Integral Design workshops: organization, structure and testing

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ABSTRACT

The purpose of this paper is to achieve an understanding of design activities in the context of building design. The starting point is an overview of design research and design methodology. From the insights gained by this analysis of design in this specific context, we present an 'organization structure and design' workshop approach for collaborative multi-discipline design management. The workshops set-up, used to implement and to test the approach, are presented as well as the experiences of the participants. The project was done in close cooperation with the professional societies with in the Dutch building design field. More than one hundred experienced professionals participated in the workshops. The workshops have become part of the permanent professional training program Dutch architectural society.

Keywords: integral design, morphological overviews, workshops

1. INTRODUCTION

In the design of buildings, the process of implementation must consider not only the needs and expectations of the client, but also of society. The importance of these dual aspects has increased significantly over the past fifteen years or so, leading to a much greater awareness of and research interest into comfort in buildings and the consequences for the environment as a results of Global Warming (Alley et al.2007).

Another significant change that has occurred within recent times is that the design process has become considerably more heterogeneous. Nowadays, it is commonly understood that several diverse actors such as architects, engineers, contractors and clients have increasingly important parts to play in the design process. A key challenge for modern design research is to develop collaborative approaches to design that manage to successfully integrate the various parties involved in the design process in a timely and productive manner. The approach developed by us and described later in this paper is the Integral Design approach.

A fundamental consequence of approaching the design process from the perspective of a collaborative team is that the roles and responsibilities of the parties understood within the traditional design process must change. This is perhaps clearest in the role of the architect, who in the traditional approach was considered as something of a master builder and was given the responsibility for the totality of the design. In contemporary, collaborative approaches, however, the role of the architect is reduced to merely one actor, albeit an important one, among others in the briefing and design phases of a complex project (Kjølle & Gustafsson 2007). Nonetheless, architects have a larger influence on the crucial conceptual design decisions during the building design process and often act not as merely an actor but as a conductor. Similarly, the role of the engineering disciplines has undergone significant change in collaborative design approaches. Previously, engineering disciplines were seen as adjuncts to the design process and were called upon, in general, to provide solutions to fit the architect's design. Now, alternatively, within collaborative approaches engineering knowledge is considered central to the development of the initial design concept, and as such is required at the beginning of the design process. In this sense engineering disciplines are being encouraged to act in a more 'designerly' way.

It is our belief that new ways of conducting design and a new ontology to describe design is necessary. This necessity can be clearly understood within the context of Dutch building practice, where it is difficult for the different disciplines in the design phase to provide good design solutions to the problems currently faced by society within the built-environment. The difficulty arises since traditional approaches to organize and plan these processes often no longer suffice (van Aken 2003). The problems of the contemporary built environment are characterized by growing complexity and scale of design processes in architecture and in building services engineering, as well as increasing demands on these processes with respect to costs, throughput time and quality.

Inadequate design processes have been shown to result in a productivity loss in the Dutch building industry of approximately 10% of the total construction costs per year (USP 2004). To reduce these failure costs collaboration between the different design disciplines becomes increasingly important. Synergy between the different disciplines involved within the building design process is necessary to reach the best designs. No longer is it sufficient to merely solve the problems which arise at the level of detailing on the borderlines of disciplines.

In sum, in the world of design and engineering, gaps between the different fields can be recognized (van Aken 2003). Getting a better understanding of the design team's role is essential for an investigation of how to achieve more added value from engineers' and designers' within the building design process. Yet, there is little understanding of what is required to design adequate on-site learn-work environments that directly facilitate learning with the learning and knowledge resources of the organization (Senge 1990, Suchman 1987). One of the complicating aspects in building practice is the different cultural backgrounds of architects and engineers and their different approaches to design (Cross & Roozenburg 1992).

There is a need to view all the different aspects of building design in a more integral way, resulting in an integral approach to building design. This integral approach can eventually lead to integral process, team and method – all the required conditions for design of the end product. This implies defining a process methodology that acts as a "bridge" between architectural aspects such as shape, color and style on the one hand, and the functions of, for example, indoor climate issues such as overheating and ventilation on the other hand.

Due to the need for more effective design in the late 1950s methods were developed to improve the design process. The origins of new design methods in the 1960s were based on the application of 'scientific' methods derived from operational research methods and management decision-making techniques in the 1950s (Cross 2007). The first design methods or methodology books based on these research trends were: Asimow 1964, Archer 1965, and Jones 1970.

However, the 1970s witnessed the rejection of design methodology, even by some of the founding fathers themselves, such as Alexander and Jones. Fundamental issues were raised and design problems were characterized as 'wicked' problems, un-amenable to the techniques of science and engineering. This resulted in a proposal for a new generation of methods by Horst Rittel, moving away from attempts to optimize and towards recognition of satisfactory or appropriate solutions (Simon 1969).

In the 1980s a great deal of work was done to develop a variety of systematic engineering design methodologies. A series of books on engineering design methods began to appear; Hubka 1980, Pahl and Beitz 1984, Cross 1984, and French 1985.

Interestingly, after the doubts of the 1970s, the 1980s saw a period of substantial revival and consolidation of design research. Since then there has been a period of expansion from the 1990s that extends to the present day: design as a coherent discipline of study was definitely established in its own right (Cross 2007).

Still, there is no clear vision of how to approach design (Horváth 2004, Bayazit 2004) and many models of designing exist (Wynn & Clarkson 2005, Pahl et al. 2006). This multiplicity of options makes it difficult to choose and implement design models in practice.

Nonetheless, we believe that one of the models developed during this period, methodical design, can be adapted for profitable use within collaborative design teams. Methodical design was developed during the early 1970s, and has been described as a prescriptive design process model (Blessing 1994): The development of the model was based on the combination of the German (Kesselring, Hansen, Roth, Rodenacker, Pahl and Beitz) and the Anglo-American design schools (Asimov, Matousek, Krick).

