

# INTEGRAL BUILDING DESIGN; COMBINATION OF REFLECTIVE PRACTICE AND PRESCRIPTIVE METHODOLOGY

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## ABSTRACT

Mostly buildings are designed by a slow process characterized by parallel development of the design proposals and of the design assignment. The process of building design is far from effective and efficient. Often it is needed to change the initial design proposals according to the changes in time of the team knowledge about the design assignment. Also the clients' perception of his own needs often changes, leading to new or altered demands for changes in the developing design. Misunderstandings as result of the evolving design (based on the rough design phases as conceptual, sketch, preliminary and final design) should be made less possible.

Previous work in design methodology based on the rational problem solving paradigm presumes objective and often universal, *a priori*, criteria for design. The focus lies on objective interpretation of essential ill-defined design problems, in order to be able to rigidly organize design process. This leads to a mismatch between design practice, lead by subjective interpretation based on experience of designers, and prescriptions by design methodology. By using the framework of Methodical Design as prescription and use it in workshops to observe and describe adjustments to the methodology used, a bridge between the 'objective' and 'subjective' interpretation can be formed. Thus a combination is made of reflective practice and prescriptive methodology. This prescriptive methodology was tested and reflected in practice in workshops with professional designers in the built environment, architects and consultants. It is now part of a permanent professional educational programme of the professional organizations involved.

*Keywords: Integral design, prescriptive methodology, use of reflection*

## 1 INTRODUCTION

In the world of designing, gaps between the different fields can be recognized (Lechner 1991, Cross & Roozenburg 1992, Reyman 2001, van Aken 2003). Many research projects have aimed at bridging the gap between the world of building design and the world of building services (simulation), so far without overwhelming success (de Wilde et al 1999). In contemporary architecture an increasing emphasis on performance aspects like energy consumption leads to use of active and passive sustainable energy. Earlier research at Delft University of Technology dealt with the integration of energy saving building components in real-life scenarios (de Wilde et al 2001). The results indicate that the most energy saving building components are selected without proper underpinning of the problem resulting from the design task in the phase of conceptual design. Getting a better understanding of the design team's role is essential for the investigation of the decision by architects to request expert analysis interventions by (building physics /service and structural) consultants.

The HVAC-industry has identified a need to better integrate comfort and sustainable energy systems in buildings. In 2000, the Royal Institute of Netherlands Architects, BNA, the Dutch Society for Building Services, TVVL, and the Delft University of Technology, TUD have participated in a research project called Integral Design (Quanjel et al 2003). The integral approach encompasses the built environment from initiative, design, construction and real estate management as a seamless whole. This is the basis for

a distinction of disciplines, avoids misunderstandings, establishing liabilities and responsibilities and fees. It prevents disruption by interference and opens the road to improvement through participation (Cuperus 2003).

As complexity and scale of design processes in architecture and in building services engineering increase, as well as the demands on these processes with respect to costs, throughput time and quality, traditional approaches to organize and plan these processes may no longer suffice (van Aken 2003).

This implies defining a methodology that acts as a “bridge” between architectural elements such as shapes and material on the one hand, sustainable energy use and the aspects of indoor climate issues such as overheating and ventilation on the other.

Sometimes design is considered a mainly problem solving activity where the need transformed to a design problem and its solutions co-evolve. In design the resources consist of knowledge, materials and building processes, while the constraints within the design process include laws of nature as well as time, organizational and financial limitations. Hence the following definition of design can be given. To design is to formulate a product model taking into account;

- the objectives to be achieved
- the available resources
- the prevailing boundaries.

The result of this activity, the product model is frequently called ‘a design’ i.e. a complete description of the object to be built. To support the design of large-scale, complex products, such as one has in the building industry, methods are needed to support the complex design process by structuring it.

