Thinking Outside the Box: Integral Design and C-K Concept Creation

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Abstract. This research set out to develop a method to stimulate concept creation in building desogn processes by applying C-K theory of Hatchuel and Weil. To demonstrate the application of this abstract theory a design method was used: Integral Design. The approach was tested on the results of series of workshops in which more than 100 experienced professionals participated. This enabled us to focus on the generation of concepts, the thinking outside the box. Using Integral Design is was possible to draw the box and see were in the process thinking outside the box occured.

Keywords: Integral design, C-K theory, Morphological Overview

1 Introduction

In the built environment there is a pressing need for new, more sustainable, soltions. Therefore the focus in building design need to be on the stimulation of new concepts. In our research we investigated how this could be achieved and how the outcome could be verified. In this paper we look into some of the factors influencing design team's creativity (method and tool), as well as use a theory, the C-K theory of Hatchuel and Weil to focus on different steps in the deisgn process to come to concepts. In section 2 C-K theory is introduced, as well as the design method Integral Design to make it more specific. In section 3 the workshops which were used to apply the approach will be presented. The result will be given in section 4, followed by discussion in section 5 and conclusion in section 6.

2 Methodology: C-K Theory as Leading Principle

Generally speaking, design thinking is a creative process based around the transformation of needs into solutions. In this process existing knowledge and information about the actual needs of the principle forms the basis to work from. This often has to be transformed into new unknown concepts if solutions based on existing knowledge are not adequate. So, in this case, we have to develop from the known the unknown. As such we can make the distinction between the known [knowledge] and the unknown [concepts]. This distinction determines the core propositions of C-K theory (Hatchuel and Weil 2007). C-K theory defines design as the interplay between two interdependent spaces having different structures and logics. This process generates the co-expansion of two spaces, space of concepts C and space of knowledge K. Within this research, in the case of a multidisciplinary building design team, the available knowledge within this team represents space K. Since C-K theory defines a piece of knowledge as a "proposition with a logical status for the designer or the person receiving the design" (Hatchuel and Weil 2002, p.11), all explicit representations of a design team's knowledge are considered to form part of space K. This is their initial object-design-knowledge,K that participants bring into design team. The overview of this knowledge is captured using morphological design tools. From the perspective of C-K theory, the initial object-design-knowledge that participants bring into design team defines space K. From here, two types of synthesis are possible: either the representations are combined, using the K→K operator, or are transformed, using the K→C operator. A space of concepts is necessarily tree structured as the only operations allowed are partitions and inclusions and the tree has an initial set of disjunctions (Shai et al 2009). A design solution is given by the first concept Ck to become a true proposition in K (see Fig. 1). The other branches of C are concept expansions which do not reach a proposition that belongs to K (Hatchuel and Weil 2007). If we add new properties (K→C) to a concept, we partition the set into subsets, see par example C1 in figure 3; if we subtract properties, we include the set in a set that contains it. No other operation is permitted. After partitioning or inclusion, concepts may still remain concepts (C→C), or can lead to creation of new propositions in K (C→K), see par example the Ck to Kk conjunction in Fig. 1.
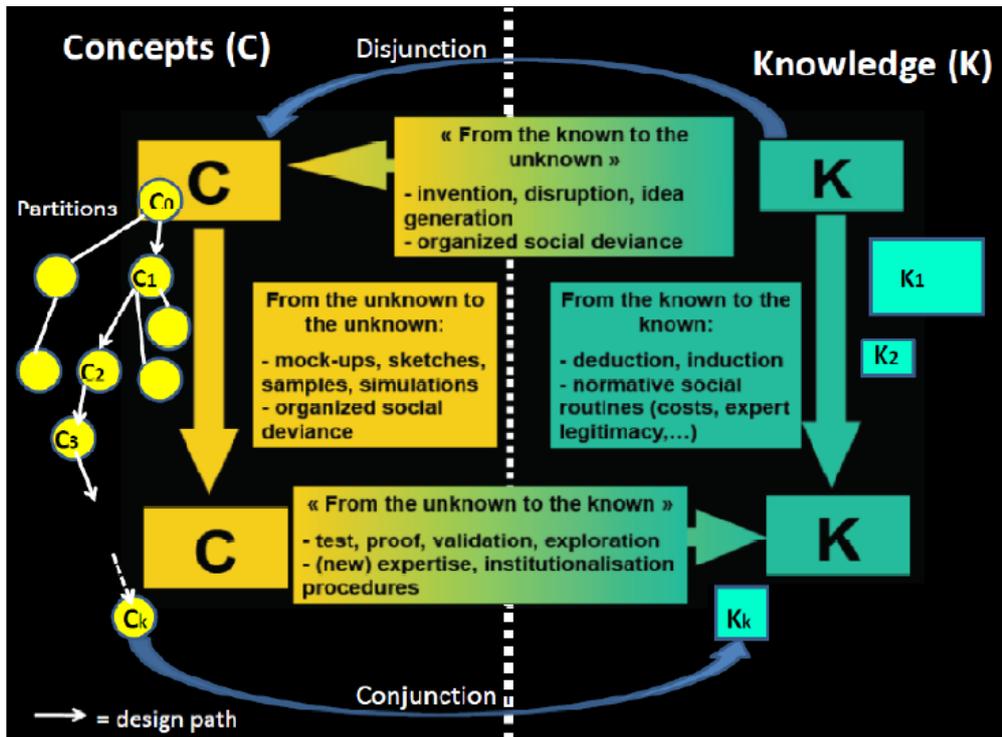
Fig. 1. The C-K design square (Hatchuel et al 2009).

