

PERMANENT PROFESSIONALS EDUCATION FOR INTEGRAL DESIGN COLLABORATION

P. Savanović and W. Zeiler

Keywords: integral design, c/k design, design workshops

1. Introduction

The estimated costs of failures within Dutch building practice are 5-10% of the annual turnover. Some of these costs, according to various researches, are caused / created during the building design processes. As complexity and scale of design processes of buildings increase, the traditional approaches may no longer suffice (van Aken, 2005). A few encountered aspects are: most important decisions are taken during conceptual phase of design even though not all relevant information is then available and some disciplines are involved too late in the process. Architecture and building services represent disciplines with different positions regarding building design process; architects being involved from the beginning, while building services consultants join the design process usually much later. The main focus of the 'Integral Design' project was to raise awareness of disciplines involved in building design about each other's positions and problems. This integral approach can eventually lead to integral process, team and method – all the required conditions for design of the end product.

Based on above considerations, and in contrast to traditional sequential building design approach, we propose that a building design team should start working on a design task from the very beginning of the preliminary design phase. Such building design team should consist of an architect, a structural engineer, a building physics consultant and a building services consultant. We integrate explicit discipline based 'object design knowledge', knowledge on the characteristics and properties of artefacts and their materials, through implementation of 'process design knowledge' (represented in our case by developing 'ID-methodology') (van Aken 2005). This integral design methodology for building design teams in practice (which consist in our case of the Dutch society of architects (BNA) and Dutch society of consulting engineers (ONRI) members) is implemented in the permanent professional education program of BNA.

2. Structuring principle

'Methodical design' (Van den Kroonenberg 1978) is used as a basis for structured introduction of discipline based object design knowledge. This framework proved its potential within the (mechanical) engineering domain (Blessing, 1994), and makes it possible to explicitly think and act on a specific abstraction level. Methodical design model is problem oriented and distinguishes, based on functional hierarchy, various abstractions and/or complexity levels during different design stages and design phase activities. An important feature of this model is use of morphological overviews, both for the overall description of design stages as for separate design activities. Based on definition of functions, morphological overviews make it possible to assess client's needs on higher abstraction levels than the program of requirements (which is often too detailed) provides. This way interaction with the client is aided, and at the same time the design process is structure.

Using morphological overviews as a tool, others' contributions activate individual interpretation of a designer, based on which he or she can make the decision to also make an explicit contribution (see Figure 1, symbol 0). Since the object of design is used as the reference, this knowledge is further specified as initial object design knowledge (Figure 1, symbol 0). From these contributions new combinations can occur, (symbol 1). 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. The reflection within the integral design method represents potential for the creation of new object design knowledge through the integration of discipline based explicit object design knowledge into integral design concepts (symbol 2). These integral design concepts are not merely a variation or combination of existing solutions but have some completely new element or characteristic not found before, (see the ? symbol in Figure 1).

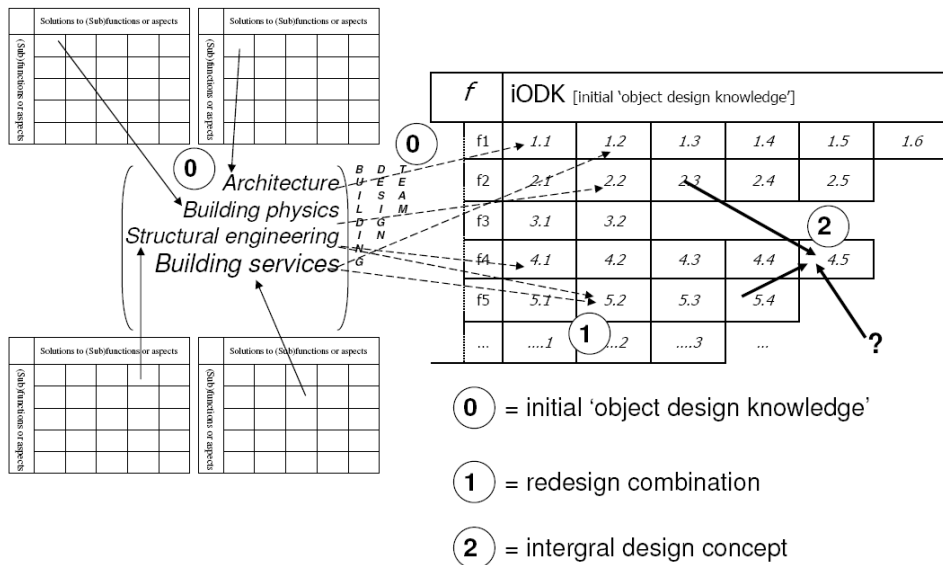


Figure 1. Morphological overviews show the initially available object design knowledge

