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DESIGN DECISION SUPPORT FOR THE CONCEPTUAL PHASE OF THE DESIGN PROCESS

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ABSTRACT:

Design is a complex process that depends very much on the information about the design task to perform. At the early design stages, usually only conceptual sketches and schematics are available, often rough and incomplete. Still at the early stages of design the most important decisions have to be taken. This leads to an information contradiction: almost no information s available and yet most of the decisions have to be taken. Integral design is meant to overcome this problem of lacking information at the start of the design process by providing methods to communicate the consequences of design steps across the different disciplines involved in the design process. The Integral Design Methodology, based on the Methodical Design approach, is meant to support all disciplines in the design process with information about the tasks and the decisions of the other design disciplines involved in the design process. Supplying and exchanging explanations about the decisions taken during the design process will improve understanding of the combined efforts by all the designer parties. In particular the use of the morphological overviews combined with the Kesselring method as a decision support tool will help to structure the early conceptual steps within the design process and make decisions taken during the design process more transparent for all the people involved. This method is used in

workshops and in different MSc theses at the Technische Universiteit Eindhoven and shows promising results.

1. INTRODUCTION

"*I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you can not express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the state of science, whatever the matter may be.*"
William Thomson, Lord Kelvin (1824-1907)

Design can be looked upon as a problem solving activity where the needs of the principal are transformed into a design problem. The design problem and its solutions co-evolve during the design process. The designer starts by describing what the intended product should do. Through reasoning on the product both the problem and its possible solutions co-evolve. During the design process much more information is gained about the needs of the principal. This process eventually results in a solution. Within design the resources consist of knowledge, materials and building processes, while constraints include the 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 solution based on given demands of the principal and taking into account:

1) the objectives to be achieved

2) the available resources

3) the prevailing boundaries.

The result of this activity, the solution, is frequently called 'a design', i.e. a complete description of the object to be built. The transformation from the principal's needs, the basis of the design brief, into a full product description involves several product states and design phases. The design brief is the first description of the desired product. In small steps over a longer period this initial state is transformed until finally a full description of the product emerges. To support large-scale, complex design processes, such as these in the building industry, methods are needed. For the client it is of course the solution that is of great importance, but also more and more important is the argumentation on which the solution is based. The design process should not only lead to a solution but also give insight in the reasoning about the design problems and the solutions themselves. Only when the reasoning is also provided is it possible for the client to make judgments give feedback on the interpretation of the briefing by the designer.

Stated in the project description are the needs on the basis of which designers can choose from among alternative solutions as rationally as possible. This indicates that there is also an amount of subjective interpretation among the designers. Design can be viewed as a big black box: ‘needs’ form the input and ‘blue print solutions’ make up the output. Going back to the formulation of the design problem and the list of requirements is often an essential consequence of gaining insight into the true nature of the problem. New information is needed as a result of the insight gained, requiring adjustments that expand or sharpen up the initial formulation of the design task.

At the early design stages, usually only conceptual sketches and schematics are available, which are 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. But the dilemma of this system is that at the early stages of design there is little information, even though nearly all the important decisions have to be made at this time, as figure 1 shows.

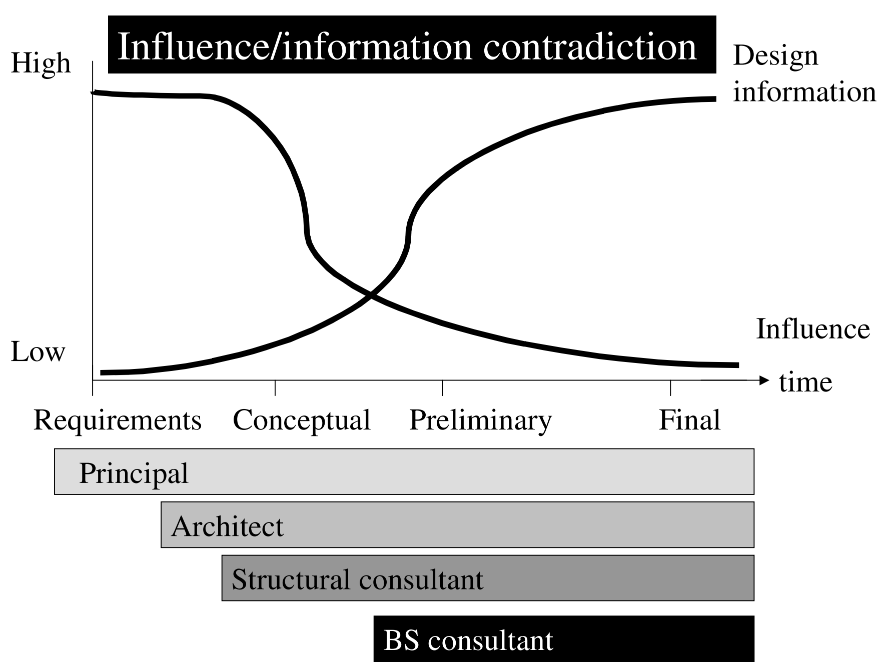

Figure 1; Influence / information contradiction at the early stages of design

The knowledge/information characteristics of the duration of the design process is described by Ullmann (2003) in two dimensions: The design freedom of the solution space and the knowledge about the problem, see fig. 2.