## **2 METHODOLOGY**

### **2.1 Methodical design**

Early seventies in Netherlands a methodology was developed to teach design to mechanical engineers at the faculty of Mechanical Engineering Technical University Twente at Enschede; Methodical design model from van den Kroonenberg (1978). Several course books were written and articles published in Dutch professional periodicals. From the start Methodical Design facilitated teaching and transfer of design methods to industry. The Dutch Royal Society of Engineers, Kivi, had its own course of professionals in 1974. It is an approach with typical and exceptional characteristics (Blessing 1994):

- it is a problem-oriented approach
- it is the only model emphasizing the execution of the process on every level of complexity
- it is one of the few models explicitly distinguishing between strategies, stages and activities

The methodical design approach was developed and formalized in the seventies (van den Kroonenberg 1978) and elaborated theoretically by de Boer (1989), Blessing (1994) and more practically by Stevens(1993). The use of Methodical Design makes it possible to improve the design process (Zeiler 1993). Methodical Design is problem oriented and distinguishes, based on functional hierarchy, various abstractions or complexity levels during different design phase activities. Methodical Design makes it possible to link these levels of abstraction with the phases in the design process itself. Methodical Design is based on the combination of the German design school (Matousek 1962, Hansen 1968, Roth 1972, Hubka 1980, Pahl 1984, Beitz 1985) and the Anglo-American school (Hall 1962, Asimov 1964, Archer 1965, Greogory 1966, Krick 1969, Jones 1970).

This framework can accommodate the different subjective interpretations of the requirements, inherent to the design team approach. By structuring the requirements the development of an exchange of restrictions and ideas is accelerated and the generation of the possible solutions is aided. Through iteration cycle of interpretation-generation steps the set of requirements is continuously refined, and with it also the design solution proposals. The same characteristic cycle of activities can be found in design and research

(Roozenburg & Eekels 1995). When discussing the step pattern, van den Kroonenberg refers to the General Systems Theory by Boulding 1956 (de Boer 1989). Incorporating the activities of evaluation and decision in the characteristic cycle of activities leads to more profound focus on the selections within the design process and an even more analogy with System Theory (Figure 1)

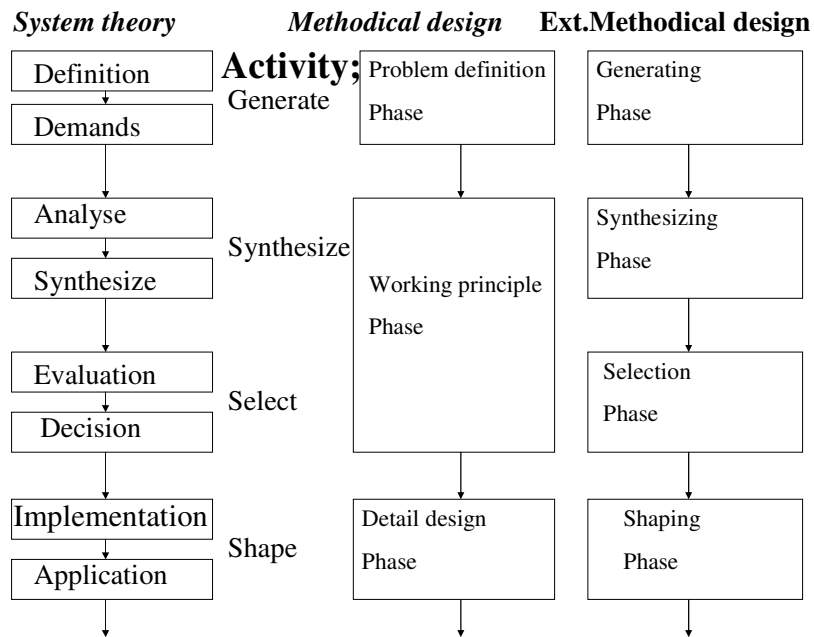


Figure 1: Comparison between system theory, methodical design and integral building design

## 2.2 Decomposition of the design task

In order to survey solutions, engineers classify solutions based on various features. This classification provides means for decomposing complex design tasks into manageable size problems. An important decomposition is based on building component functions. Functions have a very significant role in the design process. Functions can be regarded as what a design is supposed to fulfil, the intended behaviour of the object. Designers can start to think in functions before they are concerned with details about the shape like geometry. Though in architecture this strategy depends on the style of the architect ( van Bakel 1995). During the design process and depending on the current focus of the designer functions exist at the different levels of abstraction. In the preliminary design phase, functions are still independent of a working principle. In later design phases functions become more detailed, and because of that the functions become more and more dependent on the working principle that has been chosen.

The functional decomposition is carried out hierarchically so that the structure is partitioned into sets of functional subsystems. The decompositions are carried out till arrived at simple building functional components whose design is a relatively easy task. The approach satisfies three main requirements;

- independence of high level design decisions;
- simultaneity of constrains introduction;
- identification of necessary information.