2. METHODOLOGY

Methodical Deisgn

With the increasing complexity of technical systems, a unified principle for science and common ground between a variety of disciplines is needed in the study of complex systems. (Blanchard & Fabrycky 2005). General System Theory is useful for conceptualizing phenomena such as design, which do not lend themselves to explanation by the mechanistic reductionism of classic science. One approach to achieve a supportive, orderly framework is the structuring of a hierarchy of levels of complexity for basic elements in the various fields of inquiry. This framework of levels, according to General System Theory, was transformed into the decisions model as presented by Hall (1962), see Fig.1.

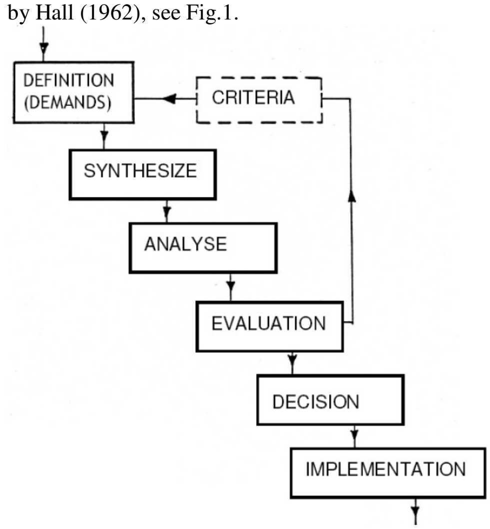


Figure 1: General System Theory Decision Model according to Hall (1962)

From a systems theory perspective the design process can be thought of as a chain of activities, which starts with an abstract problem and results in a concrete solution. Methodical Design makes it possible to link levels of abstraction with the stages and steps in the design process itself (Van den Kroonenberg 1992, de Boer 1989, Blessing 1994). Stages have been defined as a subdivision of the design process based on the state of the product under development. Dividing a design process into stages is important in order to structure and decompose the process into easier tasks. The transition between stages provides decision points forcing review and evaluation of the results of a given point. Stages, therefore, are not only important for efficient progress but also for planning of a project.

A step is a design activity defined as a sub-division of the design process related to the individual problem solving process, rather than to the state of the product under development as reflected in the stage division. Compared to stages, activities are specific design steps e.g. generating, synthesizing, selecting and shaping (Blessing 1994). This framework can accommodate the different subjective interpretations of the requirements, which is an inherent consequence of different members working together on the design process. The design process is divided into three main phases or stages: the problem definition, the selection of the working principle and the detail design phase.

A basic three-step pattern, the so called basic cycle, can be recognized within each phase of the methodical design process: diverge-systemize-converge (de Boer 1989). In this three-step pattern each step consists of a characteristic operation, which leads to a ‘basic design cycle’ of: generate-synthesize-decide. When discussing the origin of this step pattern, Van den Kroonenberg refers to General Systems Theory (de Boer 1989). This way the characteristics of the design process can be split up into those related to: strategies; stages; and activities. The strategies are related to the phases of the design process, with their focus on specific aspects of generating, synthesizing, selecting or shaping. The stages are related to the different abstraction levels in which the design process is divided. Methodical design is an approach with typical and exceptional characteristics (Blessing 1994):

1. it is a problem-oriented approach;
2. it is the only model emphasizing the execution of the process on every level of complexity;
3. it is one of the few models explicitly distinguishing between stages and activities.

The approach by van den Kroonenberg is similar to the Integrated Product Development (IPD) by Andreasen (Andreasen and Hein 1987, Buur and Andreasen 1989). This model is similar to the chromosome product model by Malmqvist as adapted from Andreasen (Malmqvist 1995).

Extension to Integral Design

A framework of application-independent principles is the basic three-step pattern (generate, synthesize and decide), combined with the 3 different design process phases that can be recognized within the Methodical Design process. The concept of open system in the domain of General System Theory, as developed and employed by Ludwig von Bertalanffy (1951, 1976), identifies interaction in every aspect of life and also in every aspect of humankind. When essential factors are disregarded, or are not recognized, the operation of the system risks being wrong or sub optimal. It could be said that the same logic applies to the design of buildings, where the aim is to find ways to incorporate all relevant knowledge from the involved disciplines in order to achieve integral results. As decisions about the results of the different design steps determine whether or not all aspects have been dealt with, decisions are essential for the integrity of the approach. The basic three-step cycle of methodical design is extended by us to stress the importance of decision making in the design process. The steps are confirmation of the universal description of the design process from general system theory, see Fig. 2.

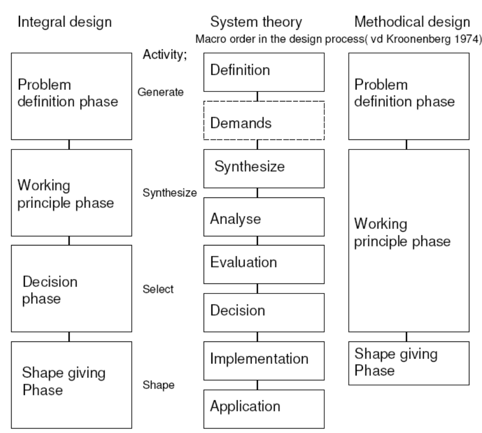


Figure 2: *Comparison between system theory steps (design activities) and methodical design by van den Kroonenberg (1974) and integral design*

Thus, a distinctive feature of the integral design model is the four-step pattern of activities (generating, synthesizing, selecting and shaping, see Fig. 3.

