Aalborg University

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Informing the Design Process

A Study of Architects' Approach to Environmental Architecture

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Informing the Design Process: A study of Architects' Approach to Environmental Architecture.

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SUMMARY - DK

Denne ph.d. tager udgangspunkt diskussioner om hvordan opgaven med at designe bæredygtig arkitektur i dag. Gennem kvalitative interviews med otte kontorer involveret i de tidlige konceptuelle faser af designprocessen; et casestudie af et design projekt på en dansk tegnestue, samt et casestudie af, hvordan studerendes tilgang til designprocessen på Arkitektur & Design, Aalborg Universitet er, udforskes dette emne. Gennem disse studier undersøges spørgsmålet om, hvorvidt og hvordan viden om de erfaringer, arkitekterne har, kan bruges til at udvikle designprocessen i en retning hvor den bliver mere fokuseret på at analysere hvordan arkitekturen kan blive bæredygtig. Derudover undersøger den om og hvordan anvendelsen af digitale værktøjer kan bidrage til at arbejde med bæredygtige parametre i design processen

Det ses, at fokus på, hvordan vi griber spørgsmålet om bæredygtighed an i designprocessen er vigtigt. Forskningen viser, at brugen af erfaringer i designprocessen er vigtig for at identificere parametre i arkitekturen, der har indflydelse på bæredygtigheden, samt at arbejde aktivt med disse i designprocessen. Desuden kræver det eksplicitte fokus på, hvordan disse erfaringer kan bruges både i det givne projekt, samt hvordan de kan videreføres til andre projekter. Dette gælder ikke kun arkitekterne men også resten af designteamet. Dette kan være med til at drive designprocessen fremad, samt en fælles forståelse for problematikkerne, der kan være med til at fremme kommunikationen i design processen og gennem dette arbejde med bæredygtigheden. Dermed bliver det også støtte for design teamet tidligt i processen til at træffe informerede beslutninger fra starten af.

Derudover ses det, at det tidligt i designprocessen er begrænset hvilken rolle brugen af digitale værktøjer spiller. Dette gælder både brugen af digitale værktøjer til at løse små specifikke opgaver i forbindelse med bæredygtighed, men også større programmer, så som "Building Information Modeling". Ved de studerende ses det derimod at brugen af specialiserede digitale værktøjer kan være med til at udforske problemstillinger i forbindelse med bæredygtighed og gennem det informere design processen. Dog kan anvendelsen af disse digitale værktøjer ikke erstatte den grundlæggende viden, da det er vigtigt at stille spørgsmål til resultaterne for at anvende dem i design processen og kommunikerer hvad det er der er gjort.

Ud fra denne forskning ses det at en bevidst anvendelse af de erfaringer man allerede har, samt evnen til at udvikle disse erfaringer til et niveau hvor de bliver operationelle i designprocessen er vigtigt for at blive bedre til at arbejde med bæredygtighed i arkitekturen. Fokus på digitale værktøjer alene hjælper ikke, da det er vigtigt at vide hvad det er disse værktøjer skal være med til at svare på, samt hvad disse informationer så kan bruges til i designprocessen. Dog kan de hvis de bruges kritisk, bruges til at udforske hvilke muligheder der er i et givent projekt gennem en mere systematisk tilgang. Dette kan så være med til at informere design processen og vise hvordan forskellige løsninger påvirker bæredygtige parametre i projektet og på den baggrund kan der træffes mere informerede valg. På den måde kan sådanne værktøjer i kombination med en bevidst og fokuseret anvendelse af erfaringer være med til at drive designprocessen fremad.

SUMMARY - UK

Present PhD takes its point of departure in the contemporary discussions about how to approach the task of designing environmental architecture. Through eight qualitative interviews with professionals involved in the early conceptual stages of the design process; a case study of a design project in an office and a case study of how students approach the design process at Architecture & Design, Aalborg University, this topic is explored. It aims at addressing the question of if and how the knowledge about the experiences architects have, can be used to develop a focused analytical approach to addressing environmental concerns in the design process. And furthermore if and how digital tools and applications can help to support that development in the design process.

From the research it is seen that focusing on how we address the environmental concerns in the design process is of utmost importance. The research shows that the use of the previous experiences in the design process to address and identify key parameters is the driver at the moment. Furthermore it is the explicit focus on how these experiences can be used both in the given project that is important. It is seen that it is the experiences of the entire collaborative team that is important both as drivers for the environmental concern but also as the basis for the communication about how they address the environmental concerns. Thus helping the design team to take informed decisions during the early stages of the design process.

The research also shows that at these early stages of the design process the use of digital tools and applications plays a very limited role. This is whether it is regarding the small digital tools and applications that can be used to address specific issues or it is a collaborative platform like Building Information Modeling. The research in connection with the students shows that the use of the specialized tools and applications can be used to explore environmental concerns from the beginning of the design process. However these tools and applications do not substitute the experiences or knowledge, but can help to drive the design process and explore specific issues. It still requires a critical questioning of what it is that is done.

From the research it can be concluded that the awareness of the experiences one already have and the ability to develop these experiences into operational knowledge is a key to addressing the work with environmental concerns in the design process. The focus on digital tools and applications does not alone allow for the analytical approach, because they do not tell what to analyze or address at any stages of the design process. Neither do they guarantee a collaborative approach. However they can, if used critically, help to support the design process and explore different issues in the design process. This can help to inform the decisions the design team takes, thus elaborating on the experiences the design team have and through that help to drive the process forward and explore the different issues derived from the previous experiences.

PREFACE

I am now sitting here in my office. The space I have spent the last three years in. An office in a heritage listed building, which, with some kind of irony, means that I have been writing about how to design buildings with a comfortable indoor environment using as little energy as possible, in an office where the temperature shifts between cold and draughty during the winter and hot during the summer. I do, however, appreciate the feeling of the sun shining in through the window with its promise of heat and energy especially during the cold winter months where I'm reminded of its light and heat. It is the work with the design of the spaces we inhabit that interests me, as well as how this is done in a way that responds to the needs we have as inhabitants and the demands the society sets out. Much of the contemporary discussion is focused on reducing our environmental impact. It is the question of how we as architects, engineers or design teams address these complex issues during the design process as we strive to create a comfortable environment to inhabit that interests me.

Being engaged in the discussion about the design of architecture with a high environmental performance also means being engaged in the discussion about the notion "Integrated Design". This is often discussed as a prerequisite for the work with addressing environmental issues in architecture. In connection with this we have seen a variety of descriptions of "Integrated Design" as for example IEA task 23 and "Integrated Energy Design" (Löhnert et al. 2003; Synnefa et al. 2008). However these are overall descriptions of a process, and discussing environmental architecture in general tends to be focused on the result of the design and not how it was achieved.

This is where the present thesis makes its point of departure: In the experiences architects have with the design of environmental architecture and how they approach the design of it. It studies how architects work with the design of environmental architecture and what their experiences are. Furthermore it discusses how the use of digital tools and applications seen in experimental approaches to architecture, as well as the simple ways digital tools and applications used by students, can be used to inform the design process.

The thesis presented here is based on a series of papers published throughout the past three years and should be understood as a paper based PhD, even though parts of the discussion, in part two, elaborate on the findings published in the papers and articles.

Outlined in figure 0.0.1 is the structure of the present thesis, which overall is based on two parts, where the first part is used to describe and define the framework for the PhD through theoretical and methodological considerations seen in chapters two and three, and the second part is build up around the papers and articles published throughout the PhD and frames them in a more overall discussion, as it is seen in chapters four to six, while chapter seven summarizes the contributions and discusses possible future research that could take off in some of the questions present PhD raises through its contributions, thus concluding the PhD. In the following paragraphs the chapters will be described briefly. At the end there are the appendices with articles and papers as well as interview guides and other things that have been used in the research.

Chapter one is an introduction to the PhD describing the background and motivation for the research conducted and introducing the different topics of interest here, as well as the initial research question that present PhD thesis revolves around.

1. INTRODUCTION

| Motivation | Research background | Overall research question | Research aim |

PART 1
2. STATE-OF-THE-ART

Design process, strategy, cognition → Sub-question 1   Digital tools and applications in a collaborative process → Sub-question 2 Sub-question 3

3. RESEARCH DESIGN

| Theory of science | Answering the questions | Research methods | Ensuring quality and validity | Research process |

PART 2
4. EXPERIENCES FROM THE DESIGN PROCESS IN PRACTICE

From brief to design development in practice   Digital experiences from the practicing professionals

5. DIGITAL APPLICATIONS AND TOOLS IN THE EDUCATIONAL PROCESS

Questions, tools and applications in the educational design process

6. CHALLENGING THE DESIGN PROCESS

Moving between practice and studio   Digital approaches in a practical context

7. CONTRIBUTIONS

Outcome of research   Future research

APPENDIXES

| Appendix 1 Publication list | Appendix 1 Interview guide | Appendix 2-8 Paper collection |

Discussion
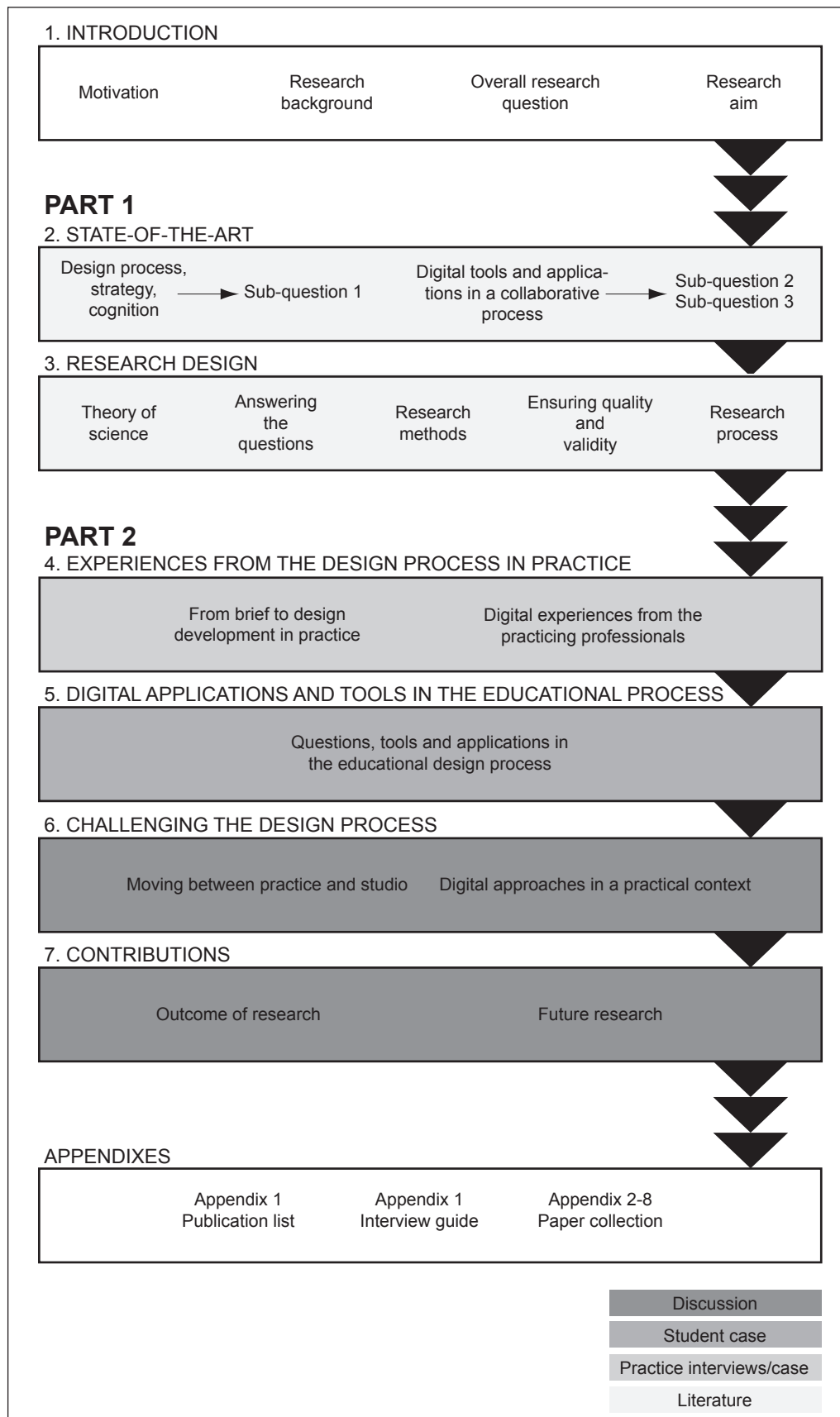Student case
Practice interviews/case
Literature

Figure 0.0.1 - Structure of the PhD with the chapters, sections and how they thematically fits in the framework

Chapter two describes the state-of-the-art that is the point of departure for the present research. Here the focus is on "Design process, strategies and cognition" and "Digital tools and applications in a collaborative process". Both of these are introduced through a literary review where they are explored in order to create a theoretical basis for the further research.

Chapter three deals with the research design and methods that are the basis for dealing with the research questions derived in chapter two. It deals with defining the guideline for gathering data and evidence in the research and elaborates on the considerations that have been a part of conducting the present research.

In Chapter four we enter into the discussion of the data and the analysis and findings in them (Petersen 2011). In this first chapter of the second part that encompasses the explanatory part of the research, the focus is on discussing the architects' experiences with the design process. It consists of the data collected through interviews with eight offices and a single case-study of the design process in practice, which is related to research question one and two. The chapter is discussing this in a more encompassing perspective, which is the result of the continuous work and studies that have been conducted since the publication of the papers. Therefore it should not be seen as a summary or conclusion of these papers, but as an elaboration of the analysis and findings in the papers. The papers being the point of departure in chapter four are in chronology from the last part of the research, however they form the main body of the research and are the core of the discussion.

Chapter five is, though chronologically conducted before the work in relation to chapter four, based on the single case-study of how students at Architecture & Design (A&D) approach the design process, as well as studies of digital tools and applications in architecture both through a literary review and through a little experiment that explores part of the subject. This chapter is encompassing the explorative part of the research. The chapter is based on expanding the analysis of the three papers and elaborating on the findings, which is connected to research question three. These three papers were written early in the research process when the focus was on a more digital approach and is in the discussion here discussed in connection with the findings in the papers of chapter four.

Chapter six is, though being part of the analysis and findings, not based on papers as the previous two chapters, but is instead an overall discussion of the main research question. It treats this overall question through discussing the findings in chapter four and five, and how these findings actually address the overall research question, thus aiming at converging the answers from the three sub-questions to address the overall research question.

As mentioned in the introduction to this section the chapter seven is elaborating on the contribution the research makes and discusses the importance of the research. Furthermore it discusses what this research could point towards in terms of future research and through that forms the concluding chapter of the PhD.

The last part of the PhD consists of the appendices with interview guides and the publications that form the basis for chapter four and five.

ACKNOWLEDGEMENTS

CONTENTS

1. INTRODUCTION

The present PhD thesis has taken its point of departure in the contemporary discussions about sustainability in architecture in a Danish context and how this is addressed throughout the design process we encounter in practice. As an example of today's discussion, we see this in relation to assessment schemes like LEED and BREEAM that have been around since the beginning of the nineties, or the focus on concepts like the German Passive house (BREEAM 2009; LEED 2009; Passivhaus Institute 2007). All of which are serving as a way to check if a building lives up to different criteria related to sustainable issues. However, these schemes do not address the issues during the design process, but are designed as after the fact checklists. In these schemes the focus is on checking and assessing different parameters connected to environmental issues in architecture such as materials, site transportation, indoor environment etc., however more interesting in the Danish context, is the focus such schemes have on energy consumption. This is of interest because the Danish discussions, seen in policy making and the professional bodies, primarily revolves around the energy consumption as it is seen in the building regulations, but also because the discussion about energy is closely related to the current omnipresent discussions about climate change and CO2 emissions from energy production (Erhvervs- og byggestyrelsen 2011). However, the mentioning of these assessment schemes is not because they are the focus of present thesis, but because they serve as examples of how sustainable issues are assessed today. My question, though, is how the increased focus, specifically on the buildings energy consumption is, and can be, handled in the design process and how the environmental issues that are exemplified in mentioning these schemes are addressed in the design process and can help to inform it – a design process where communication between the professions involved and the sharing of information and knowledge is important, as well as how this is used and informs the design process in the early conceptual stages.

The discussion about sustainable or environmental architecture is more than a discussion about the design process, as it is also hinted above. It is also about how we are in the world as humans or as Karsten Harries writes in his introduction to his discussion about "The Ethical Function of Architecture" *"Should architecture not continue to help us find our place and way in an ever more disorienting world?"* (Harries 1997 p. 4) . Architecture creates the framework for our life. It is the buildings we spend most of our time in and therefore they need a comfortable indoor environment and respond to the different needs we have as inhabitants, whether it is in for example our homes or our workspaces. Throughout history it is possible to see how the technological developments have affected the way we build and the demands to the indoor environment, where the use of fossil fuels has played a significant role in these technologies. However during the past decade our reliance on these fuels has been the focus of discussions, as have the question of how we can reduce the dependency on them. This means that we have to rethink our way of designing buildings and consequently explore how the dependency on the energy from fossil fuels can be reduced. This can for example be through exploring the qualities inherent in the site on which we are building and responding to the climatic conditions (Banham 1969; Thomas et al. 2007). This is something that has been partly lost during the past century because the modification of our environmental surroundings easily could be made by using technological solutions like mechanical ventilation, air conditioning and artificial lighting. It is the use of such technologies that have allowed for the large buildings we design today, through, they are rarely mentioned in the architectural history (Banham 1969). This dependency on

technology to control the environment in our buildings, and through that the way we use them, is framed beautifully in a quote from Lawrence Wylie's description of moving from Boston to a small French town, as used by Lisa Heschong, where he says that *"little by little, our family life, which at home was distributed throughout the entire house and which we had tried to distribute throughout the Pyerane house, withdrew from all other rooms and was concentrated in the sale…. I had to learn to work while the children were playing. The children had to learn to play more quietly. I had to learn to pick up my paper from the table so that it might be used as a dining-room table…. Without realizing it we had adapted ourselves to a necessary condition of life in Pyerane where families learn to live together in one room…. It is inevitable that the English word "home" cannot be translated directly into French. The nearest equivalent in French is the word foyer, the hearth."* (Heschong 1979 p. 43) . This, quote, which shows how the environment in and around buildings as well as our use of them is highly interdependent and becomes a part of shaping our everyday life, is not meant to imply that we should move back in time to the use of the fireplace, but to show the intricate relationship between our buildings, the inhabitants and the site. Today this is still important and the question is how we, with the increased focus on reducing our dependency on fossil fuels, our increased technological capabilities, and our constant strive to develop our buildings can let the different aspects of this inform the design process. Especially when it comes to reducing the energy consumption of our buildings, thus to some extent focusing more on the relations between the building, the site and the inhabitant, than on the technology put into the building. It is within this discussion that my initial motivation is found. It is about the design team's ability to address these issues and work with them as explicit parameters to be dealt with in the design process, was developed and also how digital tools and applications can be a part of that.

1.1 MOTIVATION

Here I will elaborate on my motivation for the research conducted in the present PhD, and on which it is based. It is this curiosity towards architecture and the emergence of a design proposal. Here the main question is what kind of knowledge and information we put into our design, as well as how it is used to inform it, during the design process and how that is transformed from ideas to finished buildings, or at least conceptual design proposals. This is something I find very interesting, especially with the increasing focus on how to address environmental issues in the design process and how the emergence of new digital tools and applications can help to inform or support the design process.

During my education at Architecture & Design (A&D), Aalborg University, I have been taught about the Integrated Design Process (IDP) and the importance of considering both technical and spatial aspects of the design throughout the process. For me the question became what such integration actually consists of and how the design process is approached in practice, as well as what it is that defines the design process in practice (Knudstrup 2004). In some respect I will argue that all architecture has an integration of technical considerations in the design process. This does not mean that it is introduced by the architect from the beginning, but that during the design process the design is going through different stages where a multidisciplinary team is evaluating and developing the design in order to move from the conceptual idea to a finished building. So the architect cannot design a building without at some stage considering technical,

formal or functional issues as described by Vitruvius' Venustas, Firmitas and Utilitas and analyzing buildings erected throughout the entire span of architectural history we will see that different issues related to these are present (Vitruvius Pollio et al. 1960; 1914). Of course, if I take this for granted I could stop the research now. However, times have changed and the impact we, as humans, have on the environment we inhabit has increased significantly, as well have our demands on the environment we inhabit. Today this means that the demands to what we build are higher in terms of technical performance and in a Danish context increasing demands to the energy performance plays a significant part in today's discussions. Our buildings have to fulfill environmental demands that have increased significantly in the past decades, which call for an explicit focus on how these can be fulfilled without compromising the architectural idea or the spatial qualities we strive for in our buildings. Where the architects work has long relied on previous experiences as the point of departure, the rapid changes in the demands today requires that we move beyond the experiences we have (Lawson 2006). But also through my limited experience from practice I started to wonder what such an integrated process is and can be. In my experience from the people I worked with, no design proposal was discussed without considering technical aspects of the design and how to solve it. This was not done solely by the architects but in a dialogue with engineers from different fields and naturally with varying success in terms of how the work proceeded, but the aim was to collaborate on the specific projects and use the combined experiences of the participants in their individual professional fields. Looking back, one of the first experiences with the importance of the collaboration between the professions involved in the design process was during my studies where we as students designed the NoRA pavilion for the Venice Biennale 2006 (FoodPlusDesign 2011). A project where I would claim that one of the reasons for being able to develop and build the pavilion was that the participants in the process took a collaborative ownership of the project. During the work with realizing the project, it became evident to me that the job of integrating the different issues in the design process was not an easy task. The problem that had to be addressed was not only immensely complicated, but was further compounded by the challenge of communicating with other professions involved in the realization in the project. And even though the starting point for the concept was the idea of adapting to the given site, which changed a few times later on, the concept was not supported by actual analyses of how for example the structure should be realized, or let alone considered environmental performance, until later stages – something that for me was part of outlining the difficulties in the design process and the use of digital tools, but also in when and if we can talk about an integrated design process. One could say that on the conceptual level there were considerations in the initial generation of the geometry, however these considerations were not supported by actual technical analyses from the beginning or experiences from other projects, thus one can question if it was actually an integrated design process. It is within this strange field of experiences and thoughts I have developed as an engineer/architect where the balance between the spatial idea and an explicit use of technical knowledge is an important parameter to drive the design. Because they are so closely interrelated, and in order to be able to utilize these interrelations in the design process, a strong collaborative effort is paramount. However to define an Integrated Design Process I will argue that it is the elaborate use of the relations between the knowledge in the traditional engineering fields and the knowledge from spatial domain traditionally assigned to the architect and let them inform the design explicitly from the very first conceptual stages of the design process.

Having an interest in collaboration and the sharing of information in the design process naturally links to today's discussion about Building Information Modeling (BIM), as a part of the design process. The discussion about BIM is focused on how to design a digital platform that allows for interoperability between the professions involved and gather the different layers of information in a single model where information about

Figure 1.1.1 - NoRA pavilion exhibited at the Venice Architecture Biennale 2006

for example, geometry, elements, and material quantities is an integrated part of the model (Eastman 2008). The potential for what such a platform can mean in terms of supporting the design process from concept to the documentation of the building and into the actual construction phase is for example seen in Gehry's work, where the development of software that does just this has been crucial to the realization of projects like the Guggenheim museum in Bilbao (Steele 2001). However, besides the focus Gehry's work has put on the use of BIM, it also touches upon a discussion about the use of digital means in relation to developing architectural ideas. Here one branch of the discussion is based on borrowing technologies from the aeronautical and automobile industry to control the different phases of the processes, as it is also seen in relation to Gehry (Kolarevic 2003b; Lynn 1999). Another direction is the use of the digital media to generate solutions or possible solutions and how that affects the way we think design (Grobman et al. 2009; Kolarevic 2003a; Oxman 2006). On a more specific level it could, for example, be the use of algorithmic architecture where the focus is on describing and defining different solution spaces the computer can work within (Terzidis 2006). Of course there are also approaches that emerged from more technical perspectives, such as the use of simulations in environmental engineering throughout the design process and a term like design engineering (Chaszar et al. 2006; Kara et al. 2008). However, when mentioning these, it is important to remember that they are still dependent on the spatial ideas. Realization of Gehry's work is made possible through the development of BIM, but it is not BIM that developed his architecture – it is the result of his spatial ideas, as for example Guggenheim Bilbao that emerged in a process where the initial analogue models informed the digital models developed throughout the process and created the basis for the final model. In connection with this it is also important to be aware of the interdependencies between the digital tools and applications used in the design process and the abilities of the architect or design team using them. In the end it is an idea about what this specific building should be and express that drives it and then the use of digital tools and applications can help to shape and realize the idea; however the digital tools and applications today undeniably allow for exploration of new design forms.

Linking the curiosity towards the design process and the discussion about digital tools and applications in architecture have proved, for me, to be of great interest as they do have different relations that can help to inform both the work with the design process, as well as the work with how digital tools and applications can be used in the design process and working with specific parts of the overall design problem. This is for example seen in relation to parametric or algorithmic architecture where specific relations between parameters can be explored through an explicit description of the problem that is investigated. This can help to create an alternative perspective where problems are treated more explicitly than it might be in a more traditional process where the previous experiences are the basis for the design process (Lawson 2006). In connection with this it is also important to be aware of that *"many of the mental processes in design (or any other creative process) happen subconsciously and can only be practiced indirectly and in complex contexts…"* (Gänshirt 2007 p. 10).

It is within this variety of interests and directions that my research is defined. Today we have, rightfully, an increased focus on the impact we have on nature and the world around us and this is something that needs to be addressed if architecture is to continue being a part of helping us to find our place in the world as Karsten Harries wrote: *"Should architecture not continue to help us find our place and way in an ever more disorienting world?"* (Harries 1997 p. 4) . We are inspired by the analytical possibilities inherent in the new digital tools and applications that are available to us as well as new technologies. However, when we design we go through complex processes that often happen on a sub-conscious level and we might not always be explicitly aware of what we do.
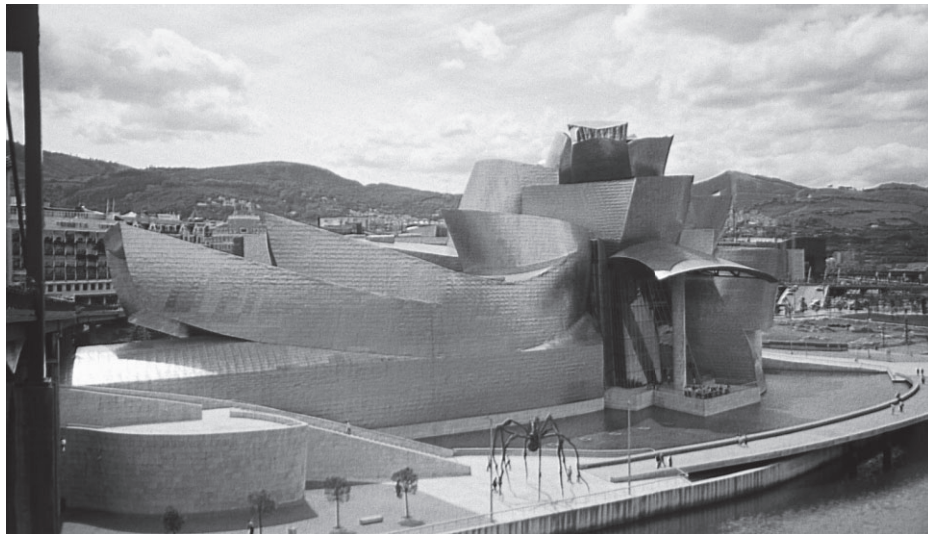
Figure 1.1.2 - Frank Gehry's Guggenheim Museum in Bilbao, Spain

However, in order not to sub-due to the increasing demands to architecture and focus on just adding several layers of technologies to responding to environmental issues, which in a Danish context is very focused on the energy consumption, it is important to study and understand what it is we do in the design process and use the interrelations between the spatial and technical considerations that are paramount to all architecture. For me this has led to the initial question of:

Can the explicit use of the design team's experiences help to identify key parameters connected to environmental concerns in the early conceptual stages of the design process and through that inform the analytical use of digital tools and applications to create a synthesis between the environmental performance and spatial considerations?

1.2 RESEARCH BACKGROUND

With the design process as driver for the current research and how architects' experiences can be used more explicitly in relation to designing environmentally responsible architecture, the first thing to focus on is the background for environmental concerns and directions in architecture. This is something I, to some extent, started exploring during my master thesis, where the focus was on studying architecture and sustainability and through that a discussion about how these two areas could inform each other emerged (Petersen 2008). In the present section I will briefly elaborate on this background, when it comes to the discussions about environmental and sustainable issues and their relations to architecture from an architectural perspective, as well as how these issues are related to the actual field of the design process I'm interested in, in order to create a better general understanding of how the they are related in this oddly defined cross field, between the architectural design process, environmental concerns, and the use of digital tools and applications in the design process.

With the starting point in discussions about environmental architecture there are a number of levels, which it is connected to, ranging from philosophical and ethical considerations to the use of strategies or approaches in the design process of the specific projects. Starting on an overall level there is the connection to how we live on our planet and how we treat it. However this is not a subject that will be treated in length here. It is important to be aware of this fact as it is important to place this discussion in our current context, because we see this increasing focus on how our of living affects the environment. Some of the significant contributors to this overall context are probably most recently Al Gore with his widely published "An Inconvenient Truth" (Gore 2006). Other books, such as Bill McKibben's "The End of Nature", and Tim Flannery's "The Weather Makers" have shaped the debate on our impact on the planet (Flannery 2005; McKibben 1989). One of the first books starting these discussions, however, is Rachel Carson's "The Silent Spring" – a book that is often recognized as the starting point for environmental movements with its focus on how the use of insecticides and herbicides has affected the natural balance (Carson et al. 1962). All of these works are aimed at mediating scientific work and knowledge to a broader audience not necessarily following scientific discussions on a daily basis. By informing people about what is happening, they have all been part of contributing to the general discussions about how we treat our environment. A shift can be seen in the focus where Rachel Carson is focusing on the pollution with pesticides and herbicides, the others are focusing more on the change of the climate. However they are primarily pointing towards the problems we have and work towards getting scientific knowledge into the public debate. This is a discussions related to the ethics of the way we live today, especially in relation to how we see nature.

This also brings us to a discussion about our considerations about ethics and how the impact we have can be addressed. This discussion can be framed by the Norwegian

philosopher Arne Næss in his suggestion to an ecosophy (Næss et al. 1989). Basically rethinking our place in the world and instead of having an anthropocentric view on the world, taking a more holistic view where we are a part of the world and where ecology and philosophy is fused into ecosophy, which is also related to using the natural diversity on the planet as the point of departure and not striving towards the same goals. More recently the focus on how we perceive ourselves in relation to nature is seen in the discussions about different "ecologies" as seen in connection with discussions about shallow and deep ecology (Sylvan 1994). These discussions are also in close connection with discussions in the seventies where the economic policies were discussed and where possible alternatives were introduced and discussed as seen, for example, in "A Limit to Growth" (Meadows et al. 1972). This is seen in Arne Næss's discussion of the Gross National Product as one of the main benchmarks for measuring growth, though it is not taking the natural resources into account (Næss et al. 1989). While the above is primarily focused on overall discussion and our general impact on the planet, even in the discussions about economy and environmental concerns we see relations to what is happening in contemporary discussions about sustainable development and consumption in connection with the built environment. Today we often have a tendency to discuss products and services uncritically in the name of sustainable developments without considering that even this increases the consumption of natural resources (Cuthbert 2006). This is not to say that we should not discuss sustainable developments Seen from my perspective it is an important point in that it may be a part of keeping focus on reducing the energy consumption in what we build and not adding energy producing technologies or energy reducing technologies as the first thing. Instead we should focus on the design of our buildings, and ensure that they are approached in a way where we are not just reducing the energy consumption, but also the reliance on energy saving and producing technologies.

Within architecture we see manifests like "Cradle to Cradle" or "Charter for Solar Energy in Architecture and Urban Planning" – a context that has great impact on architecture (McDonough et al. 2009; Herzog et al. 1996). We can see these connections between the general environmental concerns and how we see our self on the planet in a variety of different directions. Simon Guy and Graham Farmer outline six different types of sustainable architecture, each of them connected to different concerns (Guy et al. 2001). Within these six different typologies of sustainable architecture we for example see "ecotechnic logic", which is seen in connection with high tech approaches and a belief in technology as an important part of the solution. Norman Foster, Nicolas Grimshaw, Thomas Herzog and Ken Yeang are among the architects they name in connection with this approach. Another type is the eco-aesthetic logic where the focus is on the architectural form not the physical performance. The last one I will mention here and that is related to Arne Næss's discussion above is the eco-cultural logic where the starting point is the near context as we see in Glenn Murcutt's and Hassan Fathy's and as we also see in Kenneth Frampton's discussion of regionalism as an important issue. Something similar can be seen in Terry Williamson, Anthony Radford and Helen Bennets description of four different images of sustainable architecture, technological, cultural, natural and climatic, which is also connected to different concerns in connection to how we affect the environment (Williamson et al. 2003). However the focus on the environmental concerns does not tell us anything about what is required to achieve these different types of sustainable architecture and how the design process is approached.