Within Methodical Design technical functionalities needed are solved by searching in a structured way for possible solutions to a design need. First the need to fulfil is analysed and decomposed into functions before generating solutions. Starting with analyzing the design task and decomposing it into functions to fulfil before starting generating solutions is essential characteristic of Methodical Design.

The essential element in this model is the design process (Blessing 1994). The characteristics of the design process can be split up into those related to: strategies, stages and activities.

### 2.3 Extension Methodical Design to Integral Building Design

Though the Methodical Design model is one out of a great variety of design models it is the only method to make a distinction between phases and levels (Blessing 1994). The three main phases which are distinguished are; defining the problem, determining the working principle and detailing the design. The levels are a distinction based on a hierarchy of complexity. The design phases and complexity levels form the main elements of the structure or framework of methodical design (de Boer 1989).

In contrast to the design matrix presented by Van den Kroonenberg (1978) and by DeBoer(1989), an extended design model was constructed; the decision based design matrix. In the decision based design matrix the cycle (define/analyse, generate/synthesize, evaluate/select, implement/shape) forms an integral part in the sequence of design activities that take place. The decision based design matrix provides an overall structure that makes the basic design cycle recognizable as such. Essential difference with the former approach is the developing phase after the selection phase, in which the transformation to a lower level of abstraction takes place, the design is modified, developed and gets more shape, see figure 2.

Phases		Design activities; →			
		Abstraction level stages	generate	synthesize	select
Generating phase	Need				
	Design problem				
Synthesizing phase	Functional specification				
	Physical solution process				
Selecting phase	Module structure				
	Prototype structure				
Shaping phase	Engineering aspects				
	Material properties				

Figure 2. Design method/ contents matrix indicating the phases, abstraction levels, issues and steps

The method/contents matrix represents the recursion of the design steps of a design process from high abstraction level to lower abstraction levels. In the matrix the four main phases can be found as well as the four-step pattern. As with the design matrix of de Boer and van den Kroonenberg (de Boer 1989) the design process now consists of working one's way through the matrix cells from left to right and from top to bottom. The separate steps can be listed organized by abstraction level and design phase, see figure 3. These steps results in a complete framework of connected levels of complexity or abstraction. The design task can be viewed on each individual level of abstraction.

Steps Design activities; →

Phases ↓	Abstraction level	Characteristic steps design phase
Generating phase <i>Problem definition</i>	Need	<ol style="list-style-type: none"> <li>1. Describe needs goals etc.</li> <li>2. Compose problem description</li> <li>3. Select problem description</li> <li>4. Task to fulfill</li> </ol>
	Design problem (Environment)	<ol style="list-style-type: none"> <li>1. List demands, requirements, wishes</li> <li>2. Structure and quantify list of requirements</li> <li>3. Determine programme of requirements</li> <li>4. Specification</li> </ol>
Synthesizing phase <i>Working principle</i>	Functional specification (System)	<ol style="list-style-type: none"> <li>1. Determine functions to be fulfilled</li> <li>2. Combine functions to function block diagrams</li> <li>3. Select best function diagram</li> <li>4. Function structure</li> </ol>
	Physical solution process (Subsystem)	<ol style="list-style-type: none"> <li>1. List various physical processes</li> <li>2. Arrange according to importance</li> <li>3. Select most feasible working principles</li> <li>4. Principle solution</li> </ol>
Selecting phase <i>Evaluation</i>	Module structure (Machine)	<ol style="list-style-type: none"> <li>1. Generate combinations of working principles</li> <li>2. Arrange compatible combinations</li> <li>3. Select most promising combinations</li> <li>4. structure</li> </ol>
	Prototype structure (Component)	<ol style="list-style-type: none"> <li>1. Sketch lay-out of the selected combination</li> <li>2. Vary lay-out by mixing, moving, fusing etc.</li> <li>3. Select preliminary lay-out optimum</li> <li>4. Preliminary lay-out</li> </ol>
Shaping phase <i>Detail design</i>	Engineering aspects (Part)	<ol style="list-style-type: none"> <li>1. Generate different forms</li> <li>2. Vary form</li> <li>3. Select best form</li> <li>4. Definitive lay-out</li> </ol>
	Material properties (Material)	<ol style="list-style-type: none"> <li>1. List possible materials</li> <li>2. Make alternatives with different materials</li> <li>3. Select material</li> <li>4. Product documents</li> </ol>

*Figure 3. Design steps within design matrix*

The design phases and abstraction levels form the dimensions of Methodical Design method/contents matrix. The emphasis at higher levels of abstraction lies on the problem definition phase and generation, while at lower levels of abstraction the emphasis is on developing details of the design product.