3. Integral design concepts

The theoretical background on how design knowledge can be transformed into integral design concepts is found in "C-K theory" (Hatchuel and Weil 2003): the C-K stands for concept-knowledge relation. The C-K theory defines design as the interplay between two interdependent spaces having different structures and logics, a process generating co-expansion of two spaces, space of concepts C and space of knowledge K. The structures of these two spaces determine the core propositions of C-K theory (Hatchuel and Weil 2007);

- Knowledge. A piece of knowledge is a proposition with a logical status for the designer or the person receiving the design. Irrespective of the way in which this status is fixed, any form of logic, whether it is "standard" or "non standard", is in principle acceptable for a design theory. A set of knowledge is therefore a set of propositions, all of which have a logical status (Hatchuel and Weil 2002).
- Concept. A concept is a notion or proposition without a logical status: it is impossible to say that a concept, for instance an "oblong living room", is true, false or uncertain. A concept is not "knowledge" (Hatchuel and Weil 2002). Concepts capture the pragmatic notion of "brief" or "broad specifications" that can be found in innovative design.
- Space K. Contains all established (true) propositions (the available knowledge, existing solutions).

- Space C. Contains “concepts” which are unsorted propositions in K (nor true nor false in K) about some partially unknown set of objects called a C-set.

A design concept is a proposition that can not be logically valued in K. Concepts are candidates to be transformed into propositions of K, but are not themselves elements of K (properties of K can however be incorporated into concepts). If a proposition is true in K, it would mean that it already exists and all is known that is needed about it (including its feasibility). Design would then immediately stop. There is no design if there are no concepts. Without the distinction between the expansions of C and K, design disappears or is reduced to mere computation or optimization. The transformations within and between the concept and knowledge spaces are accomplished by the application of four operators, see figure 2 (Hatchuel, Le Masson and Weil, 2004).

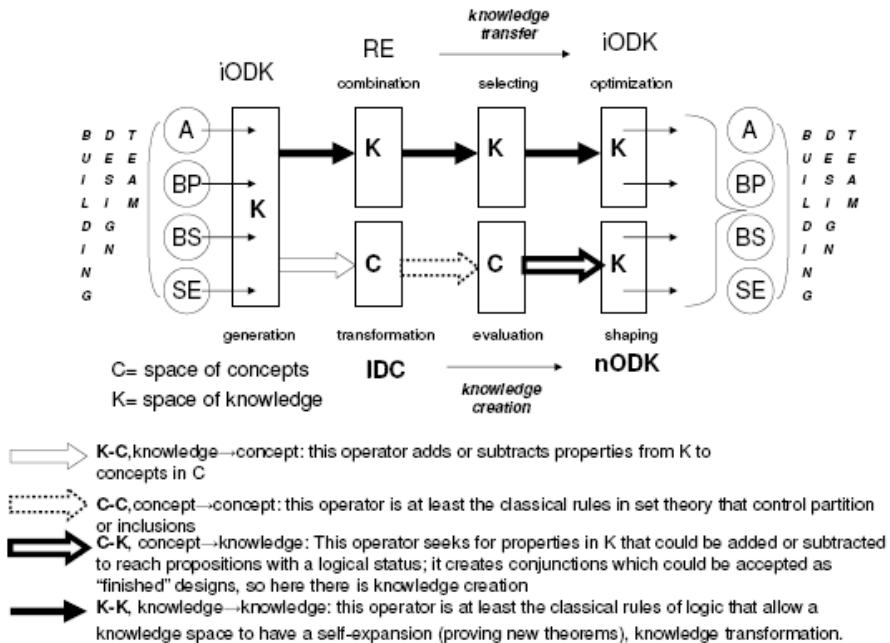


Figure 2. C-K design process scheme

The two operators $C \rightarrow C$ and $K \rightarrow K$ are internal to the concept and knowledge spaces, and are not particularly relevant to the expansion of both. The first two operators cross the Concept-Knowledge domain boundary, and are significant in the sense that they reflect a change the logical status of the propositions under consideration by the designer (from no logical status to true or false, and vice versa). Within the integral approach the space K is defined by the initial design knowledge that participants bring into design team.