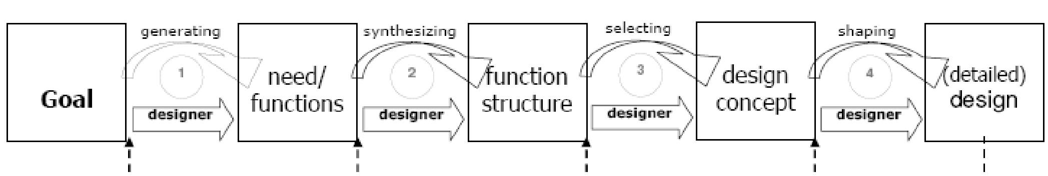


Figure 3: *The four-step pattern of Integral Design with possible iteration loops*

In contrast to other familiar models e.g. the basic design cycle of Roozenburg and Eekels, 1995 (analysis, synthesis, simulation, evaluation and decision), the ID model differs in its implementation and shaping of the design into a lower level of abstraction, and as such it places focus on the connection between the horizontal dimension and the vertical dimension of the design model. As such, the design process becomes more transparent, and this transparency increases the possibility to reach synergy between the different disciplines and designers involved in the design process.

On each level of abstraction the different steps can be described and throughout the different levels of abstraction the description of the design gradually becomes more detailed. The methodical design process therefore describes the path from an abstract problem to a solution. Though the path is described there is no telling what the results will be of the separated design steps: these depend not only on the problem solving capability of the designers involved but also on their creativity.

The process can be seen as a series of activities with an iterative process step where designers must continually reconsider decisions about different issues, due to new information or the use of different design tools to solve problems or generate possible solutions through creativity techniques. Through the iteration cycle of interpretation-generation steps the set of design requirements is continuously refined, and with it the design solution proposals also become more concrete.

The Integral Design method includes a double cycle, Fig. 4, linked to the levels of complexity, where all stages and activities are repeated for every product element (Blessing 1994). Blessing emphasizes that (the sequence of) activities are repeated many times during the design process.

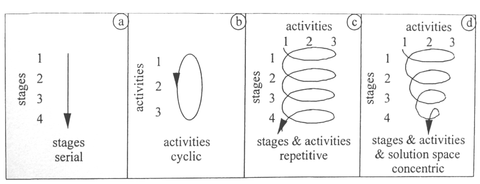


Figure 4: *Main process flows design models (Blessing 1994)*

The cycle (define/analyze, generate/synthesize, evaluate/select, implement/shape) forms an integral part in the sequence of design activities that take place. By exploiting a function/aspect-oriented strategy, the Integral Design model allows various levels of design complexity to be separately discussed and generated (sub) solutions to be transparently presented.

An important key feature of Integral Design is the use of morphological charts, which makes it possible to represent the functions that need to be fulfilled and the aspect that need to be dealt with, as well as the related solution to these functions and aspects.

Morphological chart

Morphological charts were developed by Fritz Zwicky in 1947 (Norris 1963) as a tool to investigate the totality of relationships contained in multi-dimensional, usually non-quantifiable problem complexes (Ritchey 1998).

Morphology provides a structure to give an overview of the considered functions and aspects and their solution alternatives. The functions and aspects are derived from the program of demands, which defines the outcome of the design process. Possible solution principles for each function or aspect are then listed on the horizontal rows. Different overall solutions are created by combining various solution principles to form a complete system combination (Ölvander et al. 2008).
The transformation of the program of demands into characteristics for input and output (aspects) and the formulation of the different relations between input and output (functions) that need to be fulfilled, leads to the construction of a morphological chart, see Fig.5.

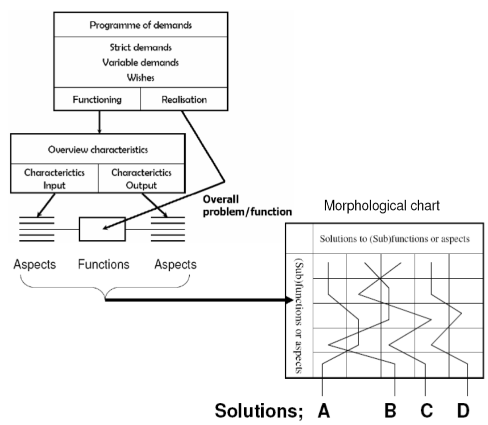


Figure 5: *The morphological overview within the Methodical design*

In order to survey solutions, engineers classify them according to various features. This classification provides the means to decompose complex design tasks into problems of a manageable size. Decomposition is based on building component functions. This functional decomposition is carried out hierarchically so that the structure is partitioned into sets of functional subsystems. Decomposition is carried out until simple building components remain whose design is a relatively easy task. This process of decomposition is in line with what is described in guidelines 2221 and 2222 of the “Association of German Engineers”, VDI see Fig. 6.

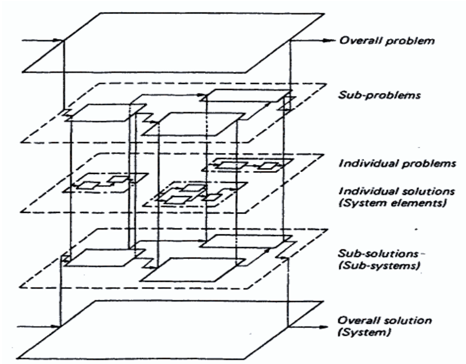


Figure 6: Functional decomposition according to VDI2221 (Beitz 1985)

Morphological Charts are essentially tools for information processing and are not confined to technical problems but can also be used in the development of management systems and in other fields (Pahl et al., 2006). Morphological charts structure the solution space and encourage creativity. The morphological charts can also be used in conjunction with overall design processes such as 6-3-5, brain writing, reverse engineering and redesign methods (Bohm et al. 2008).