Such discussions about how architecture is an expression of the time in which it is built and the concerns in it, are not new and discussions about architecture's reflection of the society in which it is build are an ongoing discussion. It is evident in architecture, because architecture's concerns are often a reflection of the concerns in our culture (Harries 1997). This is also seen connection with studies about cultures impact on

buildings and their relations to the climate (Rapoport 1969). In relation to this it can be claimed that the talk about sustainable or environmental architecture is barely a scratch in the surface of architectural history in a brief time span as it might be a temporary condition in our society (Harries 1997). In this view architecture is about creating a built environment that reflects how we are in the world and our concerns.

This should be seen in connection with architecture as a professional endeavor where the architect has to deliver something of a certain quality in terms of beauty, functionality and robustness, both in relation to the legislation, but also in relation to what is expected from the general public (Spector 2003). Here it becomes a balance between all the different parameters that are involved in the design and ensuring that the building fulfills these parameters. This can for example be seen clearly in connection with the Danish building regulations stating certain benchmarks for the buildings' energy consumption (Erhvervs- og byggestyrelsen 2011). If we expand the context to be more international it can be seen in the strive towards achieving for example BREEAM or LEED ratings for the buildings (BREEAM 2009; LEED 2009).

It is also a focus we see in publications where such measurable things as energy ratings or environmental ratings from a variety of schemes are in focus and are a part of the discussion of the finished building. This is for example seen in "Sustainable Buildings in Practice", "Energy Efficient Buildings: Architecture, Engineering and Environment", "Green Roofs" and "Strategies for Sustainable Architecture" to mention a few (Baird 2010; Hawkes et al. 2002; Earth Pledge (Organization) 2005; Sassi 2006). They are not, however, concerned with the design process, but serves as cases or examples for inspiration for other architects and are in line with both the rating schemes and legislation in that the focus is on the final product and not how to get there.

But we do see publications that are trying to address what is necessary to achieve architecture with a high level of environmental performance. The first of these were based on studies of vernacular architecture as it is seen in Victor Olgyay's studies of bioclimatic architecture (Olgyay 1992). Here it is the connections between the local climate and the building that is in focus, and through the studies different strategies are derived to respond to the climatic conditions of the site. We see a similar things in G.Z Brown and Mark Dekay's "Sun, Wind & Light: Architectural Design Strategies" that through analysis of more contemporary buildings outlines different strategies to address concerns related to the environment (Brown et al. 2001). On the other side we also see architects with experiences in designing architecture with an environmental agenda publishing books about their specific experiences and what they consider to be important. Here one of the most notable is Ken Yeang with a series of publications where for example "Ecodesign: a manual for ecological design" outlines the key issues to address in the design process (Yeang 2006). Another one in the same tradition of publishing their experiences is Feilden Clegg and Bradley with "Feilden Clegg Bradley: The environmental handbook" which outlines their experiences and presents a matrix based on their experiences, which then outlines what is needed to achieve certain goals in terms of environmental performance (Clegg 2007). They too are focused on strategies and what can be done and do not discuss how they fit into an actual design process.

However talking about environments in architecture is more than how it relates to the external environment and the impact it has on it. The other direction is internal environment in architecture which is related to acoustics, light, temperature, spatial experiences etc., both from a measurable as well as an immeasurable point of view and which are all interrelated and affects each other and our perception of space (Steemers et al. 2004; Hawkes 2008). All of these are things that affect the "atmosphere" of the buildings we design. Discussing the internal environment and how buildings have

Figure 1.2.1 - Glen Murcutts Bundannon school in Kangaroo Valley Australia

protected us from the forces of nature it has often been seen as the main function of buildings and for example when discussing the strategies used in sustainable architecture this is seen (Thomas et al. 2007; Olgyay 1992). There are also close links to the social structures in which the buildings are erected, so it is more than just a shelter protecting and responding to the climatic conditions (Rapoport 1969). Besides the measurable, regarding temperature, light and noise levels, the environment and expression of our buildings are also greatly affected by the social structures, creating connections between the people inhabiting them, as well as the site in which it is erected. They are social gathering points as seen in the baths of Japan and ancient Rome for example – and also our homes where the hearth traditionally has been the centre point in the house – the point where people gathered during the cold winter days and nights, which is still reflected in architecture today in the use of fireplaces in UK and US, though they have a more symbolic value today (Heschong 1979). The literal and physical hearth has changed with technology from the fire to central heating and to district heating and other alternatives today, however the hearth remains as a central symbolic part in many homes today (Rapoport 1969; Fernandez-Galiano 2000). This can be seen in Frank Lloyd Wrights Falling Water, where the fireplace has a central part, but where the benches around are filled with heating pipes which allow the freedom to design a space that is free from the restrictions of the limits a fireplace has when it comes to creating large thermally comfortable spaces (Banham 1969). This is not to say that we need to design fireplaces in all our buildings, but merely to focus on the spaces and buildings as a frame for different kinds of social interactions, which in the above is focused on the life in a home.

The hearth as a center point calls back to the first fires creating a zone of heat around it creating safety and warmth and where moving away from the center meant that different zones were created for different purposes, thus creating a heterogeneous environment, but it also touches upon if the materials should be used to build a shelter or create the fire. Using fire creates heat through burning the material and it is only possible to use once, whereas using it to build a protecting shelter makes it reusable (Banham 1969). This talk about the basic shelter is also seen in the phenomenological description made by Marc-Antoine Laugier, when he describes the primordial hut that is the basic shelter built of trees and branches in the forest, thus creating a place that is a rudimentary protection from the elements of nature and for the first time architecture was discussed in relation to the home as well (Laugier 1977). What is seen in these different descriptions is that both the protection from the elements of nature through constructing a shelter as well as the use of the fire as a heat source creates a social space for people to inhabit. Of course the way these are used differs, as we move around the world where people live and adapt to the different conditions during different seasons. One example is the Middle East, where the buildings enclosing the court yards have different uses according to the season. In the summer the courtyard cools the air and creates shadows while the massive building mass absorbs the heat creating a pleasant indoor environment, whereas it in the colder winter months is the courtyard that creates the frame of the life with the heating from the sun (Rapoport 1969). It is also seen in buildings dug into the ground in Northern Africa like the Matmatas and the adobe buildings in New Mexico, both perfectly adapted to their environments (Thomas et al. 2007; Steele 2005). However this also happens in western buildings. In Australia the Australian Building Research Institute recommended that outside areas such as roofs be used to sleep on during the hottest month. Also in the arcades in London and other places in the UK surveys show that these arcades can create diverse environments thus stimulating our senses and gradually create comfort through passive architectural means (Potvin 2004). So what is seen is that the social and cultural life in the buildings is strongly interrelated to the environments both inside and outside the buildings and the building envelope serves as a mediator between the two environments.

Today this has led to different standards being used when designing buildings in order to achieve an indoor environment where most people feel satisfied – standards such as CR1752, which outlines intervals for how many percent will be dissatisfied within a given interval (CR1752 1999). But we adapt to the different conditions we are in dependent on what kind of activity we are performing. Besides that we are also different as users of the buildings. As it is described already by Heschong in relation to the difference between the highly controlled environment in the American home and the traditional French building and the way one can live with that (Heschong 1979). The differentiation of zones is also something that is seen in inspiration to environmental or sustainable architecture where buffer zones between the interior and exterior can be seen in Thomas Herzogs Regensburg Haus described by Wines (Wines 2000). Today the different uses of the buildings can also be seen in research into how different climatic or meteorological zones can help to define the location of certain functions in the spaces. This is also discussed by Hensel and Menges which shows their pre-occupation with heterogeneous spaces (Hensel et al. 2006; Rahm 2009). In that respect it can be said that form follows climate instead of form follows function.

Because the social and cultural impact on the design is important, then it is also important to study how different users have an impact on the energy consumption in the building and what that means for the environmental performance in the end. Studies from Denmark show that for example the electricity consumption is closely related to our behavior (Gram-Hanssen et al. 2004). Also the inhabitants' interaction with the system and knowledge of the system in the building as well as their notion of comfort has an impact on the total energy consumption. This is also related to the cultural dimension referred to above where for example ones customs and upbringing can have a huge impact on the use of the building (Gram-Hanssen 2010). Also studies of how buildings rated in the different rating schemes show that the buildings do not necessarily perform as the calculations and simulations showed (Birt et al. 2009). So in assessing the performance of the building we see that the user can have a huge impact on the environmental performance.

Today the question is how to design a comfortable indoor environment without having a large impact on the external environment, so the two directions are closely related and the different strategies and experiences are a reflection of that. Now the use of the strategies derived studies of vernacular architecture are not novel as we have seen them used in architecture by for example great modernist architects like Le Corbusier and Louis Kahn who used techniques that today are seen as essential in sustainable architecture – Le Corbusier for example with his Brise-Soleil on Unité d'Habitation in Marseille and natural ventilation in Chandigarh and Louis Kahn also with natural ventilation in his buildings in Bangladesh. Both of them working with the local architect Balkrishna Doshi in their projects in India and Bangladesh (Steele 2005).But also further back we see Palladio making calculations for the size of windows in order to create the right amount of ventilation as Randall Thomas and Trevor Garnham describes (Thomas et al. 2007). As it is seen here the concern with creating a comfortable indoor environment through the use of natural means has played a significant part throughout architectural history and is not a concern that just emerged during the seventies and afterwards. However the focus has increased since then making this topic an essential aspect for architects today to work with.

But studying this context it is seen that architecture that aims at creating a comfortable indoor environment as well as reducing the impact on the natural environment has been present for quite some time. Looking at it from a purely energetic point of view the Passive House is a good example and has existed and been developed in Southern

Germany, Austria and Switzerland in the past couple of decades with the Passive House Institute (Passivhaus Institute 2007). Germany in general has been one of the leading countries in this field where architects like Thomas Herzog have played a crucial part in developments in environmental architecture. It is for example seen in his work with creating spaces that allows for different uses at different times of the year as was discussed above (Wines 2000). It is also reflected in the work with more sustainable materials like timber in some complex structures as well as housing projects with low energy consumption where both energy and material considerations are of interest. Another office from the same region where a similar concern is seen is Baumschlager Eberle from Austria that has vast experience in designing low energy buildings with a focus on also designing buildings that are adapted to perform in the climate where they are placed. This can be seen in their project at Mitterweg with its compact shape, the simple use of materials, and with the apartments having entrances form the protected central stairwell (Baumschlager 2000 pp. 16-29) .

This brings the question of how to address these issues, as well as how to document them, during the design process, into play. This is primarily done today through the application of different specialist computer programs that are used to simulate the performance of the buildings and that can be used throughout the design process if the knowledge to use them is present, in the end pointing towards having increased focus on documenting at least the energy performance of the designed building (Chaszar et al. 2006). Something that in the past decade has been discussed is the possibility for increased interoperability between the programs used by different professions and via that allow for more efficient communication between them, as well as quicker iterations where simulations can inform the computer model(s) they work with during the design process (Eastman 2008). This is not only related to sustainable issues but in a broad sense to the building industry.

Documenting buildings' energy performance today and in general documenting buildings today is happening more and more through the use of digital tools. Drawings today are produced through the use of CAD software, which is basically a digital drawing board (Schodek 2004). However this is now changing towards an approach using BIM where the integration of different kinds of information into the digital model allows for a far more intelligent model where production information, material information, physical properties etc. is possible (Eastman 2008). This is especially evident in a Scandinavian context where digital projects are now taking place and research in the use of it is growing (Moum 2008). Furthermore it is based on parametric descriptions which allow for far quicker changes in models and changes of elements in the models and the relations between elements in the building are the basis. This new focus on BIM is seen as an approach to the design process where the efficiency can be increased as well are the possibility for increased control of the design process for the architects, as for example seen with Gehry's projects where it is seen that they, through this increased control and the increased amount of information, allow for the realization of highly complex buildings (Steele 2001; Schodek 2004). Using BIM is also about creating a digital environment where interoperability between the different computer programs employed by different professions in the design process is in focus – an interoperability that allows for exchange of digital models and information between the computer programs and through that making the documentation of different design solutions easier while allowing for the information to be fed back into the design process in order to address possible problems in the design proposal. In connection with environmental issues the experiences so far are limited within the field and the experiences they have with it show that it is still a variety of different digital tools and different approaches to the specific problems they address that are needed (Krygiel et al. 2008).

Having explored the background for the research it is seen that discussing and working with environmental concerns in architecture is not a novel thing. It is evident in the philosophical discussions about how architecture functions in the world and in the framing in our lives as well as in terms of outlining specific approaches. It is also seen as a part of making calculations and simulations during the design process. However what is not evident in the discussions about environmental concerns in architecture is how the design process is actually approached and what happens in the design process. One could ask how the architects actually work with these issues work during the design process. Do they start by investigating what strategies are appropriate for the specific project or how do they approach the design process? From the initial research question and the background outlined above the overall research question has been outlined where the focus is on the experiences architects have with the design process.

1.3 OVERALL RESEARCH QUESTION

Can knowledge about architects' experiences with the design process and new digital tools and applications be used to achieve an analytical approach to environmental issues in the early conceptual stages of the design process and use that to inform the solutions that emerge through the process, and if so, how?

It is this question that has formed the research for the past three years. In it are two themes that need further exploring through the literary review. The first is the design process and how architects actually approach it and moving beyond the environmental focus outlined above. The second theme is the focus on the use of digital tools and application in the design process, both as individual programs and within the focus on BIM.

1.4 RESEARCH AIM

The aim of the research I have conducted in relation to the present PhD thesis is to increase the focus on how we can address environmental concerns that I started to outline above during the design process with a specific focus on the early stages where the concept is developed and explore the relations between spatial considerations and technical performance. This is done through exploring what experiences architects have with the design process and how they approach it, which in this case is taking as its point of departure discussions about competitions. Choosing the competition stage as the focus is due to the compressed time span in which it is located, as well as the focus on developing a conceptual design proposal that the client can understand and relate to and that this proposal needs to have considered in connection with basic parameters that affect the environmental performance of the building. In relation to this it is also focused on how different digital tools and applications can be used to support this work during the design process and how the relations between the technical and formal parameters that are a part of the process of designing a building can be used to explore different issues in the process, both as a tool for the architect but also as a collaborative tool between different professions in the design team.

PART ONE

The first part of the present PhD thesis is focused on elaborating on the framework for the research. In the introduction the overall research question was developed. In the second chapter the focus is first on the literary review of design process and the use of digital tools and applications in the design process. Through this three sub-questions are developed. In the following chapter the focus is on the development of the research framework and considerations about what research methods will support the data collection for the research.

The first part is built around two chapters where:

Chapter 2, State-of-the-art, is the literature review of first the design process and afterwards the use of digital tools and applications in the design process. Here three sub-questions are developed.

Chapter 3, Research design, is focused on the development of the research design.

2. STATE-OF-THE-ART

In the background the point of departure was the curiosity towards how we work with environmental issues in the design process and from that the overall research question was derived, where two themes were identified as important to make a review of. The first theme was the design process and how the task of designing is approached in architecture whereas the second theme was the use of digital tools and applications and how they can be a part of informing the design process. In this second chapter it is the state-of-the-art within these two themes that is outlined in order to develop the research question further.

2.1 DESIGN PROCESS, STRATEGIES AND COGNITION

Before starting the review of the current research and theory related to the design process I would like to provide a small explanation of how I see this term and different aspects of the term "design process" in order to clarify the following discussions. During the review I found the term used interchangeable between different understandings and explanations of the design process. All of them naturally related to the process of designing a building, or an artifact, from first idea to final construction. Some descriptions were on an overall level describing different levels of detail at a certain stage of a design process using terms like schematic design, detail design, construction stage etc.. Others were more specifically describing what the architect or design team had done to address different issues in a given design and finally some working with the actions architects took during the design process and what they actually did in the development of their design proposals. All of these are often referred to as design process. I would, however, like to split them into three groups to create a distinction between them.

In figure 2.1.1 the relations between the three groups that I have divided the design process into can be seen. The first level is the overall description of the design process which is related to discussions about the formal structures of it as it is discussed in relation to professional organizations descriptions of what needs to be done on what stage and who is involved in the different stages. The second layer is the design cognition and is concerned with how architects (or design teams for that matter) treat the information and process it in order to move from problem descriptions to a design proposal. The third and final level is the design strategies that could be described as the architect's or design team's toolbox where they can "select" methods to address specific problems they encounter during the design process or find important in specific ways.

Splitting the discussion about the design process into these three different layers is because these layers encompass the design process from the overall descriptions to the toolbox the architect have and through that outlines the framework the architect and design team work within as well as how the architect and design team approach the task of solving the design problem and using the different tools in the toolbox to address different parts of solving of the problem during the design process.

DESCRIBING THE DESIGN PROCESS

Starting with investigating the term design process from an overall point of view it is seen that the description of this is often made in relation to an entire building process from the first meeting to after the building has been finished. This is in a Danish context

DESCRIBING THE DESIGN PROCESS
Structuring the process

DESIGN COGNITION (THINKING)
Processing information

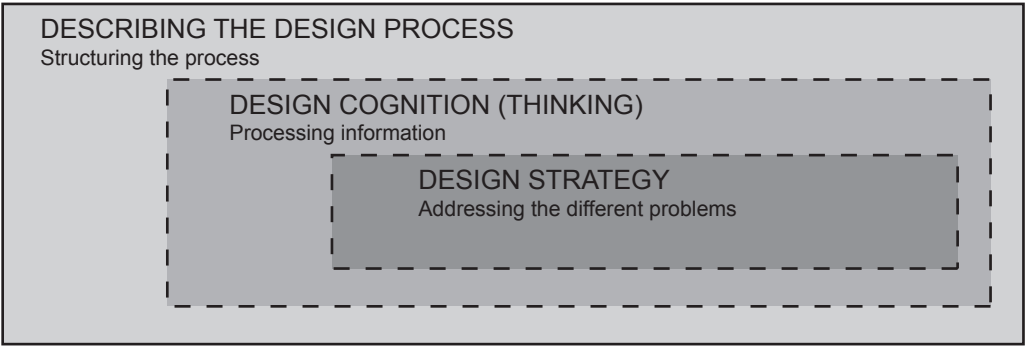DESIGN STRATEGY
Addressing the different problems

Figure 2.1.1 - The three layers in the design process, ranging from the framework that is describing the design process over design cognition and to the design strategies used when approaching specific issues in the design process

for example described by Danske Ark and in a British context by RIBA, as Lawson uses in his exemplification when discussing the term design process, in their formal documents outlining the different stages (Lawson 2006 p. 35; Fri et al. 2006). Both of these describe the traditional structure of the design process from first meetings to final building and are closely related to the fee and contract structures in the building industry. They address issues like who is responsible for delivering what at a given stage of the process, as well as formal descriptions of the level of detail that is expected during the different stages. Furthermore this can also be the basis of tendering between different stages where the project for example can change hands and move from one architect or design team to another or from one group in one office to another group in the same office. An important issue in relation to handing over the projects between the stages described by these professional bodies, whether it is internally or externally, is that the information flow in the project is broken and the information and knowledge about the project that is not specifically described in documents, drawings or models is lost in this transition, thus reducing the information and knowledge basis that is paramount to taking decisions in the project (Pittman 2003). It is such descriptions of the design process that are the framework for how the design process is approached.

However within the past decade terms like integrated design process or integrated energy design has emerged, especially in connection with discussions about environmental architecture and the publication of guidelines to the design process (Löhnert et al. 2003; Synnefa et al. 2008). Design processes that state they work with integrating solutions through multidisciplinary design teams, which should help to reduce the energy consumption in buildings when they are erected. However the design processes they describe still have to answer to the traditional process descriptions from the professional organizational bodies and go through a number of stages where the level of detail increases and with the possibility of changing hands. Comparing the different descriptions of the processes from Danske Ark, the traditional description from IEA task 23, integrated design from IEA task 23 and Integrated Energy Design it is seen that the differences when it come to stages is small. This comparison is seen in figure 2.1.2 where the four different process descriptions are seen with the different stages they run through and with Lawson's differentiation into four major stages; briefing, sketch plans, working drawings, and site operations (Lawson 2006 p. 36) . What is seen in this comparison is that these overall process descriptions take us through a range of design stages from a formal perspective and describes what needs to be done both in the traditional organizations descriptions and in the integrated descriptions and at this level there is no or very little difference between them.

When studying these four process descriptions closer in terms of what is expected of the different participants during the different stages of the processes, it is seen that differences start to appear. This is especially notable when it comes to the involvement of engineers and consultants. Here the integrated approaches focus more on the design team throughout the process as opposed to the traditional descriptions that mainly focus on client and architect in the beginning, then engineers and other consultants come in during the later stages. With the focus on the design team and the involvement of the different professions from the beginning the level of information from different professions increases and the combined professional knowledge can be used during the entire design process. In IEA Task 23 this is seen in connection with their discussion about iterations and they have goal reviews and specialist input from the design team to help guide decisions between the iterations. This is important because research shows that in order to reduce cost and increase the impact different solutions have on the final result they need to be introduced early in the design process, which is easier if the information is available to the team from the beginning, and the decisions are supported by specialist knowledge (Neuckermans 1992). So in the descriptions of the integrated

Danske ark

- Idea
- Strategic briefing
- Project management
- It coordination
- Prelimenary design
- Project proposal
- Authority approval
- Detailed design
- Project clarification
- Construction management
- Technical inspection
- Operation

Traditional design IEA task 23

- Investigation of basics
- Schematic design
- Design proposal
- Preliminary design
- Building documents
- Mass records/advertising
- Negogiation/contracting
- Construction management
- Construction supervision
- Building documentation
- Supervision after 1 year

Integrated design IEA task 23

- Basics
- Pre-design
- Concept development
- Design development
- Building documents
- Negotiation/contracting
- Execution/commissioning
- Operation

Integrated Energy Design

- Preface
- Introduction to IED
- Communication/cooperation
- The design process
- Programming
- Concept design
- Detailed design
- Construction

Legend:
- Briefing
- Sketch plans
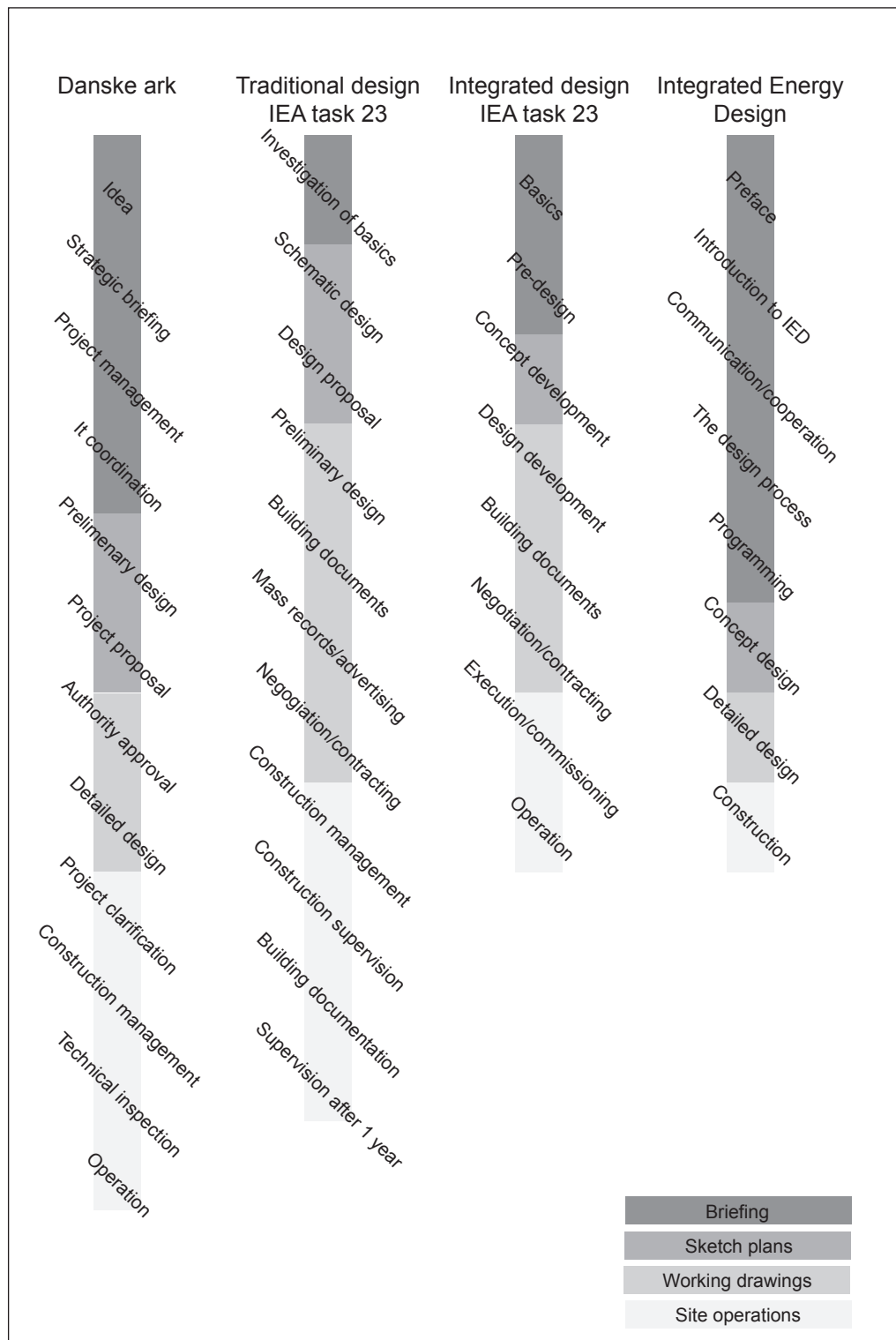- Working drawings
- Site operations

Figure 2.1.2 - Four different descriptions of the design process where the four overall stages, briefing, sketch plans, workign drawings and site operations, are described as Bryan Lawson does in relation to RIBA in The Design Process Demystified (Lawson 2006 p. 36).a

design process's we see an increased focus on the design team from the beginning in order to make decisions that are as informed as possible from the beginning, thus reducing the possibility of having to redesign different parts of the building or coming up with solutions to problems that have occurred due to ill informed decisions.

Looking closer at these differences seen in the professions involved in the traditional descriptions of the design process during the different stages it is seen that they are split, so actors rarely are a part off the consecutive phases. In Danske Ark's model it is seen that it is the architect and client that starts of the entire process and set the premises for the project. The architect then develops the sketch plans and after that the engineers are introduced (Fri et al. 2006). So in this description a clear distinction between the professions is seen which also means that the design proposal is not evaluated or tested by engineers until late in the process. The comparison between the participants in the design process is seen in figure 2.1.3 where it is seen that the engineers in the traditional processes are not involved until we reach the detailed design stages. Until then the evaluation and testing of the robustness of the solution is based on the architects' judgments, whereas the integrated design processes work with the design team from the beginning of the processes making it possible to test and evaluate the design proposal continuously throughout the process using the full scope of information and knowledge from the different professions involved. In connection with this it is also worth noting that the integrated approaches in the discussions in general talk about the design team and does not have the same distinction between the professions involved.

The review of these overall descriptions of the design process shows that the stages and the descriptions of the stages are very similar. However looking closer at the stages and who is participating in the design process during them, reveals that there are differences. Here it was seen that the integrated processes differed from the more traditional ones in their focus on the design team from the beginning as opposed to the distinctions between the professions in the traditional. Also what is important in connection with this is that the integrated processes, especially the description in IEA Task 23, focus on the iterations during the different stages and getting expert knowledge to support the decisions taken throughout the design process. Where the traditional process suggests a clear differentiation between the generation of the idea and the testing of it in relation to the technical domain of the engineers, the integrated processes suggests a more continuous process where numerous iterations can be made between the architects and engineers.

It is my observation, though, that they do not deal with the actual act of designing beyond mere descriptions of what the different participants, as well as the short mentioning of iterations, have to do during the different stages and through that outline a process description. So it is from these descriptions seen who is expected to work at the different stages as well as how involved they should be, but from my point of view the interesting thing is how the different kinds of information and knowledge these participants have find their way into the design process and informs it. So the "Integrated" approaches to the design process draws an outline for the design process that can foster a collaborative approach between the professions from the very first stages. Beyond the brief mentioning of iterations and analysis, evaluation and synthesis in the above that points in that direction it is not mentioned and in the following section this will be in focus.

Danske Ark

Programming	**Concept design**	**Detailed design**	**Construction**	**Operation**
Client Architects	Architect	Architect Engineers	Contractor	User

Conventional design process (IED)

Programming	**Concept design**	**Detailed design**	**Construction**	**Operation**
Client Architects	Architect	Architect Engineers	Contractor	User

Integrated Energy Design Process

Programming	**Concept design**	**Detailed design**	**Construction**	**Operation**
Design team	Design team	Design team	Contractor	User

IEA Task 23 Integrated Design Process

Basics	**Pre design**	**Concept design**	**Construction**	**Operation**
Design team	Design team	Design team	Design team Contractor	User

Briefing

Sketch plans
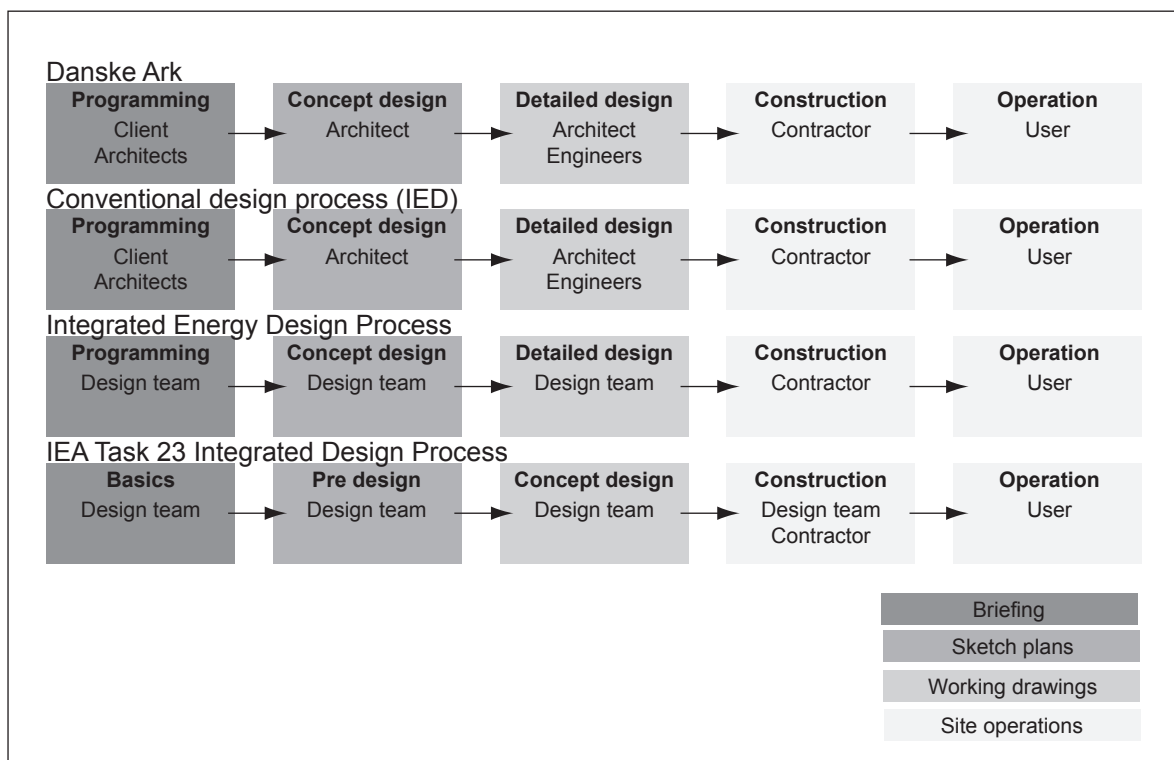
Working drawings

Site operations

Figure 2.1.3 - Participant in the design teams during the different stages in connection with the process descriptions. The sub divisision is in relation to the four overall stages, briefing, sketch plans, working draings and site operations, as described by Bryan Lawson in The Design Process Demystified (Lawson 2006 p. 36).

DESIGN COGNITION (THINKING)

Now we move the focus to how architects and design teams approach the task of solving the design problem, thus, moving beyond the process descriptions, which also points towards discussing the generation and testing or evaluation of design proposals. The starting point for such an investigation can be found in Lawson's description of the design process as a series of iterations or interactions between analysis, evaluation and synthesis (Lawson 2006 p. 49) . This discussion about the design process and how architects approach the task of solving the design problem started in the sixties and seventies. This is for example seen in Bill Hillier, John Musgrove and Pat O'Sullivan's theoretical discussion about how architects approach the design process through conjecturing from previous knowledge, as opposed to what they defines as the scientific analytical approach that was put forward in connection with environmental design (Hillier et al. 1972). In the other direction there was the more rational approach as it is for example discussed by Christopher Alexander in his quest towards creating a logical structure for problem solving, thus narrowing the field of possible solutions (Alexander 1994).