Throughout the different levels of abstraction the description of the design gradually becomes more detailed. Abstraction is the selective examination of certain aspects of a problem (Savanovic 2005). Abstraction helps the designer to decompose a complex design question into problems of manageable size. By introducing different levels of abstraction the designer can limit the complex design question to smaller sub-questions. Each level represents an abstraction of the levels below.

In applying methodical design it is not always important to go through a complete design process on each level of complexity. Often the focus can be on specific steps on specific hierarchical levels. The design

matrix presents a design process in a very condensed way. The same approach can be viewed in design practice, see the examples of the architect Herzog de Meuron. The comparison is made with the abstraction levels of VDI 2221 and presented in figure 4.

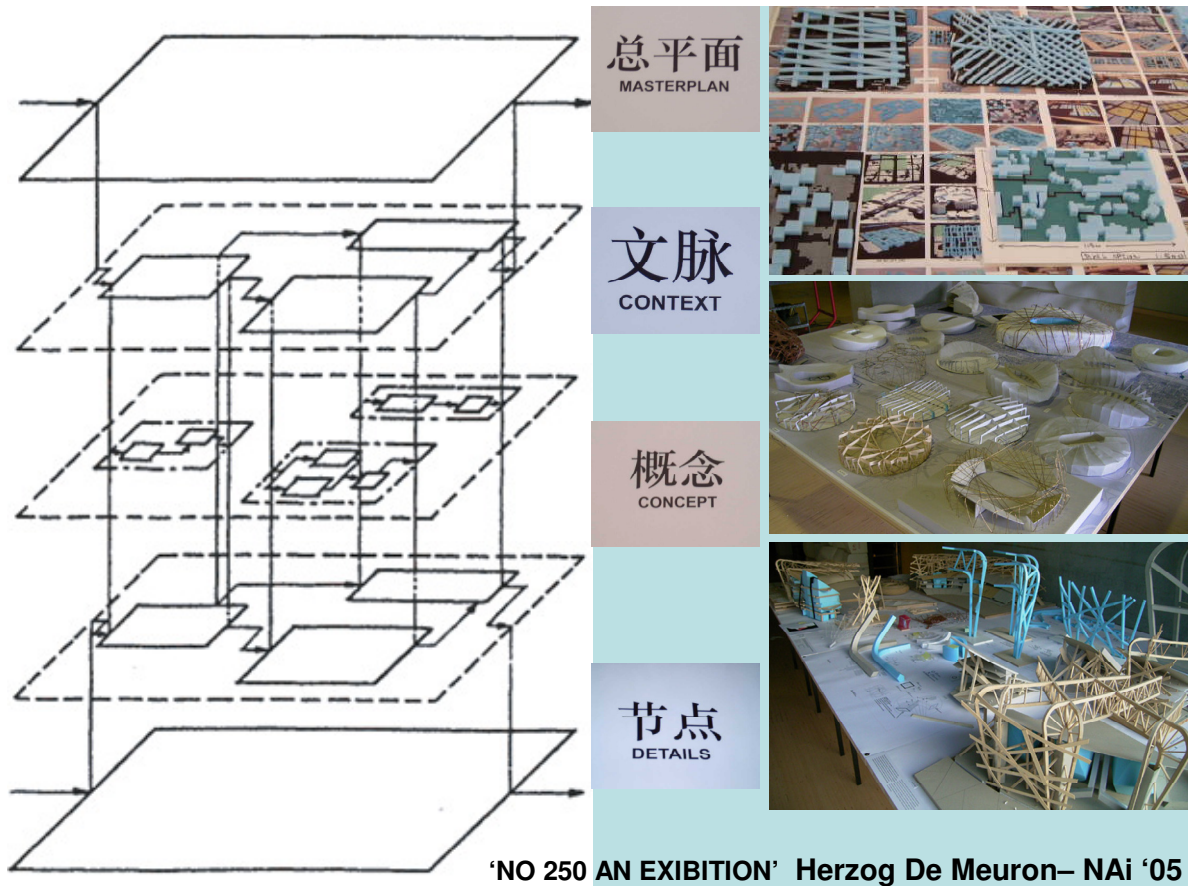


Figure 4. Comparison abstraction conform VDI 2225 and the approach of architects Herzog de Meuron

