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Behavioural-, communicative- and collaborative aspects of tools for architects and structural engineers, a review

Abstract

This paper presents the analyses of twelve interviews with structural engineers and architects integrated with a comprehensive literature review about the behaviour of architects and structural engineers when communicating and collaborating in the early phase of the design process. The focus is on *creating a tool* to deal with behavioural, communicative and collaborative problems of the actors involved when collaborating to design folding spatial structures.

After describing the types of tools architects and structural engineers use to communicate and collaborate, the *controversies* [Yaneva, 2012] between architects and structural engineers while designing spatial structures are structuring this paper. As the building industry currently can produce buildings as one-off's, 'prototypes' or 'products' in an industrial way, continuously or on demand, research into the use of 'instruments' in product design for the building industry, as described by for instance Smit, Lichtenberg and Oostra [2001], is analysed and integrated.

When the professional worlds of structural engineers and architects merge, as discussed by Bucciarelli and Schön [2007], problems in the design process, concerning the actors and the tools they use, are derived.
By analysing and interpreting various aspects of communication and collaboration in the interviews and literature, the relationship between behaviour of the actors involved and the design process is developed. Within that framework the use of prototypes, models and other tools in relation to communication and collaboration between the actors is analysed. This enables to *create tools* to design folding spatial structures taking into account behavioural-, communicative- and collaborative aspects during the early phase of the design process.

Keywords: Behaviour, communication, collaboration, tools, architects, engineers, design.

1. Introduction

1.1. Types of tools and definition

The amount of tools available for architects and engineers is enormous. But in the early design phase, derived from different sources [Heylighen & Neuckermans, 2000; Runberger, 2008; Elsen & Heylighen, 2014], mainly four types are used by architects and engineers: (1) Hand- and CAD drawings, for example the sketches of Frank Gehry as basis for three dimensional models; (2) models and prototypes, such as the box with different types of facade elements developed by Jo Coenen for the Vaillantlaan in Den Haag (Figure 1.); (3) rules of thumb, as for example described in Tony Hunts Structures Notebook; (4) and cases, as for instance incorporated in the Kinetic Design Matrix, developed by Michael Fox, describing realised dynamic and adaptable buildings and prototypes.