The starting point for the design process is the design problem as it is described by the possible client. As it Lawson describes in his anecdote from the work he did for a friend, the description the client provides is not necessarily clear cut and it requires further investigations into the problem, which in his anecdote was done through conversations with his friend and his friend's family (Lawson 2006). Though the problem he describes there is simple in the end that is not the case in general in design. These problems are what can be defined as wicked or ill-defined problems (Rittel et al. 1973). These are problems that cannot be definitively described and where there is no meaningful correct or false solution(s) to the problem. Something similar is seen in connection with ill-structured problems which can be defined as problems that lack definition (Simon 1973). From this we can say that the starting point in the design process is a problem that is difficult to define and where there are no clear or obvious solutions and no clear right or wrong.

In terms of approaching the work with addressing these ill-defined problems within design we see that the basis is often previous experiences, as Bill Hillier, John Musgrove and Pat O'Sullivan ague in their discussion where it is the architects' cognitive map that is used in conjecturing the first solutions, thus using a conjecture/analysis process as opposed to analysis/synthesis that they argue for as being restrictive to the architects creativity (Hillier et al. 1972; Bamford 2002). Recent research based on observations and interviews with practicing architects working with environmental architecture also shows that architects base their design process on the conjecture/analysis approach as opposed to an analysis/synthesis as literature suggests in connection with doing environmental architecture (Trebilcock et al. 2006). In connection with this other research directed more specifically towards working with environmental architecture has shown that when novice designers are given extensive material relating sustainable issues the solutions they develop to the design problem are less creative than the solutions less informed novices develop (Collado-Ruiz et al. 2010).

Using conjecturing as the basis basically means that the architect is guessing a solution based on previous experiences. This focus on the solution that both the theoretical discussion points towards as a way to approach the design problem as well as research with practicing architects is also seen among students as Bryan Lawson's experiment with students show, where the older architectural students had a solution oriented approach to the problem they were given, whereas the science students and newly started architectural students had a problem based approach to the problem they were

given, seen in them trying to understand the problem before moving towards a solution (Lawson 2006). However, even though the conjecture is the starting point, it is not the only thing that drives the process. Here research shows that architects also identify primary drivers in the design process, such as landscape features in order to have something specific that drives the design process (Darke 1979). So the literature points towards that the architects to a great extent are basing their initial approach to the design on previous experiences and through that conjecture a solution that is driven by specific concerns they identify and then analyzed in terms of how it solves the problem.

However the use of the previous experiences can also be seen in connection with the term case-based design or reasoning or precedent-based design, where it is an explicit use of previous experiences in the form of cases that is used (Agnar et al. 1994; Oxman et al. 1993). The use of case-based reasoning is for example seen tested in research projects for building design applications where they range from fully automatic applications that can develop a design based on the cases in the database to applications that serves as guides and provide suggestions for the design team to develop (Watson et al. 1997). So the use of previous experiences does play a significant part in the design process, both in connection with the implicit use in conjecturing as well as the more explicit use outlined in connection with case-based architecture.

So far the focus has been on the conjecturing part of the conjecture/analysis. However, when focusing on the analytical part of the process we see the sketching as an important part of this. This is seen in for example Donald Schön's observations of a tutor developing the design with a student and how the sketch is the representation of his thoughts as he talks his way through the problems and uses his experience in this development (Schön 1995). The sketch here is not only a part of analyzing the design development, but is also a way to analyze and understand the build form (Unwin 2009). Moving from architecture to the design of formula one cars something similar is seen where the sketching is a way of expressing thoughts and making different issues in the design process explicit and thus being a part of communicating the thoughts to others as well (Cross et al. 1996). So the sketch in the design development plays a vital role, not just as a representation of the space or building that is under development, but as a way to express and develop the thoughts and ideas about it. Through that, it becomes a tool to analyze and understand the spaces, both in terms of spatial qualities, as well as functional and technical aspects of it and through that studies the connections between the fields through qualitative measures.

But if the work architects and design teams do is studied closer, research shows that a series of phases and tasks can be identified in the conceptual part of the design process moving from an interpretive level to a level where the design converged into a conceptual design proposal (Macmillan et al. 2001). In continuation of this an experimental workshop with different professional actors from the building industry participating was conducted. This showed that even if the design team followed these steps progressively one step at a time without returning to previous steps that they did not necessarily come up with a conceptual design proposal that was seen as being better than the teams following a looser structure where they were not bound by progressively following the steps, but having a collaborative approach where the team agreed on the design developments were seen as being important (Austin et al. 2001).This suggests that the common understanding and a collaborative effort where there is agreement about the decisions taken is important. Having this structuring of the design process and focus on collaboration in focus the work with how a common ground and an understanding between the professions have also been explored. This is for example explored in research into Concept-Knowledge design, where it was seen that morphological overviews in the multidisciplinary design teams improved the structure

of the design process, increased the level of communication, created better insight for the designer into the other disciplines involved, and increased the amount of relevant design alternatives (Zeiler et al. 2009). Looking into the process and the development of design concepts we see that the structure of the process and the collaboration between the professions are extremely important in developing concepts that respond to the given task and it does suggest a more analytical approach is better to develop the connections between the professions involved more closely and create a common ground between them.

It is my observation that the approach to the design process and the task of solving a design problem is that it traditionally is based on previous experiences as the starting point where a conjecture is put forward as a solution to the problem. A conjecture that serves as the starting point that is then analyzed, which in turn then develops into a solution that is closer to solving the problem. Besides the previous experiences this is also driven by identifying primary drivers that become a point of departure for the design development. This is further developed in connection with the focus on precedent based design and case-based reasoning which allows for a more explicit use of the previous experiences. This explicit use of previous experiences also ought to give a better understanding of what is happening, thus increasing the level of communication and strengthening collaborative efforts. In connection with the focus on environmental concerns in architecture this raises the question of how architects working more specifically with these issues structure their design process.

DESIGN STRATEGIES

Besides the question of how structuring the design process effect the outcome there is also the question of how they more specifically approach the task of addressing the environmental concerns on which they focus during the design process and which methods they use to do it. It is about their ability to address and understand different environmental issues from the beginning as a key to be able to find and apply the solution that fulfils the requirements set out in the design problem and which is in line with the architect's environmental concerns. This means there needs to be focus on how architects work with the relations between both technical considerations related to the environmental impact and the spatial developments of the building with concerns about the more qualitative experience of the spaces the architects design. This could be described as the strategies the architects or design teams have in their "toolbox" to address the different issues or problems throughout the process. Here I will focus primarily on strategies related to addressing environmental issues.

Within the discussion about environmental architecture, it is seen that research has identified a broad range of the strategies employed in relation to sustainable architecture and how they are related to different approaches to sustainable architecture as seen in figure 2.1.4 where the relations between strategies, sustainable approach, and overall concerns are mapped (Hansen 2007, Knudstrup, Ring Hansen et al. 2009). Relative to these strategies connected to the environmental concerns in architecture there are in general two types of literature. The first one is focused on studies of existing buildings and analyses how they are adapted to the environment in which they are build. This is for seen in studies of Victor Olgyay and G.Z Brown and Mark Dekay among others (Olgyay 1992; Brown et al. 2001). The other direction is seen with architects publishing their own experiences as inspiration and knowledge sharing with the architectural community as for example seen with Ken Yeang, Fielden Clegg and Bradley and Eddy Krygiel and Bradley Nies (Yeang 2006; Clegg 2007; Krygiel et al. 2008). If we take the

Strategies in the toolbox

| **Design Principles** |
| Preserve or improve biodiversity |
| Life cycle assessment of materials |
| Reduce private transportation |
| Thermal mass of materials |
| Insulation of building envelope |
| Window area to orientation ratio |
| Surface to floor area ratio |
| Window to floor area ratio |
| Utilisation of daylight |
| Zoning |
| Mobility (of building) |
| Ventilation: Natural |
| Ventilation: Mechanical |
| Renewable energy sources |
| Energy producing elements |
| Energy-efficient installations |
| Embodied energy of materials |

Approach
Self-sufficient
Ecological
Green
Sustainable
Bioclimatic
Environmental
Low-energy
Solar

Dominating concerns
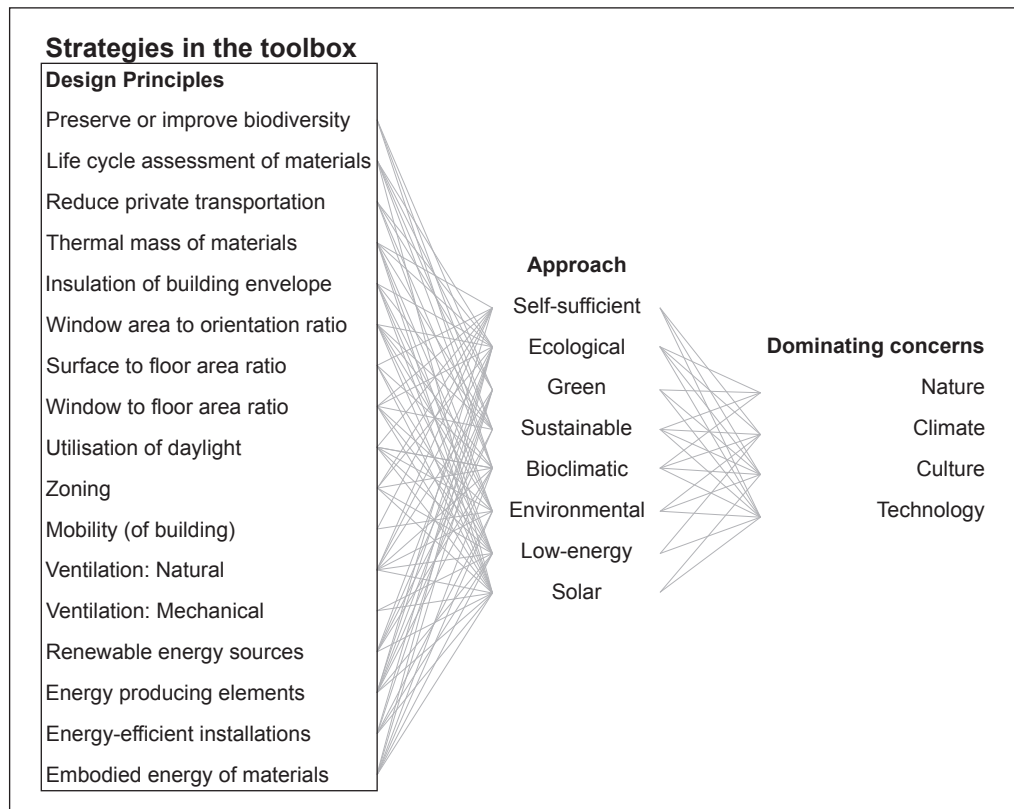Nature
Climate
Culture
Technology

Figure 2.1.4 - Design principles (strategies) described in connection with approaches and concerns within sustainable architecture. Here the focus is on showing the different tools in the toolbox, to the left, that can be used during the design process (Knudstrup, Ring Hansen et al. 2009).

experiences as the starting point, the focus is on the dissemination of their experiences within this field. Here one side of it is a categorization of different performance criteria ranging from for example a minimum standard as stated in legislation to pioneering architecture and how these should perform in different fields. This can then be combined with considerations about appropriate strategies such as thermal mass, ventilation and cooling, solar control or day lighting and how that should be considered in relation to the performance criteria (Clegg 2007). What is seen there is an outline of both a target and a possible path to follow. However the implementation of it in praxis is not outlined. Another example from this is Ken Yeang's "Ecodesign: A manual for ecological design" that goes through the different steps from considering if it is necessary to build and all the way to considering materials and detailed responses to different problems and considerations in the design process (Yeang 2006). Both of these guides do provide a large amount of information about performance criteria as well as what is necessary to respond to them and they can almost be seen as an outline of a recipe for the design process. However they do not state how to mix the strategies or how to assess them along the way.

Looking at what the analysis of existing buildings can tell about how to address environmental concerns during the design process, something similar is seen. Looking at the studies made by Victor Olgyay he identified a range of different strategies related to the environmental context and how they can help to design buildings that respond to the climatic context (Olgyay 1992). This is also seen in G.Z Brown and Mark Dekay's studies where both the analytical techniques and the design strategies are discussed (Brown et al. 2001). But again there is very little that discusses how the actual design is approached and what impact the combinations of strategies have on the performance of the building. This is an issue that is addressed in the LT method 2.0 which is a design tool for non-domestic buildings. Here analyses of the performance is combined with using drawings to assess the possible performance from early in the design process, thus providing a guideline for how the different design decisions have an impact on the environmental performance (Baker et al. 1995). This method provides a close connection between development of a possible solution and the testing of this solution in terms of environmental performance. This differs from the dissemination of the experiences and the studies of existing buildings that provides the designer with strategies seen from the practicing architects. Furthermore this approach to the design process moves towards a more analytical approach where specific analyses inform the design process.

This creates an overview of the different strategies that can be of interest for the architect. However, it is my observation that it is necessary to study them detached from the approaches to sustainable architecture, as these strategies are utilized in architecture in general. Looking at Le Corbusier and Louis Kahn it was seen that they both used natural ventilation in their buildings in Dhaka and Chandigarh and that Le Corbusier worked with the use of natural light in Unité d'Habitation where especially solar shading, in the form of his Brise-Soleil, was used as an element in the facades and as it was seen above these strategies were not particular to sustainable or environmental architecture, though they are used more explicitly in the design than might otherwise be seen (Steele 2005). This is for example also seen further back like in Palladio's work with designing windows to optimize the natural ventilation in the spaces (Thomas, Garnham 2007). So looking at the design strategies in relation to sustainable and environmental issues in architecture the application and use of them are not new. However, today the focus on the environmental performance has made the relations between such strategies and the impact they have on this environmental performance an important area.

Focusing more on the specific strategies as they are outlined in figure 2.1.4, we can see them used in different concepts within environmental architecture. One example of this is for example seen in the passive houses that have emerged in Germany, Austria and Switzerland in the past couple of decades where it, as the name suggests, is the passive means to reduce the energy consumption that is in focus. This is strategies like window area to orientation ratio, envelope to floor area ratio, thermal mass of materials, insulation of building envelope and utilization of daylight to mention a few. Through the elaborate use of such passive strategies the concept aims at fulfilling certain performance criteria (Passivhaus Institute 2007). Another discussion within these concepts that is in focus today is the Zero Energy (or Emission) Buildings (ZEB) where the focus, as the name suggests, is primarily on designing buildings with zero emissions.

An example of both zoning and orientation is seen in the before mentioned building from the late seventies by Thomas Herzog where the use of zoning and orientation have created a building that works differently during summer and winter allowing for adaptability and designing spaces that are comfortable to inhabit during the course of the year (Herzog 2011). Another example are the Eco houses in Skejby, Denmark with their large glass covered area where the intention was as an intermediate space that was used as a part of the house in the summertime and as a buffer zone during winter (Vandkunsten 2011).

From this it is seen that there are experiences within the field and numerous examples of the strategies which can be found, whether it is architecture focused on an environmental agenda or architecture focused on other agendas. But it is also seen that following lists or applying specific strategies like that might not always give the expected outcome in terms of environmental performance and in some cases actually have an environmental performance that is lower than the average of the specific region or country (Birt, Newsham 2009). Furthermore they have different areas of focus and common sense and critical reflection upon what is done is still needed as some examples show (Reinmuth 2010). So the considerations about the application of such strategies requires a critical reflection and even though these strategies are used the user is also an important part of the considerations as they do have a large impact on the environmental performance, as was previously discussed.

In talking about the design strategies it is my observation that there are specific methods the design team can use to address specific environmental concerns in the design process. This is by no means a novel thing to do in architecture, however with the increasing demands to the environmental performance put forward in legislation and in the general public demands it is today more important to work explicitly with these strategies. It is not enough to just apply them, but it is also important to focus on how they affect the final environmental performance of the building in connection with their impact on the perception of the comfort of the building. This raises the question of how architects working with these environmental concerns are assessing this in their design process today.

SUMMARY

With the overall research questions focus on architects' experiences with the design process it has here been studied what the current literature says on the topic. The starting point was the traditional descriptions seen from the professional bodies and

the design guides seen in connection with the integrated design processes. Here it was my observation that very little differed in terms of outlining different steps in the design process and they all follow a series of design stages. However what was seen, was the focus on the design team from the beginning and the focus on getting expert knowledge in from the beginning in the integrated processes, which point towards a broader foundation of information from the first stages, though, without outlining how or what to do to get the information into the project. This put a focus on the structuring on the design team and their ability collaborate in the generation of a design proposal.

Studying the literature about the design process further and focusing more specifically on what architects do in the early stages of the design process in terms of approaching the design problem has been the aim here. It is my observation that the core of the process is based around their experiences, thus forming a conjecture/analysis model. Furthermore that this experience base could be used as an implicit part of the design process as it is traditionally seen, but also more explicitly as is the case with case-based reasoning or precedence base design. So here the focus is put on the architect's or design team's ability to utilize the experiences and communicate this during the design process to create a close link between the conjecture and the analysis.

Focusing on the literature in connection to environmental architecture it was the specific strategies to address environmental issues that came into focus. Here it was my observation that these strategies were of great importance and they form the core of the work with environmental architecture. However, even though the literature does tell about the strategies and discuss them, the active use of them in the design process is not evident here, whether it is from architects publishing their experiences or studies based on the analysis of existing buildings with an environmental focus.

From section 2.1 a more focused research sub-question was formed focusing on:

1. *How do architectural offices, considered as being among the leaders within sustainable architecture, structure their design process, especially in relation to address environmental issues during the early conceptual stages of the design process?*

2.2 DIGITAL TOOLS AND APPLICATIONS IN A COLLABORATIVE PROCESS

Where the above section focused on the design process and the experiences architects have with it seen in a general perspective, I will now move to the discussion about digital tools and their application in architecture where the focus is on how they can be used in the design process. Here the focus is on narrowing in on the part of the overall research question that is focused on the digital tools and applications. This is done through a literary review of how digital tools and applications can be used in connection with the design process and the different directions they can point in. However at the core of it I will focus on them as ways of collaboration between different professions and what the tools and applications can bring into the discussions and developments during the design process, thus serving as analytical and evaluative tools and applications that can inform the design process. This also means that the discussion is not about the more representational side of the tools and applications as for example 2d and 3d CAD tools for drawing and modeling.

The literature review will be split into two different parts. The first one is about the

DIGITAL TOOLS AND APPLICATIONS
Support for the design process primarily for analysis and modeling
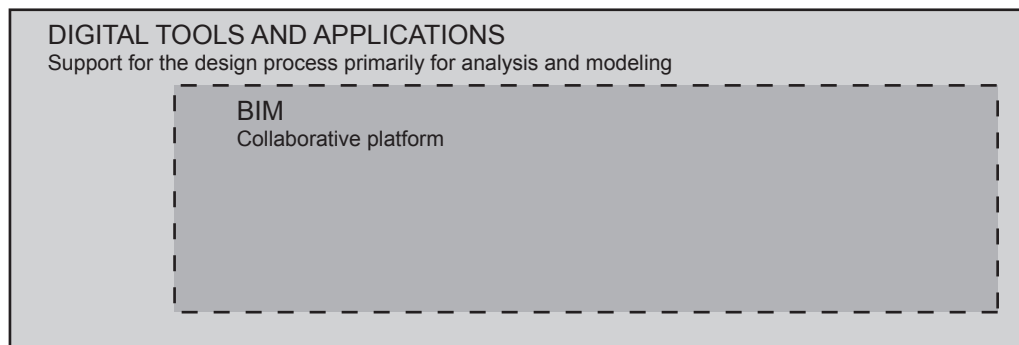
BIM
Collaborative platform

Figure 2.2.1 - Within the field of digital tools and applications in the collaborative process, there are two levels. There is the general one encompassing a variety of tools and applications that can be supportive for the collaboration and there is more specifically BIM as the collaborative platform where the aim is interoperability between different programs.

different possibilities in analytical and evaluative approaches to the design process in order to take informed decisions during the process, thus being able to focus and assess on the interrelations between the spatial developments and the environmental performance. It will touch upon how different tools and applications can set out different directions in terms of how the design process can be approached and informed.

The second part focuses more specifically on the possibilities that different types of software can give in terms of creating a collaborative environment between the different professions involved in the design of our buildings. The focus is on BIM and the collaborative platform that it creates, fusing the possibilities between different representations of the building and the linking to the analytical powers in specialized simulation and calculation software for engineers.

The relations between these two parts are seen in figure 2.2.1.

DIGITAL TOOLS AND APPLICATIONS AND THE POSSIBILITIES THEY PROVIDE

The application of digital tools or computers in architecture has been around for almost half a century where some of the first discussions and attempts to use them are seen in for example Nicholas Negroponte's work where the computer served as an architecture machine or a "colleague" during the design process and informed about solutions (Negroponte 1970). But it was also in use in order to generate architecture through taking environmental factors into consideration, as Sir Leslie Martin worked with in Cambridge (Hagan 2008). However such attempts to automate the design process, or to support it by new technologies, have not been used significantly, as in other industries, even though the technology has been there both in terms of the design and the manufacturing of buildings (Abel 2004). Instead the use of digital tools has played a big part in moving from the analogue to the digital drawing board through the use of Computer Aided Design (CAD) which started to gain ground during the eighties and today is more or less exclusively used for primarily 2D drafting during the design process, but also 3D modeling (Schodek 2004). However this introduction of the computer into the design process has not been without discussions about what such automation would do to the design process and with a certain fear of the architect becoming a bi-stander or even obsolete (Yu-Tung 2007).

In the discussion about digital tools and applications in the design process the traditional focus is on Computer Aided Design (CAD) or Computer Aided Manufacturing (CAM) and specifically within architecture Computer Aided Architectural Design (CAAD) (Steele 2001; Schodek 2004). These are tools and applications supporting the design process and traditionally we perceive it as for example drawing or modeling applications like AutoCAD. However, in talking about supporting the design process through analytical or evaluative means we need to move beyond the programs that basically are a translation of the analogue drawing environment of the desk, into a digital analogy and move into how the quantifiable sizes and the performance of the building can be analyzed or evaluated in terms of structural performance or as is the focus in present research.

So the use of these digital tools and applications is a way of automating the design process and moving from paper as the medium to drawing on to the computer, thus also allowing for the exchange of different forms of information and easier sharing of information in the design process. The question of embedding information and using that as drivers, whether it is automated or more analogue, is the focus of this review. The use of simulations and calculations in terms of documenting and evaluating the design of our buildings does prove to be helpful and be able to inform the design of buildings.

In discussions about digital tools in architecture or digital architecture there is a range of different approaches and methodologies (Kolarevic 2003a; Oxman 2006). Moving beyond the first attempts to work with computers in architecture many of the early methods and programs that were introduced to architecture were inspired from aeronautical,

Figure 2.2.2 - Gehry's Bronze Fish for the 1992 Olympics in Barcelona

ship building and car manufacturing industries and opened for the dynamic forms as well as for exploiting the use of Computer Aided Manufacturing (CAM) to create small prototypes of the models as well as scanning physical models into the computer and forming the use of CAD/CAM applications in architecture (Lynn 1999; Kolarevic 2003a). This formed the possibility for linking between the design process and development, the manufacturing and the construction, as it was explored by Gehry (Steele 2001; Schodek 2004). Through the use of such new technologies he was able to develop his designs by continuously refining his formal ideas and by making prototypes of them as well as having control over all steps in the design and building process and through that the complex sculptural forms he designed became possible to build. For Gehry this was made possible through the application of the software Catia used at the Airbus factory for controlling the design from the initial stages to the final production of their plans. This approach to the use of digital tools is also the precedent for the use of BIM and will be discussed later.

However other methodologies are also seen when discussing digital tools in architecture or in general digital approaches to architecture where the possibilities inherent in different digital applications are used to generate or inform the design more directly. This is related to the use of algorithms, evolutionary approaches, morphologies, an understanding of how technical information can be used to inform the design actively as well as a basic understanding of the mathematical principles behind the geometries in complex forms among others (Terzidis 2006; Kara et al. 2008; Hensel et al. 2006; Architectural geometry. 2007; Frazer 1995). Where it differs from the above discussion is that the architect or designer instead of designing the building designs the process that develops the building so to speak, or a range of possible solutions for the building. Something that can be done both from a purely formal point of view by describing arbitrary relations or by exploiting information about how physical parameters can be used in the description of a design. This allows the designer to create a solution space that the computer can then populate with different solutions. These different approaches to digital design has first been explored from a theoretical stand point recently where the different approaches ranging from motion based modeling, associative modeling to performance based generation has been explored (Oxman 2006). All of these explore different ways of using the possibilities presented by digital tools and applications to drive the design and cross the boundaries of what is possible in the design process as well as it can challenge the architectural vocabulary.

These different possibilities have been explored in different design processes. The parametric modeling or associative geometry in the continuous work on La Sagrada Familia by Gaudi through the work of Mark Burry (Burry 2006); a generative approach is seen in Expedition Engineering's work with a station in Naepels with Roger, Stirk and Harbour (Expedition Engineering 2011). Performance based modeling in relation to Fosters work on for example the GLA headquarter and Swiss Ree in London (Whitehead 2003). Furthermore a number of other approaches described in various articles are seen (Grobman et al. 2009; Kolarevic 2003a; Oxman 2006). So besides the theoretical dimension related to the discussion of these approaches, it is also seen that they are being used in a variety of different realized projects that moves beyond being pavilions or research projects of different natures.

In relation to these more generative methods within architecture it is seen that they are now being used to generate solutions that can help the architect in relation to environmental issues. This was as mentioned already attempted during the seventies though without any significant results (Hagan 2008). Something similar was also seen throughout the eighties and nineties where a dynamic responsive and self growing basis was considered, though still limited by the computer power (Frazer 1995). However

today we see these approaches used in architecture, ranging from experiments with generative algorithms to design structures, but also when it comes to environmental issues (Shea 2006). This is seen in relation to the generation of spaces that the architects can then use as a starting point as well as in building scale where the computer can generate a range of solutions for the architect to evaluate and work with (Grobman et al. 2008; Petersen 2008). Both of these take their starting point in parameters that can be quantified in the design, such as energy consumption, size of spaces, window openings etc., and from there generate a range of possible solutions that can serve as a starting point for the architect or design team to work from.

It is my observation here that when it comes to different approaches and directions and using digital tools and application as a way to explore architecture is that they encompass a great variety of considerations. It spans from exploring how inspiration from the growth in nature and natural systems can be used in a generation and selection process to performance based modeling focusing on different performance parameters, based both in the technical and the spatial realm. What I find important here though, is that we still need to have an idea about what it is the building we work with needs to do. The approaches above are to a great extent still experimental, but they are finding their way into the building industry through different high profile projects and I see them as interesting contributions to how we approach the design and the possibilities they open towards exploring specific issues as it is also seen in the above mentioned projects. However the focus within the realm of digital tools and application in architecture today is on the BIM platform that will be outlined in the following.

COLLABORATION WITH BIM IN THE DESIGN PROCESS

The concept behind BIM is to tie the different professions involved closer together during the design process in order to maintain the different kinds of information in the design process, which is inspired from the production processes seen in the aeronautical industry as well as in car manufacturing (Eastman 2008; Schodek 2004). This will also make it possible to take advantage of more flexible production methods seen in these industries (Abel 2004). Compared to a traditional process this also allows for a continued information flow as opposed to traditionally where such information gets lost between different steps in the design process, as the project changes hands (Pittman 2003). Besides merely coordinating the different drawing materials it basically revolves around a model of the building consisting of different levels of information and with the ability to show different representations of the project as seen in figure 2.2.3 . Both comprising geometrical descriptions, but also material description and quantities as well as manufacturing information (Eastman 2008; Succar 2009). In relation to that the digital 3d model is just one representation of the building where other representations could be tables with quantities of different elements in the building. Gathering all this information also opens the door for actually testing a prototype of the building. This is possible through the use of performance based simulations allowing the design team a variety of different issues in order to investigate how it performs and through that document it (Luebkeman 2003). Another issue that can be explored is the building process moving from the 3d world into the 4d world where the entire process is planned in connection with for example structural safety on site (Zhang et al. 2011).

However using such a methodology is not straight forward. In terms of for example making simulations from the very beginning it requires knowledge about how to set-up calculations and simulations as well as an awareness of how to translate the results (Chaszar et al. 2006). Furthermore the implementation of BIM in the early conceptual stages of the design process is not something that is easily achieved and so far

research shows that it is problematic (Schmitt 2004; Penttilä 2007). Especially when it comes to the implementation there appear to be problems. One of the problems that is encountered here is the traditional culture around the design process as seen in for example an Australian context (Gu et al. 2010).However if we return to the discussion about BIM here and the possibilities that it gives in relation to the design process there are some interesting aspects. As mentioned above the use of BIM aims at fusing the different professions closer together in the design process through creating a common platform for sharing information about the building. This can be information both in terms of geometry, but also about material properties, manufacturing, construction of the building and in the end about the running of the building (Eastman 2008). The question then, is how such tools can be applied to the design process and how it can help.

Looking at it from a sustainability point of view there is no simple answer. In general, working with these issues there appear to be a range of applications available with the software used to model over simple spreadsheets and to simulation programs designed for working with the simulations of the indoor environment (Krygiel et al. 2008). Something that is also seen in relation to the building design are more customized applications which can be made to show things like solar radiation (Whitehead 2003). Not all of these things are necessarily developed in relation to BIM, but they play a part in assessing the different strategies. A thing to be aware of here is that the application of BIM still requires an active approach towards applying different strategies and working with them. In order to make it work it is important that a hierarchy of the modeling and the investigations are made so they fit the different stages as the level of detail increases throughout the project moving from highly abstract in the beginning to very real in the end (Chaszar et al. 2006).

Looking at the projects that have applied BIM in a successful way it is seen that they are often highly complex projects. It is projects like Frank Gehry's Bronze Fish for the Olympics in Barcelona seen as his first attempts to use this technology to Foster + Partner's work with GLA headquarters and Swiss Ree to The Watercube swimming stadium for the Olympics in Beijing (Eastman 2008; Whitehead 2003; Glymph 2003). All of these projects contain high amounts of information on geometry and manufacturing information. However none of these projects have been conceived in the BIM environment, but from a highly analogue process as seen with Gehry or a more digital inspired by some ideas as seen in relation to the Watercube, GLA Headquarter and Swiss Ree. So it is seen that the technology is used and Denmark is actually one of the leaders when it comes to the implementation of it in the offices currently due to legislation (Moum 2008).

So in this outlining of BIM it is my observation that it does create interesting possibilities. However it is not the use of BIM that drives the design, but merely as a support for the process and where the information handling is increased to keep control of the different aspects in the design process. Furthermore it can be seen that the use of BIM can help to facilitate a closer integration of simulations in terms of environmental issues in the design process, thus creating a framework for letting the design be informed more by the results, though it is still a matter of being able to understand what is important to address and communicate that in the design process.

SUMMARY

In this part of the literature review the focus has been on the digital tools and applications in the design process and their contribution to the design process, thus focusing on the part of the overall research question connected to digital tools and applications. From
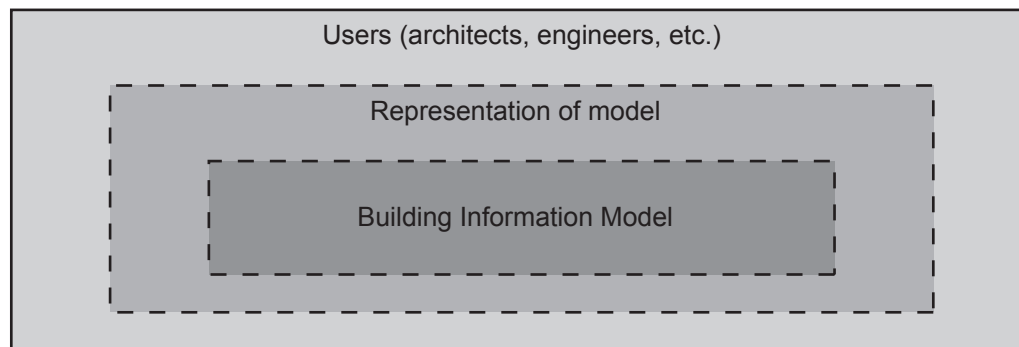
Figure 2.2.4 - The structure of BIM with the model encompassing all the information as the central point. From this central model different representations can be drawn, such as geometrical model, window or door schedules, ducts, etc.. These can then be used for further analyses by the different participants that are involved in the project. This means everybody can use data from the central model, creating a common model with information

the general perspective the use of digital tools and applications gives a large variety of possibilities and approaches to the design process. However it is my observation that no matter which direction is taken we need to be extremely critical. Even though the different digital tools and applications present a possibility to automate if not all then parts of the design process, the question is how the tools work and which tasks they solve or respond to. From there the focus is pointed towards the possibilities inherent in the digital tool or application in its own right and how that can contribute to the design process.