Morphological Overview

A morphological overview can be generated by combining the different morphological charts made by each discipline. After discussion on and the selection of functions and aspects of importance for the specific design the designers with different disciplines based backgrounds can agree on the elements from the separate morphological charts to form the morphological overview; see figures 7 and 8. Such a morphologic overview can be used by the designers to reflect on the results during the different design process stages.

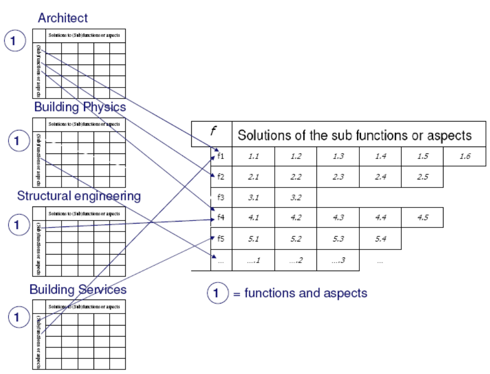


Figure 7: Building the morphological overview; Step 1; The Morphological overviews show the agreed functions and aspects (1) of the different morphological charts.

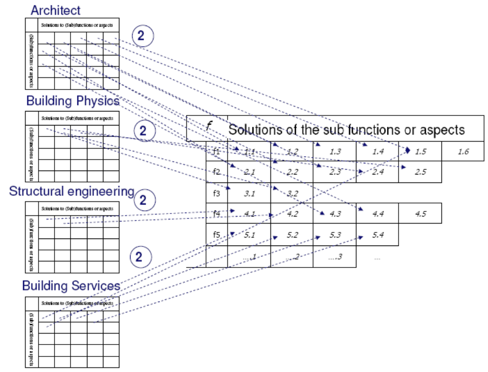


Figure 8: Building the morphological overview; Step 2: The Morphological Overview with the agreed sub solutions (2) from the separate morphological charts

The process of transforming the individual, discipline based charts into one team overview facilitates the active interpretation of all team members, and creates the possibility for team members to comment on and contribute to the content generated by other team members. By utilizing morphological overviews in this way, a reflective step is introduced within the design process, forcing reflection between individual designers and making actual reflection-in-action on a design team level possible. Thus, rational problem solving is integrated with reflective practice (Schön 1983).

By using morphological overviews all disciplines can look for the required completeness, assuming that all necessary functions and aspects are listed. The combination of the individual knowledge domains of each designer should lead to an increased problem-solution space.

Traditionally the design process in the built environment starts when a principal, or client, decides that they want a new building. The principal usually approaches a number of architects before selecting one to act as the primary architect for the design project. The chosen architect's first task is to work with the client to find out what is needed. As the architect has a limited amount of knowledge of and experience in his own domain and that of the other disciplines involved, only a part of the whole possible solution space is available to him, represented by his morphological chart, see Fig. 9A. The key problem with this approach is that the architect immediately starts thinking of a solution, see Sp in Fig. 9B, to the needs of the client, even though the design brief is not clear enough at this point. From the moment that the architect thinks of his solution, he essentially narrows the scope of the design, which results in the design proceeding on the basis of combinations and variations of that first idea. As a result of this narrow focus, there is an almost inevitable restriction of the possible solution space for the original design problem, see Fig. 9B. Furthermore, the architect's solution space is restricted by boundaries resulting from fictitious restrictions, boundaries from his limited knowledge and of course boundaries from genuine restrictions such as building codes and regulations, see Fig.9B (Kirck 1969).

The solution space as a result of a traditional design approach changes significantly when the other building disciplines, such as building services engineers, structural engineers and building physics engineers, join the architect from the start; see Fig. 9C. Here, the solution space of the architect is combined with those of the other design team members. Instead of narrowing the focus to one solution, Sp, different options from different disciplines are proposed (Fig. 9C), which leads to new interactions and new possible solutions. The resulting effective solution space of the design team is therefore in principle clearly larger than that of the architect alone.

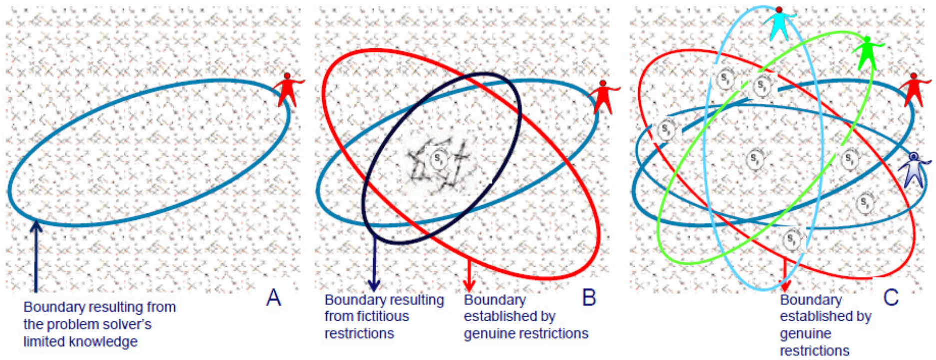


***Figure 9**: The individual solution space (A) with limitations of the solution space due to personal restrictions (B) (Krick 1969) and design teams' integral solution space (C).*

3. EXPERIMENTS

To test our approach of the morphological overviews and to determine if the theory led to positive effects when used by professionals, we arranged workshops as part of a training program for professionals (Savanovic 2009). An essential element of the workshop, besides some introductory lectures, was the design cases on which the teams of designers had to work and which they had to present at the end of each session to the whole group. These design exercises were derived from real practice projects and as such were as close to professional practice as possible.