Only explicitly presented / communicated object design knowledge within a design team is considered and the focus is on how this explicit object design knowledge is transformed / integrated within a multi-disciplinary design team setting. The relation to the design square of Hatchuel and Weil (2003), which consists of four types of transformations that take place within and between the concept and knowledge spaces, and the integral design process is explained step by step in the following section. Functions are ‘design team subjective’, meaning that all individual proposals must be agreed by others. Interpretation as an ‘extra’ step since (beforehand) objective definition of design criteria isn’t possible, see figure 3. (Sub)solutions are seen as ‘chunks’ of “object design knowledge” (Van Aken,

2005), which is mainly discipline based. Only explicit knowledge is taken into consideration. Morphological overviews show the initially available explicit knowledge within a design team, see figure 6. Making object design knowledge explicit enables designers to use it for the creation of design concepts. What we are curious about is if these concepts are integral (ID) or just plain combinations (RE). It is important to understand that integration of initially presented discipline based design object knowledge is something different than plain combination of sub-results. Combination can only lead to redesign (RE), while concept integration involves transformation of design knowledge. Contrary to redesign, the connections design team (members) make between sub-solutions in order to produce ID-concepts are subjective and design task context dependent.

1 - interpreting & 2 - generating

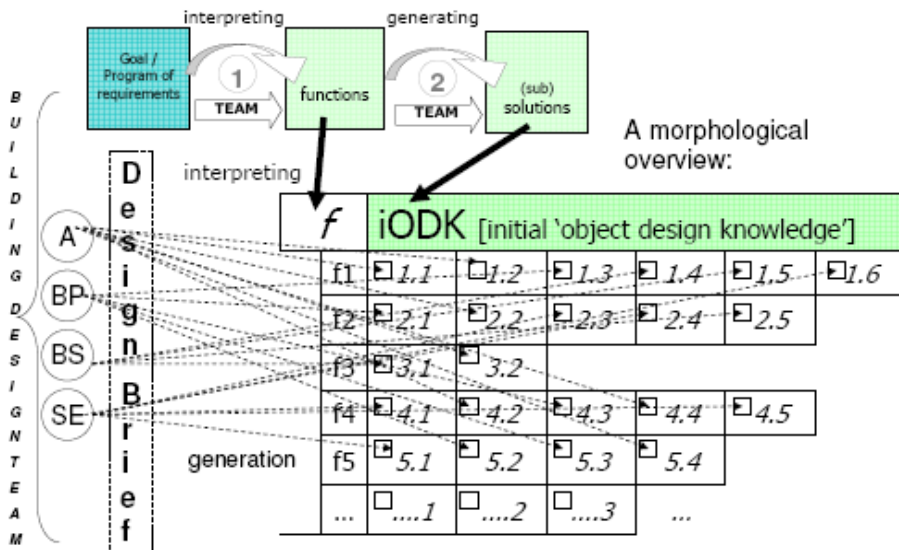


Figure 3. Step 1- interpreting [activities] & Step 2 - generating [activities]

Concepts acquired by only combining (sub) solutions are regarded as redesigns. Although a given combination might take all relevant aspects (defined by design team itself) into account, it doesn't represent an integral solution. See step 3 - combining [activities] in figure 4. Working out specific functions / solutions on a lower abstraction levels, optimize chosen redesigns will gradually lead to detailed solutions (shaping phase). These are again new iODK, only on different abstraction level. Through their transformation / integration ID's and nODK emerges. See step 4 - optimizing [activities] in figure 5.