## 2.4 Connection Integral Building Design and reflective practice

The framework of Integral Building Design can be seen as a representation of a rational problem solving view of designing (Simon, 1973) and was further developed. The rational problem solving paradigm presumes objective criteria for design. The focus lies within this paradigm on objective interpretation of essentially ill-defined design problems (as they are widely accepted to be); in order to be able to rigidly organize design processes (VDI, 1987). The objective interpretation of fundamental unique problems is however not possible. The approach of reflective-practice (Schön 1983, Drost 1997) describes the tackling of fundamentally unique problems. Schön proposes an alternative epistemology of design practice, which describes design as 'reflective conversations with the situation' (Reyman 2001).

Instead of objectively describing design assignments (as according to the rational problem solving paradigm), they should be subjectively interpreted (through reflective thinking) by the design team. This way the design team creates its own (design) criteria. This interpretation through the definition of criteria is needed in order to be able to effectively structure further actions that need to be taken to achieve integral solutions. Since these interpretations lead to non-universal and automatically non-verifiable definitions, it is scientifically impossible to compare the results of different design teams, even if all design teams use the same assignment.

The combination of aspects of reflective practice (Schön, 1983), during the interpretation phase, and rational problem solving methods, during the conceptual design phase, will help to overcome the major obstacle: a definition of 'designer objective' criteria, as a prerequisite for effective actions during design processes.

By the use of reflective workshops the structures problem solving process of methodical design is combined with the reflective practice of Schön (1983). As a result integration of a prescriptive matrix and a descriptive / reflective focus on its use results in a virtual connection between the different approaches, see figure 5.

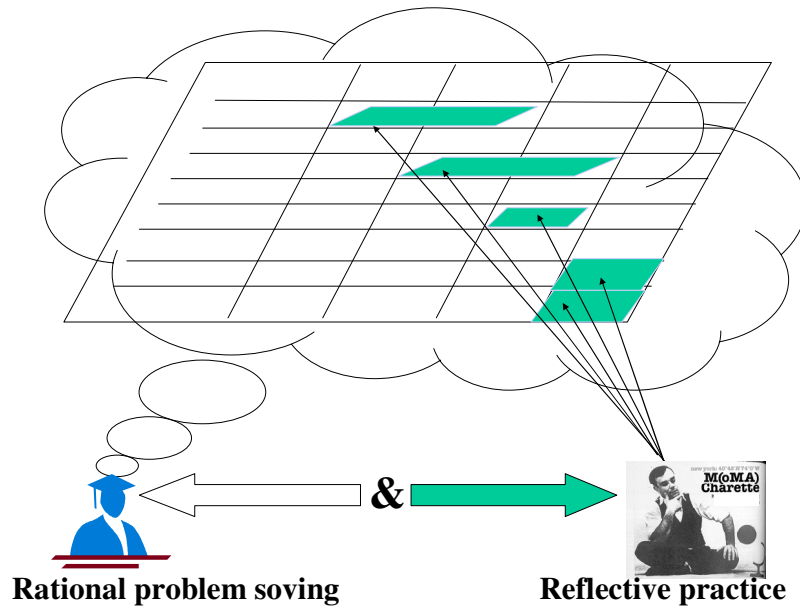


Figure 5. The relation between rational problem solving and reflective practice.

Here a descriptive element in the prescriptive model is introduced. Integral Building Design is an example of integration between rational problem solving, of which methodical design is a good example, and the theory of reflective practice of Schön (Schön 1983), (Roozenburg & Dorst 1998).

## 2.5 Workshops Integral design; combination of methodology and reflective practice

Integral design shows high promises to reduce failure costs and to improve design quality. That was the reason for the Royal Institute of Dutch Architects (BNA), the Dutch Society for Building Services (TVVL) and Delft University of Technology (TUD) to start a research project on Integral Design in year 2000. This project resulted in a series of workshops for architects and HVAC consultants. This project was succeeded by new research within the Knowledge Centre Buildings and Systems (KCBS), in which Technische Universiteit Eindhoven (TU/e) and the Netherlands Organization for Applied Scientific Research (TNO) cooperated.