In the more traditional sequential design process the designers design in solitude and they only get together to discuss results with each other. In current design practice there is the trend to design in a more collaborative setting. After the first conceptual design of the architect the designers of other discipline generally join in.

Since 2005 we organized 5 series of workshops with experienced professionals, architects and engineers, voluntarily applying to participate. The participants of each discipline were randomly assigned to design teams, which ideally consisted of one architect, one building physics consultant, one building services consultant and one structural engineer. All sessions were videotaped and in addition photographs were taken every ten minutes. The end presentations and all used material, sketches etc. were also photographed.

Starting with a three day practice-like 'building team' concept, in which all disciplines are present within the design team from the start, the integral design method workshops have evolved to a final two-day series encompassing four design tasks. The experiences of these workshops series led to adjustments for the final workshops series 4 and 5, see Fig. 10. The 4th workshop was held in May 2007 and the 5th workshop was held in February 2008. In these two last workshops series the same configuration, setting and set design tasks were used. More information about the first three series of workshops can be found in (Zeiler et al. 2005, Savanovic and Zeiler 2007).

In the current configuration (Fig. 10) stepwise changes to the traditional building design process type, in which the architect starts the process and the other designers join in later in the process, are introduced in the set up of the design sessions. Starting with the traditional sequential approach during the first two design sessions on day 1, which provide reference values for the effectiveness of the method (amount of integral design concepts), the perceived "integral approach" is reached through phased introduction of two major changes:

(1) all disciplines start working simultaneously within a design team setting from the very beginning of the conceptual design phase,

(2) the integral design model / morphological overviews are applied.

The second set up of the design sessions allows simultaneous involvement of all design disciplines on a design task, aiming to influence the amount of considered design functions/aspects. Additional application of morphological overviews during the set up of the third design session demonstrated the effect of transparent structuring of design functions/aspects on the amount of generated (sub) solution proposals. Additionally, the third setting provides the possibility of one full learning cycle regarding the use of morphological overviews.

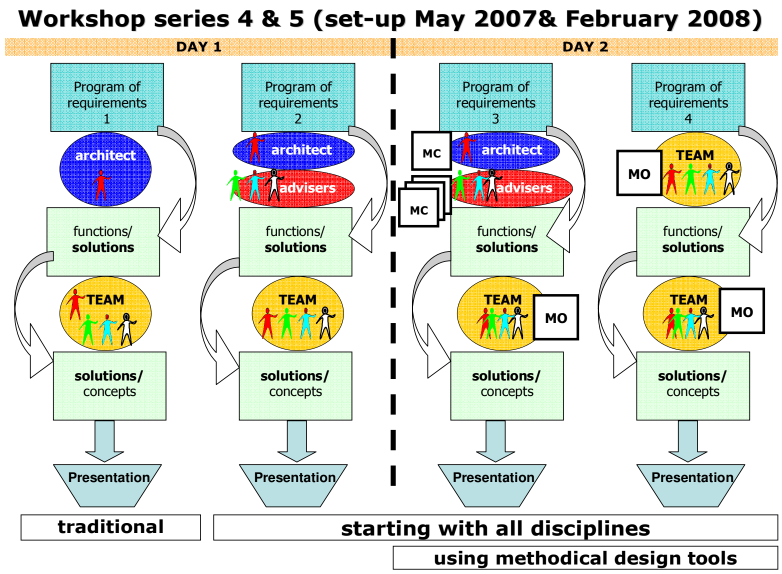


Figure 10: *Workshops series 4 & 5, four different design set ups of participants and Morphologic Overviews (MO) during the design sessions within two days.*

4. RESULTS

The 5 workshops series conducted over the last four years typically included around twenty participants and lasted for two or three days. A total of 108 designers participated in the workshops series, of which 74% of the designers were present during all days. The average age of the participants, either architect or engineer, was 42 and they had on average 12 years of professional experience.

In the analysis that we present here we focus on the first two steps of the Integral Design process: the generation of functions/aspects and step 2 synthesizing from functions/aspects to possible solutions. Here we show the results of session 3 of the workshops held in 2007. Fig. 11 gives the results of morphological charts and the design team session.