Concepts acquired through transformation of iODK are regarded as integral concepts. This is a result of so-called designer's 'creative leap', triggered by (aspects of) presented (sub) solutions and their possible connections. [implicit knowledge is regarded as the other catalyst]. The same principle of transformation applies also for other abstraction levels – see figure 3, where initial iODK on lower abstraction level is introduced. See step 3' - transforming [activities] in figure 4. Through evaluation of ID-concepts, new object design knowledge emerges (C-K theory) since iODK is not sufficient for explanation. This nODK represents potential for creation of innovative design solutions. See figure 5 step 4' - evaluating [activities].

3 combining & 3' transforming

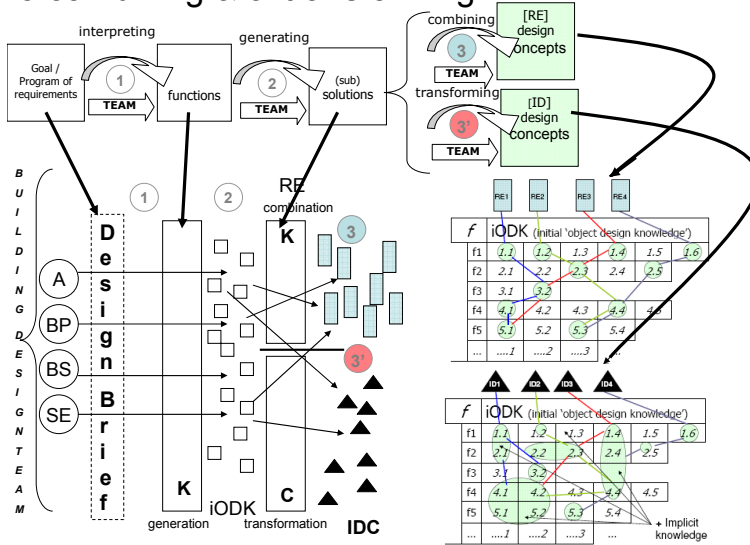


Figure 4. Design process step 3 and 3', combining and transforming activities

4 selecting & 4' evaluation

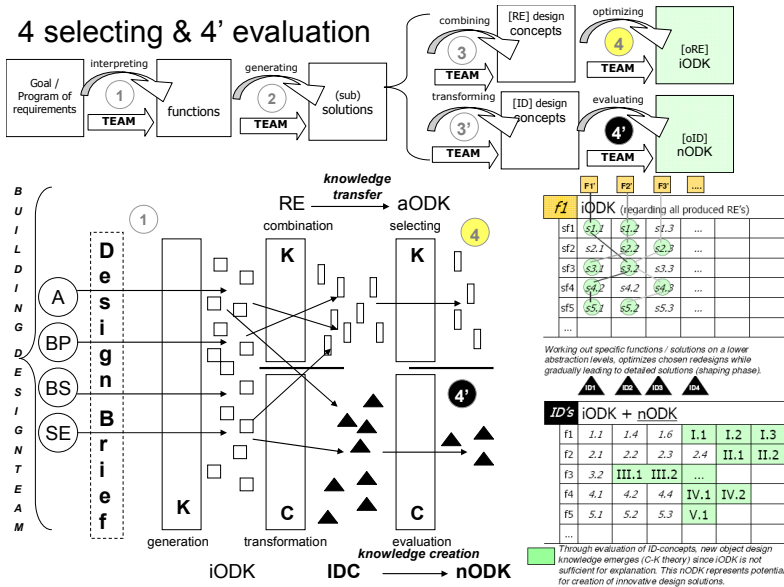


Figure 5. Design process steps 4 and 4', optimizing and evaluating activities

“A concept not being true or false (within space K), the design process aims to transform this concept and will necessarily transform K” (Hatchuel and Weil 2003, p.6). During the processes of generation and integration of concepts, transformation of the within design team existing object design

knowledge into integral design concepts takes place, offering design team members the possibility to acquire new knowledge. However, in order to realize the potential for the creation of new object design knowledge a separate evaluation step is needed (Figure 6); something that does not customary happen in building projects. This is the reason why the extension of methodical design into integral design is important, to make the evaluation step explicit.