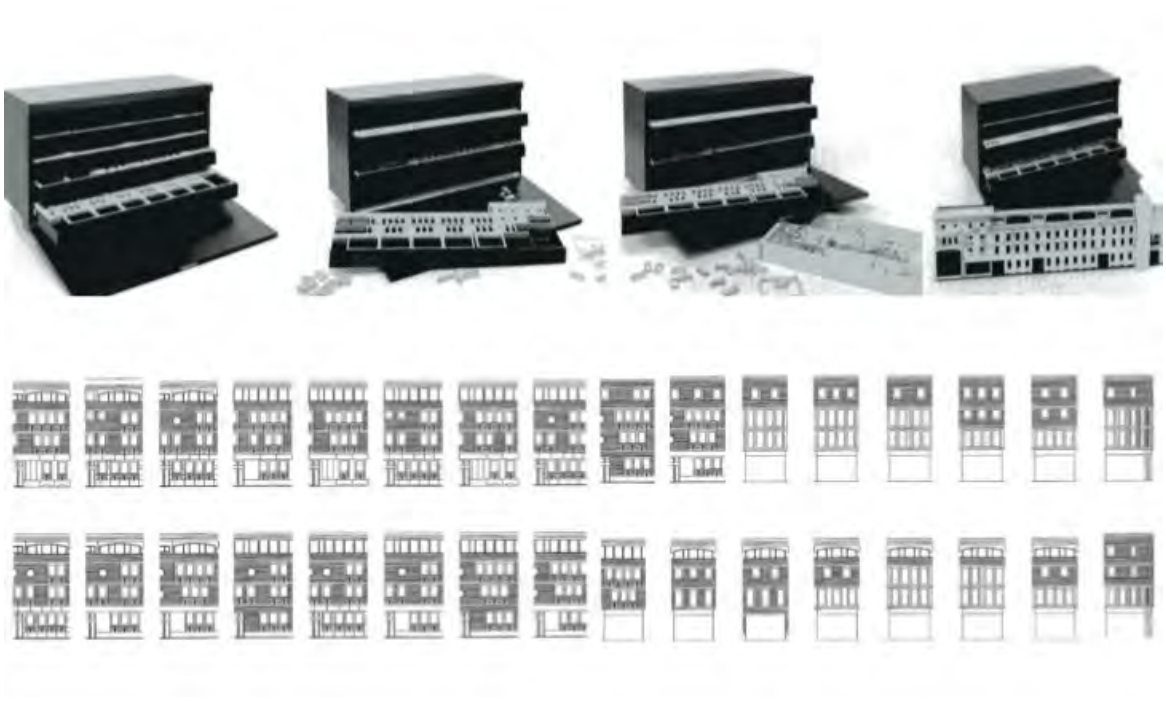

Fig. 1. Toolbox with different facade elements for the Vaillantlaan, Den Haag, by Jo Coenen.

Derived from the work of Runberger tools in this paper are defined as artefacts or strategies to communicate and collaborate with other actors in the design process. For example working models, scenario's or prototypes to feed a learning organisation, or for instance collaborating architects and structural engineers. Adjustable and re-finable objects or platforms of continues investigation and reflection. Tools can transgress borders between disciplines, can act as a protocol for communication, or be an incentive for collaboration. The tools operate in different media, ranging from physical and digital models through drawings and diagrams to operational installations [Runberger, 2005; Runberger, 2008].

1.2. Context and problem definition

1.2.1. Process aspects
As the building industry currently can produce buildings as one-off's, 'prototypes' or 'products' in an industrial way, continuously or on demand, a review of research into the use of these 'instruments' in product design for the building industry is used as context for this paper.

In the work of for example Eekhout, Smit, Lichtenberg, Hamel and Oostra process tools are developed to deal with the problems in the design process of product design in the building industry. These process tools focus on how to organize a design process well and how to deal with splitting of tasks; how to delete barriers of design culture between different disciplines in the design team, and how to organize information in time during the process; and how to deal with risks, time management and different interests of the design actors involved [Oostra, 2001].
It shows that next to problems in the design process not caused by humans there are humanly caused problems, or as Cross writes: "Few engineers and composers "..." can carry on a mutually rewarding conversation about the content of each other 's professional work. What I am suggesting is that they can carry on such a conversation about design, "...", and can begin to share their experiences of the creative, professional design process" [Cross, 2001].

1.2.2. Dynamic aspects
Next to the design process a focus in this paper is on dynamic aspects of architecture. This ranges from accommodating and adaptive architecture, to (continuously) dynamic architecture [Da Conceição van Nieuwenhuizen, 2016].
In current practice these aspects are often ignored, but in the text: Give me a Gun and I make buildings move [Yaneva & Latour, 2008] described as follows:

"Everybody knows—and especially architects, of course—that a building is not a static object but a moving project, and that even once it is has been built, it ages, it is transformed by its users, modified by all of what happens inside and outside, and that it will pass or be renovated, adulterated and transformed beyond recognition."

"We should finally be able to picture a building as a navigation through a controversial data scape: "…" That is, we should finally be able to picture a building as a moving modulator regulating different intensities of engagement, redirecting users' attention, mixing and putting people together, concentrating flows of actors and distributing them so as to compose a productive force in time-space."

Within this context the literature review combined with the interviews sheds light on what problems occur in collaboration and communication between structural engineers and architects. From the language and behavioural aspects a framework is constructed to create a tool to enhance communication and collaboration in the early phase of the design process.

2. Used methods of research

Schön informs us that in architecture and structural engineering drawing and talking are parallel ways of designing and together make up what he calls the 'language of designing' [Yaneva, 2011]. However the interviews in this research are not just answering a set of questions, but a dialogue in search for in depth information. Interviewing and writing can be part of a design process and design research. The usefulness of interviews as technique for design research is described by Heylighen [Heylighen & Neuckermans, 2002] amongst others.