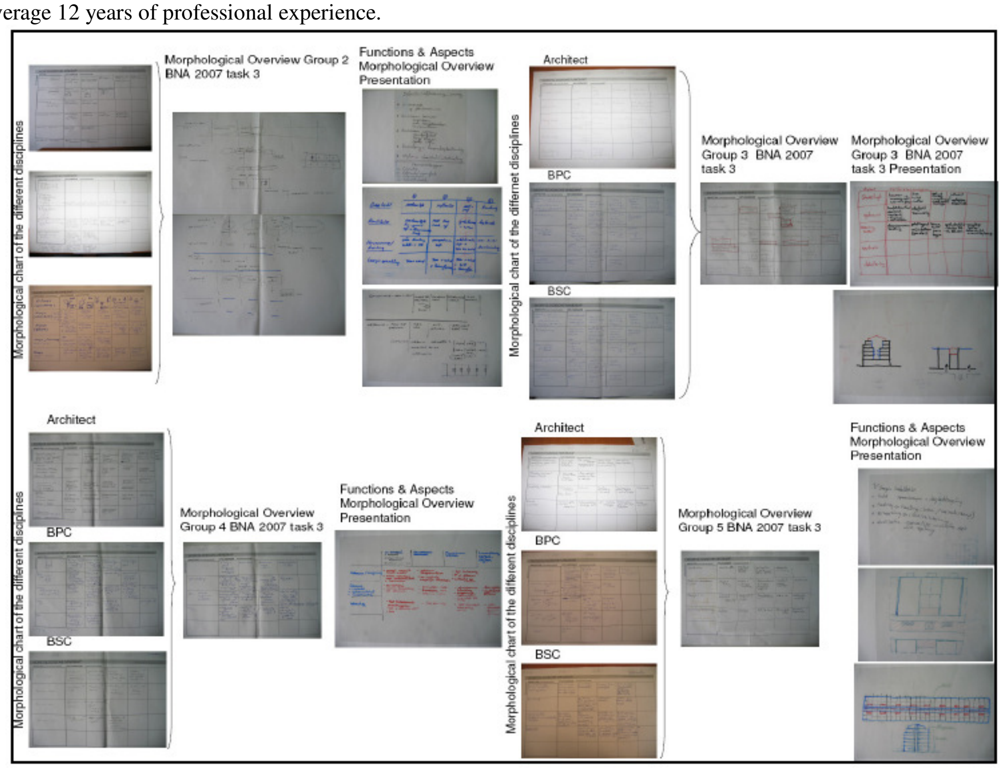


Figure 11: *Morphological charts and morphological overview of group 2 to 5 of the workshops series 2007.*

Fig. 11 shows that all teams used the morphological charts to produce their morphological overview, and that 3 out of 4 teams even used their morphological overview to present their final design. More important is that we now have the possibility to look into the design process in more detail. As an example we give the results from groups 2 to 5 of the workshop 2007, session 3, step 1 of the Integral design method: the generation of functions and aspects from the design brief, see Fig. 12.

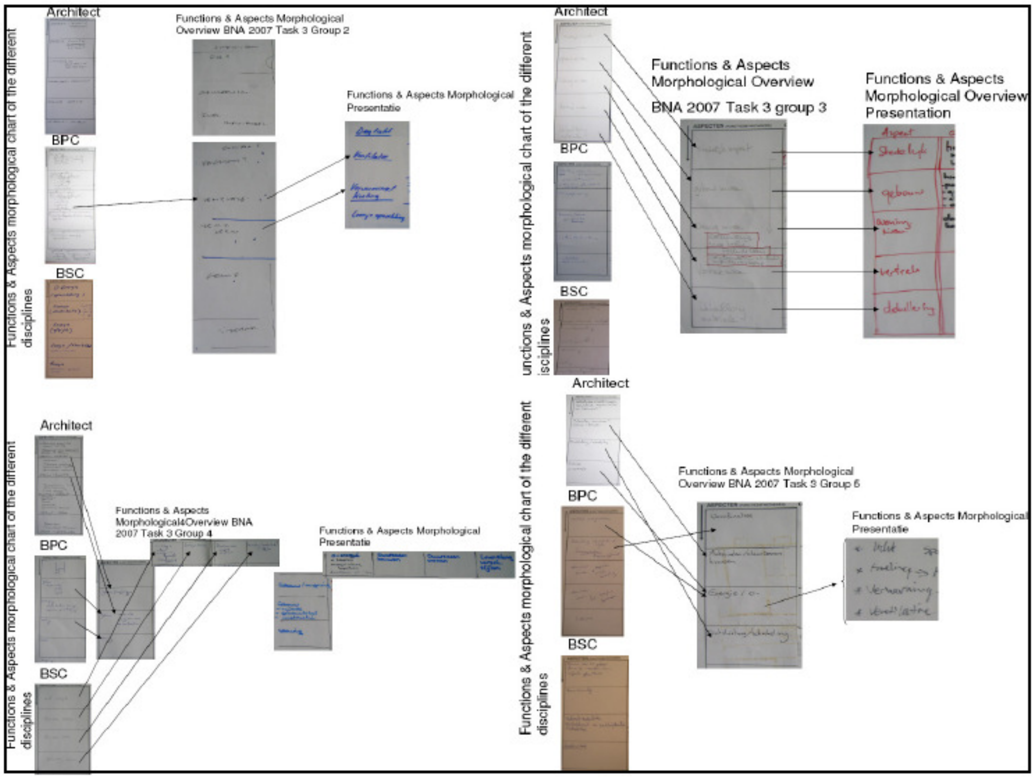


Figure 12: *Morphological representation of step 1 generation of functions and aspects with the Integral Design process*

Immediately one can see that all groups had a different outcome of the process. In group 3 the architect remained dominant and no extension of the design space took place; no aspects or functions were added. In group 5 there is a little input from the building physics consultant, but still the architect is also dominant here. In group 2 something strange occurred as the design team made their own interpretation of the morphological overview and started the process from that interpretation. Only in group 4 did the interaction between the different design disciplines lead to a clear picture of the expansion of the design space: besides the 2 functions/aspects of the architect, 2 functions/aspects awere added by the building physics consultant and 4 from the building service consultant. More examples of the results of the workshops and their analysis can be found in Savanovic (2009).

The effect of different settings was investigated to determine the added value of the use of morphological chart for design teams. To determine the effect of the change at the start of the design project of starting with all designers instead of starting the project only with the architect, the set-up of setting two it must be compared to setting one. The main point of interest is to assess whether requiring individual disciplines to consider the task from the outset had any effect on the number of sub solutions generated when the individuals came together as a multi-disciplinary team. In order to make this comparison two tables are presented below: the first table contains the aspects and sub solutions from each individual team in setting I, while the second table contains the aspects and sub solutions from each individual team in setting II.

	Team 1	Team 2	Team 3	Team 4	Team 5	Average
No. of aspects	5	7	2	5	7	5.2
No. of sub solutions	13	16	12	16	17	14.8

Table 1. *Additional aspects addressed and (sub) solutions produced by design teams (setting I)*

	Team 1	Team 2	Team 3	Team 4	Team 5	Average
No. of aspects	5	2	3	3	3	3.2
No. of sub solutions	13	5	7	8	7	8.0

Table 2. *Additional aspects addressed and (sub) solutions produced by design teams (setting II)*

As can be seen from the table, contrary to what one might have expected, the intervention of introducing other disciplines into the design process from the outset did not result in the generation of a greater number of aspects and sub solutions. On the contrary, in setting two fewer aspects and sub solutions were generated than in setting I, which represented the status quo. The graphic below clearly demonstrates that the intervention lead to a declining number of generated aspects and sub solutions, see Fig. 13.