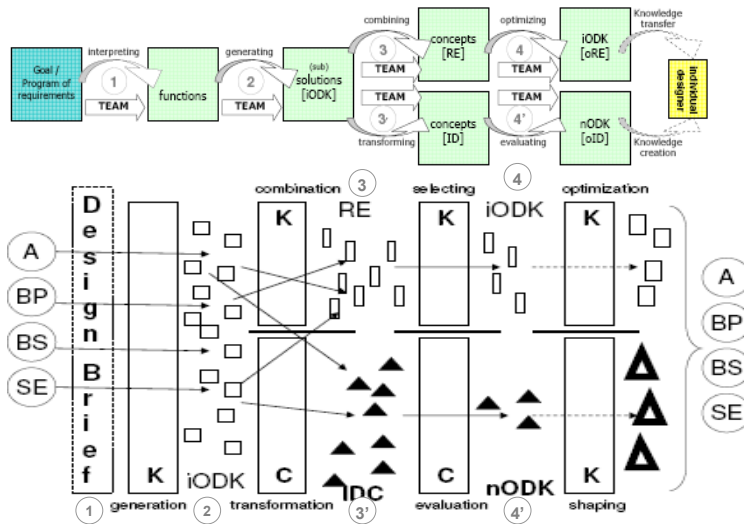


Figure 6. Combination vs. transformation, knowledge transfer vs. knowledge creation

Making object design knowledge explicit enables designers to use it for the creation of design concepts. Integral design concepts (IDC) and plain combinations (RE) are distinguished. It is important to stress that integration of initially presented discipline-based-design-object-knowledge is something different to the plain combination of (sub) solutions. Whereas combination can only lead to redesign (RE), concept integration involves transformation of design knowledge. The actual representations of the discipline-based object design knowledge are considered to be (sub) solutions to a design task, which are proposed in order to define and/or change the object being designed. The (sub) solutions are the result of individual / discipline-based generation activity, and are the answers to the defined functionalities that a design has to fulfil. The focus is on the possibility of expanding the concept space with integral design concepts (Figure 7, ID), in order to produce potential for creation of new object design knowledge (Figure 7, nODK). From a standpoint that a concept not being true or false (within space K), the design process aims to transform this concept and will necessarily transform K (Hatchuel and Weil 2003). At the end of the process of generation and integration of concepts, transformation of existing object design knowledge within the design team into integral design concepts takes place, offering design team members the possibility to acquire new insights.

4. 'Education model'

In order to let designers experience the benefits of 'ID-methodology', a two-day learning-by-doing workshop course was developed. The development of workshop setting was a learning-by-doing process as well. Instead of making a theoretically 'optimal' configuration, workshops are continuously adjusted and improved based on evaluations of participants and analysis of observation results.

In the current configuration stepwise changes to the traditional building design process type are introduced. Starting with the traditional sequential approach during the first two design sessions on day 1, which provide reference values for effectiveness of 'ID-methodology' (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) methodical design model / morphological overviews are applied. The second design setting 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 third setting demonstrates 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. It concerns an individual, rather than collective/team learning cycle, because in order to be able to effectively apply a new approach, one has to first understand it and make it his own (Jones, 1992).

Design team arrangement is the crucial element of the education model. To be able to compare different types of design processes, while at the same time excluding team development aspects (Tuckman, 1965), we do not observe the same design teams during two workshop days, but compare the average results of each design setting. For each setting the arrangement of design teams is changed. However, all design teams are composed out 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 importance; reverse or mixed order is not possible because learning effects would not allow for valid comparison of results (Herzog, 1996).

5. Results

Regarding professionals' education, and in addition to the above mentioned references where immediate participants' evaluations are discussed, we attach great value to the results of so-called 'after evaluations'. All designers who had participated all of the design sessions were approached six months after their workshop participation, 59 out of a total of 89, in order to get their 'second opinion' on the proposed approach, but also to assess the effects 'ID-methodology' has had on their practices. Even though the response was significantly lower than immediately after the workshop sessions (53% (37 participants) compared to more than 90%), it provided important insights into practitioners' impressions of (mainly usability of) 'ID-methodology'.