2.1 Integral Design as Tool to Elucidate C-K

In the past a number of prescriptive design methods were developed, which were largely based on the view of design as an ill-structured problem solving activity (Simon 1969). Even though design undoubtedly includes stretches of 'normal' ill-structured problem solving (Dorst and Rooyakkers 2006) any model or description method that tries to reduce design to ill-structured problem solving is bound to miss important aspects of the design activity (Hatchuel 2002). Recognizing the fact that design is not a scientific or merely a problem solving activity, we wondered if any of the existing and largely neglected prescriptive design methods could help us to understand design by using them for research, rather than (as originally intended) for design activities. The motivation behind this idea was that, being developed on the basis of a scientific approach to designing, these prescriptive design methods 'automatically' meet the requirements for being methodical – one of the key characteristics of valid design research (Cross 2002).

A specific design method, Methodical Design, was developed at the University of Twente in the 1970s and theoretically elaborated by de Boer and Blessing (1994). Using the analogy of System theory van den Kroonenberg thought of a design process as a chain of activities, which starts with an abstract problem and results in a solution. Methodical Design distinguishes three main phases or stages (the problem definition, the working principle determination and the detailed design), and four specific design steps (generating, synthesizing, selecting and shaping). Dividing a design process into stages and steps is important to decompose and structure the process around more manageable tasks. The transition between steps provides decision points, forcing review and evaluation of the results generated so far. The Integral design method, though based on methodical design, is an extended design method; the cycle (define/analyze, generate/synthesize, evaluate/select, implement/shape) forms an integral part in the sequence of design activities that take place, see Fig. 2.
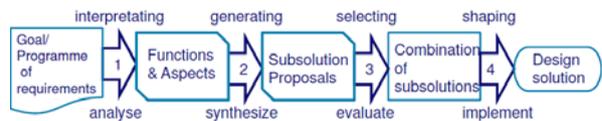
Fig. 2. The four-step pattern of Integral Design with possible iteration loops