But as the design process is a collaborative effort involving a range of participants from different professions the second part was focused on how the digital platform can be a part of supporting this. This focus on collaboration also pointed towards the information in the design process and the exchange in terms of informing and developing. From this it is my observation that the common platform for exchange of information can be a significant contribution to the support and management of the design process. So in this part the focus was on the digital tools and applications as a collaborative platform.

From these two sections two other sub-questions to the overall research were formed, first of all questioning if architects working with environmental concerns in architecture use such digital tools and applications and secondly if we can use the knowledge we have of the different parameters from the design strategies and their interrelations to drive the design process. In elaborate form the two sub-questions are:

2.   *Do they currently use digital tools and applications to address environmental issues in the design process, and if so, how?*

3.   *Can parameters related to building form and expression affecting the energy consumption be implemented in the design process to inform it directly through exploring their relation to the architectural form and expression, and if so, how?*

2.3 CONCLUSION

In the literature review the focus has been on exploring two parts of the overall research question, the experiences in the design process and the digital tools and applications, and through that elaborate and refine the scope of the research. This has led to three sub-questions of the research question that address different aspects of the overall question. The full range of research questions is the:

Can knowledge about architects' experiences with the design process and new digital tools and applications be used to achieve an analytical approach to environmental issues in the early conceptual stages of the design process and use that to inform the solutions that emerge through the process, and if so, how?

1.   *How do architectural offices, considered as being among the leaders within sustainable architecture, structure their design process, especially in relation to address environmental issues during the early conceptual stages of the design process?*

2.   *Do they currently use digital tools and applications to address environmental issues in the design process, and if so, how?*

3.   *Can parameters related to building form and expression affecting the energy consumption be implemented in the design process to inform it directly through exploring their relation to the architectural form and expression, and if so, how?*
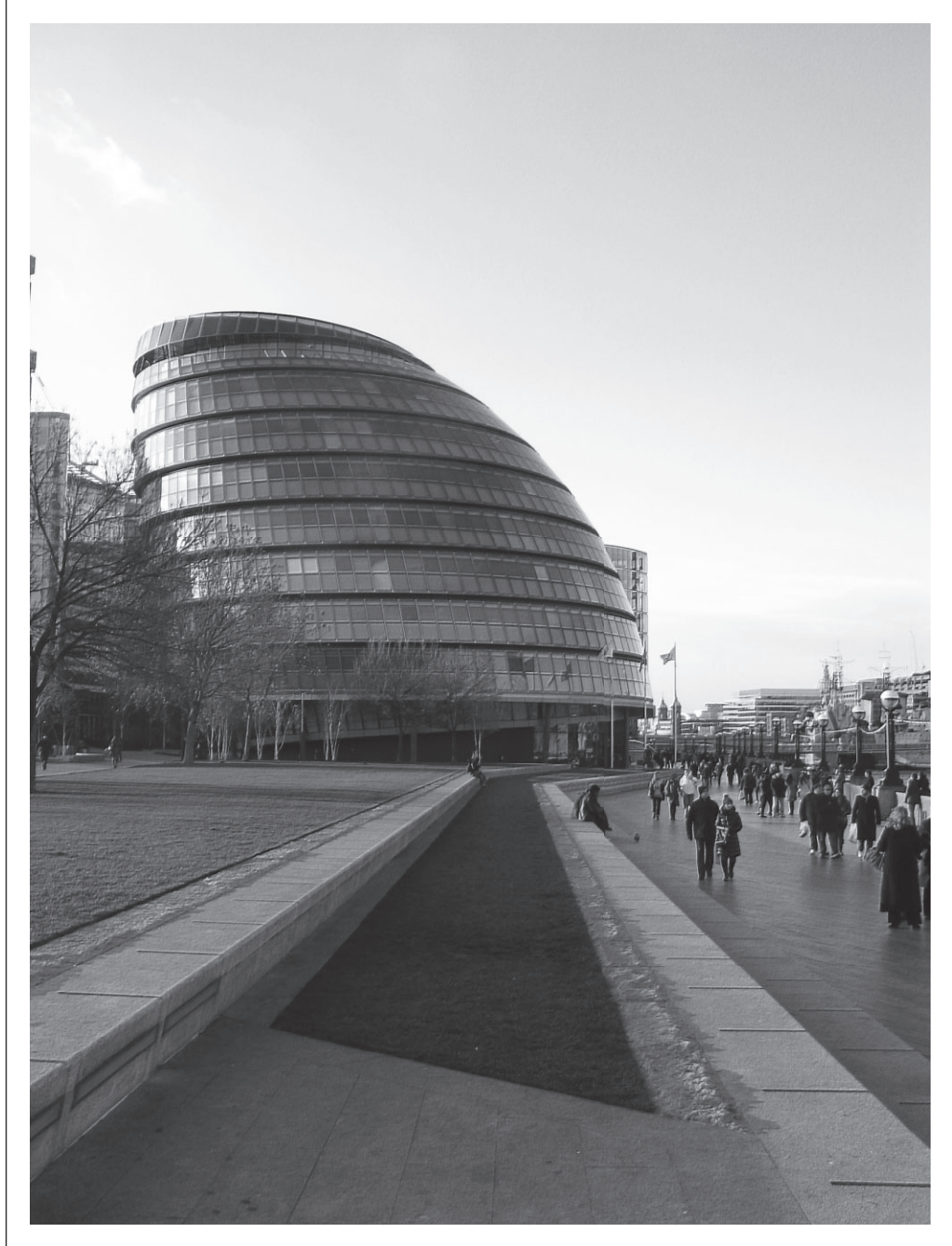
Figure 2.2.4 - GLA headquarter by Foster + Partners

3. RESEARCH DESIGN

Through the literary review the research questions were introduced, which brings up the problem of how to answer the questions, and most importantly how to collect data that can help to answer these questions. It is the considerations about which method(s) to use for the collection of the data that is in focus in the present chapter.

The starting point of this research is these research questions as it is often seen in traditional social and natural sciences (Andrews 2003). With the starting point being a curiosity towards how architects experiences can be used in connection to direct the design process towards first the initial research question was formed which led to the overall research question. This was then further qualified through the literary review that formed three sub-questions. These three sub-questions are all a part of responding to the overall question (Andrews 2003). It is the collection of data to address these questions that is in focus here. However the path through present research is not the shortest path from A to B, but a path that is the result of searching .

The context in which this research is conducted, is in a cross field between the different topics that was described in the previous chapter. In this chapter the way the research methods used within this cross field is described and discussed. All of the themes discussed above come from a diverse field of studies and are based on a variety of methods borrowed from different traditions within research ranging from natural scientific experiments to social scientific studies, as well as more philosophical discussions of how we are in the world as can be seen in the humanities. So we see a nebulous field of possible approaches to this research. However in the present research it is on how architects work with environmental concerns in their design process that is in focus. This is traditionally something that has been seen in relation to optimization of the environmental performance of the building, but here the focus is on understanding how architects and design teams work with this as an integrated part of the design process where it is their experiences working within the diverse field of topics outlined above that is in focus.

Now as the main focus in the research question deals with the experiences architects have with the design process in practice especially in relation to environmental issues, the main focus in present chapter is to outline a path that can help to, if not answer the question, then illuminate a part of the answer which is also reflected in the sub-questions to the research question. As it is seen in the literature review concerning the design process there are differences between the ways in which the term design process is used. In the present research the focus is on the level of the design thinking and the use of design strategies when it comes to addressing environmental concerns in the design process. In relation to the present research this means that the main focus is on creating a basis for understanding the design process encountered in practice through the architects' experiences and then relate these experiences to the theoretical context. Through that it is discussed how these experiences in working with environmental concerns during the design process can help to develop an elaborate focus on the interrelations between the environmental concerns and the building expression and how the analytical and evaluative powers of the digital tools and applications can help to inform the design process about the impact different solutions have on the environmental performance.
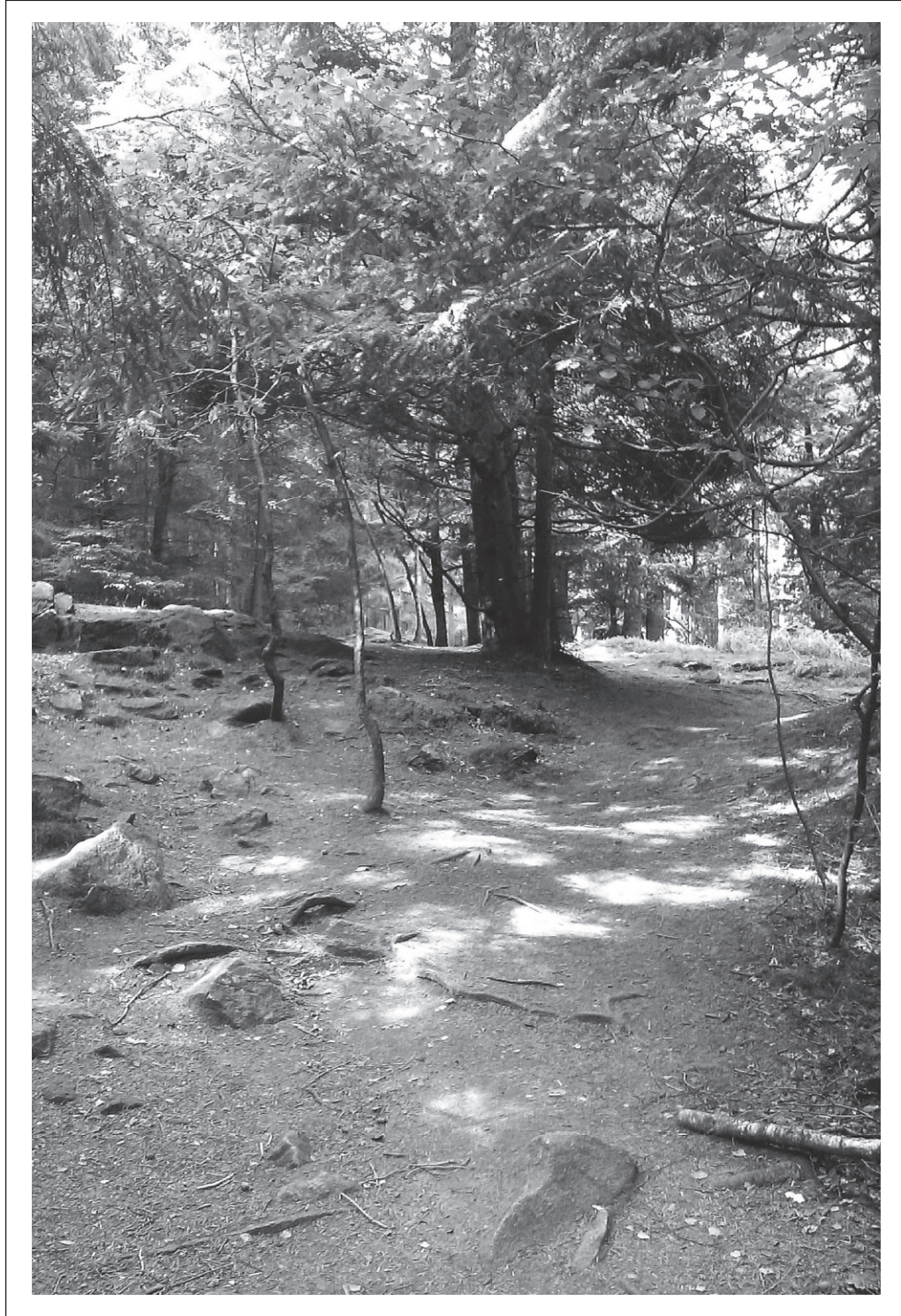
Figure 3.1 - The research path in the wilderness

3.1 THEORY OF SCIENCE

As an introduction to the considerations about methods in the present research I would like to place myself in a scientific context – a context where the methods are borrowed from other fields of studies such as social sciences. Architecture emerges within a cross field of topics that can be studied from a social scientific point of view, a natural scientific point of view, or from a perspective within the humanities. However I am neither a social scientist nor a natural scientist, but have the title of being an engineer, thus placing me somewhere in the field of applied sciences. In a Danish tradition, I'm a hybrid between an engineer and an architect having a background where the connections between the spatial and technical parts of the design have been of great importance for developing design proposals as it is seen in the IDP (Knudstrup 2004). This is also something that is evident in my approach to the research and in the analysis of the data. I will never claim to be fully neutral in the matters discussed, as I am colored by my educational background as well as the experiences, though being limited, I have from practice. This also means that the research is affected by the considerations about the methodologies borrowed from the social sciences, but also from the practical experiences as an architect, creating a framework being informed from both of these worlds.

When looking at previous research into the design process it is seen that it is a nebulous field, as seen in figure 3.1.1, of methodologies that are used, ranging from interviews, observations, experiments, digital simulations and even research related to neuron science, psychology and systems thinking, just to mention some (Lawson 2006; Alexander 1994; Darke 1979; Schön 1995; Akin 1986; Cross 1990; Lawson 1994). The present section is based on a paper published in an internal publication at A&D, though, it must be said, it has been significantly re-worked from this (Petersen et al. 2010a). This update is also a reflection of the research process where continuous work and studies have been used to develop not only the research, but also the realization of my scientific position within this field, as primarily a researcher, but also to some extend as a practitioner. Throughout the past three years this PhD has been under development, this double sidedness has been a way of informing and continuously considering how the two parts can inform each other, as for example when studying the design process, where my own experiences have affected the way it is described. One could say that we cannot discuss architecture and fully describe the design process without having an understanding of how the mechanisms in it can affect it, especially when it comes to approaching a complex problem like architecture.

This then raises the question of how this research should be seen in the perspective of theory of science, as well as in theory development. As mentioned in the beginning of this section it is influenced by my background as a researcher and a practitioner, thus maintaining the architect's or designer's perspective on the following discussion and analysis, which is placing it in a naturalistic or constructivistic tradition (Bryman 2004; Groat et al. 2002). Here I will focus on where this research is placed in relation to theory of science, as well as how the research contributes. In talking about how the research is placed in relation to the theory of science the question is how we can see research in architecture placed in this discussion, as it spans the width of scientific traditions, therefore this question is of great importance.

With this I start to focus on how I, as a researcher, am related to the topic I am doing research in. As I have already stated I see myself as interacting with the research field I am in and not detached from it, thus placing myself in a qualitative approach to the research I'm doing according to Linda Groat and David Wang (Groat et al. 2002). Now this means that I do not see the phenomenon I am studying as being something that has an existence that is independent of its actors towards being highly dependent on who

Author	Research focus
Lawson 2006	Review of research in the field and related to experiments with students
Alexander 1994	System thinking aiming at the synthesis of form
Darke 1979	Interviews with architects about how they worked on specific projects
Schön 1995	Observations of interaction between architectural student and tutor in meetings
Akin 1986,	The psychology of architectural design and the decisions taken in the process
Cross 1990	Explorations between the nature and nurture of design
Lawson 1994	Interviews with architects about their design process

Figure 3.1.1 - Previous research into the design process with titiles and scientific directions ranging from studies based in the social sciences to neural and medical sciences, thus showing the broad field that research withiin this field can encompass

is participating in a design process, thus multiple possible perspectives exists (Bryman 2004 p. 20) .

The phenomenon in focus in the present research is the design process. A phenomenon that is important, though we see that the approach to the design process differs from architect to architect as Lawson describes in connection with interviews with different high profile architects or as seen in the variety of different descriptions of the design process (Lawson 1994; Lawson 2009). With this in mind it is seen that it is a topic that is highly dependent on the architect or designer one talks to and observes in the process. The process is highly dependent on the context in which the design is emerging. Furthermore my own background and understanding of the design process is a part of the research context, so to claim that the research conducted here can be generalized to a recipe to follow is not possible, because both my own context as well as the context of the research subject plays a significant part here and is highly individual.

Through the considerations about methods in the present research a more objective or generalizable approach could have been chosen. It could have been experiments where different professions or students had been asked to solve a problem as Bryan Lawson has done in parts of his research (Lawson 2006). It could have been using protocol studies of different teams working on a set assignment that should be solved within a limited time frame (Kruger et al. 2006). Or it could be observations of an experiment (Macmillan et al. 2001). However as Bryan Lawson states in "Design in Mind" *"It could be argued that it is more useful to know how a few outstanding designers work and think than to conduct experiments on a large number of less able ones"* (Lawson 1994 p.3) . This quote very precisely outlines the starting point of present research where the question is how architects work with the environmental issues during the design process and what their experiences are in order to learn from that. This is important because the design process is of a complex nature, not just with the different considerations about spaces, materials, technologies that goes into the actual building, but also because of the interactions between the team members and the different professions. Each of these have been explored individually earlier, however, very little research is made into how architects work with addressing environmental concerns in the design process and how that can help to inform us about this issue.

As mentioned above, my own context and my understanding of the design process is also a significant part of the present research, especially coming from a, in a Danish context, hybrid education between architecture and engineering. This does not have an impact on the methods used to collect data. In the interpretation and the analysis of the data it moves from being a descriptive approach to the research to being more of a suggestion to how the focus on the interrelations between the environmental performance and the architectural expressions can be used actively in the design process without, however, being a recipe for architects to follow. Here it is important to keep in mind that the design process cannot be seen as a singular path moving from problem to design, but is a process that allows the architect and design team to explore the specific problem at hand and through that suggest a design solution that answers the clients brief.

The question then is how such a naturalistic approach can contribute and with what it can contribute? As it is seen in the discussion above the design process seen, from an architect's point of departure is a highly personal thing and as Bryan Lawson mentions in his introduction to "Design in Mind" it is actually not something that is often discussed by architects in practice (Lawson 1994 p. 2) . The contribution here lies in the discussion about the possibilities and what an awareness and discussion about the design process can mean when applying it in a practical context. It also contributes through a discussion about how this focus and how inspiration from the experiments in research can help to

inform and direct the process and through that develop the way the architect work – a contribution that is the result of the analysis of the data as well as the context from where I am coming.

However, I would also like to briefly touch upon the design process as an endeavor into research, meaning that the design process can be seen as a way for architects to explicitly gather information and knowledge that can then be used in later projects. The discussion about how architects approach the design through conjectures discussed in the state-of-the-art, is based partly on this discussion where the argument that came up during the seventies was that an analogy between the design process and the change in scientific paradigm during the past century could be seen as related (Hillier et al. 1972). This has been elaborated later where the difference between a design process based on analysis/synthesis and conjecture analysis is discussed in relation to the scientific paradigms of Descartes/Bacon and Popper (Bamford 2002). Now, one can question why this is important here. From my perspective as both a designer and a researcher it is important because it is dealing with how we see and understand the design process. This discussion opens up not only for a discussion of the result, but also how we get from problem to result. Something that is becoming more important when the complexity of the projects increases, when it comes to stricter demands in terms of the buildings' performance in terms of energy consumption and environmental performance on a more general level, as well as when we need to understand why our buildings do not perform as they should. Furthermore it has to do with the way we approach the design problem. It was seen that architects, designers and design teams are working with wicked problems, which means they are complex problems where the problem reveals itself throughout the process and where there is no clear right or wrong (Rittel et al. 1973). This also means that addressing these problems requires knowledge and experience that is deemed to come from previous projects and experiences, making the reflection on what we do in the design process extremely important. Thus we need to focus on the design process as a part of our research to help develop our knowledge base.

Having focused on the considerations about my position as a researcher I admit to being affected by the background I have as an engineer/architect. I do not claim to be neutral in the discussion, but I do claim to be objective in the collection and treatment of the data collected throughout the process. And as it has been discussed above research into the design process is a nebulous field to work in. With this in mind I will move into the discussion about the methodological discussions and how they are used in order to collect data to answer the research questions.

3.2 ANSWERING THE QUESTIONS

Having established a scientific position and the system of enquiry in the above where I argued for how both my position as a researcher and an engineer/architect played a role, the focus will now be on developing a framework of methods that can help to explore and answer the research questions. Looking at the process of working with these questions, both in terms of forming them and answering them, we need to see the research design as an overall framework of both the literature review with the existing knowledge and theory within the field and the collection of empirical data. In the present research this has happened through a continuous process. It can be described as a process where the initial research question has demanded studies of existing knowledge through a deductive process, refining the questions and through collecting empirical data through different methods new information is brought in that has further refined the questions, thus creating a series of iterations. So the literature review can be described as the

deductive side of the research whereas the inductive side is formed by the gathering and analysis of empirical data as Alan Bryman describes (Bryman 2004).

In figure 3.2.1 the overall research design is outlined with the initial overall research question as the starting point; the structure of the research, comprised of literary studies and collection of empirical data, in the middle and the contributions in the bottom. In order to approach both the explanatory and exploratory part I have focused on two different groups where the explanatory part is focused on the experiences architectural offices have in practice and the exploratory part revolving around the students' work at A&D, Aalborg University. In relation to the considerations about these two parts there is also the theoretical development within the research where the two parts mentioned above is forming an inductive part of the research where the theory is developed through the analysis of the data whereas the literary review is forming a deductive part of the research. As seen in figure 3.2.1 all of these different parts inform each other, with the initial research question as the point of departure moving to the deductive part where the general theory is studied in connection with what it means for the hypothesis and finally the inductive part where it is documented through collecting data as described and discussed by Charles S. Peirce where it is a continuous process where the three steps inform each other and narrow in the scope as the research progresses forming a circle of enquiry (Peirce et al. 1998 pp. 267-288) . This circle of enquiry is based on the hypothesis or initial question that is the abduction or the starting point that then leads to research into the existing field of knowledge, and further into the gathering of empirical data that through analysis leads back and helps to refine the initial point of departure, thus creating an iterative process for the research.

3.3 RESEARCH METHODS

With the overall system of enquiry in place, the next step is the development of the actual framework of methods within this system of enquiry in order to address the research questions. However, in the research questions two aspects are seen. There is the focus on the experiences architects have as seen in research sub-question one and two and there is the focus on if parameters can be implemented in the design process in research sub-question three. The focus on the experiences architects have points towards an explanatory approach, whereas the focus on how parameters can be implemented points towards a more exploratory approach (Yin 2003).

In this section I will focus on the collection of empirical data and the inductive part of the research with the explanatory and the exploratory parts, both of which are informed by the literary review in chapter two. In connection with these two parts of the study, thus moving from the system of enquiry to the use of methods or strategies as Linda Groat and David Wang describes (Groat et al. 2002 p. 10) Looking at figure 3.3.1 it can be seen how the different research questions are linked to the methodological considerations, as well as how it fits within the overall picture that was shown in figure 3.2.1. However it is also important to mention here, that the explanatory part has been the main focus throughout the research, which also means that it will be most elaborately discussed here. In this figure it is seen that two overall methods have been chosen, namely interviews and case-studies. The collection of data is based on three different approaches that are directed towards different stages of the design process as seen in figure 3.3.2. I will elaborate on these in the following.

Forming the idea

Can the explicit use of the design team's experiences help to identify key parameters connected to environmental concerns in the early conceptual stages of the design process and through that inform the analytical use of digital tools and applications to create a synthesis between the environmental performance and spatial considerations?

Abduction

Structuring the research

Theoretical

Empirical

Deduction

Induction

Research question

Research methods

Literary studies
Design Process
Digital architecture
Descriptive

Practice
Architectural offices
Consultancy
Explanatory

Students
Student works
Exploratory

Contributions

Answers to the research questions in connection with the importance of the research and what present research can lead to of new research

Figure 3.2.1 - The overall research design with the connection between the hypotheis, forming of the idea and the contributions the research gives, with the middle section being the actual research done with the literary studies, the methodological considerations, the data collection and the theoretical developments

Forming the idea

Structuring the research

Literary studies

Deduction

Induction

Overall research question

Research methods

Explanatory

1. Research sub-question

Interviews
Semi-structured interviews with eight different offices

2. Research sub-question

Case 1
Observations of a live design process

Exploratory

3. Research sub-question

Case 2
Work with the students during supervision

Contribution

Figure 3.3.1 - The connection between the research questions and the methods used to collect the data for the different questions

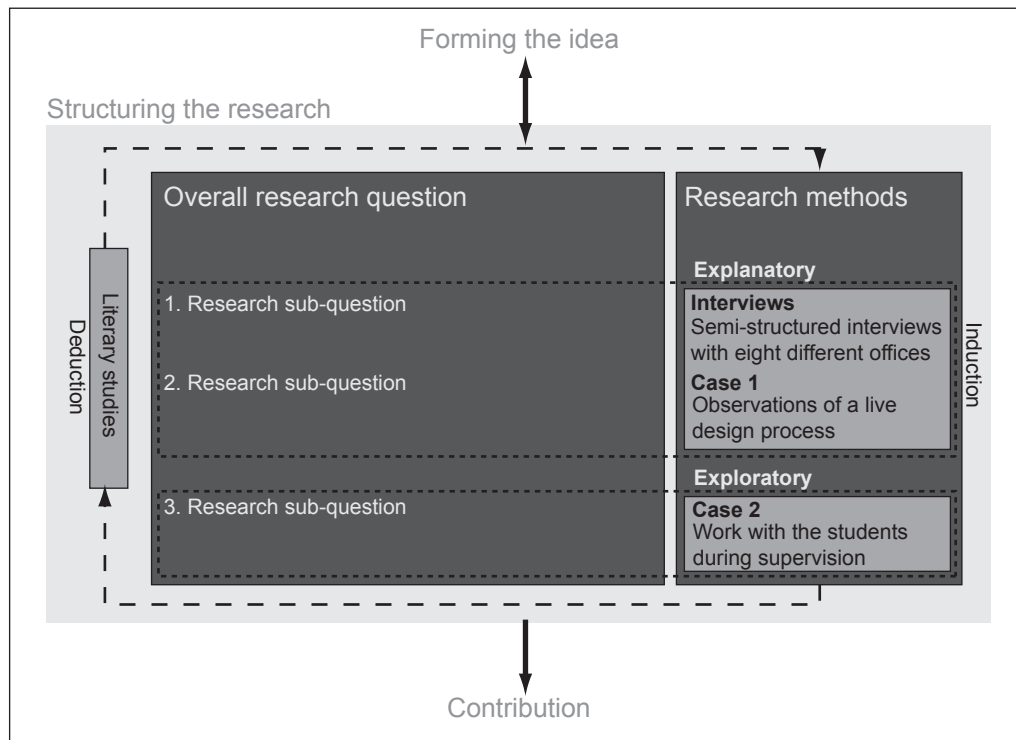**QUALITATIVE INTERVIEWS WITH EIGHT OFFICES INVOLVED IN THE DESIGN PROCESS**

The first part of the explanatory study are qualitative interviews with eight offices involved in the early conceptual stages of the design process, as seen in figure 3.3.3 with the relations to research sub-question one and two. In these interviews seven architectural offices and one environmental design consultant having a background in mechanical engineering have been interviewed. In order to explore their view and understanding of their own design process, it has been chosen to interview them about how they work during the design process in relation to a competition and their experiences with it. However, it must be acknowledged that the competition is a very compressed and limited part of the process. The reason for focusing on the competition is to focus on the early conceptual stages of the design process. Selecting the interview form for this part of the research is due to the wish to understand what the experiences of the eight offices interviewed are. However, this is done in the context of discussing how they work with environmental concerns and in order to understand how they currently work with digital tools to address the different environmental concerns, especially with a focus on how BIM is and can be used. This discussion is framed within the discussion of collaboration in multidisciplinary design teams and the importance of this collaboration.

These interviews have the form of conversations with the participants from the eight offices in order to gain knowledge about how they work in the early conceptual stages of the design process and what their experiences are with addressing these environmental issues and followed the interview guide seen in appendix 1. They are designed as qualitative semi structured interviews, where the aim is to gain an understanding of what their experiences are within these fields (Kvale 1994). Choosing a semi-structured interview form to explore this allows me as a researcher to discuss the different themes within the interview more freely and allows me to follow different paths during the interview that can help to elaborate upon the interviewees' knowledge in this field. This is then related to the literary studies made in relation to the state-of-the-art that forms the starting point for the research and is the theoretical framework for this topic. The interviews revolve around three main questions that outline three main themes in the interviews. These have a primary relation to the first and second research sub-question as seen in figure 3.3.4, though not using the wording from these two sub-questions.

As one can see the questions aim at providing an understanding of how environmental concerns are affecting the early conceptual part of the design process, as well as what problems they may encounter during this stage of the design process in relation to their work with environmental issues. The setup for the interviews is a conversational setting where the participants from the eight offices through the conversation are encouraged to reflect upon their work through questions – a setup where their experiences and expert knowledge can be drawn from the conversation (Kvale 1994). Here the literary review of previous research in the theoretical fields of the design process, environmental architecture and digital tools and applications and architecture is forming the framework for understanding these interviews. The interviews are seen as examples that are focused on discussing how architects approach and experience working with environmental issues in the early conceptual parts of the design process and through that discuss how this in relation to the exploratory studies can be a part of working towards a more analytical approach to the design process when exploring questions about environmental issues in the design process.

The selection of the eight offices seen in figure 3.3.5 was based on their current interest in environmental issues, as well as knowledge about how they addressed the design process in order to explore that further. Through the process four Danish architectural

Qualitative interviews with eight offices
involved in the design process.

A single case-study of the design
process in practice.
(follows the structure from Danske Ark)

Idea
Strategic briefing
Project management
It coordination
Preliminary design
Project proposal
Authority approval
Detailed design
Project clarification
Construction management
Technical inspection
Operation

A single case-study of students'
approach to the design process at A&D

Briefing
Sketch plans
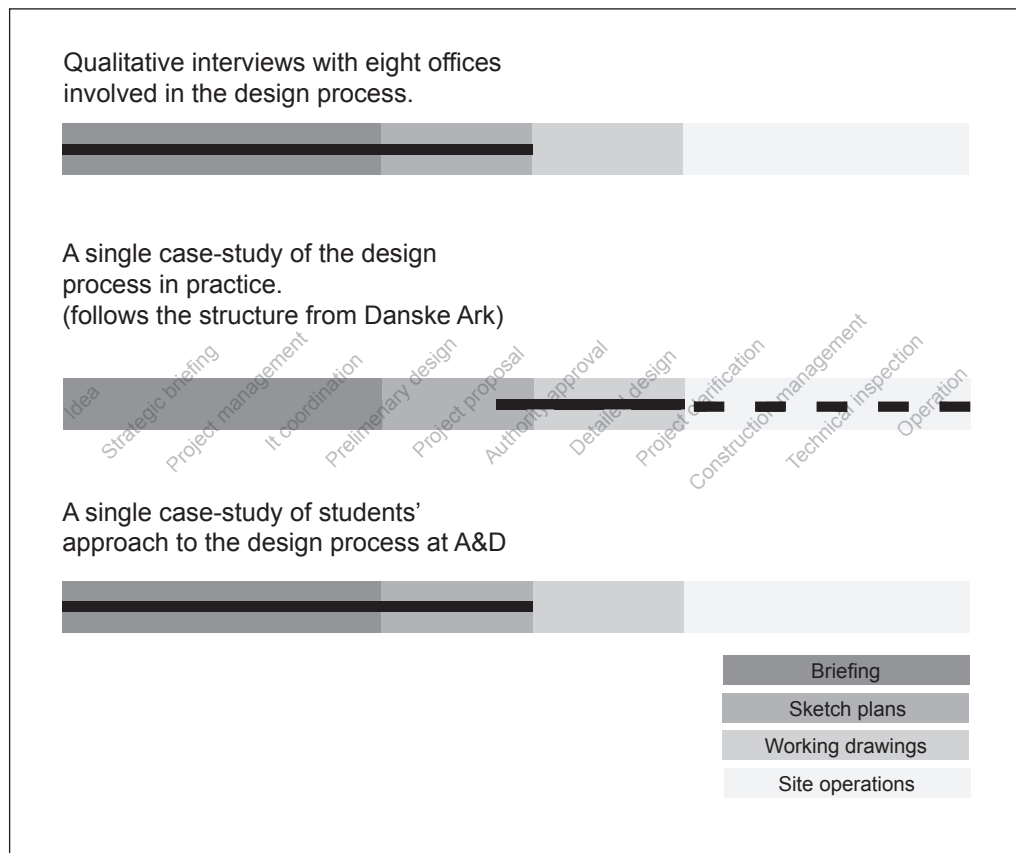Working drawings
Site operations

Figure 3.3.2 - The three parts of the research and to what stage of the design process they are related. The single case-study is represented here in the framework developed in practice, though it is important to stress that it is different from the what is described in practice. Here it is only to make a comparison between the stages addressed in the different parts of the research

Forming the idea

Structuring the research

Research question

Literary studies
Deduction

1. How do architectural offices, considered as being among the leaders within sustainable architecture, structure their design process, especially in relation to address environmental issues during the early conceptual stages of the design process?

2. Do they currently use digital tools and applications to address these environmental issues in the design process,and if so how?