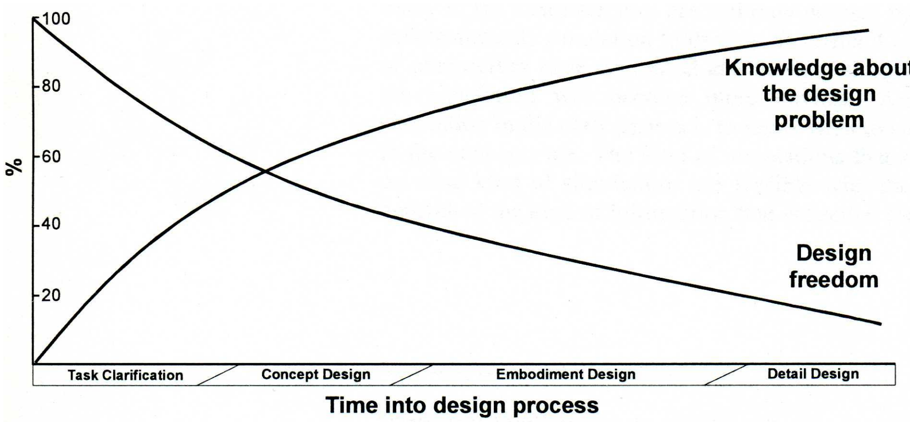

Figure 2. Schematic description of knowledge/information versus design freedom during the design process (Ullman 2003)

During the design process more and more information about the problem and the solution will become available, while the freedom to make decisions in the solution space will decrease. In the early design phases there is little knowledge and the freedom in how to solve the design problem is great. At the end of the design process there is much more knowledge on the design task while the design freedom comes to be strongly limited. Decisions taken in the early phases of the design process have a higher effect on the final outcome compared to a decision at the end of the design process, although the early decisions are based on less knowledge about the goals to be reached (Derelöv 2004). The fact that the architect has to make all kinds of decisions without adequate information and knowledge is felt by the architect to be depressing, or even monstrous (Koolhaas 2004). The architect has to make decisions, make choices and all this leads to a reduction of possibilities and of his or her creative solution space (figure 3).

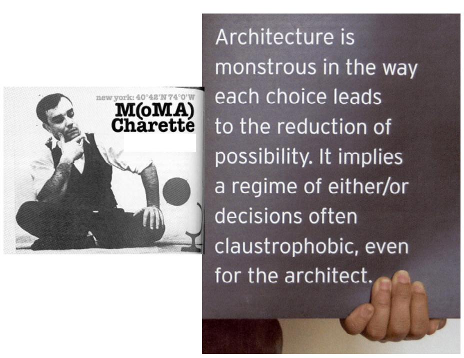

Figure 3. Information contradiction leads to claustrophobic effects for architects (Koolhaas 2004)

Nowadays design is conducted more and more in multi disciplinary design teams with a view towards integrating all aspects of the life cycle aspects of a design. It involves information exchange between the participants in the design process in amounts not known before. This makes decision-making even more complex. Most of the choices in the design process may be made by intuition and according to simplified decision rules, which is necessary and inevitable (Roozenburg & Eekels 1996). There is a need for formalized discursive methods to structure the decision process (Derelöv 2004).

2 METHODOLOGY; METHODICAL DESIGN

During the early seventies in the Netherlands a design methodology was developed to teach design to mechanical engineers at the faculty of Mechanical Engineering of the Technical University Twente: Methodical Design. The Methodical Design approach was developed and formalized by van den Kroonenberg (van den Kroonenberg 1978) and elaborated theoretically by de Boer (1989), Blessing (1994) and more practically by Stevens(1993)and Siers(2004). 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. This framework can accommodate the different subjective interpretations of the requirements, which are inherent to the design team approach. By structuring the requirements the development of shared understanding is accelerated, facilitating the generation of possible solutions. Through an iteration cycle of interpretation-generation steps the set of requirements is continuously refined, and with it also the design solution proposals.
The Methodical Design model is the only design model to make a distinction between phases and levels (Blessing 1994). Three main phases are distinguished:

- defining the problem;
- determining the working principle;
- detailing the design.