The ultimate goal of this integral design methodology is direct stimulation of application of sustainable energy within built environment. In order to enhance integration of sustainable energy in conceptual building designs, multidisciplinary design teams incorporating architects, structural engineers and both building physics and building services advisers were observed during designing. Design teams, formed by members of BNA and ONRI, worked within workshop setting organized by the KCBS. All design team members were experienced professionals. The workshop series consisted of three half-day sessions, with one week in-between them.

One of the aims of this experimental research was to find out if 'integral approach' through multidisciplinary teams results in creation of new and innovative building concepts regarding sustainable energy and sustainable comfort systems. For this purpose the results of 'traditional approach', simulated during the first day of workshop series, were compared with the results of 'integral approach', set-up during second and third day of workshop series. The produced building designs were analyzed regarding integration of sustainable energy solutions within coherent building design concepts. Besides the distinction between 'traditional' and 'integral' approach, design processes during the third day of workshop series were aided by a 'methodical design' framework. The second aim was therefore to investigate if application of 'methodical design' aspects would further enhance integration of sustainable energy in conceptual building designs.

Preliminary tests of methodology have been conducted in a series of workshops for both experienced professionals as for students. This has been done in order to explore possibilities for improvement of design attitude and capabilities in practise as well as in education. Parallel the workshops are implemented as a part of the the education of master students at the TU/e. The workshops are continuously developed within 'Integral design methodology in context of sustainable comfort systems' PhD-research project (Savanovic 2006)

Besides their role as a part of continuous professionals' education, the workshops are used as experimental settings for research on building design teams during conceptual design phase. The observed teams were consisting out of an architect, a structural engineer, a building services adviser and a building physics adviser. Our primary research interests concerning building design teams are: how is communication between different design disciplines influenced by use of (integral building design) tools; does use of (integral building design) tools enhance generation of different design solutions within design team setting; how are these two aspects related to each other?

Various aspects during design sessions were analysed. For this purpose the type of activity, its occurrence in time and frequency were all registered; using methods as: direct observations, questionnaires, content analysis. The teams have also been photographed and/or videotaped in order to get an accurate picture of design processes (Savanovic et al 2006). Integral design is meant to overcome, during design team cooperation, the difficulties raised with the early involvement of consultants (Savanovic 2006a). This is achieved by providing methods to communicate the consequences of design steps between the different disciplines on areas such as construction, costs, life cycle and indoor climate at early design stages. The aim is to support all disciplines with information about the tasks and decisions of the other disciplines. Supplying explanation of this information will improve understanding of the combined efforts (Savanovic 2006b, Zeiler et al 2006).

### **3 RESULTS**

#### **3.1 Methodical design**

Methodical Design led to a wide range of applications. Besides two PhD theses, over 170 MSc. theses and 25 BSc. theses at the TUT, there are many students reports on practical assignments in industries, that have been conducted as part of a design course (de Boer 1989). Furthermore there are over 100 reports on design activities of the staff on the projects that have been carried out in the fields of;

- underwater technology
- non-waste technology
- wind pumps for developing countries
- bio-medical devices

Methodical design is considered suitable to be used and taught as a way to solve (at least mechanical) engineering problems more easily by ( de Boer 1989);



- providing a basic problem solving approach for engineering;
- flexibility, because it can be used in many different applications;
- effectiveness, as it assists in obtaining suitable results.

Also systematic feedback on the use and teaching methodical design (de Boer 1989);  
enables novices to apply it without much difficulty;  
enables further development by students themselves, depending on their own ideas and preferences;  
stimulate professionals to use and adapt it.

The method was taught at the Technische Universiteit Twente (TUT) as a general way of solving technical problems. However this caused considerable problems as many students apparently could not make the conversion from the abstract general method to their own specific case. Students take the general way as a recipe and thus often did the opposite of the intended attitude. The method appeared for them as a harness in which they were forced to battle. Still many students saw the real value of Methodical Design as a way of structuring the process and the communication during the design process. At present Methodical Design is still taught at a large percentage of the Technical High Schools in the Netherlands.