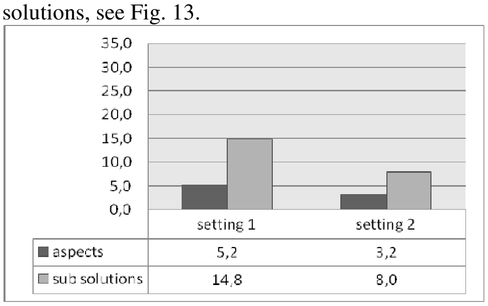


Figure 13: *Averages of the amount of design aspects and sub solutions generated by design teams during design settings 1 and 2*

In brief, a likely explanation for this is that the teams proceeded with the design task in what can be described as an integrated rather than the desired integral approach. In effect, this integrated approach led to the teams seeking to quickly assimilate aspects that were seen as workable in terms of the final design. This approach therefore did not lead to the accomplishment of the first goal of this research.

The aim of setting three was to train the participants to produce morphological charts and morphological overviews. The morphological charts are used to record and structure discipline knowledge of individual team members. The morphological overview is the end result of the combination of the morphological charts.

From the analysis of the results of the workshops it could be concluded that the solution space, resulting from the number of functions and aspects considered, was significantly increased by applying morphological overviews. A good example of this increase can be seen from the results from session 1 (without morphological charts and morphological overview) compared with the results of session 4 (with use of morphological charts and morphological overview). The increase of the number of considered functions and aspects leads to a larger number of partial solutions, which logically implies an increase in the solution space. The table below contains information on the number of aspects and sub solutions generated by the teams in the setting 4.

Table 3: *Design aspects addressed and (sub) solutions produced by design teams (setting IV)*

	Team 1	Team 2	Team 3	Team 4	Team 5	Average
No. of aspects	5	11	11	5	10	8.4
No. of sub solutions	24	26	39	20	46	31.0

In order to offer a clear demonstration of the effect of the intervention Fig. 14 is provided. Here, the result is abundantly evident, especially when Fig. 14 is compared with Fig.13. Clearly, putting all design disciplines together from the beginning without the design tool in setting 2 proved to be less productive than setting 4, in which there was early cooperation of designers and the inclusion of the design tool.

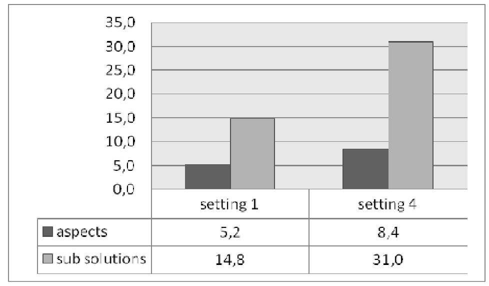


Figure 14: *Averages of the amount of design aspects and sub solutions generated by design teams during design settings 1 and 4*

Directly at the end of the workshop the participants were asked to fill in a questionnaire in which questions were asked about the importance of the use of morphological overviews within the design process and about the design of the workshops themselves. The participants had to rate the different aspects between 1 (very poor) to 10 (excellent), and their results were then transformed to an average group rating; see figure 14.

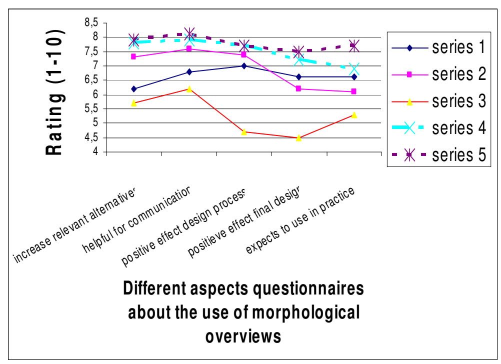


Figure 14: *Overview results questionnaires participants professional workshops series 1 till 5.*

The results of the questionnaires indicated that the participants of the workshops considered the use of morphological overviews to benefit both communication within the team, and also the number of relevant alternatives generated within the design process.

The improvement in the workshops setting from setting 1 till the final setting in series 4 & 5 can clearly seen in almost all aspects.

Participants of the five series of workshops were approached six months after their workshop participation in order to get their 'second opinion'. Only the reactions from designers who participated during all design sessions of a series were taken into account. The number of participants is given in table 4.

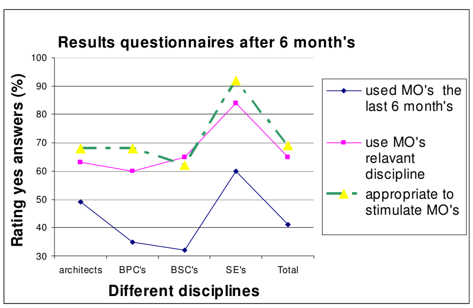
Table 4: *Number or returned questionnaires workshops series 1 to 5 after a working period of six month's*

	architects	BPC's	BSC's	SE's	Total
Number participants	24	22	19	8	73
Percentage returned questionnaires	67%	68%	58%	63%	66%

BPC = Building Physics Consultants
BSC = Building Services Consultants
SE = Structural Engineering consultants

The results of the most relevant questions of the post-test questionnaire relating to the integral design method and morphological overviews are given below in Fig. 15. One remarkable finding is that almost same difference of almost 25% between expected use and real use of morphological overviews of all the different disciplines is found. Still, on average 40% of the participants used morphological overviews in their practice after their experience of the workshops.