Research methods

Explanatory

Interviews
Semi-structured interviews with eight different offices

| 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 |

Case 1
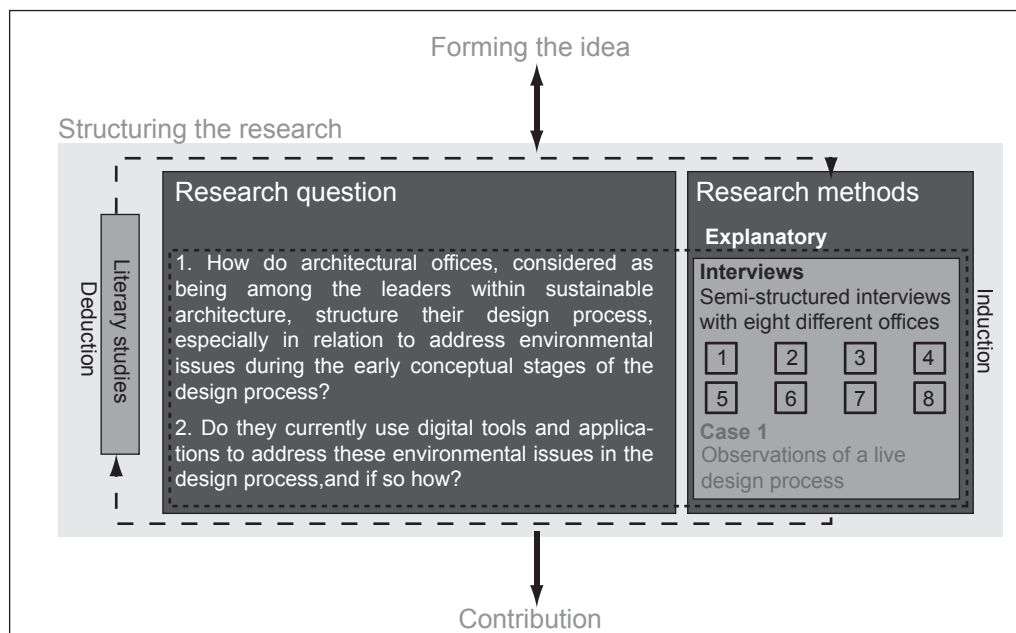Observations of a live design process

Induction

Contribution

Figure 3.3.3 - Unfolding the interviews with the eight offices in connection with research questions they are aiming at addressing

offices was selected as well as three English architectural offices and one English environmental design consultancy. As seen in figure 3.3.5 these offices range from large offices with an international profile and recognition to smaller offices with a more limited project portfolio. Furthermore they range from having national to international profiles. The size of the office is based on their profile data at LinkedIN. Their awareness of the design process and their explicit descriptions of their environmental concerns and approach to the design process all differed on their homepages. However all of them had worked with environmental issues in different competitions as well as in realized projects of different scales, so all of them were familiar with the discussions and the requirements they are likely to meet in such projects. The persons interviewed in the offices were specialists within the field of environmental architecture and had vast experience within the field and they worked as specialists with it in the offices or they were leading figures in the office. The selection of the offices was aimed at studying a broad range of office profiles in terms of getting information from both small and large offices. Furthermore interviewing the seven architectural offices about their experiences in the design process as well as the environmental design consultancy with the expert knowledge was done in order to understand if there could be any possible differences in how it was approached in the early conceptual stages of the design process. At last there were both the Danish and the English offices, which was due to aiming for a broader profile and a broader range of experiences. The four Danish offices were selected because the focus primarily is the Danish context, whereas the four English offices were selected as reference, because they have worked with these issues for some time and therefore have more extensive experiences.

Before the interviews an interview guide was made in order to help direct the conversation and ensure that the three main themes were addressed as seen in appendix 1. All the interviews were conducted in the offices of the participants and were planned in order to have sufficient time to get around the three different main themes in the interview guide. This interview guide was not sent to the interviewees and therefore they had no possibility of preparing for the more specific questions asked. All of them quickly looked at it as part of signing formal papers about the use of the interviews just before the interviews started. In these papers it was agreed that the interviews were made anonymous so no names or company names are used in the publications. Furthermore the interviews in Denmark were conducted in Danish and afterwards parts of the interviews used in publications and in interview report were translated into English.

The only information the eight offices had before the interviews were made was a brief mail explaining why I was interested in interviewing them about this topic as part of introductory presentation of what I did, a phone conversation to follow up on the initial mail where they also agreed to do the interview, and then a mail after that where a further elaboration of my interest in the different topics were made. This model was chosen due to the fact that it was important that the interviewees did not have the possibility to prepare specific answers to the questions and through that prepare something that they thought I would like to hear, but instead had to reflect upon their own design process and through the questions asked reflect upon the experience they had, as experts working within the field of architecture.

All of the offices were interviewed once and while it was meant to be one person from the office being interviewed, two offices showed up with several persons because they felt it would give a more detailed picture of the different issues they addressed, thus changing the setting from a qualitative interview with a single key person in the office to a qualitative interview with a focus group in the office, which also changes the dynamic in the interview situation, where the participants can interact and elaborate on the different directions they bring up during the interview. However in the analysis the data
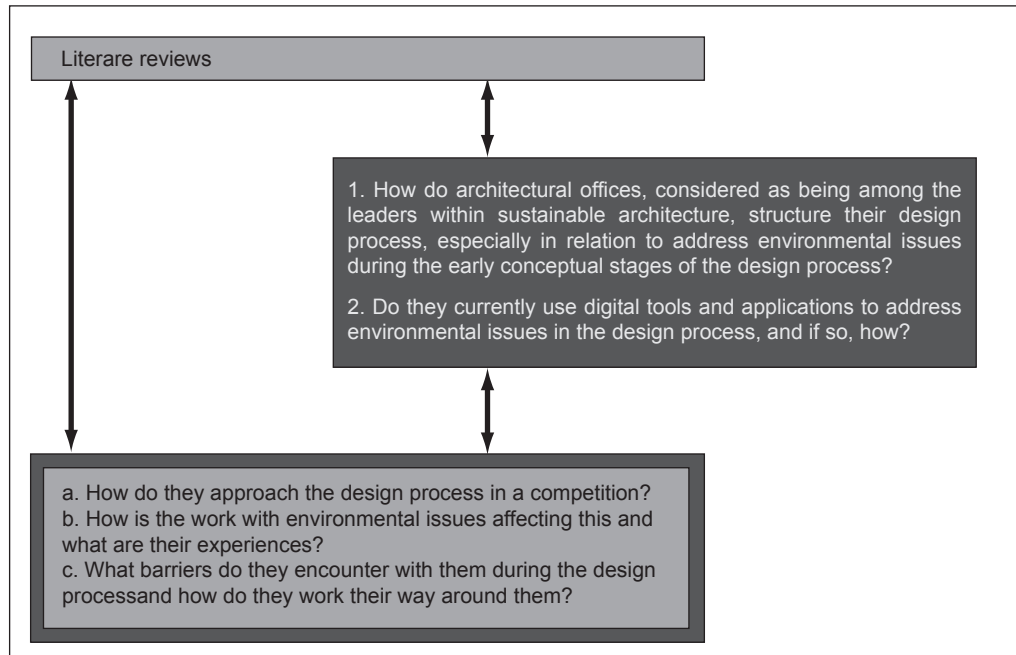
Figure 3.3.4 - The interview themes and their relation to deriving them from the research questions and the literature review

Office	Office type	Nationality	Profile	Emp.	Interviewee positions
1	Architectural	Denmark	National	11-50	Partner, Architect
2	Architectural	Denmark	National	51-200	Associate partner, Architect Architect Sustainability comptency leader
3	Architectural	Denmark	International	51-200	Partner, Architect
4	Architectural	Denmark	International	51-200	Associate partner, Design & Sustainability man., Architect
5	Consultancy	England	International	51-200	Principal
6	Architectural	England	National	1-10	Director, Architect
7	Architectural	England	International	51-200	Senior partner, Architect
8	Architectural	England	International	1001+	Urban designer, Sustainability researcher Environmental design analyst, Associate partner Head of info & design systems

Figure 3.3.5 - The eight offices interviewed and the interviewees position in the office, as well as the size of the office, the country where they are placed and their primary profile

have been analyzed and treated in similar ways. One of these offices was interviewed over two sessions, because of external circumstances that prevented all participants from being there during the first session.

The interviews ended up with 150 pages of transcripts and the analysis of them in this part of the research was done through coding the interviews in order to relate them to the theoretical fields studied – especially in relation to the studies of the design process. From the three main themes for the interviews the initial and primary coding scheme was designed. The first theme that focused on the approach to the design process in a competition was named "design process"; the second focused on how they worked with environmental concerns was named "environmental concerns" and the third concerning challenges and barriers in the design process was called "challenges and barriers". In figure 3.3.6 a figure of the coding is seen. First a list of keywords was made that related to the three themes, which was then the basis of a content search in the transcriptions of the interviews, which was done in both Danish and English. These keywords were in both Danish and English, as the interviews were conducted in different languages. From the content search the different sections of the interviews were read and they were expanded to get the keywords into the right context. This created the basis for an analysis of what the eight offices interviewed focused on in the different sections of the interviews to create a basis of data that can be used for further discussion of the research questions (Gill 2000). A maximum of five sections of the interviews within each office and each theme were selected and within these different discourses in the discussion were identified to elaborate on the discussion in an interview report (Petersen 2011). All together the coding formed the starting point of the analysis and was made through the qualitative data analysis program Nvivio 8, where the process of gathering, coding and analyzing the data happened (Lewins 2007).The use of the software is similar to an analogue process, though it allows for quicker searches and testing different schemes to study the data from different perspectives. In the following when referring and using interview quotes they will refer to the office number, as they are listed in figure 3.3.5.

A SINGLE CASE-STUDY OF THE DESIGN PROCESS IN PRACTICE

If we now move to the case-study in the explanatory part seen in figure 3.3.7, which is a single case-study, I will here elaborate on the different sources of empirical data that is forming this case-study (Yin 2003). Choosing the case-study for this part of the research it was determined that it allowed me as a researcher to study the design process from a different perspective. Using the case-study allows for a different evidence base and it allows for studying the design process directly, as opposed to using the participants' accounts as the only source of evidence, as it is seen in the interviews with the eight offices. Of course it can be argued that a multiple case-study of several projects in the one architectural office or of different projects in multiple architectural offices would make the outcome more reliable. A single-case design was chosen, because the focus is not on generalizing the design process, but to collect data about what the possible problems in the design process can be and through that create a second layer of data that can expand on the discussion from the interviews with the eight offices. Thus the case-study is also informed by the eight interviews.

The aim for the single case-study of the design process in practice was to focus on how the architects in this case approached the design process and how the design was developed. In the present case it was an existing project that needed to be developed from a conceptual idea that was approved by the client to construction work and finished building. Furthermore it was a project that was won in a tender and not a concept they had developed themselves. Throughout this single case-study of the design process
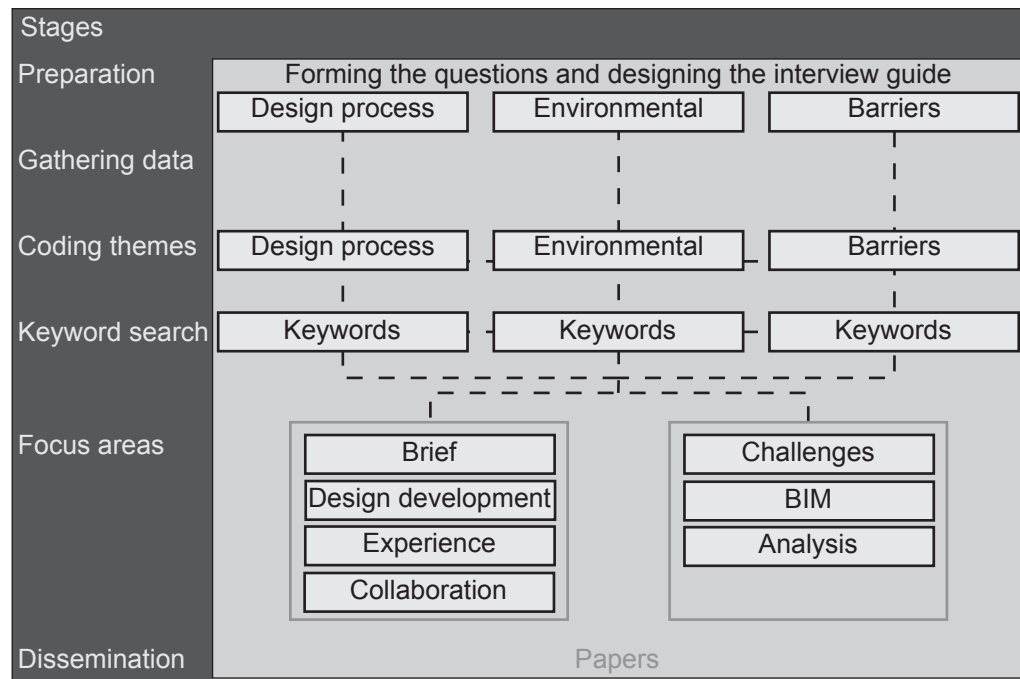
Figure 3.3.6 - The coding of the interviews and the steps that have been part of it from the deigning of the guide to the dissemination of the information
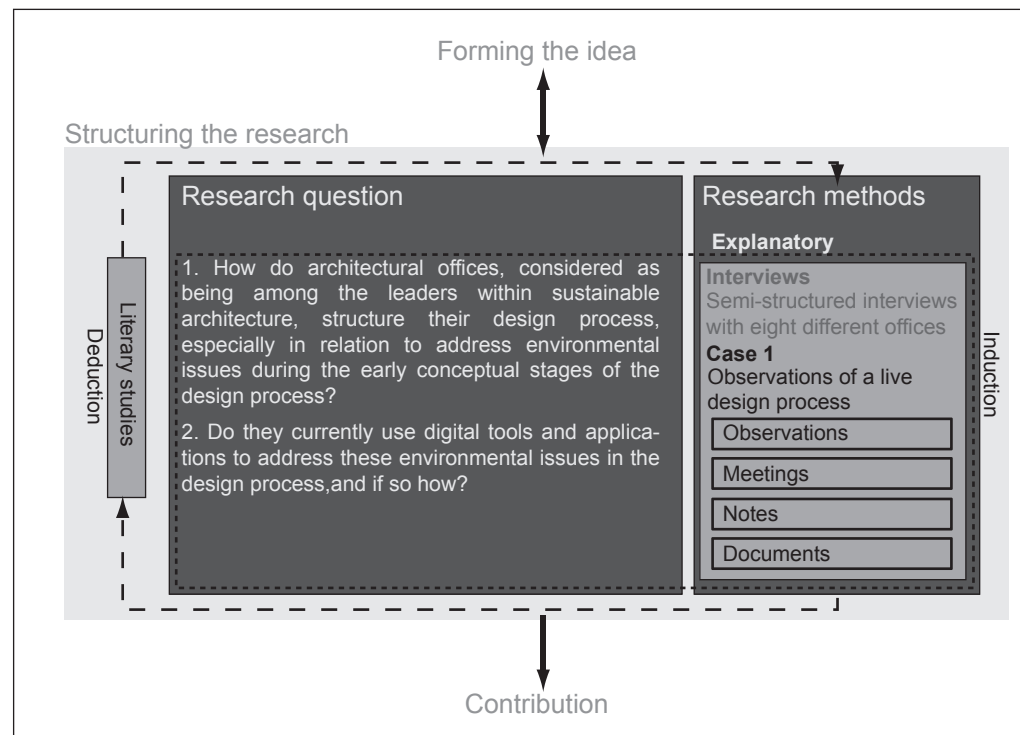

Figure 3.3.7 - Unfolding the case-study of the design process in practice with the connection between the research questions and the collection of data, as well as the sources of data

in practice data was collected to help analyze the process in relation to the interaction internally in the office as well as with other partakers in the design process at the given stage; the communication and mode of communication in the process and how they dealt with the information they got during the process as well as how they implemented that in the design.

In this single case-study different kinds of data have been collected to create multiple sources of evidence, thus making a triangulation of data possible (Yin 2003). As seen in figure 3.3.7 the data consists of observations of the daily work in the office; observations during meetings with consultants, clients and users; note taking and reflections during the day, as well as studies of documents in the form of mail correspondence during the process, minutes and agendas from meetings and documents from the early part of the design process where the concept was established. I will briefly elaborate on the reason for working with these sources of evidence in this case-study.

The observations during both the daily work and the meetings are based on the researcher being a passive observer of the events taking place and the observations are based on notes taken during the meeting and the daily life in the different settings as the work progressed (Bryman 2004). Besides these direct observations of the daily work and during meetings, the documents produced throughout the process have also been of importance. It has been the minutes and agendas from the meetings where the topics discussed, and the progression of the project can be tracked as well as drawings presented and discussed during the different meetings where the decisions can be seen in the building. Furthermore the understanding of what had been important in the building concept was crucial, as the observations did not encompass that stage of the process. This meant that previous documents, such as the brief of the project, the mail and document correspondences between the previous architect and the client were in focus and of primary importance.

As with the interviews, the observations of the live design process, consisting of notes, images, and documents as well as other material related to that, is stored in Nvivo8 that serves as a tool to help store and analyze the data from both the interviews and the observations creating a database with all the data from the case-study with the possibility to code and search the data and explore different ways to create coding schemes as well as explore different ideas and directions that can be seen in the data (Lewins 2007). In relation to the observations, their use has been focused on keeping a diary in the program of impressions of the different days and the progression of the live project, as well as storing minutes from meetings and including commentaries about thoughts and possible interpretations as well as images and drawings also with commentary. These have then served as the basis for the descriptions and analyses made later.

A SINGLE CASE-STUDY OF STUDENTS' APPROACH TO THE DESIGN PROCESS AT A&D

The aim of this part is the exploration of the third research sub-question, as it was seen in figure 3.3.1, thus aiming at the use of parameters affecting the environmental performance during the design process and if they can be used as drivers in the design process. This third research sub-question is related to the explorative part of the research.

The second single case-study is based on the work of the students at A&D, Aalborg University. Again this is a single case-study based on multiple sources of evidence (Yin
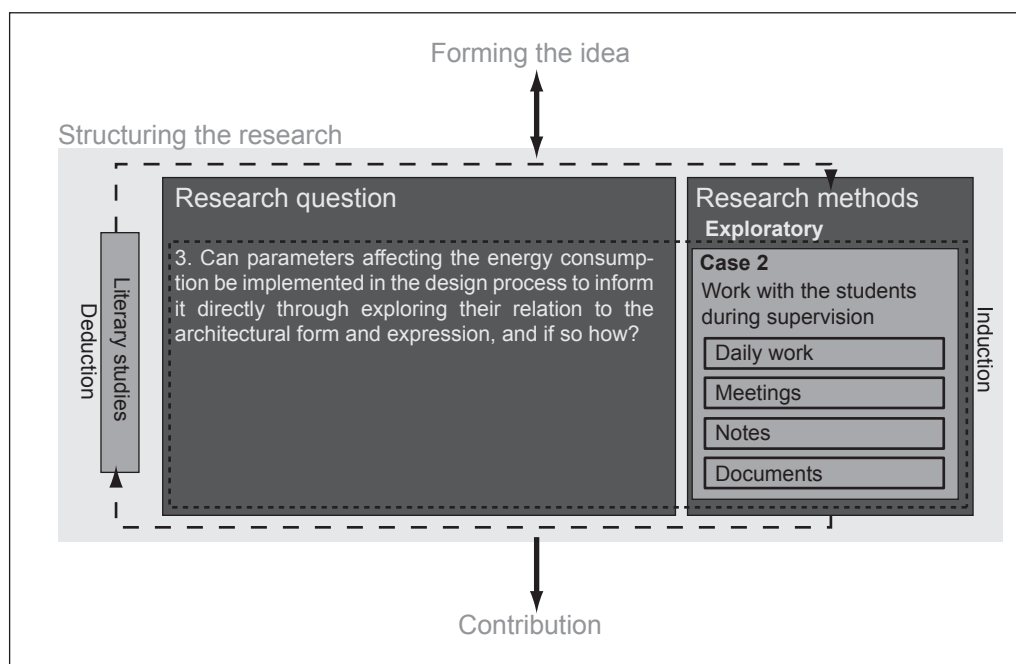
Figure 3.3.8 - Unfolding the case-study of the students' work with the connection to the research question and the data sources used for the case-study

2003). It aims at exploring how the explicit focus on environmental concerns, specifically low-energy performance, can be used in the design process as the students' work is based on working with passive houses and Zero Energy Buildings. In the observations of the students, it is important to stress that in the publication related to the present PhD, it is only the work of one student that is the basis and therefore it is only a single case-study. However in the role of a supervisor throughout the past three years working with these issues, a range of other observations have been made that supports the single paper published and the experiences within have played an important role in the understanding and reflection of this work. All of these observations are related to the students' work on the 8th semester at A&D, Aalborg University. Where the focus in the explanatory part of the research is related to the design process in practice, as it is discussed in section 2.1, the design process here differs and is located within an educational context. Here it is based on the IDP that is developed in an educational context and with an interdisciplinary focus (Knudstrup 2004). This is also described in the paper "Tools for Environmental Simulations and Calculations in an Integrated Design Process" (Petersen et al. 2010b).

With the students the observations made in connection with this case-study take a more active role and are aimed at driving the design process forward through putting out specific tasks and questioning the work, though, still without taking a direct part of the design process. This places the observations in a more participatory mode of observations (Bryman 2004). Working with the students in relation to this allows for having the complications and different demands seen in a live project in an office, though, with a better possibility of exploring specific issues and pushing it in different directions. The aim in this part is working with how specific focuses in relation to environmental considerations can help to drive the design process forward and create a design with a balance between the aesthetics and the technical demands.

In the work with the student(s) it is observations of their work. As seen in figure 3.3.8, there are different sources of evidence in this case-study. These are observations made during meetings with the students where the current developments in the project were discussed; observations during examination where the final project was discussed and evaluated; presentations during the process; documents produced during the process; the final report consisting of analysis, vision, process as well as plans, sections, elevations and visualizations of the project.

In the work with the student(s) the analysis of the data occurred as a continuous part of the work. It has been part of getting the student(s) to evaluate and test their ideas during the process and also forcing them to challenge the brief of the project. In the analysis I have focused on the way they have used the different tools and applications in the process to test and develop ideas as well as how they have used their knowledge about the environmental performance during the process. However, as it is a process of learning they have been in, the information they have had from the teaching has also played an important part in the development of the project.

SUMMARY

In the above the methods that create the basis for present research have been discussed. It is seen that the research is based on qualitative interviews with eight offices; a single case-study of the design process in practice and a single case-study of students' approach to the design process. They address the different themes of interest and the different research questions spanning both the explanatory part, focusing on the experiences of the architects and the exploratory part focusing on the use of parameters

affecting the environmental performance as drivers in the design process. However these different methods should not be understood as small detached units, but as a part of a whole that informs the overall question and part of working with the initial research question described in connection with the section "answering the questions". So the methods outlined here not only attempt to focus on their own specific area, but are part of a coherent research design that aims at addressing the overall research question. The question of quality and validity of the research, however, have not been addressed so far in this discussion and will be the focus in the following section.

3.4 ENSURING QUALITY AND VALIDITY OF THE RESEARCH

One of the key issues in the research design, besides creating a research design that allows you to explore the subject of interest, is to ensure that the research is of high quality and validity. This research is placed within a system of enquiry that is heavily influenced by changing concepts and a variety of different approaches – placing it in relation to what Groat and Wang calls a naturalistic system of enquiry, however other names are seen in this field as well, such as qualitative and hermeutic or constructionism (Bryman 2004; Groat et al. 2002) . The research design has taken its form throughout the research process and even though there were intentions about how it should be done in the beginning changes have appeared as the research has progressed as it has been mentioned above in relation to the research process.

The terms used traditionally when discussing quality of the research are internal validity, external validity, reliability and objectivity, however they are related to a positivistic paradigm and in a naturalistic paradigm where present research is placed these terms are can be described as credibility, transferability, dependability and confirmability (Groat et al. 2002 p. 35) . Both of these are seen in figure 3.4.1 . However when looking at the description of the case-study by Yin we see four similar steps; construct validity, internal validity, external validity, and reliability, for ensuring quality for the research (Yin 2009 p. 41) .In the present research, as seen in the last column in figure 3.4.1 it is the two latter that will be used.

The first issue to address is the truth value or construction of credibility in the research, which is closely related to the collection of data and the possible truthfulness of the data as it is seen in figure 3.4.1 Constructing the validity in the present research in relation to the case studies has been done by using multiple sources of evidence. This is seen in using several different sources in the interviews, where the transcriptions of the interviews also have been checked by the interviewees, as well as observations of a design process. In the Danish offices it is only the Danish transcripts that have been checked not the translated parts of the transcripts. In connection with the two case studies it is the use of observations in different situations as well as documents from different stages of the process that allows for the triangulation of data that is helping to construct the validity. An important issue in connection with this is also case-study protocols and interview guides that ensures that the procedure of the work can be seen.

Moving to the matter of applicability or transferability descriptions of the context in which this is set are made, being the design process and architects experiences with it. Furthermore in the treatment of the data a structure of coding has been developed where the three themes from the interview guide are also reflected in the overall coding themes. However, the coding is based around content search through keywords related to the different themes and discourse analysis of the quotes the search came up with. This also means that the themes in the quotes are overlapping, highlighting how interdependent the different themes are of each other. In relation to the observations

the diary is the primary source of information. The diary is composed of notes from the observations in the office and reflects the immediate observations of conversations during the daily work and meeting. This ensures an account for what has happened during the different stages. Besides the observations made it also takes comments and conversations with the parties involved into account, thus showing their opinion about the matters discussed, and the general progression of the design process in which they were involved. The diary allows others to follow the work and the building of the case and argumentation in it. Of course a natural part of ensuring the transferability of the data is the descriptions of the methods, as well as the peer-review process of the published conference papers and journal articles where external reviewers have validated the methodological approach and the results, as well as this having led to discussions about the research at conferences.

Looking at the last issue in figure 3.4.1, neutrality, this is seen in the use of keeping track of interviews, notes and literature through using Nvivo8 that has also allowed for using it as a database. From this, the raw data can be searched, coded, and analyzed in relation to the coding scheme developed for the research (Lewins 2007). This has been chosen because, it from my point of view, made an overview of the data better, as well as supporting the work with the analysis of the data. As for the reliability, the research with the case-study has followed a protocol. Interviews have been conducted by using an interview guide ensuring that the same issues have been discussed though the order in which topics are discussed can vary as can the wording. This is due to the structure of the interviews where the aim has been to make the interviewee use their own words and descriptions as the interview progressed and not suggesting wordings through the questions asked. The approach to the observations has been considered carefully, as have the different possibilities that could be a part of the observations. Also a diary of the observations made is important as it is a part of the data in the observations. Again the different sources of information have been of great importance in the work, as have the cooperation with the different participants in interviews and observations.

3.5 RESEARCH PROCESS

The use of the methods has been described in their separate ways above and from there it seems like a structured research process. However, it is not a reflection of the actual research process, but more of an idealized description of it. Looking back at the process it has been an iterative process where new information continuously has informed the research process. The starting point was focused on a much more experimental approach, exploring the use of existing digital applications in the design process and then moving towards more focus on exploring how the architects actually experience the design process – especially in relation to their work with environmental architecture, or to be more specific working with low energy architecture. Throughout this process the work with defining the methods has also been developed. So in relation to the overall research design there have been changes in how the different methods are used in the research. Especially the work with the practicing architects has been a challenge here and only at the very end found its final form. This also means it changed from what was very much intended to be participatory observations or action research, where I had a much more active role in the actual design, to being much more passive observations. However this was something that was anticipated from the beginning, because working on a live project with an architectural office could be difficult. Not because a lack of abilities from my side, but because my role in the design team could be difficult to define because I would have to be able to focus on an agenda with environmental concerns that would exceed what was in the design teams interest, thus pushing the design team in a direction that they had very limited interest in. After the collection of data for this

Standard	Positivism/ Postpositivism	Naturalistic	Case study
Truth value	*Internal validity* Equivalence of data of inquiry and phenomena they represent	*Credibility* Check data with interviewees; trinagulation, multiple sources data collection	Mulitple sources of evidence Establish chain of evidence Have key informants revise draft report
Applicability	*External validity* Generalizability	*Transferability* Thick description of context to assess similarity	Do pattern matching Do explanation building Address rival explanations Use logic models
Consistency	*Reliability* Instruments must produce stable results	*Dependability* Trackability of of expected instability of data	Use theory in single-case studies Use replication logic in multiple-case studies
Neutrality	*Objectivity* Methods explicated; replicable; investigator one-step removed from obejct of study	*Confirmability* *Triangulation of data;* *practice of reflexivity by* *investigator*	Use case study protocol Develop case study database

Figure 3.4.1 - Schematics outlining the quality and validity in the research and the different terms

single case-study the office actually realized that it could have been more interesting for them if I had worked along with them on a competition project instead.

But also on a different level iterations appear. Looking at the interviews they are all built over the same themes and the same main questions, but the way of asking slowly progressed into being more conversational in the later interviews. Also from the interviews conducted in Denmark in late 2009 to early 2010 and to the interviews conducted in England in the autumn of 2010 a difference can be noticed, though being based on the same literary studies. However, the experiences from the Danish interviews have had an impact on how the interviews in England were made. This is due to the fact that the information from the Danish interviews had started to be analyzed, which then slowly started to inform the interviews in England, making some of the wording more precise and giving a better idea of where more precision should be demanded of the interviewees. This is not something that has an impact on the actual result, though it can be argued that it would have beneficial to have had pilot interviews first to test and develop the model more than had happened. This is also something that would have been beneficial for the case-studies.

Throughout the process the reviews of the literature have continuously informed the process and the different steps taken in the research. Especially in relation to the work with the design process that through the research process has become more and more important. A "map" of the developments and the different iterations, at least in a rough form, can be seen in figure 3.5.1 where the process can be seen following the timeline, with the connections between the evidence base consisting of literature, interviews, and case-studies and the output of the research.
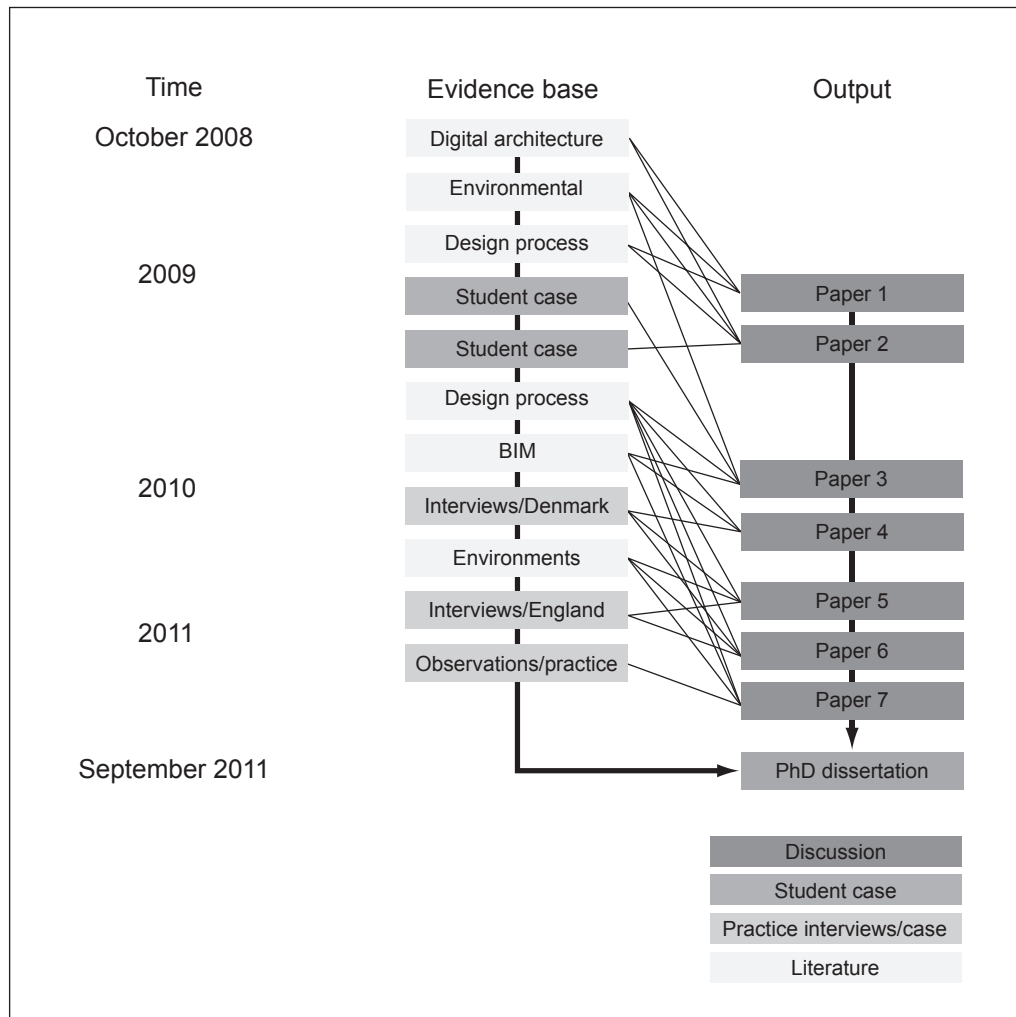
Figure 3.5.1 - A rough map of the research process showing the connection between the timeline, the evidence base and the source of the evidence and the output of the research

PART TWO

Where the first part was focused on building the framework for the PhD, the second part is focused on the discussion and analysis of the empirical data collected and through that addresses the research questions. This is based on the publications made throughout the course of the PhD research; however it is not limited to conclusive remarks on these publications, but aims at developing the discussion further. The final chapter in this part is also a discussion of the contributions the present PhD is bringing into this field.