So, a distinctive feature of the integral design method is the four-step pattern of activities (generating, synthesizing, selecting and shaping, see Fig. 2), which

occurs on each level of abstraction with the different phases of the design process. After each step in the design process a decision is made to either move forward in the design process or to go backwards via an iteration loop. Within the Integral Design method, like in the Methodical Design method, morphological charts are used to support the generation and synthesizing steps. A distinguishing feature of Integral Design is the intensive use of morphological charts to support design activities in the design process. Morphological charts were derived from the Morphology approach by Zwicky (1948). Morphological charts are used in the Integral Design approach to aid in developing solutions using a systematic method of developing and combining potential design solutions, The morphological chart is formed by decomposing the main goal of the design task into functions and aspects, which are listed on the first vertical column of the chart, with related subsolutions listed on corresponding rows. The functions and aspects are derived from the program of demands, Possible solution principles for each function or aspect are then listed on the horizontal rows. The use of morphological charts within the integral design method supports step 1 and step 2 of the integral design method's four step pattern, see Fig. 2. The morphological charts made by each individual designer can be combined into a (team) morphological overview, see Fig. 3, after discussion on and the selection of functions and aspects considered important for the specific design. The advantage of this approach is that the discussion begins after the preparation of the individual morphological charts. As each designer uses his own interpretation and representation, in relation with his specific discipline based knowledge and experience, this gives an overview of different interpretations of the design brief resulting in a domain specific morphological chart from each design team member. Importantly, this encourages and allows engineering based disciplines to think and act in a more 'designerly' way than is common in the traditional design approach. In sum, this approach allows a greater freedom of mind of the individual designers and results in more creativity in interpretation of the design problem and generation of subsolutions from the different disciplines. Such a morphologic overview can be used by the designers to reflect on the results during the different design process stages.
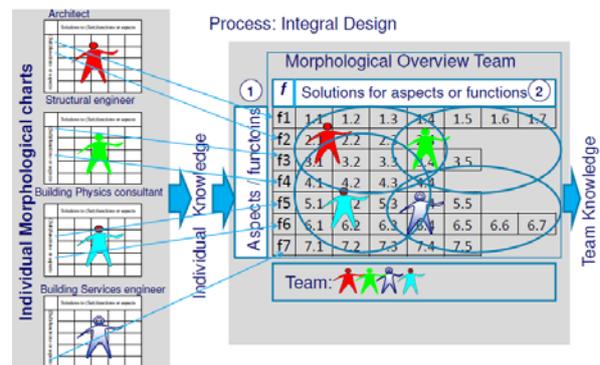
Fig. 3. Building the morphological overview; Step 1; The Morphological Overview shows the agreed functions and aspects (1) of the different morphological charts. Step 2: The Morphological Overview with the agreed on sub solutions (2) from the separate morphological charts.

2.2 Applying C-K Theory to the Conceptual Design Phase

Morphological charts and overviews can be used to generate, define and record design aspects/functions and sub solutions. Within the Integral Design approach, after the first step of generating discipline specific morphological charts and discussing the results as a team, the individual charts are combined into one morphological overview containing all of the useful sub solutions from the individual team members. The next step is for the team to take the knowledge and ideas from the overview and translate them into a proposed design solution, see Fig. 3. This step can take two forms: either the design team combining known sub solutions into RE-designs (K-K) or the design team starts transforming object-design-knowledge into new concepts (K-C). The Integral Design model combined with the C-K theory enables the focus on the distinction between redesign (K-K transformation leading to RE) and integral design concept generation (K-C transformations leading to ID-concepts). To illustrate this an example is presented in Fig.4, where after step 2 there is a transformation of known sub solutions or from a specific aspect or function to a new concept of fuction (Y) or to a new concept as possible sub solution (IDx). The elements IDx6, IDy1 and IDy2 represent conceptual sub solutions as a result of the concept generation K-C, see Fig. 4. This distinction is crucial since, we firmly believe, that the development of new concepts is essential if we would like to generate creative solutions to the highly complex contemporary design problems that our societies face. In this research the main area of interest lies in the conceptual phase of the design process. Here, the focus is on K-K and K-C relations. Nonetheless, C-K theory also offers

value in subsequent building design stages, where it can be used to focus on C-C and C-K relations. In essence, in the current research ID-concepts are seen as essential for the creation of new, innovative building designs, which increase the possibility to