The levels are distinguished in terms of a hierarchy of complexity. The design phases and complexity levels form the main elements of the structure of methodical design (de Boer 1989).The phases and levels can be placed in the form of a method/system matrix: the design matrix. This design matrix consists of the design phases on the horizontal columns and the different abstraction levels in a hierarchical order on the vertical rows. There is an emphasis on the higher levels of complexity in the problem definition phase, while at the lower levels of complexity the emphasis is on the design details. In the design matrix a ‘main stream’ can be drawn from the top left corner to the bottom right corner, see fig. 4.

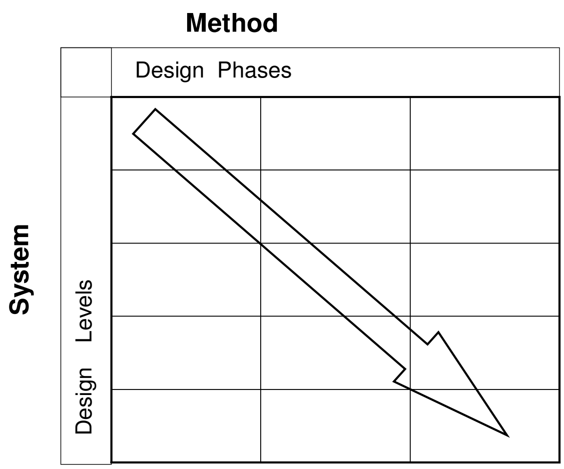

Figure 4: Design matrix of methodical design (de Boer 1989)

A basic three-step pattern, the basic cycle, can be recognized within each phase of the Methodical Design process. When discussing the step pattern, van den Kroonenberg refers to the General Systems Theory by Boulding 1956 (de Boer 1989). The three-step pattern is similar to more ‘basic design cycles’ e.g. that of Eekels, which consists of: analyse, synthesize, simulate, evaluate and decide (Roozenburg & Eekels 1995). As the relation with General Systems Theory was not worked out completely within Methodical Design, the basic design cycle is extended by us into the Integral Design Methodology (IDM) (Zeiler 2000).

The design matrix of MD is extended with a selection phase into the IDM matrix and the phases are renamed more fittingly to the specific design activities. Within the IDM matrix the cycle (define/analyse, generate/synthesize, evaluate/select, implement/shape) forms an integral part of the sequence of the design activities that takes place. An essential difference from the former approach lies in the shaping phase after the selection phase, in which: the transformation to a lower level of abstraction takes place and the design is modified, developed and gets to be further shaped, see fig. 5.

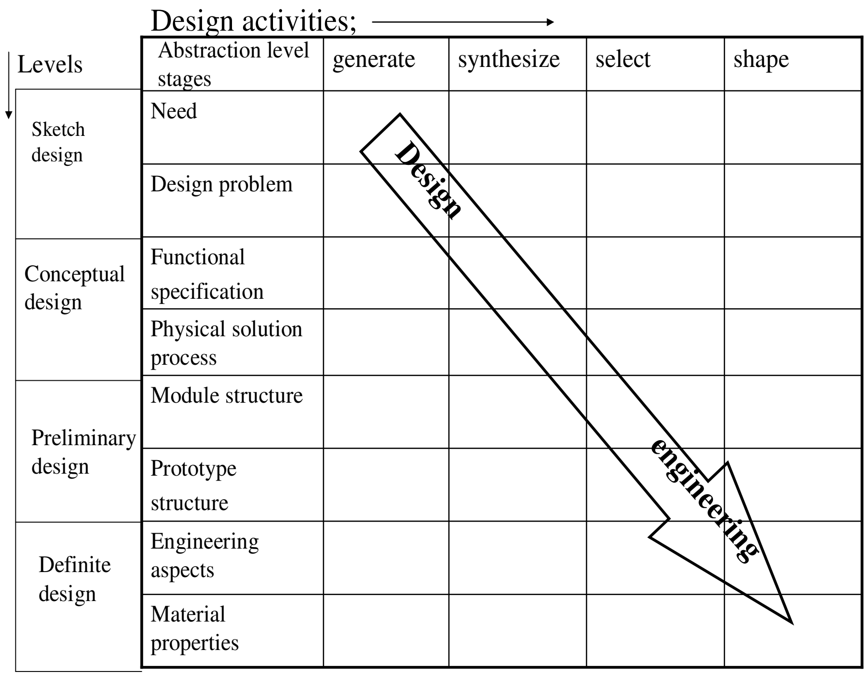

Figure 5: Design method/ contents matrix indicating the phases, and abstraction levels

Our method/contents matrix represents the recursion of the design steps of a design process from the high abstraction level of design to the lower abstraction levels of engineering. In the matrix the four main phases can be found as well as the four-step pattern. IDM as an extension of Methodical Design is now in more analogy with System theory, see figure 6.