Semi structured interviews with open explorative questions where conducted with experienced Dutch architects and structural engineers to obtain in depth information directly from actors working in the field. The population was selected upon two criteria: First, being an architect or structural engineering working for many years in the building industry. Second, most likely to be able to answer in depth about behaviour, communication and collaboration with other architects or engineers. Thirty-six interview questions where used as guide line to interview twelve respondents.

The qualitative analyses of these interviews is interwoven with the literature review and forms the backbone of this paper.

3. Interviews with experienced architects and structural engineers from the Netherlands

3.1. Character / Attitude / Behaviour

3.1.1. Differences in character between architects and engineers
Yaneva published papers and other publications about her research into social and cognitive aspects of architecture processes with respect to what she calls the Mapping controversies method (Figure 2.). This method was initially developed by the French sociologist Bruno Latour and applied across a variety of disciplines. "It offers new opportunities for enquiry in social sciences based on Actor-Network Theory, which consists in following, documenting and mapping ongoing controversies" [Yaneva & Heaphy, 2012]. As mapping is a technique already widely used in architecture this method offers possibilities to ground a tool upon.

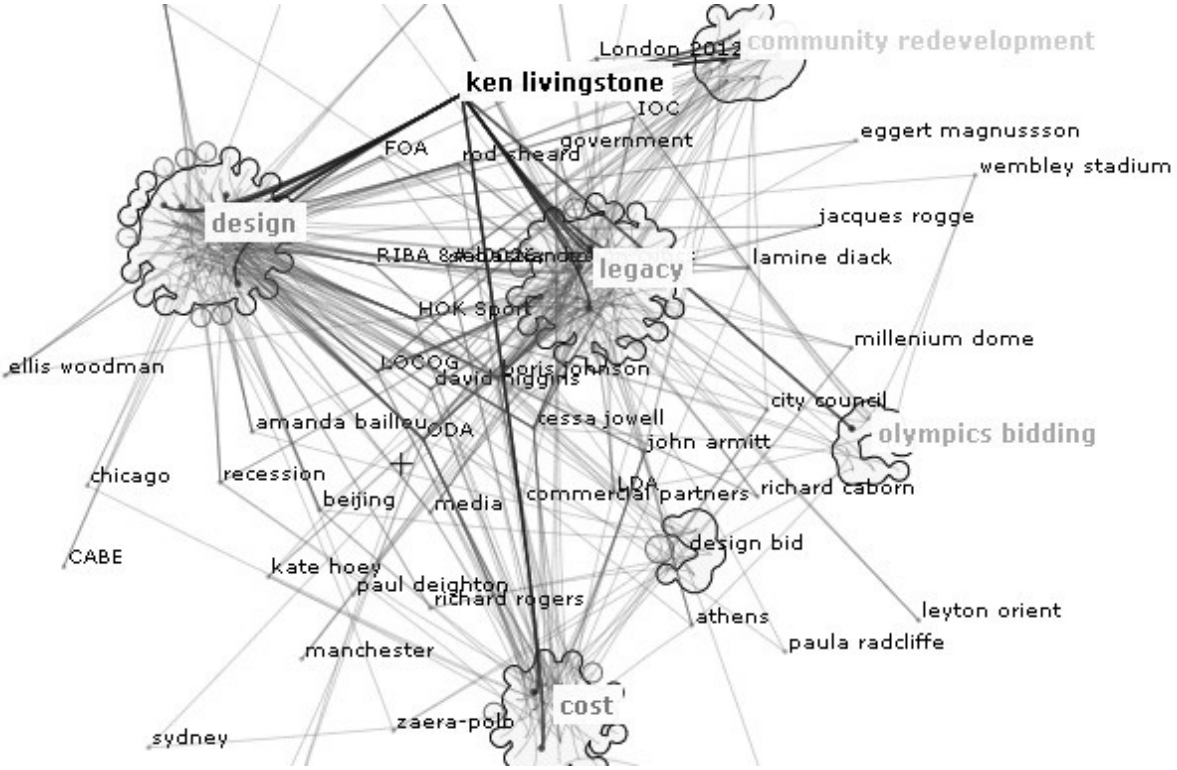

Fig. 2. Example of mapping controversies by Yaneva, London Olympics Stadium.