This second part is built up around 4 chapters, where:

Chapter 4, Experiences from the design process in practice, deals with the experiences architects have with the design process in practice and addresses research sub-question one and two. This is based on the qualitative interviews with eight offices involved in the design process and the single case-study of the design process in practice.

Chapter 5, Digital applications and tools in the design process, is based on the discussion about digital tools and applications as a part of the design process and which deals with research sub-question three. This is based on the single case-study of students' approach to the design process at A&D.

Chapter 6, Challenging the design process, is focused on how the experiences from the design process can be used to inform the design process and address the challenges seen in the offices today and deals with the overall research question. This chapter focuses on the overall research question thus merging the two discussions from chapter four and five and discussing how the conclusions from these can be used to develop an analytical approach to the design process.

Chapter 7, Contributions, focuses on the contributions that the present research brings forward, as well as the future of the research where research areas related to the present research is briefly outlined.

It is through this discussion that the overall contributions will be found and through this general perspective that the relations between the theoretical standpoint and the data is connected.

4. EXPERIENCES FROM THE DESIGN PROCESS IN PRAXIS

In the literature review about the design process it was established that the term "design process" is often used interchangeably. It is used to cover the span between how the design process is seen in an overall perspective described through formal stages of the design process, to design strategies and to design cognition. In this chapter, which encompasses the main body of the data collected, the research conducted will be discussed, and it is based on primarily one conference paper and three journal articles, "An Integrated Design Process: One Step Further?", "Environmental Challenges in the Design Process: Qualitative Interviews with Eight Offices", "Approaching Environmental Issues in Architecture: A Single Case-Study of a Design Process in Practice", and "Reflections on the Design Process", as seen in figure 4.1 where the methodologies have been qualitative interviews with the eight offices, as well as the single case-study of the design process in practice. Thus, the chapter is focused on addressing the first and second research sub-question.

1. *How do architectural offices, considered as being among the leaders within sustainable architecture, structure their design process, especially in relation to address environmental issues during the early conceptual stages of the design process?*

2. *Do they currently use digital tools and applications to address environmental issues in the design process, and if so, how?*

This part of the research was conducted from late 2009 to the beginning of 2011 and revolves around how architects structure their design process in relation to environmental considerations in architecture and if they use digital tools and applications in the design process. In the papers based on the empirical data from the explanatory part the following concluding remarks can be drawn out:

a. Focus on identifying the pre-requisites for the competition as a mean to define the driving forces in the competition. (publication 2, 3, 4)

b. Utilization of previous experiences as a way to approach the design task from the beginning of the design process. (publication 1, 2, 3, 4)

c. A focus on how to address and analyze specific issues during the design process to assess their impact on the performance (publication 2, 3, 4)

d. Increased focus on the collaborative approach to the design process as a means to address environmental issues early in the process (publication 1, 2, 3, 4)

With these concluding remarks as the starting I would, in the following, like to focus on two issues with a point of departure in the interviews with the eight offices and the single case-study of the design process in practice and elaborate on the papers and the conclusions drawn in them. This will be done in two sections taking the different concluding remarks into account. The first section (section 4.1) will be focused on the brief and the analysis of it in order to define the prerequisites and the interrelationship between the brief and the design development thus expanding on remarks a and b. The second section (section 4.2) will be focused on how they address the environmental concerns in the design process and the way digital tools and applications are used in the work with the environmental concerns thus expanding on remarks c and d.

Papers

4	**An Integrated Design Process: One Step Further?** Petersen, M. D. & Knudstrup, M. 2010, in *SB10 Finland: Sustainable Community – buildingSMART*. Espoo : SB10 Finland Conference Secretariat s. 520-528. 9 s.
5	**Environmental Challenges in the Design Process: Qualitative Interviews with Eight Offices** Petersen, M. D. & Knudstrup, M. 2011, in *Architectural Science Review (Submitted)*
6	**Approaching Environmental Issues in Architecture: A Single Case Study of a Design Process in Practice** Petersen, M. D. & Knudstrup, M. 2011, in *Design Principles and Practices: An International Journal (Submitted)*
7	**Reflections on the design process!** Petersen, M. D. & Knudstrup, M. 2011, in *Scroope Journal (Accepted)*

Figure 4.1 - Papers primarily related to this chapter

4.1 FROM BRIEF TO DESIGN DEVELOPMENT IN PRACTICE

The starting point for the interviews with the eight offices and the single case-study of the design process in practice was the design process and how the architects, considered as being among the leaders within environmental architecture, approached and structured their design process. This came from the focus on how to solve the design problem that can be described as ill-defined or wicked problems (Rittel et al. 1973). Furthermore the literature review showed that there were different ways of approaching this. From the concluding remarks in the papers it was seen that it was about defining the prerequisites and using them to drive the design process; and about using their previous experiences to address the different issues they encounter during the early conceptual parts of the design process, including when it comes to the environmental issues. However, even though these issues are mentioned in the interviews they are only briefly discussed in the publications based on the interviews (Petersen et al. 2011b; Petersen et al. 2011c; Petersen et al. 2010). The problem with the understanding of the brief is seen more clearly in relation to the observations of the live design project and dealt with more thoroughly there, where it was seen that the understanding of the basis of the design proposal and the pre-requisites is extremely important in order to understand the basis for the design decisions taken during the process. In that case the project had to be taken from the concept that was developed by another office and to a finished building (Petersen et al. 2011a). In the present section the focus is on how the brief is approached and helps to inform the design process.

IMPORTANCE OF BRIEF AS THE POINT OF DEPARTURE IN THE DESIGN PROCESS

If we start by exploring the brief and its importance in the design process we see that five of the eight offices interviewed mention it as crucial for their understanding and development of the design, as seen in figure 4.1.1. For them it is the brief that explains what it is that the client desires and it elaborates on the different needs and demands of the client. In the interviews it is seen that they use it to *"…quickly say what it is that does that we win this competition. Afterwards you try to design your process in a way, so that you know which things need to be in focus..."* (Office 2). However in reading the brief, it is not necessarily everything that is defined clearly and it might point in different directions. As one of the interviewees expresses it, it is about *"…unlocking the brief. There might be other things in the brief that you are not aware of, because the people who wrote the brief aren't aware of it..."* (Office 6). This causes them to interpret what they think the client actually needs in order for the design team to be able to focus on issues that they find the client is concerned about. It furthermore establishes a hierarchy of what is important in the given project. Especially when it comes to environmental concerns, it is something the offices encounter during the initial stage of the design process where *"…the starting point is always the client's brief and the site and these two things always come together… I mean it is always in the back of our minds, to what extent can we push the boundaries of new ideas about sustainable design, to what extent do we just want to do something that is a kind of good or best practice building and what opportunities the client will enable us to explore? And there's quite a variety obviously according to the cost constraints and the commitment the client has towards environmental issues…"* (Office 7). So in the quotes here we see that it is important for the offices to know what the starting point for the design process is and to be able to understand what the client is aiming for. This is both on the general level, but also, more importantly, when it comes to working with the environmental issues. However if the client does not define any criteria's or what the offices consider as being insufficient criteria the office can themselves define *"…additional criteria's from a professional*

Office	Office type	Nationality	Focus
1	Architectural	Denmark	General talk about design brief
2	Architectural	Denmark	General talk about design brief
3	Architectural	Denmark	No talk about the design brief in general
4	Architectural	Denmark	General talk about design brief
5	Consultancy	England	No talk about the design brief in general
6	Architectural	England	General talk about design brief
7	Architectural	England	General talk about design brief
8	Architectural	England	No talk about the design brief in general

Figure 4.1.1 - Five of the eight offices talks about the brief in general terms as the point of departure for their design process.

perspective that then becomes a part of the project. These are what you have from your own knowledge and in fact they limit the amount of possible solutions to a few models…" (Office 1).

The importance of focusing on the environmental concerns from the beginning is also seen in the single case-study of the design process. Here it was seen that if it was something that came in at a later stage it was difficult to solve and it was something that was more time consuming, because the design team had to work with identifying the initial idea for the concept and at the same time respond to the problems the concept in itself posed in terms of the environmental performance (Petersen et al. 2011a). So the clarity of the intentions outlined in the brief and the ability and experience of the design team in addressing what the brief says are important.

EXPANDING THE BRIEF AND DEFINING THE PREREQUISITES FOR THE PROJECT

With the brief as the initial description of the design problem, it is the starting point in the design process. However, the question is how the architects or design teams actually address the work with the brief. One could put it, as how they analyze the brief. In figure 4.1.2 it is seen that seven of the eight offices interviewed use additional parameters to define more precise prerequisites for the project. Here the interviewees talked about the importance of the analysis and understanding of the brief and what was needed in the specific project. There were, however, differences between how they approached it. The first step was already revealed above, where one of the interviewees said that they define *"…additional criteria's from a professional perspective that then becomes a part of the project. These are what you have from your own knowledge and in fact they limit the amount of possible solutions to a few models…"* (Office 1). However, the focus on the experiences as the starting point is not something that defines a separate stage in the design process. For example there is one that says that for them to work with the environmental concerns their *"…approach is to do an awful lot of understanding of the site and brief etc...I'm part of a school of thought that says you should jump in and splash around with ideas, so you start to draw quite early on and see what emerges from it. If anything my own particular tendency is to jump to conclusions quickly. That's fair enough and those conclusions are based on all kinds of previous experiences to do with how buildings perform. So building physics is part of the initial moves you're making. Orientation is key to it and massing is key to it..."* (Office 7). So even though there, in this quote, is the focus on that there is a need to be thorough when it comes to the understanding of what is required, it is still based on previous experiences. Furthermore two parameters are mentioned that are important to address as one of the things in the development of the project when it comes to environmental concerns. The focus on the increased understanding of what the pre-requisites are is also seen when one of the offices says that *"…it is about early on to figure out what the prerequisite for this competition is and define not only the program, but also the climatic preconditions and the infrastructural conditions for the competition..."* (Office 4). This quote also mentions specific issues in connection with climatic considerations and how that affects the building. Further down in the same section of the interview it is elaborated upon when the interviewee says that *"…we have to rethink these things, because we need these contextual and climatic prerequisites actively when we design low-energy buildings today. Therefore it is important that these prerequisites are precisely defined…"* (Office 4). Now these two quotes point towards a focus on exploring specific issues in connection with the environmental concerns and actually making a thorough analysis before they start to design and sketch, though one of them is actually contradicting himself in the quote, when mentioning that he jumps to

Office	Office type	Nationality	Focus
1	Architectural	Denmark	Defining the prerequisites from the design brief
2	Architectural	Denmark	No specific talk about defining the prerequisites
3	Architectural	Denmark	Defining the prerequisites from the design brief
4	Architectural	Denmark	Defining the prerequisites from the design brief
5	Consultancy	England	Defining the prerequisites from the design brief
6	Architectural	England	Defining the prerequisites from the design brief
7	Architectural	England	Defining the prerequisites from the design brief
8	Architectural	England	Defining the prerequisites from the design brief

Figure 4.1.2 - In talking more specifically about approaching the design process seven of the eight offices mention that it is important that they define the prerequisites with the brief as the startingpoint. Furthermore they add their own layers of information to create a more specific framework for the process and in talking about the environmental concerns the seven of them are stating that it is something they are very aware of and talks about different parameters they use in connection with that.

conclusions. Again seven of the eight offices have similar approaches and they mention specific parameters that they use in the early stages.

Even though the seven offices above state that defining the prerequisites through the brief is important for them, the interviews show that the work with defining these prerequisites is very closely interrelated with the development of the design. In figure 4.1.3 it is seen that all eight offices are quick to go into sketching and to explore the design through different parameters they have identified as important in connection with the environmental concerns. This is especially seen in one office that has a very straight forward approach where they *"…follow two tracks. They will start simultaneously. One will be an analytical approach to the project where we try to map everything that has to do with the project's context, program and problems, site analyses, analyses of program and previous projects within the field, what has been done before and what hasn't been done before. A thorough analysis of what has to do with the program and assignment…"* (Office 3). In this quote it is seen that even though there is a focus on what has previously been done, there is just as much focus on what has not been done. They try to move beyond precedents in the design and challenge the traditions. Furthermore the quote explicitly shows that the understanding of the brief is closely related to the sketching and design development and that the information travels both ways in the process.

In talking about the analysis of the brief and the understanding of the prerequisites there is one office that stands out as having tried to address the issues from a different point of view. Where the above quotations are focused on previous experiences, there is one that besides that has attempted to *"…turn the design process around and started by setting out the technical parameters and then sketch from there. That means that we had to try to draw a house where the surface area cannot exceed this. If the heated floor area is like this, the surface area of the building should be like this there should be this many windows towards south and north. Then let's start to draw from here…"* (Office 1). Such an approach is, as they say themselves, to turn things upside down and start from the technical point of view. In this case they then explicitly work with developing information and making it more focused in order to guide the design process more precisely and to make the response to the brief better informed.

However looking closer into how the sketching and briefing informs each other there is not necessarily one specific way an office does it. One direction is using the sketching as an analysis as one interviewee expresses it when saying that *"…it can also be sketches that do not give you the solution, but we know that it is in this area it should be. We need to define an edge on the site… Now we made this solution, but it does not correspond with the first sketches in the analysis..."* (Office 2). This is something all of the interviewees express, though not mentioned as directly in the quote, but it is seen that they use the sketching or modeling as a part of their analysis and understanding of the brief and that these sketches become part of the development of form and expression of the building.

On the other hand there is the work with the sketches as the driving force in the design development. This is expressed in a quote when saying that *"…it's the nature of being a creative person you know. The minute after briefing, get the napkin out and start drawing something. It doesn't mean you're gonna be stuck with that..."* (Office 8). This eagerness to start sketching and exploring the possibilities is also something that is expressed by all the offices, which also means that it changes in the office and that the sketch can work as a way of analyzing as well as being analyzed. So it serves this interchangeable part of the design process and through the sketching both brief and form is informed.

Office	Office type	Nationality	Focus
1	Architectural	Denmark	Brief and development of design informs each other
2	Architectural	Denmark	Brief and development of design informs each other
3	Architectural	Denmark	Brief and development of design informs each other
4	Architectural	Denmark	Brief and development of design informs each other
5	Consultancy	England	Brief and development of design informs each other
6	Architectural	England	Brief and development of design informs each other
7	Architectural	England	Brief and development of design informs each other
8	Architectural	England	Brief and development of design informs each other

Figure 4.1.3 - All of the eight offices have a close connection between sketching, or using other forms of representations, and the analysis of the brief. Though there are differences in their specific focus in the office the interrelationsship between sketching and analyzing is very close.

This is made even more evident in the interviews where the design development is expressed as something that can be described as a convergence of ideas and thoughts into a final design proposal. This is not necessarily a linear or logical process. One of the interviewees says *"…the physical models become some kind of an evolutionary process that moves from something maybe very basic like studies of the building program to something that becomes much more complex and consists of multiple layers of information. It moves in thousands of directions with thousands of different ideas that need to be tested. Some of them are discarded because they don't work, some are kept alive and some ideas are paired into a third thing. We often describe this as an almost biological evolutionary process and you see a general evolution towards something more and more complex as it progresses through the different iterations..."* (Office 3). This quote states what happens in the design process very clearly. In another quote the same interviewee exemplifies what this process can lead to and how they use specific parameters in the process to push it forward. Here it is said that *"…the offices typically suffer from overheating but still wants the views, but without the direct sunlight… apartments can use the passive solar heating… so when you arrive at home in the evening it's good that the apartment has been heated by the sun during the day and you feel compelled to sit and enjoy the sun. It has made this tower a folded or bended version… where the apartments point towards the south and up to the sky, and the offices… gets light in from high in the sky and deep into the offices… and is orientated towards north to avoid direct sunlight..."* (Office 3)

The importance of addressing such basic parameters, as expressed in the interviews, from the very beginning is also seen in the single case-study of the design process in practice. Here it was seen that even though a environmental agenda was outlined, the basic parameters were not considered in terms of the environmental performance of the building. At the point in the process where the project was handed over to the office the research was conducted in, it became quickly evident that fulfilling the requirements became reliant on technological solutions. In the end the calculations showed that they could fulfill the requirements, but the work with fitting it in and all the adjustments took longer time and in the end one can speculate whether or not the solution became more expensive (Petersen et al. 2011a).

THE EXPERIENCES OF THE DESIGN TEAM AS THE POINT OF DEPARTURE

In the close interrelationship between defining prerequisites in the brief and developing the design it is seen that it is the previous experiences that are of importance. This is expressed by all eight offices as seen in figure 4.1.4. But there are differences, because the four English offices actually show a very structured approach to using the experiences seen in figure 4.1.4 whereas the four Danish offices shows a much more unstructured approach to using it, though they all say they use it and it is important as the point of departure for the design process. This more elaborate focus seen in the English offices were used explicitly in the communication with clients as well as collaborators in the design process and to help develop the design by outlining what the possibly solutions could be in the specific problems they encountered in the design process.

If we start by focusing on the move from the brief to the development of the design, it is seen in all of the offices that the work with the brief and the development of the design are closely interrelated and actually are dependent on each other. Here it is the previous experiences that are the thing that helps them to make the first moves. This was expressed in one of the previous quotes where the interviewee said that *"…I'm part*

Office	Office type	Nationality	Focus
1	Architectural	Denmark	Use of experience but without specific developments
2	Architectural	Denmark	Use of experience but without specific developments
3	Architectural	Denmark	Use of experience but without specific developments
4	Architectural	Denmark	Use of experience but without specific developments
5	Consultancy	England	Structured use of experience and development of it
6	Architectural	England	Structured use of experience and development of it
7	Architectural	England	Structured use of experience and development of it
8	Architectural	England	Structured use of experience and development of it

Figure 4.1.4 - All of the offices in the interviews stresses the importance of using previous experiences they have in the design prcoess. However the four English offices have a very structured process where they, in each their own way, have made their experiences operational through checklists, matrixes or other things. Through this they have a powerfull tool to help guiding the process and explicitly use and communicate their knowledge in the design process.

of a school of thought that says you should jump in and splash around with ideas, so you start to draw quite early on and see what emerges from it. If anything my own particular tendency is to jump to conclusions quickly. That's fair enough and those conclusions are based on all kinds of previous experiences to do with how buildings perform. So building physics is part of the initial moves you're making. Orientation is key to it and massing is key to it..." (Office 7). Another interviewee outlined that their approach started with two tracks where one is the analytical investigating of all kinds of issues they could find in connection to the project and where it in the continuation is told that *"…at the same time we have another track where we have a physical approach to the design process and we start to test and study what the analysis means on relation to the form, studies of the form, studies of program and volumes and how they are connected. So there we always build physical models..."* (Office 3). These are just two quotes showing the close interrelationship between the work with the brief and the sketching process and the use of their experiences.

Now in the above, the use of previous experiences appears to be applied randomly in the design process. However in the interviews with the four English offices, it was seen that they worked elaborately with transforming their experiences into an operative *"tool" or approach to the design process. This is very clearly seen in the quote saying that "…we have something called Sustainability Health Check...we use that to collect information on each project in the office, in each stage of the design process, so once completed we go back and collect the operational energy and feedback from the tenants and building users…that allows them to start challenging M&E's [mechanical engineers] and other consultants as well…"* (Office 8). Here it is a very elaborate gathering of information that is used. Of course, going to the extents of collecting data from the finished buildings in terms of energy consumption and feedback from users is not possible for everybody, though it must be considered as being of great value to know how the buildings actually perform as opposed to the calculated performance. But even the small companies can develop ways of making sure that their experiences are used explicitly in the design process, as seen in a quote from a small office where they say that *"…when we started out, we found on the first two or three projects that there was a decision tree we went down, which had a certain order and a certain logical sequence to it and we thought that actually we could break it down into a map. And the decision we made first had the biggest impact with regards to the environmental performance of the building…"* (Office 6). In this last quote the experiences are of a different character than the first and the evidence base with regards to assessing the finished buildings are not nearly as high. But it is a way to make their experiences operational in the design process and in supporting decisions and identifying key parameters in relations to the brief. Furthermore, it also allows for a coherent approach to the design process if others are involved, because the reasoning made by using these previous experiences becomes much more explicit.

When looking specifically at what the environmental design consultant from office five expressed, it is still the experience that is the most significant way to benchmark and evaluate the project throughout the project. As it was stated in the interview, when focusing directly on how they assess and evaluate the design solution early on in relation to the environmental performance, *"…I think we very often in the early stages of the project will do these things by reference to other projects. So you would look at exemplar projects from around the world, studying case studies and think about how that might apply to what we're doing… I guess the essence of being a good consultant in our field is 60% intuition and 40% perspiration in the modeling later..."* (Office 5). So it is seen that the use of the experiences in these early stages of the design process plays a significant part in the approach to the design process and how and which environmental issues are addressed.

Looking at these experiences and the importance of them in the design process the single case-study of the design process confirms what is said in the interviews. Here it was seen that it was experienced architects and engineers that were working on the project during the stages of the design process that the case-study was focused on. During the meetings they used their experience to assess the possible impacts and suggest solutions. However the point of departure for their work was a concept that was not informed by such experiences, which meant that the work they had to do, became much more difficult and there was discrepancies between the clients stated goal of achieving a low energy consumption (Petersen et al. 2011a). It also clearly shows the problems encountered later in the design process if the knowledge or experiences are not a part of the first design developments.

THE EXPERIENCES WITH COLLABORATION AND THE IMPORTANCE OF IT

When focusing on the collaboration, as it is stated in the literature review in section 2.1 it is important, that it is not just putting the different professions in the same team. It is seen that it requires an effort from all the involved parties and figure 4.1.5 shows that it is something all offices mentioned. One of the issues that is often mentioned is that architects and engineers work differently, therefore making the collaboration difficult. This is also expressed in the interviews where some interviewees mention that the engineers, generally speaking, are not used to working in an iterative process. As one of the interviewees says *"…some engineers have the impression that there must be some kind of recipe where you can say one, two, three, four, five, and six and then we're in – a very linear process. And often they have difficulties understanding that our process is circular and we have to return to different issues…"* (Office 2). However, it is important to be aware of that a quote like this is very general and one of the other interviewees contradicted it strongly and instead focused on the architects and client as being part of the problem, which is expressed when saying that *"…we tried this on a job yesterday where the client's ambition is way too big, the budget is way too small and an architect that is way too ambitious and a fee that is too small for the project. Our best interest would be served by doing the simplest most oversized air-condition job in the history… Instead I will argue with him for the next six weeks to get him to refine the building to make it better, because it is rubbish and I'm just trying to make it work, so that we can air-condition it sensibly, so the plant can be half the size it would be otherwise…"* (Office 5). It is the ability of the design team to move from the thoughts about what the project should be to actually develop a conceptual solution within the boundaries of the brief that they respond to.

In the interviews it is seen that all eight offices mention the need for working collaboratively between both architects and engineers and other consultants. When it comes to the experiences everybody mentions positive stories and experiences, however beneath those stories there are less positive experiences. As one of the interviewees expresses it in the interview *"…if I have to look back in relation to the different processes, then we have a traditional process where we try to pull it in a direction where we have challenges. It is when we get the program and start and the first meeting with our collaborators maybe is one week into the process and the engineers maybe show up unprepared. They haven't done their homework and can't come with the contributions they should…"* (Office 4). This is a very clear statement regarding the problems that can occur during the early stages of the design process. This is supported by another statement where the interviewee directly states that *"…we have been known to sort of go behind their backs and get other advice in order to reinforce the environmental design aspects of the scheme…"* (Office 7). Of course these are two negative accounts of it, but there

are positive sides that are mentioned during the interviews, that shows that a fruitful and positive collaboration is possible, as seen when an interviewee says that *"…I experienced that in [a project] where the engineers sometimes sat down here with their energy calculations and assessments of the PV-cells' efficiency, then you would sit for half a day or an entire day and test different things…"* (Office 2). And the power of this collaboration is seen when an interviewee says that *"…if we have a chance to influence the appointment of, particularly the mechanical services engineer life becomes a lot easier for us…"* (Office 7). So there is the recognition and awareness of the importance of the collaborative approach to the design process. Though, it is seen that it is not an easy task, because of the differences between the professions. But it is not only the differences that cause the problems. The amount of work that happens in such a collaborative way is limited as an interviewee outlines in saying that *"…probably most of our work comes from projects where the architect has already secured the work and seeks tenders from 2 or 3 engineers to take on the engineering role. In maybe 10% of project cases, very unusual, the client comes to us directly and says we have appointed an architect and we want you to be the engineers. That happens with a few projects but not many…"* (Office 5).

The importance of addressing the environmental issues from the beginning and possibly do it through a collaborative process with a multidisciplinary team is also seen in the single case-study of the design process. Even though the collaboration between the architect and the consultants in that project was good at that stage and they were focused on solving the task, it was seen that it was difficult for them to address the problems that were caused by, what in terms of the environmental concerns were ill-informed decisions (Petersen et al. 2011a).

SUMMARY OF THE STRUCTURE AND APPROACH TO RESPOND TO THE ENVIRONMENTAL ISSUES DURING THE DESIGN PROCESS

From the above, it is my observation that the brief and the prerequisites for the design process play an important part for the architects and design teams for the success of the project. It is the prerequisites such as considerations about environmental performance that are important here. It is in this phase that the basis for the project is defined, both through the reading of the brief and applying other layers of information through implementing previous experiences, as a starting point in the process. It is this analysis and the definition of the prerequisites that are used to benchmark the project throughout the process in terms of giving direction and focus to the design developments. Here it was seen that the English offices had a more structured approach when it comes to implementing their experiences in the design process. This could be because of their more extensive experiences when it comes to working with environmental issues in architecture. This also makes the communications with others in the design process more explicit as they can point directly to problems and solutions that might appear, thus showing possible solutions and problems during the design process. An important note that is made in relation to this is that this initial stage, where the first developments are made, must be much more collaborative that it actually is today so that experiences from the entire design team can become part of the design process from the very beginning. It is seen in the interviews that it does happen, but there are mixed experiences and it still is a rare thing even for the leaders within environmental architecture and that conflicts in the collaboration evidently appear, though the interviewees also mention the good sides of it. This collaboration is something that all the offices point towards as being an important issue for the continuous development of architecture with a high environmental performance. It is at this stage that the first work with analyzing and solving the design problem described in the brief and program happens and therefore it is seen that there is

Office	Office type	Nationality	Focus
1	Architectural	Denmark	Focus on importance of collaboration
2	Architectural	Denmark	Focus on importance of collaboration
3	Architectural	Denmark	Focus on importance of collaboration
4	Architectural	Denmark	Focus on importance of collaboration
5	Consultancy	England	Focus on importance of collaboration
6	Architectural	England	Focus on importance of collaboration
7	Architectural	England	Focus on importance of collaboration
8	Architectural	England	Focus on importance of collaboration

Figure 4.1.5 - All offices in the interviews mentions that collaboration between architects and engineers are of great importance in order to address environmental issues from the very beginning of the design process. They all have mixed experiences with it, but in general they all focus on the positive ones, though there are three offices that elaborates more precisely about the problems in terms of culture and traditions in the building industry

a realization about the importance of getting the needed information in at this early stage in order to help develop and assess these first developments from multiple perspectives. Working with developing the response to the brief is closely related to analysis and understanding of the brief and to split them into two different stages is not possible from these interviews. What they show is that it is still the experiences that drive the process forward. It is through the experiences that they identify key parameters, though here we see that these parameters are focused on environmental issues in the design process. The interviews also show that there is no singular right path that leads to the conceptual design proposal, but there are different ways. However they are all dependent on their ability to identify and use the key parameters in connection with the brief to drive the design process. This is confirmed by the single case-study of the design process in practice where it was my observation that the design team encountered problems at this stage because key parameters in connection with the environmental concerns had not informed the design process from the beginning. Something that in the interviews are closely related to the experiences of the design team, as well as a strong collaborative effort, even though the collaboration at such an early stage may not consist of explicit analysis of the environmental performance using simulations or calculations, so I find three things are evident from this section:

- Defining the prerequisites through the brief, thus creating benchmarks for the project. Furthermore to elaborate and expand on the criteria defined within the brief is important and requires explicit use of experiences from the participants.

- The work with the brief and the development of the design are highly interrelated and they help to inform each other, thus the design emerges in the span between the written brief and the development through sketches or other representations.

- Experiences are the key to define the prerequisites and develop the project from the very first stages and through the experiences layers of information are built on the project and filling in the possible blanks in the brief and development of the design solution. In order to address the environmental issues from the beginning it is the experiences from the entire design team that is needed, thus the collaboration is very important from the very beginning. This can be supported by the explicit utilization of experiences seen in the English offices.

4.2 DIGITAL EXPERIENCES FROM THE PRACTICING PROFESSIONALS

So far the focus in the discussion about the experiences of the eight offices interviewed, have been on the structure of the design process. However, the second research question was focused on if they used digital tools and applications and if they did, how? This is related to the themes about how they specifically work with environmental issues and the challenges they encounter in the design process. In the above discussion of the data from the eight interviews and the single case-study of the design process in practice the focus on the use of digital tools and applications in the design process have been omitted, but the approach to the design process is naturally related to the use of these tools and applications and how and if they can help to support and direct the design process. Returning to the literature review within this topic, in section 2.2, it was seen that there exists a variety of different approaches to it, and especially when it comes to the collaboration the digital tools and applications plays a significant part through the discussions about BIM. In this discussion about digital tools and applications in the design process two different directions could be identified in the interviews.

The first one was the uncritical and positive one where there is a slightly uncritical belief in what the increased possibilities within the digital tools and applications can give.

The second one is a more critical and experienced direction, though still being positive about the potential within using digital tools and applications, but through their experience and knowledge they are aware of that it is not an easy task and there are huge challenges within this field.

BIM AND THE COLLABORATIVE DESIGN PROCESS

I will start here by focusing on the collaborative aspect of the process and how the digital tools and applications, which primarily focuses on BIM, can be an essential part of the development and is considered, as being something that will be important in the future.

Looking at the critical direction, the focus is on different issues, though none of them are questioning the potential of the technology. Figure 4.2.1. The starting point for the discussion is that *"…the BIM philosophy is really about opening the information up, opening the process up, collaborating effectively..."* (Office 8). It is primarily three issues which are in focus when discussing the challenges with BIM from the critical direction. It is the culture within the building industry, the collaboration, and the level of detail. As one of the interviewees says *"…it has all to do with culture, behavior, practice, and we've got, you know, very many people, very experienced people in our industry, who, since they first entered the industry, has always known people to blame one another, not share the blame, not share the risk, not even sharing the reward..."* (Office 8). And the same interviewee continues in the interview by focusing on *"…the other thing I think we truly need, to foster that collaborative working, is standards and interoperability of the technology. I attended a BIM conference last week where I heard a number of people from the industry saying 'yes we can work effectively on a project if we're all using the same toolset.' And how can we live in a world where there is only one toolset? And it might not be cost-effective and it might not be the best thing. We have to make technology move on with the pace it does move, fairly fast, and improve our opportunities to do things better..."* (Office 8). So there is one of the interviewees that outlines the problems and challenges very clearly seen from their point of view and with the experiences they have in relation to using it. Keeping the focus on BIM as the collaborative platform opening for the possibilities of greater interoperability between the involved parties one office frames another issue quite precisely in saying that *"…if the architect is working on the same parametric model, which would be ideal, then you work on a moving target, but at least on an up to date one..."* (Office 5). Just by focusing on the collaboration it is evident there are lots of considerations that are needed.

If we move to the positive and uncritical direction we see that they actually focus on the benefits, but the collaborative challenges are not mentioned. This is for example seen in a quote when an interviewee says that *"…BIM is super cool. Here I primarily think of Revit, which we have fallen in love with in our office and that we use on many of our large projects. Where it becomes interesting for us and where we really can bring something in, is in relation to the architect's role as project administrator, which because of Revit, or other BIM tools, becomes more significant, because the main geometry is controlled by the architect..."* (Office 1). Here the tone is much more positive and uncritical in terms of the possibilities and the entire discussion about the collaborative challenges between the professions is left out of the discussion. In that respect such uncritical comments appears to point towards thoughts of BIM being able to solve the problems that are clearly seen and expressed in connection with the collaboration in the design process. Of course it is also seen that this quote is related to a very positive

experience when it comes to using BIM.