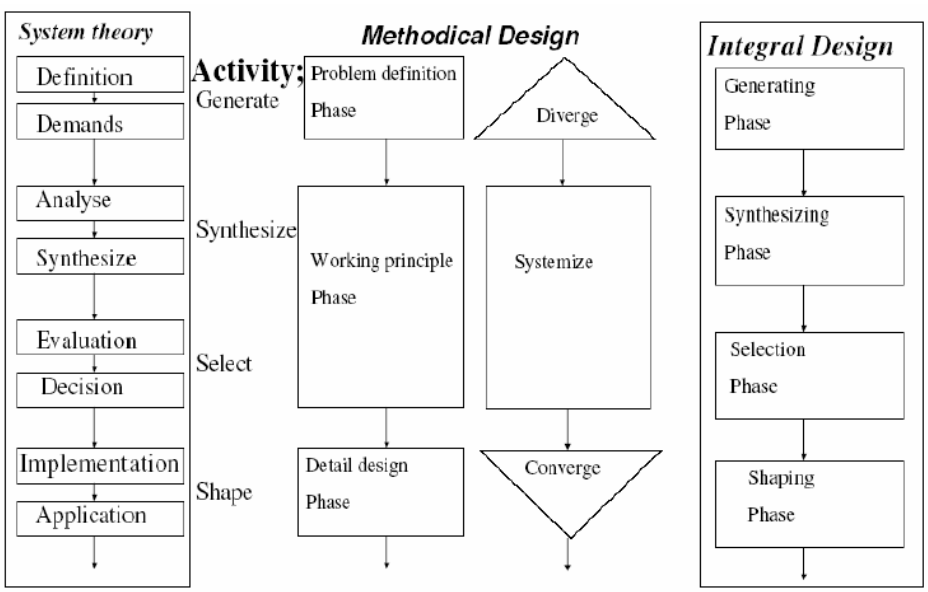

Figure 6: Pattern of System theory, Methodical Design with its basic three-step pattern and Integral design

The design matrix of Methodical Design is extended with a selection phase was (figure 6). Comparing the IDM model we propose with the basic design cycle proposed by Roozenburg and Eekels (1992) shows that our basic design cycle is more complete. The essential difference lies in the shaping phase of our model with steps to' shape' the design, it becomes more concrete and takes the step to a lower abstraction level, see fig. 7.

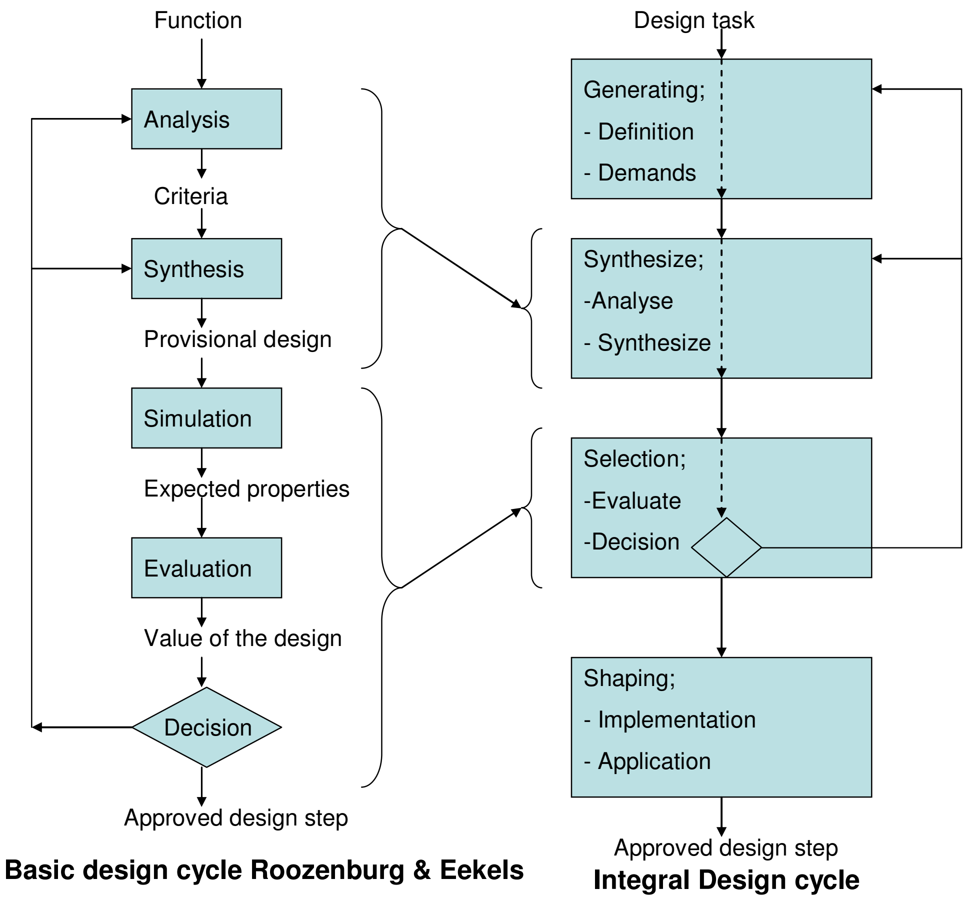

Figure 7: Comparison between design cycle presented by Roozenburg & Eekels and Integral Design

The IDM cycle provides an overall structure that makes the basic design cycle recognizable as such. Through an iteration cycle of the interpretation-generation steps the set of requirements is continuously refined, and with it also the design solution proposals.