Many controversies are acknowledged by the interviewed, they are important factors influencing the design process. For instance according to interviewed architect TO the structural engineer more often has the role of problem solver while the role of the architect is of more about interpretation of the context, to create design solutions and manage the process. The interviewed architect MH declares: "I think structural engineers many times are solving problems instead of analysing problems. I think a structural engineers should also analyse problems." Runberger states: "Important obstacles in successful collaboration are the different agendas, premises and capacities of collaborating parties" [Runberger, 2008].

Further interviewed structural engineers as well as architects point out the architect works on clearing out the actual question of the principal, while engineers work on a structural solution as answer to the proposed solution of the architect. Architects like to be surprised by structural possibilities, structural engineers want to know the objectives of the architect.

In the Mapping controversies method [Yaneva, 2012] mapping is the tool, or as Yaneva puts it: "The cartography of controversies is conceived as a toolkit to cope with the different hybridisations of actors and knowledge, as an effort to follow disputes when they cut across disciplinary boundaries.
The word “controversy "…" does not mean that there is a fierce dispute nor that it has been politicised; we use it as a general term to describe shared uncertainty. Follow the actors in a controversy, how they agree and disagree, how they shape alliances, how they scale and rescale the spaces where they move and create spatial disjunctions. Here is where you find the social" [Yaneva, 2011].

3.1.2. Education
According to almost all of the twelve engineers and architects interviewed the difference in attitude and behaviour of architects and structural engineers has an important cause in education (next to personality, market circumstances, and culture of a building industry in a certain country). Because of this ‘learned attitude’ they experience that colleagues are not always open to learn from new insights. For instance in order to grow their knowledge and skills, to be able to design creatively and with intuition.
The interviewed further state that often structural engineers and architects in education are completely separated; that in civil engineering reality is put into models and often one separated problem is worked out; while architects integrate problems from many fields into the design and base design on the use of the building.
Structural engineer WI: "Structural engineers in the Netherlands are trained to make calculations." Architects on the other hand, the interviewed state, are not properly trained in realising projects and in the properties of materials. A few of the interviewed mention literally that they think Dutch education currently is enhancing the difference in character of the structural engineers versus the architects.

3.2. Process / Collaboration / Communication

3.2.1. Process
Both architects and engineers state the architect first has to come with a conceptual idea, and then the engineer acts. But this is challenged by other interviewed who give examples of assignments where structural knowledge and other technical knowledge is leading, for instance when designing an underground metro station. Many interviewed state the design process goes from object and context, to structural and spatial system, to elements and then to details and back again in loops. Both actors must be able to switch between all scales back and forward during the design process. This corresponds with the statements and findings published by Yaneva & Latour [2008].

3.2.2. Role and position
Structural engineers are searching for a more level playing field with architects (structural engineers WI and FV state that literally). They mean their role, task and position in the design process in The Netherlands is often more serving the architect than collaborating on the same level. Architects however are concerned with their position in the building process becoming weaker and smaller. Architects are concerned with creating proper conditions to make architecture through the process, structural engineers do not consider that. Architects tend to try to direct the process, while engineers try to fulfil their tasks. This mirrors the research of Smit [2008] and Oostra [2001].

Smit created a Cyclical Iterative Design Process (Figure 3.) to accommodate the design process of components and products in which, as he describes it: "An architect can acquire knowledge and experience efficiently from comparable design projects and use them in current and future projects without sacrificing creativity." Learning from feedback, learning from experience. This is relevant to architectural design as the building industry currently can produce buildings as one-off's, 'prototypes' or 'products' in an industrial way, continuously or on demand.