ultimately realise sustainable building solutions. Perhaps more importantly, ID-concepts represent the potential for the definition of new object design knowledge, which can then be exploited to solve future design problems in the building design domai
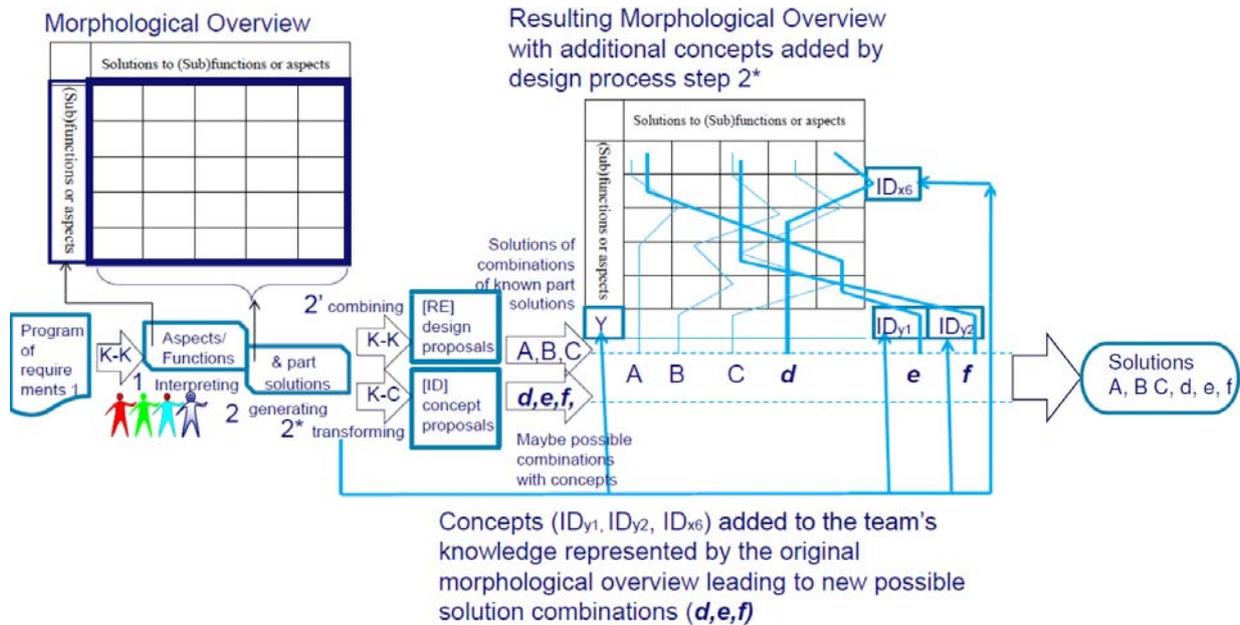
Fig. 4. The ID-method steps according to the C-K theory operators.

3 Workshops

In order to test our approach of Integral Design with its use of the morphological overviews in combination with C-K theory to analyze it, we arranged experiments within workshops as part of a training program for professional architects and consulting engineers [structural engineers, building services engineers and building physics engineers]. A workshop setting was used to test the theoretical model of the Integral Design model. As other research fields show, using human subjects in laboratory experiments as a study object can provide valuable insights (Frey and Dym 2006). However, generalizing the results from experiments entails a certain risk. The real-world setting requires activities in ways that artificial settings can rarely simulate. Schön (1987) has proposed a practicum as a means to 'test' design(ing). In Schön's practicum an actual 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).

Crucial is the simulation of the 'typical' design situation. A workshop can be seen as a specific kind of practicum. It is a self-evident 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 full design team line-up there are a number of other advantages of workshops with regard to standard office situations, while at the same time retaining practice-like situation as much as possible. Workshops make it possible to gather a large number of professionals in a relatively short time, repetition of the same assignment and comparison of different design teams and their results. Never the less the workshops are a virtual world; "contexts for experiment within which practioners can suspend or control some of 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).

Including the experiments in the workshops made it possible to get the participation of a great number of professionals. On average these professionals had 12 years of experience in the field. The goal was to determine if the approach led to a positive effect for building design professionals. An essential element of the workshop, besides some introductory lectures, was the design cases, on the basis of which the design teams worked and presented their ideas/design at the end of each session to the whole group (Savanovic

2009). These design exercises were derived from real practice projects and as such were as close to professional practice as possible. In the current configuration 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 session. An example of fully completed task, including charts and morphological overview is displayed in Fig. 5 below. The new concepts which were not part of the morphological charts are marked by the squares and their coding (IDy and IDx) in the morphologcal overview of the building design team.