As with the design matrix of van den Kroonenberg's (de Boer 1989) the design process now involves working one's way through the matrix cells from left to right and from top to bottom. However, "working from abstract problem formulations to concrete solutions and splitting problems into subproblems are iterative and recursive processes that rely upon anticipations of possible solutions (Cross & Roozenburg 1992)". As the prescriptive model intends to structure

and not to predict design behavior, the iterative and recursive processes do not disqualify the model. The separate steps can be organized by abstraction level and design phase. These steps result in a complete framework of connected levels of complexity or abstraction. The basic design actions form the frame of reference for the discussion of the effectiveness of the model.
The design phases and abstraction levels form the dimensions of the Methodical Design method/contents matrix. 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. This approach is also seen in mechanical engineering design in VDI 2225 as in architectural practice, e.g. the work of Herzog de Meuron (figure 8).

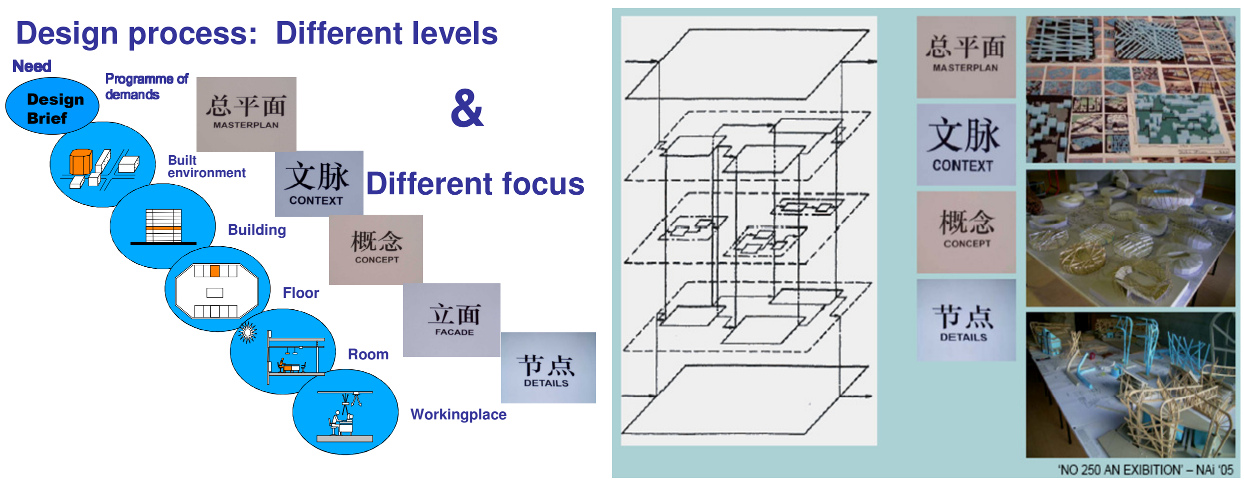

Figure 8. Abstraction levels for the design process example VDI2225 and architect Herzog de Meuron

All the requirements and wishes that apply to the design brief are gathered. In the project description, the design brief, needs are described in terms which designers can use to choose from among alternative formulations as rationally as possible. After the generating of the requirements of the design task, sub functions can be defined.
Functions have a very significant role in the design process. Functions can be regarded as what a design is supposed to fulfill i.e., the intended behavior of the object. Functional decomposition is carried out hierarchically so that the structure is partitioned into sets of functional subsystems. The decompositions are carried out to arrive at simple building functional components the design of which is a relatively easy task. To ensure good overview of and information exchange between different disciplines during the conceptual phase of design functional structuring can be used: the morphological overview of Zwicky (Zwicky 1948). On the vertical axis of the matrix the required

functions or sub-functions are given. On the horizontal axis the possible solutions to provide for these functions given. The combination of the functions on the vertical axis and the solutions on the horizontal axis leads to a combinatorial explosion of possibilities as different combinations of sub-solutions or aspects can be selected from the chart.

Morphology (Zwicky 1967) makes it possible to generate solutions for design problems in huge numbers. The search problem of design can thereby be transformed to a decision problem. Essential within the Morphological Approach is the strict separation between the generation of 'solution principles' and choosing between these alternatives:

"*Utmost detachment from prejudice is the first and foremost requirement of the morphologist* (Zwicky 1967)".