EXPERIENCES WITH USING BIM IN THE DESIGN PROCESS

However, offices with both a critical direction and the more uncritical direction have experiences in working with the BIM platform and both of them seem to use it at later stages in the design process where there is consensus in the design team about the concept for the design proposal as it is seen in figure 4.2.2. There is for example, one of the interviewees that claims "…We don't use it from the very beginning. We must be honest and say that. There we model in more forgiving programs you can say, where our focus primarily is on the spaces, the form, the geometry and the context and things like that. The bigger lines where Revit maybe have a tendency to ask too many questions on an earlier level and therefore also gives a different design process…" (Office 1). This is a quote that comes from the very positive and uncritical part in terms of the possibilities. So even here it is seen that there is an awareness of the fact that it is different. And as another one outlines in talking about BIM in the interview "…that you quickly be able to reduce the energy consumption in the building by 10% just by shuffling some of the products in the building around. And I think that at that moment when you don't have to make a major revision of the drawing base for a project, but it is a question of what you have chosen in the database, then I think there is a huge potential for development within that field…" (Office 3). In the last part the benefit is primarily seen as a way to manage the different components in the building and not as a way to inform it through expanding the range in the collaboration, so again it points at the benefits in the later stages of the design process when the design moves towards optimizing or adjusting a single design proposal.

But even though all the offices at the moment question the use of BIM early in the design process, there are some offices that have experiences with it and they are positive in terms of the experiences. This is for example seen in when an interviewee says that "… The team that is ArchiCad based are all Hungarian, interestingly, working in our office… They are led by a couple of people that know how to get the best out of that modeling process and who also have very good design eye and ability to produce the renderings that are used at the early stage. It's proved invaluable at that school project that's now going through [RIBA] stage E. Incredibly useful for cost management and area management at the early stages of the design" (Office 7). And again there are some of the offices that work with projects that are so complicated that they need a collaborative platform. This is for example seen in an interviewee's remark that "we always collaborate with our consultants. We've been doing it, had this integrated model with our consultants, in our complex buildings. You can't…build these very complex things without having a platform to collaborate from. Because this real-time collaboration with the engineers is needed and the contractors, because there is nothing fixed…" (Office 8). So the use of BIM is still challenging and there are multiple factors in using it in the design process, and when it comes to addressing environmental issues specifically there is nothing that suggests that it is making a significant contribution.

THE USE OF DIGITAL TOOLS AND APPLICATIONS FOR ANALYSIS AND EVALUATION IN THE DESIGN PROCESS

Having explored the questions about BIM and the possibilities in terms of collaboration and contribution to the design process, I will now move on to the more analytical tools and applications that are, or can be a part of the design process. These can also be a part of a BIM platform, but here they will be discussed purely on the basis of how they are used to contribute to the design process. Again I will use the two directions from

Office	Office type	Nationality	Focus
1	Architectural	Denmark	Uncritical reflection on BIM in the process
2	Architectural	Denmark	No specific mentioning of BIM in connection with this
3	Architectural	Denmark	Uncritical reflection on BIM in the process
4	Architectural	Denmark	Critical approach to what BIM can in the process
5	Consultancy	England	Critical approach to what BIM can in the process
6	Architectural	England	Critical approach to what BIM can in the process
7	Architectural	England	Critical approach to what BIM can in the process
8	Architectural	England	Critical approach to what BIM can in the process

Figure 4.2.1 - IN the interviews five of the eight offices had a critical appraoch to the use of BIM and through their experiences stated what the current challenges are with the program. This goes back to the collaboration and culture in the building industry. Two of the offices were much more uncrtical and focused on the positiv things without reflecting on the possible problems.

Office	Office type	Nationality	Focus
1	Architectural	Denmark	Experiences with BIM
2	Architectural	Denmark	No mentioning of experiencese with BIM
3	Architectural	Denmark	Experiences with BIM
4	Architectural	Denmark	No mentioning of experiencese with BIM
5	Consultancy	England	Experiences with BIM
6	Architectural	England	Do not use BIM
7	Architectural	England	Experiences with BIM
8	Architectural	England	Experiences with BIM

Figure 4.2.2 - Five of the eight offices mentions directy that they have experiences working with BIM and there is one that specifically mentions that they do not use it becasue their office is too small to make use of it and it is not worth the investment for them at the moment. Then there are two that are indefferent discussing it.

before as the point of departure and the discussion about the tools and applications for analytical purposes as it is seen in figure 4.2.3.

The starting point here will be the uncritical direction. Here it is seen that a dream among them is that there can be one tool that can be used to take the project from the first conceptual stages to the final stages where the building is on site, as it is expressed by an interviewee when saying that it would be good if we *"…could have the program that could go all the way through and where you maybe have one side of the program for the architect from the beginning where they sit with volume studies and basically are using planes and volumes and then later you dig out the volumes and cut holes and still is in the same program and during that process you start to extract the consequences of it in terms of daylight and energy calculations and even later you can study consequences of choices of different materials. It should be possible, because it is just a matter of programming…"* (Office 2). Another quote from the same office is also a part of outlining the problem when they say that *"…what we missed was a tool that could tell if the buildings should be orientated like this or how much of the facades that could be openings…"* (Office 2). Both of these express a somewhat uncritical belief in that the use of programs, or a program, can solve the problems and remove parts of their considerations.

On the critical side, the awareness of what the programs can and cannot do is much greater and much more diversified. A quote that shows the problems if they are not critical towards the programs they use is when an interviewee says that he has *"…been presented to projects in teaching and also by architects that have done their own Ecotect with outputs that demonstrates that their design is crap and they put it up on the wall, and say they've done an Ecotect analysis. 'But what does it tell you?'…"* (Office 5). From the critical side it is the use of specific programs for different tasks that appears to be important. For the interviewees it is also seen that there is an awareness of customizing small tools and applications, whether it be spreadsheets or more technical applications. This is for example seen in one of the interviews where they say that *"… We often for a particular project build a small spreadsheet and it will start to optimize glass performance typically, shading coefficient versus solar transmission, how do you tune that up. We tend to use quick and dirty spreadsheets and Ecotect early…"* (Office 5) or another quote where it is said that it is *"…tools that give them an understanding of the performance in terms of surface to volume ratio, a few simple indicators are so important at the beginning of the design process, because that will tell you so much…"* (Office 8). Furthermore they are aware of the limitations within the different programs that are used, which one of the interviewees outlines in the elaboration of what digital tools they use and at what stages, when he says that *"…we use TAS and even TAS struggles with some of the things we ask it to do…"* (Office 5). TAS is short for "Thermal Analysis Simulation software" developed by Environmental Design Solutions Limited.

So when looking at the work with digital tools and applications for analytical purposes in the design process and for evaluating possible conceptual solutions, it is seen that it is still a difficult thing. It requires a critical approach to the results and knowledge about what is important at the given stage of the design process. Furthermore, a division between the experienced and critical users and the more uncritical users are seen. Here the critical users have the ability to navigate and define what they need at a given stage in the design process, where as the others rely heavily on other collaborators in the design process and thus might not be able to question the design as thoroughly as they would like to. Here the critical people have either many years of experience with working with the environmental issues in architecture, or they are trained in engineering and have worked with architects on numerous jobs.

Office	Office type	Nationality	Focus
1	Architectural	Denmark	No explicit mentioning of digital tools and applications
2	Architectural	Denmark	Uncritical discussion about digital tools and applications
3	Architectural	Denmark	Uncritical discussion about digital tools and applications
4	Architectural	Denmark	Critical discussion about digital tools and applications
5	Consultancy	England	Critical discussion about digital tools and applications
6	Architectural	England	Critical discussion about digital tools and applications
7	Architectural	England	Critical discussion about digital tools and applications
8	Architectural	England	Critical discussion about digital tools and applications

Figure 4.2.3 - In talking about analytical tools and applications as a part of the design process it is again seen that there are five offices with a critical reflection on the topic. This is not because they do not use it, but because they are critical towards using it without questioning what it is used for and if it actually informs the design process.

SUMMARY

In the interviews it is my observation that the architects work with different digital tools and applications in the design process and I identified two groups, one being slightly uncritical in their approach to it and the hopes they have for what it can bring, and the other one being critical through the experiences they have had with it so far. Furthermore, three topics were identified in the interviews that were related to the use of the digital tools and applications in the design process. It is my observation in the interviews from both groups is that a critical approach is needed. However the critical group is much more elaborate and focused in the discussion and here they have an understanding of how specific questions can be explored in connection to working with different parameters. Also it is seen that even though BIM is a collaborative platform that can create a more streamlined process, it is not something that is used in the early conceptual stages of the design process, except for in a few examples. Instead, this part of the design process is focused on exploring different specific parameters with simple tools and applications, if they are used at all, and the collaboration between the participants.

- A critical use of digital tools and applications is required if they are to inform the design process and knowledge about the background and what the output from the tools and applications can tell you is needed to inform the design process.

- The use of digital tools and applications does not substitute the experiences or the focus on collaborations, but through a critical approach to their contributions they can help to inform the design process. This is especially seen in the discussions with the four English offices and one of the Danish offices

4.3 CONCLUSION

In the present chapter the focus has been on the experiences architects have from their practical work and is based on interviews with the eight offices, as well as a single case-study of the design process in practice in order to answer research sub-question one and two. It is my observation that it is a diverse field of interests and directions that drive the design process. In the discussion above, two main themes are discussed that involve the design brief and how it is approached as well as the use of digital tools and applications in the design process.

The first question that this part of the research aimed at responding to was:

1. *How do architectural offices, considered as being among the leaders within sustainable architecture, structure their design process, especially in relation to address environmental issues during the early conceptual stages of the design process?*

The first thing that is of importance is the brief and the understanding of the design brief. It is the design brief that formulates what it is the client wants and all the formalities for the design to fulfill, as well as the economy, thus outlining a framework for the architect and design team to work within. However, as it is also seen in the literature review, the design brief may not describe the full range of what they want or there might be uncertainties. So this is not new. What is interesting is that in the interviews the architects working with environmental issues then use their previous experiences to inform the brief and identify what it is that could be used to drive the design process in terms of addressing environmental issues. So they push for an agenda and they actively inform

the design process to push the boundaries as much as they can within the boundaries of the brief, especially in terms of meeting the economical demands. In connection with this the single case-study shows what the problem can be if the experience is not a part of the design process from the very first stages of the design process where the work with meeting the clients demands were made significantly harder at the later stages.

In the approach to the brief different directions were seen. There was one office that specifically mentions that they investigate what has not been done before and then twists their project in new directions. There were offices that have a more analytical approach and work hard on defining the prerequisites before the project takes form and there are offices that are using the idea generation as a basis for developing and understanding the brief. So there is no coherent approach to it and both the approach based on the generation of ideas quickly and the more analytical start is used interchangeably. However there is a common focus on that they try to push their agenda when they work with the brief and inform it beyond what it actually says, if there are undefined issues in it. This is done through using their previous experiences. Something the English offices do through a structured use of their previous experiences that have been made operational in different variations, whereas the Danish offices use their experiences in a more undefined and what can be seen as an unstructured way. However though there are differences in how they approach the work with the brief, it is seen that the work with the brief and identifying the key issues is closely related to the sketching and the design developments, thus informing each other.

As a last thing, the collaborative approach to the design process is mentioned. Here everybody was positive about the prospects of it, though there were mixed experiences where they felt they missed feedback or they felt the collaborative effort did not pay of due to bad collaboration. Here, experiences ranged from the engineers that did not do their homework to architects that had too high ambitions and too little experience in working to achieve the benchmark they set out. So even though there is agreement on the fact that the collaboration is extremely important when it comes to addressing environmental issues in the design process there are problems from both sides. Here it is seen that at the moment it is a matter of the persons they work with and not the companies. Though some companies might have more experience in the field than others, thus increasing the chance of getting collaboration with the experienced people, also because an equal level of experience can help to make it more of a dialogue. In connection with this the single case-study showed that the collaboration is important to ensure that knowledge about how to address the environmental from the beginning is needed. In this case the architect did not have that knowledge or the experiences that allowed them to address the basic questions related to the environmental considerations in the beginning of the design process. In terms of collaboration both the interviews with the eight offices and the single case-study showed that the formal structure of the design process is a barrier. In section 2.1 in the literature review this structure was discussed and the difference between the "traditional" and "integrated" was seen in connection with the manning of the design team at the different stages.

From this it is seen that it is the architects' and design teams' experience that is the core of working with the environmental issues in the design process and to identify what it is that can make the specific project move beyond what the client expect in terms of the environmental agenda. It is through the experiences they push the boundaries and they benchmark their projects, so two points can be drawn out as concluding remarks here.

- The use of previous experiences is the basis for working with the design brief and defines more precise benchmarks and prerequisites if the brief have uncertainties. Furthermore the experiences are the starting point for working with the development of the design solutions.

- The collaboration is key to being able to address the current environmental concerns in the design process and delivering projects of both high architectural and environmental quality where the environmental performance is reduced. Thus it is seen that the process is moving slowly and experiences in doing it are mixed.

The second research question is focused on

2. *Do they currently use digital tools and applications to address environmental issues in the design process, and if so, how?*

In the literature review it was my observation that the use of digital tools and applications in the design process can play a part in the design process and can help to inform it. However, most of the literature is directed towards the more experimental parts of the design process. In the interviews the architects did focus on the topic as something that is important, though the application and use of them needs to be done with a critical mind. Talking about the use of digital tools and applications two things were evident. First of all there were two groups of architects where one was experienced and critical towards the discussion and one was much more uncritical and appeared to be inexperienced in working specifically with digital tools and applications. Second there was the discussion about BIM as a collaborative platform and the focus on smaller and more specialized tools and applications in terms of informing the design process.

It was my observation that all of the interviewees used different kinds of digital tools and applications. The most widespread at the moment was the focus on BIM and the possibilities inherent in it as a collaborative platform for the entire design team and not only as an analytical tool, though analytical tools can be a part of it. On an overall level BIM is seen to be able to contribute to the collaboration in the design process and it is possible on a theoretical level. But as the discussion about BIM as a collaborative platform has shown, it might not be the technology itself that is the problem. Instead it is the lack of interoperability between the different tools within BIM. And another discussion in relation to this is the level of detail, because what kind of detail is needed at what stage differs. All the offices, if they use it, use it at later stages when there is a geometry that is set and they can start to derive data in the form of, for example, schedules with product information from it. However nothing in the interviews suggests that it actually helps to inform the design process about the environmental performance. Instead it seems to be more focused on coordinating constructions, and ensuring that there is coherency between the models used by the different collaborators, especially if it is complex buildings they work with. The environmental consultant expresses that, in theory, it would be good, because they would at least work on an updated model, even though it would be under constant changes, thus being a moving target.

What they inform the design process with when they use digital tools and applications in the early conceptual stages is small specialized tools like, for example, simple quick and dirty spreadsheets. So they move outside the BIM platform and focus on something that can help them to analyze specific parameters through a limited amount of information, thus moving this work to a more abstract level. This is something that should also been seen in connection with their previous experiences. Again it is their experiences that are at the core and are what they use to critically address the environmental agenda that

they are aiming for in working with the digital tools and applications. What is seen in connection with the digital tools and applications here is that they aim at being adaptable to the project. This goes especially for the critical group whereas the less critical and inexperienced group seem prone to hope for a grander solution.

In the discussion about these digital tools and applications my observation was that they are used and it ranges from the small special applications like basic spreadsheets and up to the complex simulation programs, however with the latter coming in at the later stages. But even though these digital tools and applications are discussed, they do not appear to be determinant for the process or the outcome. Seen in connection with how the architects and design teams approach and structure the design process it is the previous experiences that are the most important as well as the collaboration between the different parties involved in the design process that is the most important. It is the experiences of and the collaboration with the entire team that allows them to identify the key parameters and to develop the work with them through their experiences or through using specific digital tools and applications. Here two concluding remarks can be drawn out.

- The use of digital tools and applications are not paramount to achieve a collaborative design process or address environmental issues during the design process.
- The use of digital tools and applications requires a critical approach where experiences and professional knowledge are used to define the framework for the use of the tools and where the results are critically assessed to derive information to the design process and is no substitute for experience of knowledge.

5. DIGITAL TOOLS AND APPLICATIONS IN THE EDUCATIONAL DESIGN PROCESS

Above the discussion was focused on experiences from the design process as they are encountered in practice. Among the things seen, there was the use of digital tools and applications as a part of their work. This was focused on the use of them when addressing environmental issues during the design process. In the present chapter the discussion about digital tools and applications will revolve around the students at A&D's experiences, as well as how such digital tools and applications can help to answer questions specifically posed in the design process, thus moving from describing experience to working directly with it through supervising students and my own work with small practical issues related to the design process. As outlined in the paper "Tools for Environmental Simulations and Calculations in an Integrated Design Process" the students work with the IDP where it is the interrelationship between the technical and aesthetical considerations are used to drive and develop the design process (Petersen et al. 2010b). This approach is also the basis for my own educational background. Here the focus will be solely on this and how the digital tools and applications can be used to explore the relations between parameters affecting the environmental performance and the considerations about what they tell that can help to inform the spatial developments. Here in chapter five the focus is on answering research sub-question three.

3. *Can parameters related to building form and expression affecting the energy consumption be implemented in the design process to inform it directly through exploring their relation to the architectural form and expression, and if so, how?*

In the state-of-the-art it was seen that digital tools and applications are playing an increasing role in the way architecture is developed today, ranging from the use of 2D-CAD programs in the drafting process to the generation of form by using different approaches and methods based on digital applications (Oxman 2006; Kalay 2006). It is these digital tools and applications that are in focus in present chapter and the research is primarily conducted in a time span of about 18 month, from the end of 2008 to the beginning of 2010, and the findings made in three conference papers "Performance Based Parameters as Generators in Digital Architecture: An Environmental Approach", "Implementing Calculations of Solar Gains in Parametric Models" and "Tools for Environmental Simulations and Calculations in an Integrated Design Process", as seen in figure 5.1. The three conference papers are a reflection of the explorative part of the research where the methodologies used range from literary studies of state-of-the-art over a small experiment with implementing data about solar radiation into a parametric model to a single case-study of students' approach to the design process at A&D. In the papers that the present chapter is based on, a summary of the conclusions shows that:

a. Tools or applications exists both in terms of generating solutions as well as utilizing the analytical possibilities early on both from existing commercial tools and applications but also through implementing the information directly in parametric models. (publication 5, 6, 7)

b. A critical approach and knowledge about the specific areas and relations is needed to achieve a positive use of the tools and applications (5, 6)

c. A possible means to communicate specific information in the process and through that create or emphasize relations between the technical and spatial considerations (5, 7)

Papers

1 **Performance based parameters as generators in digital architecture: An environmental approach**
Petersen, M. D. & Knudstrup, M. 2009, in *Architecture and stages in the experience city*. Hans, K. (red.). Institut for Arkitektur og Design, Aalborg Universitet pp. 115-122.

2 **Implementing calculations of solar gains in parametric models**
Petersen, M. D. & Knudstrup, M. 2009, in *Design Modelling Symposium Berlin: Concepts Beyond Geometry*. Gengnagel, C. (red.). Universität der Künste Berlin pp. 167-176.

3 **Tools for environmental simulations and calculations in an Integrated Design Process**
Petersen, M. D. & Knudstrup, M. 2010, in *Re.building: 98th Annual Meeting*. Goodwin, B. & Kinnard, J. (red.). Washington : ACSA Press pp. 202-209.

Figure 5.1 - Papers primarily related to this chapter

Three themes will be explored under the headline "Questions, Tools and Applications in the Design Process" here in chapter five. The first will be the questions and what kind of questions it is, the second is the way the tools and applications can be used to analyze these questions, and the third is the collaborative dimension of the use of the tools and applications.

5.1 QUESTIONS, TOOLS AND APPLICATIONS IN THE EDUCATIONAL DESIGN PROCESS

In this fifth chapter the focus will be on how different digital tools and applications are used to analyze specific issues in the design process and through that help to inform it in the controlled environment of the studio where the focus is on teaching the students. The work the students do with the use of different digital tools and applications in connection with their design process and working with environmental issues, like reducing the buildings' energy consumption, is seen in the paper which discusses how the use of these can help the students (Petersen et al. 2010b). The students' work with these tools and applications is of interest in this discussion, because the tools here are used as a way to develop both skills and experiences when it comes to addressing environmental issues in the design process. Not just as an evaluation of the possible solutions, but as a way to study different relations between the architectural expression and the environmental performance. So the teaching of the students are focused on giving them experiences in explicitly exploring the complex relations between the architectural vision and the environmental performance of the building and using it actively in the design process. The questions that the students traditionally explore through the use of these tools are about orientation, compactness of the building, percentage of window openings, solar shading, and the orientation of spaces. All questions that are closely related to the first developments where the plan and volume of the building starts to take form. Furthermore these questions and the parameters they represent are also closely interrelated, which makes it important for the students to understand them and be able to address them on an explicit level, which also points towards communicating how these parameters affect the design and the decisions taken during the design process and through that inform the design process.

ASKING QUESTIONS THAT INFLUENCES THE ENVIRONMENTAL PERFORMANCE OF THE BUILDING

I will start here by focusing on what kind of information it is we need from these digital tools and applications and what kind of questions to ask them. This focus on posing the right question at the right time in the process is also something the publications are addressing. This is for example seen in the students' work with exploring the different parameters and get a feel for how they have an impact on the building expression and how that can be used to inform the design of the buildings. The question posed in relation to addressing for example solar insolation is discussed in connection with implementing the data directly in a parametric model in Grasshopper and getting a direct feedback as seen in figure 5.1.1 (Petersen et al. 2009a). The work with solar insolation is of importance, because it can help to inform the orientation of openings in the building and to achieve passive heat gains that the building can benefit from or it can cause overheating in the summertime. This was a small experiment with implementing data from the Design Reference Year (DRY) directly into a parametric model, and through that it created a direct feedback to the architect working on the model. So implementing this into the parametric model could be useful if the design team focused on solar insolation and they could expand it into working with the heat balance as the project progresses as
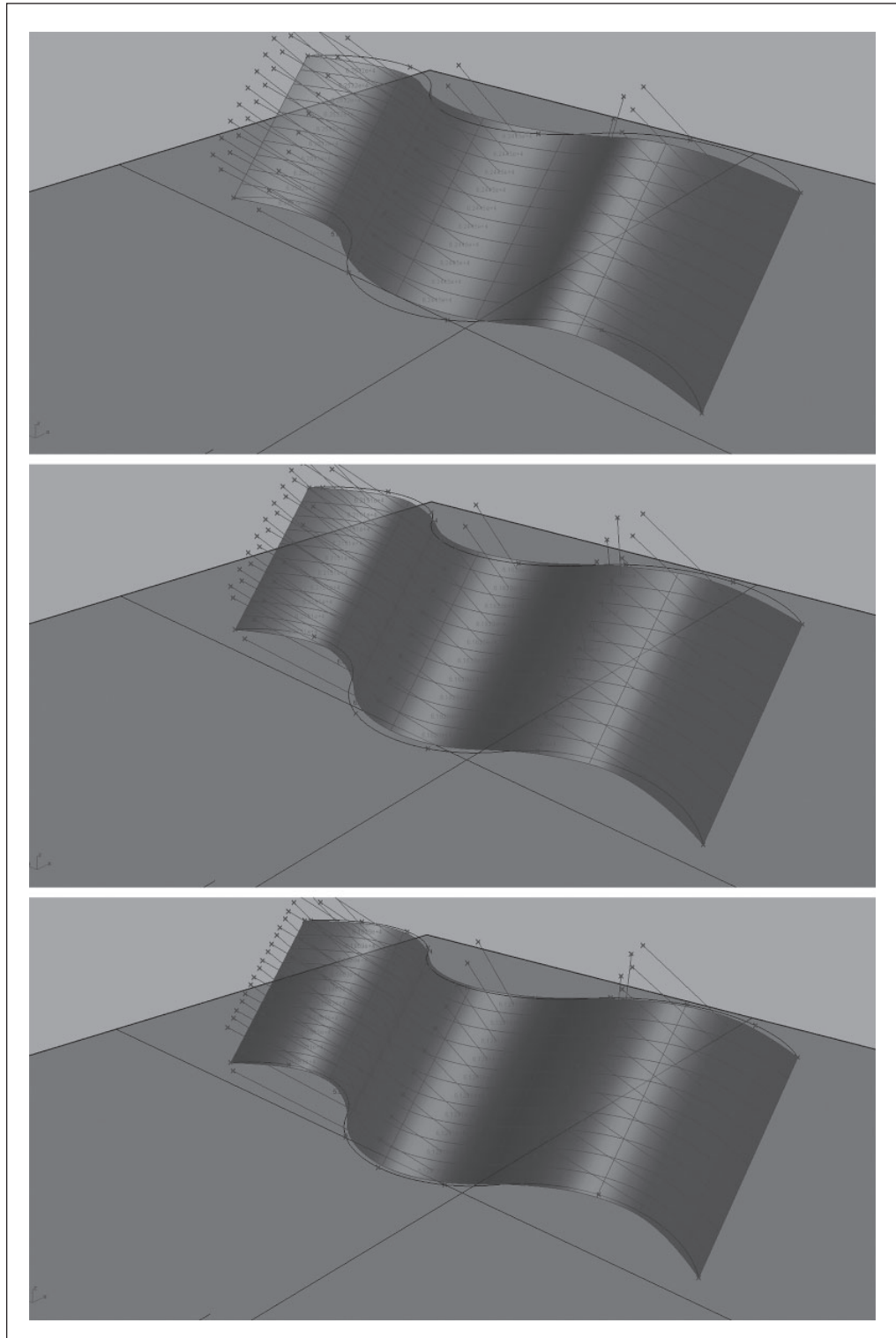
Figure 5.1.1 - Images from workong with implementing work with insolation levels on surfaces directly into Grasshopper

well as optimizing surfaces and orientations for PV-cells. Something similar was done by a student, but using Ecotect to optimize the orientation of the surfaces in relation to the idea about the outdoor and indoor spaces they wanted to create. The starting point there was the access to the sun and an orientation towards south in an angle with a maximum deviation of 25 degrees from south. Through these considerations a wave like plan was designed as the starting point as seen in figure 5.1.2 . In the end the student then used the first analyses to help define window sizes to optimize the passive gains in the building. In both of these examples it is just one parameter that is investigated and analyzed early on. However, as it is discussed in the example using a parametric modeling program and seen in the design the students did, it can inform the design process if the questions are posed critically and connected to the overall visions and ideas for the design. So both examples show that through using it critically it can help to inform and it can be done through using existing software or developing small scripts for specific projects. This focus on the solar insolation was one part of the studies the student made, however studies of volume to floor area ratio and studies of shadows was among the things that were explicitly addressed in the analyses as seen in figure 5.1.3.

ANALYZING HOW PARAMETERS CAN INFLUENCE THE ENVIRONMENTAL PERFORMANCE

Now we have already started to move into how the questions we ask the digital tools and applications are analyzed and how we can use them. In the work the student did, it was Ecotect and the implementation into a parametric model was Grasshopper. Traditionally the tools and applications are used in order to evaluate a given design and then make possible changes or discard it if it is not done too late in the design process. This is for example seen in some of the quotes in the interviews where they discuss the collaboration. Used like this the tools and applications serve as an evaluative tool and are used differently from the intentions of the developers. However in the work with the students the focus is on using tools to analyze parts of the problem and using the information such an analysis gives to inform the design process as it was seen in figure 5.1.2 and 5.1.3. In order to be able to work with the tools and applications in this way, it is important that the users (in this case the students) are aware of what it is they are trying to answer. Furthermore they need to have an idea about how it corresponds with their visions and how the program can help to work with informing these visions about the impact the questions can have. This means that it is paramount that the results of such analyses are critically questioned in order not to make decisions on a wrong basis. And in order for others to use the results, it is required that the approach to the specific analyses are transparent and systematic, because it is specific issues they address. So where the two above examples are focused on the solar insolation, another example could have been an analysis of the balance between the window openings' impact on the balance between the daylight factor and the passive heat gains.

What the approach seen among the students and in the studio in general opens up for, is that the use of these tools can be used as an analytical approach and explore the relations between the key parameters in the design process, thus linking the qualitative intentions of the spaces and buildings we design and the more quantitative assessments of the performance. It can help to address parts of "what if" or "how does" questions from the beginning and inform the design process. The approach to use the explorations of these parameters as drivers in the design process using digital tools and applications was also seen in the more theoretical study, where the possibility for using the parameters related to environmental performance were explored. Here it was seen that it does happen, though it is either in research, as seen when using multiple
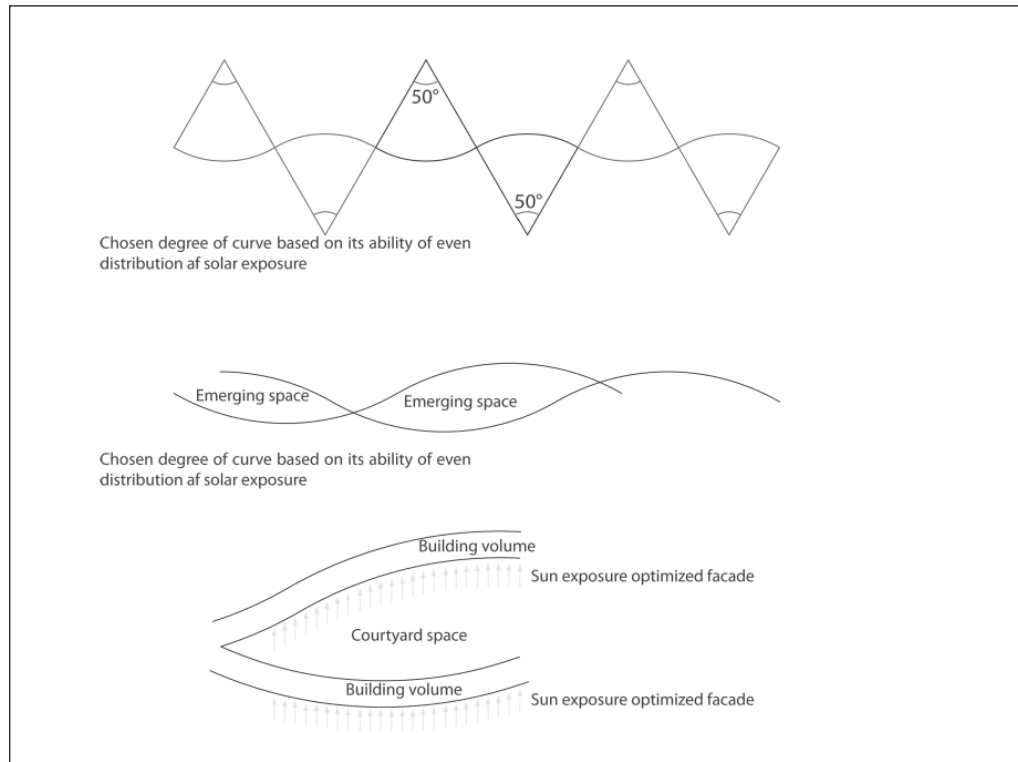
Figure 5.1.2 - Plan development informed by considerations about solar insolation by a student. Coutesey of Jonas Arsø Larsen
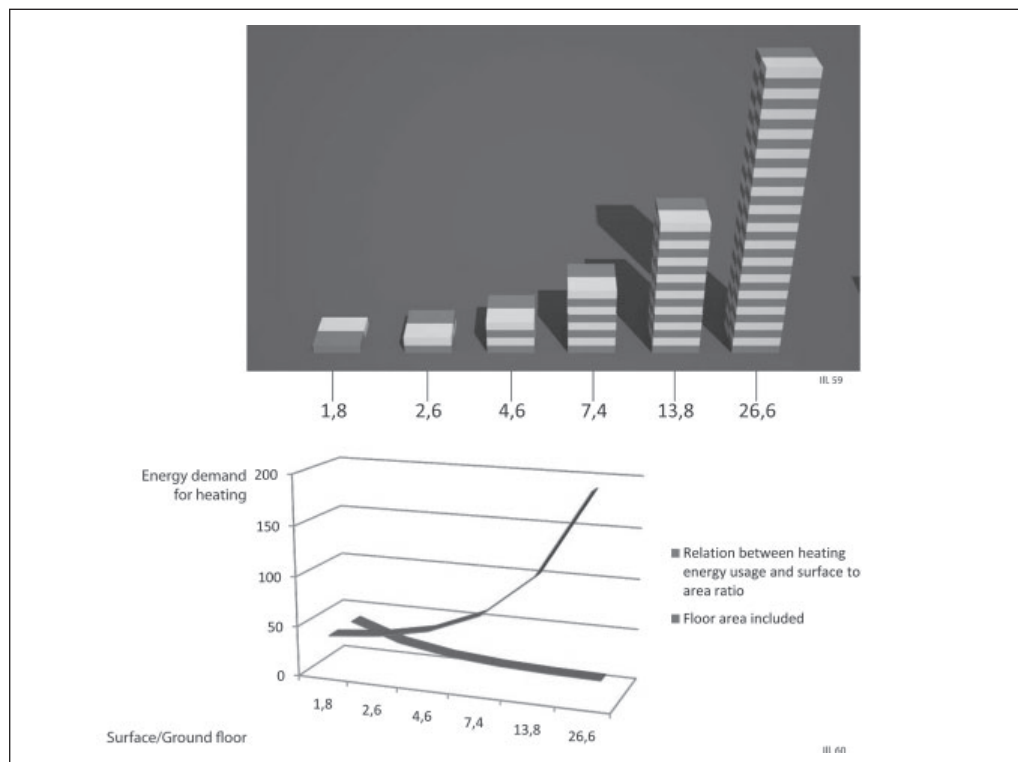

Figure 5.1.3 - Ananlysis of reletaions between height, floor area and energy consumption in order to develop the masterplan for a project. Coutesey of Jonas Arsø Larsen

performance envelopes or in experiments with different partakers in the building industry (Grobman et al. 2008; Petersen 2008). But it is rarely seen in practice. However, from the students' work, it is seen that it can be used to inform the design process, by making specific enquiries through the use of the programs. It is important to keep these enquiries on an abstract level, to maintain quick responses in the early conceptual stages of the design process and to make it actively inform in relation to the design process and not evaluations of actual design proposals.