Relatively low score can be seen for both building physics consultants and building services consultants. Both of these disciplines generally become involved in a later phase of the design process, often after the conceptual design phase. This meant that they were not in a position to introduce the morphological overview. Also, most of the participants reported that the large, ongoing projects which they were working on had already past the conceptual design phase, again preventing the implementation of morphological overviews. These points might well explain the low score.



BPC = Building Physics Consultants
BSC = Building Services Consultants
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Figure 15: *Results of questionnaires on different aspects of the use of MO's in workshops series 1 to 5 after a working period of six month's*

5. DISCUSSION

The aim of the Integral Design project was to demonstrate, explore, and evaluate the method's practical effects in use; its application also meant that the acceptance of the method was tested through 'verification by acceptance'. The method prescribes use of a 'morphological matrix', which just as a 'morphological field' is essentially a specific version of the Zwicky's box. The approach is quite new for architectural purposes, and application in design and in design teams provide new and interesting insights for the designers.

To stimulate knowledge exchange during design processes a design support tool was tested in different workshops series with professionals within the setting of Reflective Practice (Schön 1983). Use human subjects in laboratory experiments to study design theory provided some useful insights. However, extending results from laboratory experiment to conclusions for engineering practice is not without risk. The effect of Macro cognition describes the differences in cognitive functions performed in natural – versus artificial, laboratory – settings. The real-world setting requires activities in ways that artificial settings can rarely simulate. Schön (1987) has proposed the practicum as a means to 'test' design(ing). Where a practicum is "'a virtual world' relatively free of the pressures, distractions, and risks of the real one, to which, nevertheless, it refers (Schön 1987, p.37)".

In Schön's practicum a person or a team of persons has to carry out the design. A practicum can asses a design method and the degree to which it fits human cognitive and psychological attributes (Frey and Dym 2006). It is crucial, however, that the practicum provides a simulation of the 'typical' design situation. A workshop can be seen as a specific kind of practicum. It is a common sense way of working for designers that occurs both in practice as during their education.

As such, a workshop provides a suitable environment for testing the approach. Besides allowing for a 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 characteristics as much as possible. Workshops make it possible to gather a large number of professionals in a relatively short time; to repeat the same assignment; and to compare different design teams and their results. Nevertheless, the workshops are a virtual world; "contexts for experiment within which practitioners can suspend or control some of the everyday impediments to rigorous reflection-in-action (Schön 1983 p. 162). Schön refers further to the dilemma of rigor and relevance in professional practice: there is a choice to stay on the high, hard ground ("A high, hard ground were practitioners can make effective use of research-based theory and technique") , or to descend to the swamp ("a swampy lowland where situations are confusing") and engage the most important and challenging problems? (Schön 1983 p. 42).

A crucial element in this research was the arranging of the design team. To be able to compare different types of design processes, while at the same time exclude team development aspects (Tuckman 1965), the same design teams were not observed during the two workshop days, instead the average results of each design setting of all participating teams are compared. For each setting the arrangement of design team members is changed (although all design teams are composed of the same group of participating designers). The only rule is that no two designers can be in the same team twice. The focus is on the comparison of the same activities within different types of design processes. The sequence of used design settings is of utmost importance. Reverse or mixed order is not possible because learning effects would not allow for a valid comparison of results (Herzog, 1996). This is different in practice as the design team stays the same during the design process and learns during the process.

Replacing an individual designer in a ‘reflexive practitioner scenario’ with a design team increases the chance of achieving integration through consideration of every relevant aspect of the design task at hand. The relevance of aspects is subjectively decided by design teams themselves, by continuously (re)interpreting the design brief and design proposals. The objectivity and transparency that we look for is found in the presentation of their interpretations, which explain their interconnection instead of isolating the how and the why in separate interpretation cases.

The result of the questionnaires showed that participation in the Integral Design workshops, which exploited the design tool of morphological overviews, was considered a great support by the experienced professionals from Dutch Royal society of architects (BNA) and the Dutch society of engineering consultants (ONRI). Although the outcome has no strict statistical validity and therefore the empirical evidence is not significant, the outcome of the questionnaires nevertheless indicates its value. Strict statistical approaches are hard to apply to this kind of research as it is very difficult and expensive to secure the participation of experienced professionals, who always have a heavy workload and are frequently under time pressure within their projects.

6. CONCLUSIONS

The focus in this paper is on a design method to support designers within the built environment. The added value of morphological overview as a tool of the design method was tested in workshops. In these workshops experienced professionals from BNA (architects) and NLingenieurs (consultants) participated. The results of the workshops as well as the questionnaires led to the following conclusions:

- morphological overviews help to structure the analysis of the design problem as well as structure knowledge of design team members

- implementing the new Integral Design approach is only practically possible at the beginning of a project

The experiences of participating architects with the Integral Design workshops were so positive that since 2007 the workshops have become part of the permanent professional education program of BNA, and since 2009 have also became part of the professional education for the engineers. We think that this not only goes a long way in vindicating our approach, we also feel that embedding the approach in professional education programs will increase the acceptance and improve the chances of the approach being used on authentic tasks in practice in the future.

An additional indicator of ‘proof’ of success is the fact that the largest Dutch building services consulting company asked us to provide training for their employees within the company, based on the concept of the workshops. This was after several employees of this company had participated in the professional workshops. This workshop was held in company on March 31, 2008. Sixteen professionals attended this workshop and their overall rating of appreciating was 7.5 on a 1-10 scale.

In conclusion, we presume that by using our integral design workshops with the use of morphological overviews, we provide professionals with a useful design method for the multi-disciplinary design problems they are currently facing in practice.

7. ACKNOWLEDGMENTS

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