Of great importance in connection with this selection problem of design alternatives is the work originated by Kesselring in his book Kompositionslehre, Study of Composition, (Kesselring 1954). Kesselring developed a simple but very effective decision support method for the design process.

2.1 Evaluation and Decision making; Kesselring decision support

Decision support methods are intended to help designers in making decisions. As people are limited in their capacity to process information, evaluation should be conducted in terms of each criterion separately. Subsequently, the values determined have to be aggregated into a score for the 'overall' value of each alternative. Kesselring developed a visualization technique, with which different variants can be compared with each other.

Within the Kesselring method, the criteria for the requirements are separated into a category for realization and a category for functionality. By doing this the strong point can be seen in the so called S-(Stärke) diagram. To visualize the scores the criteria of the program of requirements are separated in groups with relating requirements. The first group of criteria has to do with the functionality of the design and the other group of criteria with the realization, see figure 9.

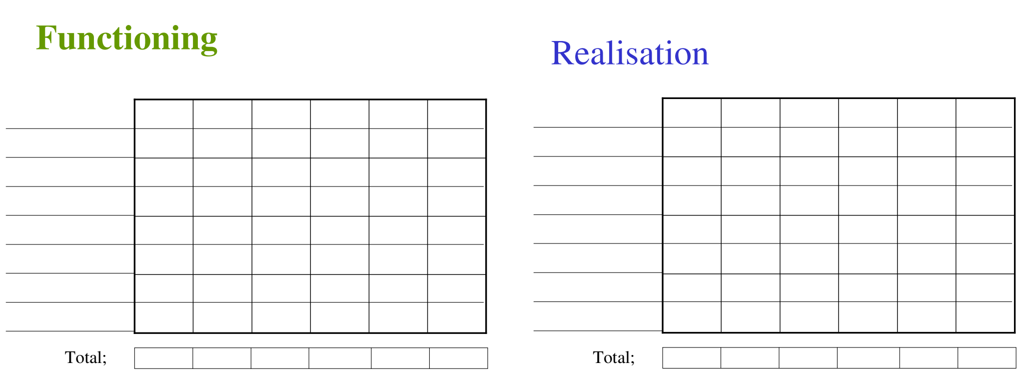

Figure 9: Separation into Functional and Realization aspects

Each group of criteria is evaluated and supplementary to the total score of each group of criteria. These criteria are derived from the program of requirements, the design brief.

The total score of the functional and realization criteria is expressed as a percentage of the maximum score to gain. In the diagram the percentage of the criteria for functionality is set out on the y- axis and the percentage of the criteria for realization on the x-axis (figure 10). The best variants lie near the diagonal and have high scores. It is wise to set values to limit the selection area. A practical suggestion is to divide the area in two with a minimum border set by the x- and y-value of 40 and by (x+y)-value of 55% (figure 10). The Kesselring method makes singularities visible, whereas that in the normal choice tables and bar diagrams only could be retrieved with much effort. In the Kesselring diagram it is easy to see if the improvements must take place in the functionality or on the realization side.

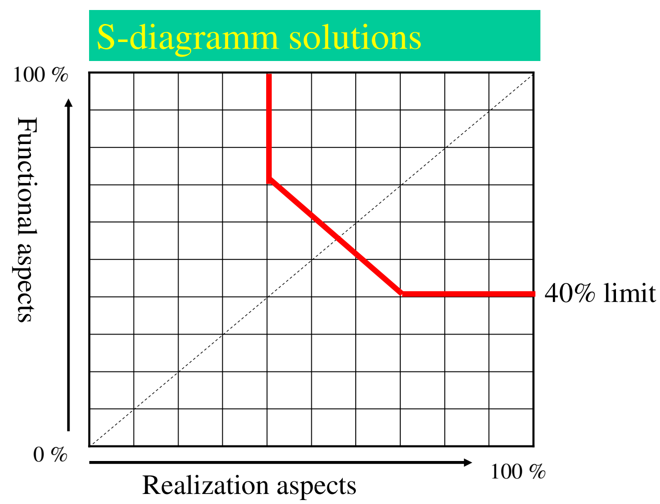

Figure 10: S-diagram of Kesselring showing the evaluated functional and realization aspect of the 4 design proposals of the legenda.

3. RESULTS

At the Technische Universiteit Eindhoven the Kesselring method was used as a decision support tool during the Integral Design process (e.g. van Schijndel 2006, Verdonschot 2006, Verwer 2006). The study by Verdonschot will be discussed as an example of the application of the Kesselring method as a design decision support tool. In this project an optimal solution for the façade of a building had to be designed.