Working within design teams from the beginning of the preliminary design phase was positively experienced by $\frac{3}{4}$ of participants; with 70% of them even thinking that it lead to the creation of synergy within design teams. The average rating of the workshop course was similar to the average rating directly after the workshops: 7.2 respectively 7.1 on 1-10 scale. The importance of the proposed approach in the last six months of their practices was rated 6.4, the main explanations being that their individual way of working did not radically change, but that the general awareness of others' positions within building design process was increased. For some, the approach was too theoretical and therefore hard to apply in such a short period of time. However, because projects usually last far longer than six months, the majority of participants were not able to (try to) apply the approach during preliminary/conceptual design phases (because of being 'stuck' in ongoing projects). The lack of application in practice resulted in lower ratings regarding relevance of working with morphological overviews: 6.4 compared 7.4.

In case practitioners were in position to experiment with morphological overviews during projects, they found that both type of projects and clients' attitude towards 'integral approach' had to be favorable in order to be able to effectively use them as during workshops. The majority of respondents were however still in favour of stimulating use of morphological overviews and regarded the workshop series as highly important for (BNA-ONRI) professionals' education (average rating of 8.4 out of 10).

6. Conclusion

Crucial point by using experiments, in relationship to the 'theoretical' model of the Methodical Design combined with the C/K theory, is the connection to a 'realistic' model which is part of the design-practice. To use human subjects in laboratory experiments to study design theory provide some insight

(Frey & Dym 2006). However, extending results from laboratory experiment to conclusions for the engineering practice is a risk. Real-world setting requires activities in ways that laboratories can rarely simulate. Schön has proposed another means to test and use methods, a practicum (Schön 1983);“.. a practicum...is really a virtual world in the sense that it represents the world of practice, but is not the world of practice.” In Schön’s practicum an actual person or a team of persons has to carry out the design. A practicum can assess a design method and the degree to which it fits human cognitive and psychological attributes (Frey & Dym 2006). Workshops are a kind of practicum or something very similar and could be used to evaluate design methods.

We have found a suitable workshop formula to scientifically sound assess effectiveness of ‘ID-methodology’, as described in relation to knowledge creation. Besides developing and testing, workshops are also meant to transfer this ‘ID-methodology’ to four main building design disciplines (architecture, building physics, building services and structural engineering), in a ‘learning-by-doing’ way. Maybe the best proof for this is the fact that the workshops have become a part of the permanent professional education programme of the Royal society of Dutch Architects (BNA).

Acknowledgement

Knowledge Centre for Building and Systems (TNO-TU/e), Kropman bv and the foundation “Stichting Promotie Installatietechniek (PIT)” support research on ‘Integral design’.

References

- Aken , J. E. van,2005, *Valid knowledge for the professional design of large and complex design processes. Design Studies*, 26, 379-404.
- Blessing, L. T. M. ,1994, *A process-based approach to computer-supported engineering design. Enschede, Universiteit Twente.*
- Boden, M. A. ,1990, *The creative mind: myths & mechanisms, London, Weidenfeld and Nicolson.*
- Frey D.D., Dym C.L., 2006, *Validation of design methods: lessons from medicine, Research in Engineering Design 17:45-57*
- HatchuelL, A. & Weil, B.,2003, *A new approach of innovative design: an introduction to C-K theory. 14th International Conference on Engineering Design. Stockholm.*
- Herzog, T. ,1996, *Research methods in the social sciences, New York, HarperCollins Publishers.*
- Jones, J. C. , 1992, *Design methods, New York, Van Nostrand Reinhold.*
- Kroonenberg , H. H van ,1978, *Methodisch ontwerpen, Enschede, the Netherlands, TU Twente (dutch).*
- Roozenburg, N. F. M. & Eekels S, J. ,1994, *Product design : fundamentals and methods, Chichester, Wiley.*
- Tuckman, B. W. ,1965, *Developmental sequences in small groups. Psychological Bulletin, 63, 384-399.*

Prof.ir. W. Zeiler
Professor Building Services
Technische Universiteit Eindhoven
Department Architecture, Building and Planning
Vertigo 6.28
Den Dolech 2
5600 MB Eindhoven
Netherlands
Tel.:00312473714
Email: w.zeiler@bwk.tue.nl
URL: <http://www.tue.nl>