Fig. 5. Design team 1's morphological overview in setting 3, see the diagram on the left; note that only a selected group out of the aspects/functions and subsolutions are taken over from individual morphological charts into the morphological overview. A new function is added as well as some new subsolutions.

4 Result : Transformation of Initial Design Knowledge out of the Box

If we look at the design process we can represent the the knowledge of the individual designers as a morphological chart and project these knowledge boxes into the space of C. Meaning that all that lies outside these MC boxes are unknown concepts for the individual design team members, see Fig. 6.

Fig. 6. Morphological charts as initial knowledge representation K

After the discussion in the group about the relevance of different functions and aspects in relation to the desgin task, a selection is made from the morphological charts and put into the morphological overview, see fig. 7.

Fig. 7. Morphological Overview as initial relevant team design knowledge

Now the knowledge of the design team relevant to the design task is put in the MO box. Through interaction between the different designers with each their own disciplinary background sometimes an interaction and inspriration occurs which leads to the formulation of new aspects or functions added to the MO box. Also new additional possible subsolutions can be added, see Fig. 8.

Fig. 8. The expansion from the team knowledge within the morphologial overview by K-C transformations: thinking out of the box.

So by using the morphological overview the design team has a more and clearer overview of the interpretations and possible solutions from each discipline, which can lead to synergy between the different disciplines. This in itself rendered the design process more efficient as it removed an unnecessary iteration, that is, the architect beginning the design task on his own before receiving input from engineering disciplines. However, what the disciplines within design teams ended up doing in many instances amounted to no more than seeking to fit solutions to design tasks. In essence, the design teams' approaches could best be categorised as 'integrated' rather than the desired 'integral' design, leading to redesigns (RE) rather than the desired integral design concepts (IDC). Over the past four years the Integral Design approach has been tested in a series of 5 workshops, typically including around twenty participants and lasting for two or three days. A total of 124 designers participated in the workshop series, in which 74% of the designers were present during all of the days. Directly at the end

of the workshop the participants were asked to fill in a questionnaire on the importance of the use of morphological overviews within the design process and on the concept of the workshops themselves. The participants had to rate the answers between 1 (very poor) to 10 (excellent). The average results were then determined; they varied between 7,5 to 8,1, see table 1. So the experience by the professionals is positive, see Fig. 8.

Table 1. Results questionnaires participants workshops series 1 till 5

	series 1	series 2	Series 3	series 4	series 5
Duration workshop in days	3	3	3	2	2
Number participants	20	20	22	27	18
Percentage returned questionnaires	88%	96%	98%	96%	97%
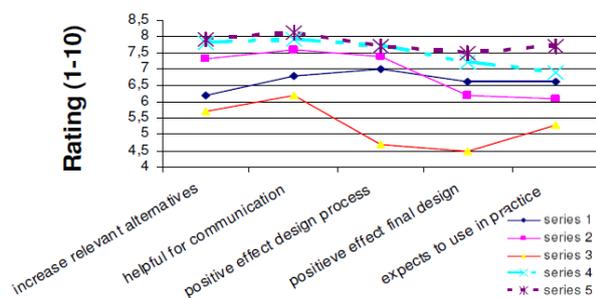
Fig. 9. Overview results questionnaires participants' professional workshops series 1- 5.

The results of the questionnaires indicate that the participants of the workshops thought the use of morphological overviews of value to communication and the number of relevant alternatives within the design process. The improvement in the workshops setting is clearly seen on almost all aspects.