The aim of this example was to compare different solutions on a conceptual level of façade design for a building, ranging from ventilated double facades to a single skin façade, and determine which façade has the best overall performance and can be developed further in the design process. The method of Kesselring was used to compare four façade concepts. Fifteen functional aspects of thermal and visual comfort, energetic and acoustical performance, ventilation and maintenance have been determined, next to eight realization aspects of costs, sustainability, flexibility and architecture.

The information for evaluating the design criteria were based on the specific parameters of existing building facades: the single skin façade of the Effenaar, the second skin façade of the Kennedy Business Centre, the ventilated double window of the ABT office and the second skin façade of the Bouwhuis. These results of the evaluation of the concepts are put into the diagram of Kesselring, figure 12, which directly shows which façade concept has the best balanced performance and which façade concept needs improvement on the functional or realization aspects.

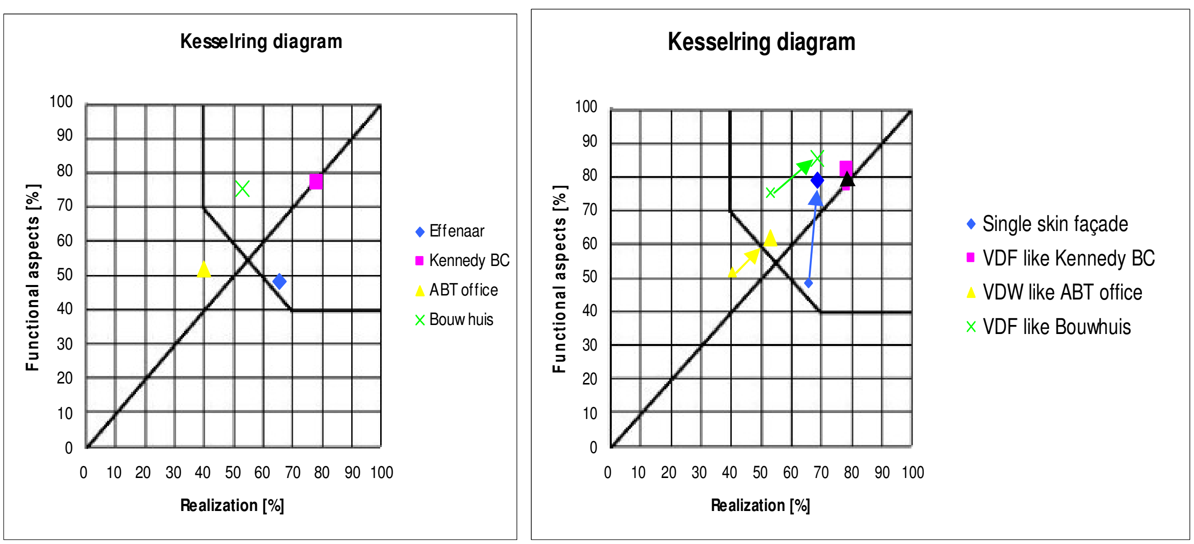

Figure 12. Kesselring diagram and Kesselring diagram of the improved types of façades.

The evaluation criteria are given scores according to the method described in the previous paragraph. The possible improvements of the functional and realization aspects are analyzed for all the four façade concepts. These adjustments result in the Kesselring diagram for potential improvements of figure 12. This diagram shows that the single skin façade can be improved mainly on the functional aspects. The ventilated double window and the ventilated double window multi-storey type can be improved on the functional as well as the realization aspects. The diagram also shows that there are not many improvements possible for the ventilated double façade partitioned by storey.

4. DISCUSSION

Design can be considered a problem solving activity involving the transformation of needs to a design problem and its solutions co-evolve. Fully accepted methods do not yet exist for design (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 the identification of an issue or problem that is investigatable and worthy of investigation

The Integral Design Methodology (IDM) fulfills these requirements. The aim is to support all the disciplines involved in the design process by structuring the process in steps and structuring the information flow about the tasks and decisions of the other disciplines. Supplying explanation of this information will improve team members understanding about each other's tasks and results in combined efforts to further improve the design within the design process. In particular the use of the Kesselring method as a decision support tool will help to structure the decision to be taken and make the decision process more transparent and understandable for all the designers from the different disciplines involved in the design process.

IDM is meant to overcome design team cooperation difficulties concerning miscommunication raised by the early involvement of consultants. This is achieved by not only earlier involvement of the consultants but also by providing methods to let the consultants act as designers rather then consultants sec. The IDM and its tools let the consultants communicate the consequences of design steps taken in the different disciplines on areas such as construction, costs, life cycle and indoor climate at early design stages. The aim is to support all the necessary design disciplines with information about the tasks and decisions of the other disciplines. Supplying explanation of this information will improve understanding of the combined efforts.