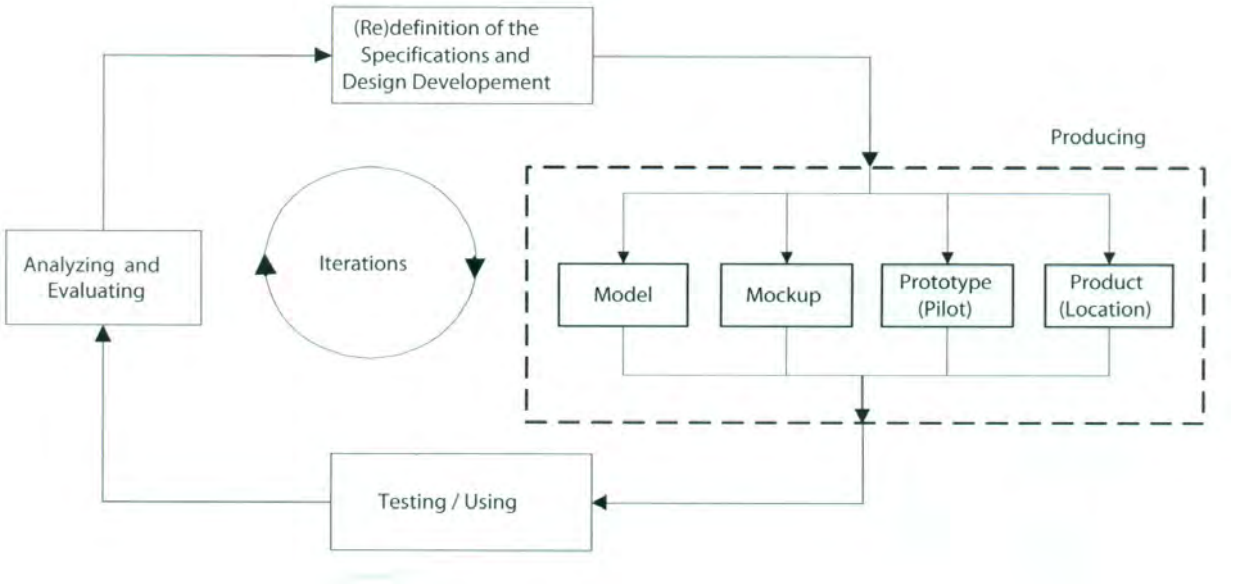

Fig. 3. The Cyclical Iterative Design Process by Smit.

3.2.3. Process conditions, organisation
Contracts for only a part of a project or with limited budget are seen by the interviewed as problematic for collaboration in the process. Often this causes the splitting of tasks in the process. The impact on communication and collaboration is negative as it implies more and different people with different characters, roles, tasks and interests.

3.3. Language and digital design tools

3.3.1. Language
From the interviews can be derived that for architects and engineers the same words have a different meaning. Architect MC thinks the problem is even more complex: "No they do not speak the same language, definitely not, and less more and more."
Other remarks in the interviews support this. For architects the context is urban planning, the location and orientation. For structural engineers the context is the type of soil on the site, surrounding existing buildings, accessibility of the building site en what building systems are available in the market for the project.
This corresponds with Bucciarelli & Schön [2007] where Bucciarelli states: "It seems that in engineering design we talk in a harder technical dialect." And Schön states: "Think of the interaction of an architect, a constructor, a structural engineer and a user in the design of a building. Each brings to their roles different bodies of language, knowledge and interests."

This also shows the influence of education. Architects MA and MI and structural engineer FV state that architects occupy themselves with space, engineers with matter. Another example: According to the structural engineers the hinges and secondary the stability are the most important aspects of

folding architecture, and therefore for a tool. Architects however wonder more about wider topics, such as climate, spatial effects, and eventually the stability, but not the hinges.