The participants also think that the application of the Morphological Overview increases the number of relevant alternatives generated during the design process.
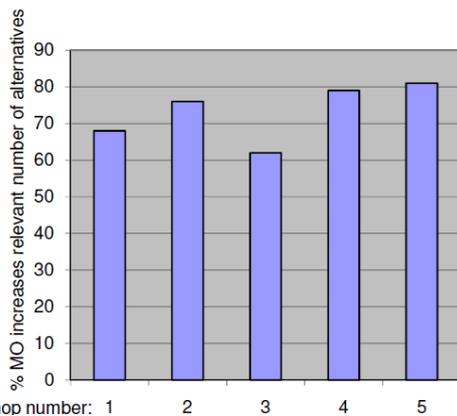
Fig. 10. Result questionnaires about the effect of the use of Morphological overviews (MO) on the increase amount of relevant alternatives

5 Discussion and Further Research

The results of Savanovic 2009 showed that there were no overall integral concepts generated in the workshops. After further analysis of all teams in the 4th and 5th workshops series, we found that there was only concept generation on the level of sub solutions and that also not always. Therefore we are looking for possible ways to stimulate the design team to expand their morphological overview with concepts. In the next stage of the research the use of so called C-constructs, some times called C-projectors, of the KCP-method by Hatchuel and Weil will be investigated to stimulate the creation of new concepts in our Integral Design workshops. The intended effect of the C-projectors is the expansion of the solution space in C, after which, by means of research and evaluation, is the expansion of space K, via the transformation of C-K, Fig. 11.
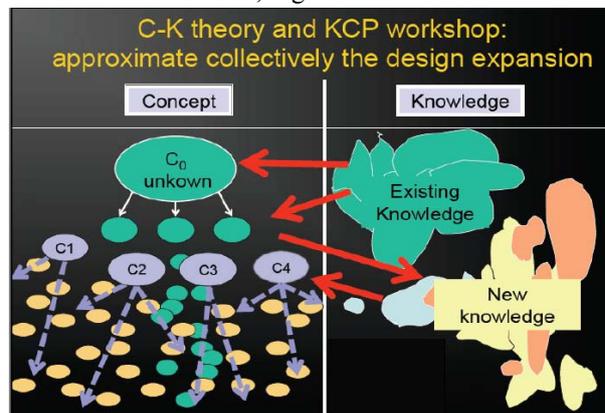
Fig. 11. The transformation between space C and space K by the use of C-constructs (Hatchuel et al 2009).

The KCP workshops were held in different companies in France and more recently in Volvo in Sweden (Elmquist en Segrestin 2008, 2009). To evaluate and position this method in the constellation of other collective creativity method, Hatchuel and Weil propose an integrated framework based on their C-K theory. This led Hatchuel and Weil to the identification of four main dimensions of a collective creativity method (Hatchuel et al 2009): explore the whole conceptual potential of the initial concept, involve and support people in a rule-breaking process, enable relevant knowledgeactivation, acquisition and production and manage collective acceptance and legitimacy of rules (re) building. The KCP method can address all four dimensions in contrast to the traditional collective creativity methods (Hatchuel et al 2009). This performance comes from the fact that this method contrasts with classical creativity techniques, insofar as (Hatchuel et al 2009); it insists strongly on knowledge sharing, the design

reasoning is strongly oriented by the organizers when they propose the C-projectors and it ends with a design strategy and not with a set of selected ideas. How to apply this to the Integral Design approach leads to possibilities using the morphological overview to make the knowledge domain related to the design task in relation with the C-projectors. This could be used to further stimulate connections between space C and space K. From these new connections it may be possible to derive new concepts. These C-constructs are domain strange concepts, which are used as a source of inspiration for further research to make a connection between the existing domain knowledge in space K, and so determine the possibility of concepts resulting from these new connections. After this evaluation these concepts become part of K, allowing the C-K transformation to take place.

6 Conclusions

The results of analyzing the transformation of initial design knowledge into design concepts with the help of morphological charts and morphological overview showed that the Integral Design method did prove successful in facilitating the inclusion of engineering knowledge from the outset of the conceptual design phase. Integral Design method is a helpful method with the morphological charts and morphological overview to focus on the creation of integral design concepts as the result of K-C transformations. Looking at the development of KCP workshops we hope that it will give us an additional supportive intervention. The use of C-constructs of the KCP workshops could lead to increased effectiveness of the Integral design workshops and especially to an increase of the conceptual solution space out of the morphological overview box.

Acknowledgements

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