5. CONCLUSION

"*If a man begins with certainties, he shall end in doubts: but if he will be content to begin with doubts, he shall end in certainties*."
Francis Bacon (1561-1626), *Advancement of Learning* (1605)

IDM and the use of the Kesselring method should not be considered as a recipe to support decisions within all design processes, but it is a method which can be used in the conceptual phase of a design process. Integral Building Design could be a frame work of connected process elements with which designers can work. The Kesselring method within Integral Design is tested in the field of mechanical engineering and building design. The structure of a design process itself however is unfortunately only one of the factors resulting in a good design. It helps to use a structured method to make the design process more transparent, but gives no guarantee to the true value or quality of the resulting design. It just helps to exchange information and motivations about design decisions. Nothing more and nothing less. Still we designers need all the help we can get! The Kesselring method is not only used in MSc-theses by students but is also used in multi disciplinary master design workshops for master students as part of their educational training. The workshops in which well over 80 students participated so far clearly showed the added value of decision support in the Integral Building Design process.

Acknowledgements

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References

Archer L.B., 1965, Systematic method for designs, Council of Designers, London

.Beitz W. ,1985, Systematic Approach to the Design of technical systems and products, VDI 2221 0 Entwurf, VDI, Düsseldorf.

Blessing L.T.M., 1994, A process-based approach to computer supported engineering design. PhD thesis Universiteit Twente.

Boer S.J. de, 1989, Decision Methods and Techniques in Methodical Engineering Design, PhD-thesis, University Twente, ISBN 90-72015-3210

Cross N., Roozenburg N.F.M., 1992, Modelling the Design Process in Engineering and in Architecture, Journal of Engineering Design, vol.3, no.4.

Cross N., 1994, Engineering design methods: strategies for product design, 2nd.ed., John Wiley & Sons, New York

Derelöv M., 2004, On Conceptual Design Reliability, Linköpings University, Thesis No.1121, Licentiak

French M.J., 1992, The Oppertunistic Route and the Role of Design Principles, Research in Engineering Design, Vol.4, No.3

Jones J.C., Design methods, Seeds of human futures, Wiley London, 1970

Kesselring F., Die starke Konstruktion: Gedanken zu einer Gestaltungslehre, Zeitschrift VDI (1942), C.5, p.321

Kesselring F., Technische Kompositionslehre (Study of Technical Composition), Berlin/Heidelberg: Springer-Verlag, 1954

Koolhaas R., AMO OMA, 2004, Content, Taschen, Köln, ISBN 3-8228-3070-4

Kroonenburg H.H. van den, 1978, Methodisch ontwerpen, TU Twente, WB 78/OC-5883, Enschede (dutch)

Mijers J., Pohl J., 1992, ICADS expert design advisor: an aid to reflective thinking, Knowledge Based Systems Vol.5 No.1, March 1992, Butterwurth-Heinemann.

Reyman I.M.M.J., 2001, Improving Design Processes through Structured Reflection: Case Studies, SAI Report 2001/3, Eindhoven, ISSN 1570-0143

Ritchey T., 2002, General Morphological Analysis, A general method for non-quantified modeling, 16th EURO Conference on Operational Analysis, Brussels 1998.

Savanović P, Zeiler W, Trum H.M.G.J., Borsboom W.A.. 'Integral building design methodology in the context of sustainable comfort systems', CIB W096 Architectural Management, Technical university of Eindhoven, July 2006.

Schijndel H.M.van, 2006, Individual Comfort with Thermally Activated Building Systems, MSc thesis Techniche Universiteit Eindhoven, june 2006

Siers F.J. 2004, Methodisch ontwerpen, .Wolthers-Noordhoff, Groningen, Third edition, 2004, ISBN 9001509010.(dutch)

Stevens J.H.W., 1993, Methodical Design and Product Innovation in Practice, International Conference on Engineering Design, ICED'93, The Hague, August 17-19.

Ullman G.D., 2003, The mechanical design process, third edition, McGrawHill, ISBN 0072373385

Verdonschot J.H.A., 2006, Performance of ventilate double facades compared to a single skin façade, MSc thesis Techniche Universiteit Eindhoven, june 2006

Verwer J.J., 2006, The façade: Half of the Building Services, MSc thesis Techniche Universiteit Eindhoven, june 2006

Zeiler W, Savanovic P. Quanjel E.M.C.J., 2006, 'Methodology for dynamic briefing of adaptable buildings' , CIB W096 Architectural Management, CIB-meeting Adaptables '06 dynamic briefing, Technical university of Eindhoven, July 2006.

Zwicky F., The Morphological Method of Analysis and Construction, Courant Anniv. Vol., New York: Wiley-Interscience, 1948

Zwicky F., Wilson A.G. (eds.), 1967, New Methods of Thought and Procedure. Contributions to the Symposium on Methodologies, May 22-24, Pasadena, New York Springer Verlag