### **3.1.1 Current Methodical design applications**

At present many applications can be found in Dutch industry. In the Dutch heating industry two innovative successful companies, Nefit (Poelman 1993) and Biddle (Stevens, Heurs 1995) use Methodical Design in their product development design. Stevens IDÉ partners, Industrial Design & Engineering, transformed Methodical Design into Strategisch Ontwerpen (Strategic Design) and since 1992 use this as a basic approach for industrial design consultancy for mechanical engineering, industrial design and mechatronics. IDÉ's client list includes Shimano, Koga Miyata, Nefit Buderus, Medical Measurements Systems and many others.

## **3.2 Integral Building Design workshops**

All applications mentioned of methodical Design so far are found in the mechanical engineering domain, but in recent years at the Technische Universiteit Eindhoven (TU/e) several MSc. theses were conducted in the building construction domain. Two PhD students are working on research on application of Methodical Design in the building domains. At the TU/e Methodical Design has been extended to Integral Building Design and is taught to master students of the Faculty of Architecture, Building and Planning since 2001. Since year 2002 Integral design has been propagated within Dutch building design industry, through continuously developing 'learning by doing' workshops.

These workshops are implemented as a part of permanent professional education of BNA and ONRI, where they are meant to trigger the changes in work cultures of involved disciplines. During the last five years, more than 250 engineers from these two professional organizations have participated in the workshop as part of their professional educational development. By following these workshops these professional participants supported the development of design workshop from an early experimental setting into a more balanced approach to achieve knowledge transfer.

### **3.2.1 Working with experienced designers versus student groups**

When verifying a new methodological concept, it is not common to work with experienced designers from different disciplines. This is mostly done by experiments with student groups (Segers 2002) or with design groups within one company (Blessing 1994). However, the relevance of research for the daily design practice improves by using experienced designers, as there is a major difference in approach between novice and experienced designers (Ahmed et.al 2003, Kavakli et.al 2003).

Preliminary tests of methodology of Integrated Building Design have been conducted in a series of workshops for both experienced professionals as for students. This has been done in order to explore possibilities for improvement of design attitude and capabilities in practise as well as in education. Initial

results of observations of 'Integral Design' workshop participants show differences in design methodology use between experienced designers and students (Savanovic et al 2006b).

#### **4 DISCUSSION**

Fully accepted research methods do not yet exist for design research (Reyman 2001), but new process design methods should at least be (Cross 1992):

inquisitive: seeking to acquire new knowledge;

informed: conducted from an awareness of previous, related research;

methodical: planned and carried out in a disciplined matter;

communicable: generating and reporting results which are testable and accessible by others

purposive: based on identification of an issue or problem worthy and capable of investigation;

At the early design stages, usually only conceptual sketches and schematics are available, often rough and incomplete. Architects tend to develop their designs in a drawing-based, graphical way (prototypes are used to investigate the design concepts). It is important to mention here that (building) design is a creative process based on iteration: it consists of continuous back-and-forth movements as the designer selects from a pool of available components and control options to synthesize the solution within given constraints. As the design proceeds, more information and detail will be developed.

As no design method can claim to be the 'one and only', Integral Building Design should not be considered as a recipe for all situations, but as a good procedure or framework to learn and improve design. Gradually designers will modify the method they use and improve it to their own taste and preferences. Integral Building Design should be look upon as a set of procedures and framework with which designers can start as well as improve upon.

It is assumed that designers survey a problem, form a judgment about critical areas in the design matrix and make decisions about how the focus of attention may be optimized. By introducing a descriptive element from the reflective practice in the prescriptive model of Methodical Design an new Integral Building Design method is introduced. The resulting Integral Building Design method makes it possible to work in a structured and transparent way using the framework of the resulting design matrix. It is for the designer to make the decision about partly use of the matrix elements of the design method.

On this aspect it is good to remember French:

*"Engineering designers do not on the whole use the systematic approaches to design advocated by academics. This is partly explained by their wealth of experience: very often the steps followed by the academic appear to the practical designer to be superfluous, since the outcome is obvious and the result can be gone to directly. In this conclusion they will generally be right, but occasionally they will be wrong, and will miss opportunities for better design as a consequence. (French 93)".*

#### **5 CONCLUSION**

It is stated that Integral Building Design should not be considered as a recipe for all processes, but it is a good recipe to learn cooking. Gradually designers will modify the method they use and improve it. Integral Building Design should be a set of rules with which designers can start, as well as improve upon

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