Some of the interviewed state the toolbox of the architect and of the engineer must have the same tools, or at least partly. Although described differently, architects and structural engineers create zones, zones for structure and for the use of space. A tool can become a common ground, a common language and that as basis for communication and collaboration.

3.3.2. Digital design tools
When working in BIM often the model of the architect is not the model of the structural engineer. Some interviewed also state BIM is creating a bigger gap between the actors as they work in different worlds in their own language. The fact that some of the interviewed think BIM could be a tool suited for collaboration therefore is strange. According to Runberger BIM is more about optimization of processes and logistics than to promote architectural innovation; secondly about time compression and control of mishaps and mistakes in the process; thirdly BIM communicates in between the models and is more a process control tool [Runberger, 2008]. BIM seems to create more distance then communicating by drawings, which is more distant than communicating in person. This seems adverse to what a tool should do, enhancing the communication and collaboration between the two actors when designing.

Parametric design seems to be more promising as it works with a set of parameters that are not fixed, but dynamic. If both actors can ‘play’ with these parameters this can connect both worlds. As Yaneva states: "This experiment with parametric modelling "..." also shows the potential of architectural tools to map human and non-human relationships, to follow multifactorial dynamics and time-track the trajectory of issues" [Yaneva & Heaphy, 2012].

4. Conclusion

As well in the work of Runberger, as in the work of Oostra, Smit and Eekhout the behavioural, communicative and collaborative aspects between architects and engineers, including their controversies, ‘disappear’ into process models and need further research. A multi layered tool should motivate, activate and inspire architects as well as structural engineers to ‘map their controversies’. Based on the findings in literature and the analysis of the interviews, a framework to create tools to design folding spatial structures should consist out of the following layers:

4.1. The first informative layer

It is striking how little examples come to mind of the interviewed architects and structural engineers concerning dynamic or folding architecture. The first layer of the tool therefore should be an informative one. Not only about folding projects, but also creating a language which can become a common language for both the architect and engineer. It categorizes folding architecture and shows who designed it and who engineered it. This is supported by research into case based learning, which starts from the premise that designers learn designing by experience. This can be split in learning from projects of others and projects of one’s own [Heylighen & Neuckermans, 2002]. This first layer can be a website or a matrix full of information.

4.2. The second educational layer

The second part of the tool can be educational. To change the way architects and structural engineers think addressing behaviour, communication and collaboration during the process of designing (in this case) foldable spatial structures.
The tool has to bridge two different cultures and help to delete the lack of knowledge from each other’ s field by inspiring and motivating the actors. Under the interviewed there is a big difference

in character, function and how they use tools. Therefore the tool should be designed from the perspective how one can design together using the tool and not how two actors must do that. The result can be a module, elective or online course structural engineers and architects can enlist for.

4.3. The third activating layer

The activating part of the tool is not a digital BIM extension, as the tool should not be two distant people staring at two screens. They should be acting – and reacting to each other, creating a social process towards a solution. Like working on a common model, a cooperative act by humans. Like playing with ‘a mecano of folding space'. Working with the same toolbox from layer 1, and if necessary educated by layer 2, the architect and engineer encounter in mapping their controversies. This process is not about objects, but about behaviour, communication and collaboration, a learning process. Or as Yaneva says: "W□e do not simply learn what design is; rather we learn about what design does." This third part can be a box full with possible concepts for folding spatial structures. Encouraging a discussion about the controversies that occur between the architect and the structural engineer to mutually find solutions.

5. Discussion and future outlook

A limitation to the interviews is they where only conducted with Dutch architects and structural engineers. On one hand this limitation seems to neglect cultural, juridical and other aspects. However, as the tool is still under development and the stance for developing the tool is not this is how you must do it, but based on research, this is how you can do it, this can not be a huge problem.

Future research will involve International Master students, starting practitioners and experienced practitioners to further develop the three layers through different actions. This in order to develop a design tool for architects and structural engineers they can use when designing folding spatial structures.

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