related rows of the functions/aspects of the first column. Based on the given design task, each design team member approaches the problem according to his/her active perception, memory, knowledge, and needs. The morphological charts represent *individual interpretations* of reality, leading to active perception, stimulation of memory, activation of knowledge and definition of needs. These individual morphological charts can then be combined by the design team to form one morphological overview (Fig. 3 step 2_T).

The morphological overview of an integral design team process is generated by combining in two steps the different morphological charts made by each discipline. First, in step three, functions and aspects are discussed and then the team decides which functions and aspects will be placed in the morphological overview. Then, in step 4, all participants of the design team can contribute their solutions for these functions and aspects by filling in the rows within the morphological overview. Putting the morphological charts together enables *individual perspectives from each discipline to be put forward*, which in turn highlights the implications of design choices for each discipline. This approach supports and stimulates the discussion on, and the selection of, functions and aspects of importance for the specific design task.

It is important to encourage *individual creativity* during the development of the morphological charts. The works of Paulus et al. (2012), (Korde and Paulus, 2017) on group creativity, and of Jansson and Smith (1991), Smith et al. (1995), Ward et al. (1999) on fixation, show how group creativity tends to increase fixation. Design fixation is a

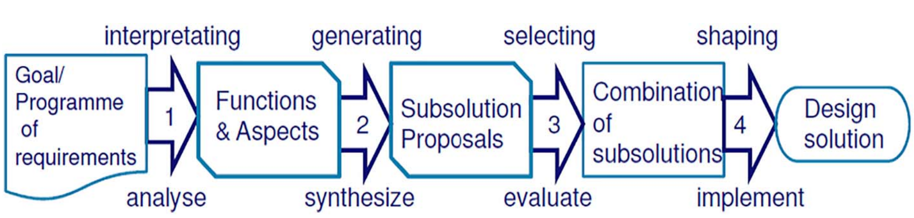

Fig. 1. The four-step pattern of Integral Design.