Looking at the tools and applications that are used by the students, it is primarily quick and dirty spreadsheets that can help to inform them on what impact for example the volume of the building or the orientation of windows have. Otherwise it is tools like Ecotect or Radiance that can help to give an impression of for example light performance. So it is tools that can help to inform through analyzing the specific issues they want to investigate. Later in the process they start to use other programs that can help to evaluate on the performance of the building as the design becomes more detailed. Here it is for example BE06 (or BE10 today), PHPP or Bsim. So in the beginning it is rough tools that will tell something about how different parameters can affect the performance, whereas the later stages are focused on more precise calculations and simulations to document the performance and work in a more detailed manner with the design.

USING DIGITAL TOOLS OR APPLICATIONS IN COLLABORATION

Part of the discussion here is also on what kind of tools and applications they are. In the state-of-the-art in section 2.2 and in the interviews above, some of the focus is on BIM as the platform for the collaboration. And in order to work with these issues outside of the studio environment the students are in, a collaborative approach is needed. But the question here is if and how a BIM platform that is a collaborative platform can inform the design process. Returning to the experiences with the students and the type of questions that are asked, as well as the work conducted on this stage in the process, there is very little that points towards BIM being a crucial thing to actually work with these questions during the early stages of the design process. Above the analyses made are small secluded parts of work where information is drawn out and presented in order to inform the design process and help generating ideas. It is not information drawn out to evaluate a design proposal or necessarily related to a specific design proposal that needs refinement. The question is how the analyses can inform the process and how the information finds its way into the process. This actually points in a different direction from traditionally where the question is how we can derive information and analyses from the models the architects work with.

At the moment the question is not as much how the tools and applications actually work together as the stage of the design process addressed here is what you could almost call a pre-design stage or a track running parallel with the first stages of the sketching and design development, where different parameters related to the first thoughts about what the given building should be are investigated, as it was also mentioned in the interviews. Therefore, in terms of collaboration, the work is more dependent on the communication between the persons and the way the analyses are presented than being able to derive data directly from each other's models. Of course during the later stages when the design needs to be detailed and the geometry moves into a more set stage, a more collaborative platform, where information from the model can be used in more detailed analyses, can be a benefit for the design process.

SUMMARY

It is my observation that a critical use of the different tools and applications introduced to the students and seen in the more theoretical discussions can be used to inform the design process. However, it requires a critical focus on what kind of questions we need to answer at the given stage and how that can inform the design process. The level of abstraction early in the process should be high and through the analyses they can help to inform the decisions taken during the design process by serving as a knowledge or experience base making the information explicit. Furthermore the analyses can be a help in communicating the more quantifiable parts of the decisions basis in connection with the qualitative considerations about the spaces and the experiences of them. So it is not about making evaluations of design solutions at this stage, but about analyzing parts of a design problem and through that, informing the design process.

Expanding the discussion to encompass the discussion of BIM, there is nothing in the work discussed above that calls for it as being an decisive aspect of the work at such an early stage. The question is how the information we derive from the analyses are used in the design process in the early stages. So actually the data that needs to be implemented needs to inform the build form and not vice versa as seen in the case-study with the student. In the work the students make the communication is not dependent on a collaborative platform. All information is held within the group and their work is not dependent on interoperability between programs. However it must be considered as being something that in the documentation of the project can help, but during the early stages of analyzing specific parts of the problem there is nothing that points towards it being a benefit.

- Digital tools and applications can be used to analyze possible impacts of different parameters on a pre-design stage, thus helping to inform the design process from the very beginning through the explicit use of knowledge in the specific field.

- Collaborative platforms are not a prerequisite for successful environmental designs during the early stages of the design process, instead an adaptive approach is needed where the specific questions are addressed specifically

5.2 CONCLUSION

The focus in chapter five has been the third sub-question.

3. *Can parameters related to building form and expression affecting the energy consumption be implemented in the design process to inform it directly through exploring their relation to the architectural form and expression, and if so, how?*

In the above the discussion about the possibilities for working directly with parameters affecting the energy consumption through passive strategies is explored. From the state-of-the-art, the students' work and the small project with direct implementation of solar insolation data in a parametric model, it is seen that it is possible. However, the three things address three different levels of the discussion. Overall it shows that it is possible to inform the design process directly with these concerns. However, it does not solve the problems by themselves. First there is the connection between the question asked and how the digital tool or application can help to address it. It is the critical question of what it specifically is, we want to know and then investigating that on an abstract level in the conceptual stages with the aim to inform the design process that

is important. This is seen both in the literature, in the students' work, and the work with the parametric model. Furthermore implementing the data in the models or making the simulations or calculations in the programs is not the problem, but the problem is what it tells us and how we use it. This is also important because these analyses are not of the build form, but aimed at informing the process thus being a part of directing the design and giving form.

On the other hand there is the question about the small specialized tools and or the collaborative platform that can help to optimize and direct the information flow and have all information in one model. In the perspective of the three publications this chapter is based on there is nothing that suggests that a central system, as BIM platforms at the moment points towards, will be beneficial for addressing the environmental issues at these early stages. Instead the focus in this discussion has been on the adaptability and the application of our knowledge to the process. This also ensures transparency in the process, because we are forced to consider what it is we put into the program. What are the formulas in the spreadsheets or in the script for the parametric modeling? Or what are the formulas, rules, and mathematics outlined in relation to the more advanced scripting referred to in the paper discussing the use of environmental parameters as generators in digital architecture (Petersen et al. 2009b). It is the ability to work with the knowledge we have at this stage and make it operational during the early conceptual stages of the design process that is important. This is not, at least at the moment, dependent on a collaborative platform, as it was also seen in chapter four, but on our ability to work with the specific issues and still have an eye for the greater context of the design process. Also because there are many other parameters that are not measurable and that still need to be discussed as all of the papers related to this fifth chapter also mentions.

In chapter five I have moved from discussing the experiences of the eight offices interviewed and the single case-study of the design process in practice in chapter four to discussing how an elaborate use of digital tools and applications can be used to analyze specific issues in relation to environmental concerns in the design process – a discussion that has been based on students' work, small experiments, and theoretical studies. However the question of how the use of these digital tools and applications can be used more elaborately in the design process has been left out so far. In the following chapter I will focus on how the information and knowledge discussed in chapter four and five can inform the design process. Here two issues can be drawn out:

- The use of digital tools and applications is possible during the early stages of the design process to analyze how different parameters can be used to drive and inform the design process in terms of environmental performance.

- The use of the digital tools and applications requires knowledge about the specific fields and critical questioning in order to be able to inform the design process in a meaningful way where specific issues related to the environmental performance are addressed.

6. CHALLENGING THE DESGIN PROCESS

Having addressed the three research sub-questions in chapter four and five, the present chapter addresses the overall research question:

Can knowledge about architects' experiences with the design process and new digital tools and applications be used to achieve an analytical approach to environmental issues in the early conceptual stages of the design process and use that to inform the solutions that emerge through the process, and if so, how?

In the previous chapters it was found that the design process is highly dependent on previous experience and the expert knowledge of the participants in the design teams as well as the participants' ability to communicate their knowledge. Furthermore critically questioning the design developments during the early conceptual stages of the design process or as the students do, exploring the relations between the environmental performance, the site and the architectural expression of the building was seen as being important.

It is in this sixth chapter that experiences from the practice and the work with the students is starting to come together. This also means the gathering of the explanatory and exploratory part of the research that is one of the key elements in the methodological considerations. Here the discussions about if an analytical approach to the design process can be achieved will be explored. This will be done through two discussions. The first is a discussion about the move from practice to studio thus exploring the educational design process and the practical and if they can inform each other. The second is how the work with digital tools and applications seen in the studio can be used in practice.

6.1 MOVING BETWEEN PRACTICE AND STUDIO

From the discussion of the students' approach to the design process, it was seen that they used a variety of different tools and applications during the design process to be able to address the different issues in relation to designing environmental architecture. These were tools such as spreadsheets to quickly evaluate the energy consumption based on basic studies of the form, solar insolation on different surfaces and comfort in the building. All studies of importance for them and all issues that the student wanted to become an active part of the design process and help to drive the design forward. In the case described in the paper the main driver for the students were the sun and the orientation of the apartments, and their functions in relation to that (Petersen et al. 2010b). In practice these parameters also appeared as being important for the offices, however there they based their decisions primarily on previous experiences through specific analyses.

EXPERIENCE AND ANALYSIS FOR INFORMING THE BRIEF

Of course we need to recognize the differences between the students' work in the studio and the architects' work with the development of their projects and what the aim of the two things are. Where the studio is focused on teaching the students, practice is about designing buildings for a client. Therefore a direct comparison between the two things

cannot be made. However the work the students do can help to inform the process in practice and possibly direct it towards being able to address or explore the work with increasing the environmental performance.

In the eight interviews it was the previous experiences that were the driver in the design process. They served as the starting point for the design developments as well as a way of benchmarking the project in various ways, as did the agenda of the office. However the experiences were helping to investigate and define what could be the important thing in a project and they were the basis for the first developments of the design proposal. Where it becomes interesting is that the eight offices interviewed use their experiences to identify and interrogate the brief. It is their experiences they use to pin point the important issues in the given project and it is their experiences they primarily use for evaluation of the design proposals as the design process progresses. For the students the starting point is rarely their own experiences, as the experience base is limited. Instead they work through analyzing specific parts of the problem and using that to drive the design process forward and develop experiences. The question is if the previous experiences could also be used to identify specific questions that could help to drive the design process in terms of the environmental performance, thus using the previous experiences to generate specific focus points that can be investigated more systematically. This could be a part of moving further in this direction and using this questioning to focus on developing new knowledge and experience as an explicit part of the design process, thus also focusing on communicating this knowledge in a way that is understandable for the entire design team.

Focusing on exploring the brief through addressing specific questions and their relations to the overall ideas can also be a way to discover new ways and possibilities within the work. Approaching the design brief and the problem it describes from different directions or at least parts of the problem with an explicit focus on how this can inform the design process, the focus moves from being purely on solving the design, but also about understanding the problem and take that knowledge to other projects. So what we can see is that there can be a dichotomy between the tradition in architecture with working in a solution based tradition, as it is seen in the interviews, and the problem based approached that is seen in an educational setting. This means that it is becoming increasingly important to be aware of how the design process is approached on a very explicit level and work with developing ones experiences into knowledge that can be communicated and made operational during the design process. With this knowledge the design process can then be informed explicitly and the communication about the decisions taken and the reasons for it can be expanded and supported by explicitly referring to the previous experiences.

EXPERIENCE AND ANALYSIS FOR CRITICAL QUESTIONING IN THE DESIGN DEVELOPMENTS

However, as it was seen in both the interviews and the work with the students, the work with responding to the brief is also closely related to gaining an understanding of the brief and the problem described it in. This means that a critical approach is needed in connection with the design development. This is already seen in the interviews, however there is limited evidence about to what extent. All of them do, though, have some kind of pinups where the project is discussed from different directions and where it is tested

against the brief and other constraints in the process. So here we see that the testing of the design proposal is formalized in the offices. So we already see this and the work with testing the design progressions is an integrated part of the procedures in practice. Not necessarily directed towards the environmental concerns, but as a general quality assurance and making sure that the design is a response to the brief and have the focus they intend it to have.

In these developments it is the experiences the design team have, whether it is from years of experience in practice or experiences from analyses exploring certain relations connected to environmental performance. Here the students' analyses can be used to inform the form and help direct the design developments through outlining how specific parameters can affect the environmental performance as well as the architectural expression of the building, whereas the practicing architects use their experiences to benchmark and derive what possible solutions could be a response to the design brief.

In connection with this it is important to be able to work between the different professions and cross the boundaries between the participants in the design team. This is possible for the students in the cases because they are trained in the field between the different professions and move between the professional boundaries through an interdisciplinary approach. However in the design teams we encounter in practice it is important that they are able to behave in a similar way and be very curious towards each other and critically question the work they do as one of the offices expressed it in the interviews. This is something they need to learn. Today it mostly happens through experiences as expressed in the interviews, but professional programs are in place, both for professionals as half times studies where they learn to collaborate across the traditional professional boundaries and for students where students from engineering and architecture learn to collaborate through a cross disciplinary approach. Both of these differ from the students in the case-study here though, as they are working with an interdisciplinary approach. Through the focus on how the participants can help to inform each other, the scope of the critical questioning of the project can also be increased, thus broadening the questioning. This is something that the interviewees are aware of, but it is rare, therefore it is something that is important to develop as a skill and as a thing that is not only dependent on the participation of engineers, thus helping to focus the specific analyses related to the environmental concerns.

SUMMARY

It is my observations that the interrogation of the brief can be informed through the knowledge we have about the experiences architects have with the design process. Here it is the ability to critically question the design developments and the brief through the use of previous experiences and analyses. It is something we see done by architects already, but by focusing on the development of new knowledge in the field of environmental architecture, I will claim that a more critical approach can be achieved that can help to direct the design process even more and increase the focus on the matters that the offices find the most important and through that focus more on how to use analyses to inform the design process and move beyond their experiences. In connection to the present research, this regards reducing the energy consumption. Here students with their hybrid education show that it is possible. In practice this requires that the collaborative effort is strengthened and the work from the different professions is used explicitly to inform the design process from the beginning.

- The focus on how experiences can be used to develop through the projects is paramount for a continuous critical development of the prerequisites for the projects that can move towards more focused work with the environmental issues in architecture.

6.2 DIGITAL APPROACHES IN A PRACTICAL CONTEXT

The next question in connection with the challenges of addressing environmental concerns in the design process is the use of digital tools and applications and if they can be used to inform the design process. In the practical design process they are primarily used for evaluating a design proposal and usually not until later stages of the design proposal where there is a single design proposal as it was seen in the interviews with the eight offices. This means that the digital tools and applications are used for optimizing a design that primarily is based on previous experiences. However in the student's work it is seen that the digital tools and applications are used and they can inform the work that is done, before there is a final form or final concept. This moves the tools from evaluating to informing the design work. In terms of the practicing architects this can be of further use because they can ask more specific questions than the students and when working in a multidisciplinary team they can use the expert knowledge of the engineers to inform it further, thus defining a broad critical basis for the design developments that move beyond the precedent experiences.

Of course the use of these tools is also focused on the communication of how different parameters affect the building performance and how different strategies can be used actively in the design development. This can be further expanded in the collaboration between the different professions. In that respect it is not just about challenging and developing it in terms of environmental performance, but also about doing it in a way that explores the expert knowledge from the different fields involved within the design process and communicating it between the parties involved in the design process. In the end it means that it can be a part of developing the ability to address environmental concerns during the design process more thoroughly.

One of the concerns that can be at this stage though is the work with the different tools and applications. At the early stages the work with them is at the moment limited and it seems to be focused on the work with spreadsheets. This is even seen among students or it can be scripting that can help to implement it directly in that process. However, implementing it directly in a parametric program requires both knowledge about what it we want to investigate and how to actually do it, and it requires knowledge about scripting. On the other hand using a spreadsheet is more abstract and the output might not be as easy to interpret for the architect, so this might require closer collaboration with the engineer, thus increasing the possible workload on both.

SUMMARY

It is my observation that using the digital tools and applications as a part of the design process encountered in practice is possible. In fact, it is starting to emerge in the offices. The key is to critically question it from the different professions and to use that as part of analyzing parts of the problem described in the brief. It is about being able to define what it is that is important to know at any specific stage and know how to achieve answers to the questions. In that respect we move from an evaluation of a given design proposal to informing a design proposal in the very early conceptual stages. As seen with the students, the use of the digital tools and applications can help to define guidelines to

work within as well as communicating what possible effects different design decisions can have, thus it opens up for a more explicit use of the information that is affecting the design process.

-       Using the digital tools and applications requires awareness of what questions to ask at any given stage of the design process and also how to use this information in the design process so it is used to develop and inform the design solution.

6.3 CONCLUSION

In this sixth chapter the focus has been on the overall research question that was:

Can knowledge about architects' experiences with the design process and new digital tools and applications be used to achieve an analytical approach to environmental issues in the early conceptual stages of the design process and use that to inform the solutions that emerge through the process, and if so, how?

As discussed above there are differences between studio and practice. In the studio the aim is to teach our students to design, and a part of this is to teach them to reflect over the design they work with and teach them to evaluate the design from different directions. Here the focus is on the environmental performance. In practice the aim is to use the experiences and their knowledge about designing to develop projects for a client where environmental concerns are just one parameter that needs attention. Furthermore there are differences between the use of digital tools and applications outlined in the state-of-the-art in section 2.2 and the use of digital tools and applications encountered in practice. Where practice asks very specific questions when using the digital tools and applications and primarily uses them to evaluate solutions they are not the primary way to drive the design, the approaches outlined in section 2.2 are exploring the possibilities in using the digital tools and applications as the drivers in the design process and derives information that informs the design process.

It is my observation, in this chapter six, is that by studying and learning from the design process the individual offices use and gain knowledge about what it is that happens the work with addressing environmental issues can progress. The experiences from the offices show that they can use their experiences to be more operational in their process when it comes to addressing environmental concerns. Therefore the reflection of what we do becomes important in order to move beyond just using our experience in the process, to use the experience to challenge the boundaries of what we design. To challenge that is not necessarily a question of using digital tools and applications, though, but it is a question of being able to challenge the traditions and use that to drive the process forwards through helping to define guidelines and show the impact different decisions can have on the environmental performance. So the experience needed is both in general terms of the design process and in terms of being able to analyze and address specific issues in the design process. This also points towards an increased focus on collaboration the use of the experiences and the expert knowledge of the entire design team from the very beginning.

This also means that it is necessary to reflect explicitly on what we can learn from the design process and from the different projects we do, whether it is in practice or in teaching students. This point back to the discussion about how architecture is related to the scientific paradigms that were briefly mentioned in section 3.1. With the current

developments in the building industry and the increasing demands to the performance in our buildings the ability to learn from the previous projects and bring that into new projects is paramount. Not just for the architect but for the entire design team. This is not to say that architects and design teams from now on need to sit down and discuss the details in the projects endlessly, but there should be an increased focus on making explicit critical reflection of the work conducted and use that to form a knowledge base in the different offices, which will also help to move the knowledge from the individuals to the entire team. From this two concluding remarks can be drawn.

-       It is important to have explicit focus on how the previous experiences can be transformed into knowledge that is operational in terms of informing the design process and address the questions about environmental issues specifically during the design process from both technical point of view about the quantifiable environmental performance and a qualitative point view about the architectural expression of the building.

-       The design developments needs to be challenged from all directions during the design process and they need to be informed by the knowledge of all parties involved in the design process in order to be able to address the environmental issues during the design process and respond to them.

7. CONTRIBUTIONS TO KNOWLEDGE

In the past six chapters, the first three outlining the background and framework for the research and the last three discussing the results, the present PhD thesis has unfolded the research and the work towards addressing the research questions. In this final chapter it is the conclusion of the PhD, the contributions that will be in focus. It is here the ever present question of the contribution the research makes to the already extensive knowledge about the design process and the work with environmental concerns in architecture is addressed. The research questions were, as it has also been mentioned in the three previous chapters:

Can knowledge about architects' experiences with the design process and new digital tools and applications be used to achieve an analytical approach to environmental issues in the early conceptual stages of the design process and use that to inform the solutions that emerge through the process, and if so, how?

1. *How do architectural offices, considered as being among the leaders within sustainable architecture, structure their design process, especially in relation to address environmental issues during the early conceptual stages of the design process?*

2. *Do they currently use digital tools and applications to address environmental issues in the design process, and if so, how?*

3. *Can parameters related to building form and expression affecting the energy consumption be implemented in the design process to inform it directly through exploring their relation to the architectural form and expression, and if so, how?*

Throughout the present PhD thesis it is these questions that have been in focus. In order to explore them I have been through studies about the environmental considerations in general, philosophical and ethical considerations as well as stduies bordering to economics. All of these fields have a huge impact on the work we do within architecture, whether it is within practice or within research. Even though many of the considerations these studies causes are not directly mentioned in the analyses of the data in the past three chapters they are there informing our thoughts.

I am sitting writing this while looking and Picasso's picture of Don Quixote on his noble steed Rosinante with the windmills he is about to fight in the background is coming into mind. And why is it this comes to mind in writing the concluding remarks of my PhD? Well mostly because the discussions that often spring from environmental concerns or sustainability in general can seem like fighting these windmills. And the discussions about how to approach the design process likewise. But my aim here was not to fight windmills or to come up with a new windmill others can fight, but to take the experiences architects considered as being among the leaders within environmental architecture have and the experiences we have from our students and their approach to the design process and use them to inform each other and through that suggest a possible way that can help to cope with the challenges within architecture we have today. So even though these are concluding remarks they are not the recipe for designing environmental

architecture. But they are suggestions to how we can approach the design process in order to be able to address the challenges we have in architecture to day and meet those demands in a way that lets them inform the design process.

The task, one could say, is to be able to condense all of the concerns and ideas that are reflected in the studies here into something that informs the design process through critical reflections of what it is the given project should respond to. As it has been established here the brief is the starting point, but architecture is more than responding to the brief. It is basically the architect's or design team's response to how our built environment should frame our lives and to return to the introduction of the PhD and Karsten Harries' quote saying that *"Should architecture not continue to help us find our place and way in an ever more disorienting world?"* (Harries 1997 p. 4).

In the following sections I will summarize on the outcome and bring the final conclusion forward, as well as the future possibilities that the research in present PhD brings forward.

7.1 OUTCOME OF RESEARCH

First a brief answer to the research questions.

Starting with the overall research question we see that it is possible to use our knowledge about the experiences architects have with the design process to derive a more analytical approach to the design process, though it is not more analytical in terms of analyzing everything from the beginning, but in terms of focusing on specific areas identified from the beginning in connection with environmental concerns. Furthermore the experiences with digital tools and applications can help to analyze these specific areas and inform the design process through that. In fact we see that the use of these digital tools and applications starts to emerge as active parts in the design process.

1. *The eight offices interviewed and the single case-study of the design process in practice showed that the architects had different approaches to the design process and structured it somewhat differently. However three key issues surfaced in all of it. This was the understanding of the brief and the ability to move between the sketching and design development in the project; the ability to analyze and evaluate the design solutions quickly and through that inform the design developments and finally the importance of being able to collaborate on the entire design team, thus creating closer connections by working in multidisciplinary, cross disciplinary or interdisciplinary design teams in order to address environmental issues from the beginning. For all of them this was focused on how to address the environmental agenda as an integrated part of their other considerations.*

2. *All of the offices did use some kind of digital tools and applications to address environmental issues during the design process, some of them operating them themselves, others collaborating with environmental consultants. However their work was not tied up on the use of the digital tools and applications, but they*

were, if and when they were utilized, used to analyze specific issues in the given project and mostly seen as a way to get an understanding of how the specific project could be "optimized" in terms of basic environmental performance, thus being an evaluation of the solution. Furthermore they were often used late in the process when one solution was developed. All of the offices with more extensive experiences in the field had a very critical approach to the use of them and early on they were much more prone to use their previous experience to assess and drive the design forward.

3. *In the last part, being the explorative one, it was seen that students use parameters related to environmental performance or energy consumption and spatial considerations to drive the design process forward. Through that they explored the possibilities of the site and the intentions for the building they are working on. Furthermore it showed that the work with assessing the impact of the different parameters can have on the building is possible, though one needs a critical understanding of what the output tells and how to use it to inform the design process. Thus it is possible to use knowledge about these parameters and their relation to the building expression in the design process.*

In the following I will elaborate on these as contributions to the present field of research about how to address environmental issues as a part of the design process. I will do this through the brief, the act of design developments, and the collaboration.

INTERROGATING THE BRIEF

In order to interrogate this brief and unlock it, it is necessary for the design team to apply their knowledge and experience to it. Through the application of this they can be seen to start suggesting in what direction they should point it in order to respond to the brief and do it in a sensible way that also responds specifically to the environmental performance that is outlined. So already when unlocking the brief and setting out the direction for a given project the architects need to use their experience and it is also here the ideas about the expression of the building starts to emerge. Here it is also important to stress that the client has a responsibility in communicating clearly through the brief and help to set a framework for the design process. They can be seen to ask two basic questions at this stage. Have we worked with projects that has similarities to the one we have now? If we did, then how did we approach the project(s) and what did we do to address the issues? Thus a starting point is defined, but not to copy the projects, but to learn and develop from them. This can also help the design team to point towards where the problems were during the design, thus directing the design team to be aware of that and avoid problems they previously had through the increased awareness. In this respect an explicit focus on deriving experiences from previous projects is an important issue.

In order to unlock the brief a more analytical approach can be detected in the interviews. Here the English offices used their previous knowledge explicitly to unlock the brief and benchmark it. Through that they could point at what parameters and standards they should aim for. In the students' work it was also seen that the focus on exploring specific parameters could be used to drive the design process. So here two different ways of analyzing or approaching the core of the problem is outlined. What it points towards is an explicit approach to what is important and the exploration of the relations between the environmental performance and the intention of the architecture and the spatial considerations that move beyond the measurable performance. So it is seen that it is about identifying parameters and making knowledge about how they can be made operational in the design process and help to drive the design process.

It is my observation that the unlocking of the brief potentially can be explored through combining the two analytical parts outlined by the architects and the students. Where the architects rely on analyzing through experience, the students does it through small tools and applications. However we also see that small tools and applications are used in practice. This is mentioned by several of the offices.

DESIGN DEVELOPMENTS

From the brief the design starts to develop. This can happen while the brief is explored, thus helping to direct the work with unlocking the brief, or it can be more in continuation of it, thus the brief and the prerequisites in it already defines the benchmarks. These are the two general directions that are seen in the interviews and the case studies. However, the two approaches are used interchangeably by the offices. So even though the English offices rely heavily on their previous experiences to define the pre-requisites they are still exploring the brief and the possibilities in it through sketching while the design is developed. This relation between the analysis of the program and brief and the sketching and design development is seen more specifically in the quote where an interviewee says that *"…they will start simultaneously. One will be an analytical approach to the project where we try to map everything that has to do with the project's context, program and problems, site analyses, analyses of program and previous projects within the field, what has been done before and what hasn't been done before. A thorough analysis of what has to do with the program and assignment…"* (Office 3) and continues by saying that *"…the physical models becomes some kind of an evolutionary process that moves from something maybe very basic like studies of the building program to something that becomes much more complex and consists of multiple layers of information. It moves in thousand of directions with thousands of different ideas that need to be tested. Some of them are discarded because they don't work, some is kept alive and some ideas are paired into a third thing. We often describe this as an almost biological evolutionary process and you see a general evolution towards something more and more complex as it progresses through the different iterations..."* (Office 3). So the two processes inform each other and the sketching can help to inform what is important in the brief and vice versa. What is important here is that the parameters are made operational and are used explicitly to inform the design of the building.

When talking about working with environmental issues during the design process this also important, because the work with both understanding the brief and developing the design needs to be informed by the environmental concerns, so an understanding of how the environmental concerns can inform both is needed. Here the previous experiences are important, because they allow for going back to see how they worked with the specific issues. Or it requires the ability to be able to analyze and suggest how to address the specific issues and through the sketching develop it into an answer or response to the design brief. No matter how we see it someone needs to have the ability to investigate the specific issues that can help to explore the environmental performance that the brief calls for in order to be able to identify how to respond to it. If it is through the use of experiences as the English offices primarily do, including the environmental design consultancy, or it is through the analytical approach with small digital tools and applications seen by the students is not that important. The important thing is that it is addressed and it is done explicitly and that there is a reflection of how it supports the design and the idea. This point in a direction where the architectural idea responds to the environmental agenda in the brief.

It is my observation that it is between the design development and the brief that the environmental considerations are explored and addressed. Both of them are informing

the work in their different ways, though the brief and the importance of it is mostly in creating the benchmarks for the project whereas the design developments help to uncover potential questions and dimensions that were not necessarily a part of the design brief. It is this awareness of the interrelationship between them that needs to be fostered to be able to address the environmental concerns and develop our architecture today.

COLLABORATING

The starting point in the present PhD thesis was the discussion about the integrated design processes and their dependency on the multidisciplinary design team in the design process. In the research conducted it is seen that we are moving in a direction where the multidisciplinary design process is gaining more ground. However as the interviews show it is a slow process and in the single case-study of the design process in practice it is seen that it is not just an issue between the professions, but just as much a problem that is related to the traditional structures in the building industry where the architect makes the first sketches and the engineers are introduced later in the process and have to solve the problems as both interviews with the eight offices and the single case-study of the design process in practice showed and as the quote from one of interviewees clearly states *"…probably most of our work comes from projects where the architect has already secured the work and seeks tenders from 2 or 3 engineers to take on the engineering role. In maybe 10% of project cases, very unusual, the client comes to us directly and says we have appointed an architect and we want you to be the engineers. That happens with a few projects but not many…"* (Office 5). Today where the requirements of the environmental performance are increasing, it is important that the basic parameters like orientation, massing and window areas are considered from the very beginning. What is seen is that even though it is highly experienced architects with years of experience working with environmental architecture, they still rely on close collaboration with environmental engineers to really move forward and address the issues related to the environmental concerns to their full extent.

But the environmental concerns are just another area that requires this increased focus. Therefore the collaborative effort is even more required than earlier, because the architect and the design team cannot just dismiss another profession from the team. Therefore the ability to collaborate and work with all of the different issues during the design process is important. But collaboration is also communication and being able to explain why an idea is good or at least why it is better than another. This is very elegantly framed by the environmental design consultant in talking about how to collaborate where it is said that *"...the real trick is, and this sound very cynical, but the trick is to make it so obvious that what you're suggesting is the right solution. You make them think they thought of it. You get the best traction from people if it seems to be a collaborative decision. The minute you start to bang them on the head with a hammer you don't get that far..."* (Office 5). This is also confirmed by the other interviewees as seen when one for example mentions that *"…I experienced that in [a project] where the engineers sometimes sat down here with their energy calculations and assessments of the PV-cells' efficiency, then you would sit for half a day or an entire day and test different things…"* (Office 2)

The collaboration is not about the digital tools or applications, but about the communication and openness towards the other professions. In this respect the architect is the one with the general knowledge that knows a little bit about all of the different things whereas the engineer knows a lot about a specific area. It is the communication between them and the ability to question what is outside of their boundaries that can help to drive

the design process and move it forward. So it is about the ability to move between the professions and challenge the participants by moving outside of their comfort zones. We see this in the interviews and it is also seen in the students' work. It is the critical questions that help and they can help to guide the use of tools in the search for the particular answers. This is not to say that the digital tools and applications are not needed, but the collaboration is not driven by them. And the use of BIM does not mean that the collaboration is easier or improved, but the use of BIM or other digital tools and applications can most certainly help to support the design process and the decisions made if used critically during the design process.

RECOMMENDATIONS

It is in the interchangeable field between the brief, the development of the design, and the collaboration that the answer to the overall research question in the present PhD is found, and it is here its contribution when it comes to addressing environmental issues in architecture lies. Addressing environmental issues in architecture is not a novel thing, however with the increasing focus today on the environmental performance and the focus on achieving a high environmental performance it requires us to consider how we approach this during the design process. It requires that expert knowledge becomes a part of the design process from the beginning to be able to make informed decisions in relation to the environmental performance of the buildings we design, thus achieving a building of both high environmental performance, but also with high quality in terms of architectural expression and the spatial qualities demanded of our buildings. And spatial qualities is both about the comfort in terms of temperatures, light and air, but also the immeasurable spatial qualities that makes a room "good" to be in.

What is seen is that in order to move towards a more analytical approach to the design process:

- A collaborative effort is needed from the beginning where everybody contributes with the expert knowledge they have to inform the design process, thus using their combined knowledge and experience to inform the design process and explore how they explicitly can inform the design, as well as a framework there can help to foster such a collaborative design process.

- The focus on the environmental issues is not an extra thing that is added, but an extensive elaboration on relations between the spatial considerations and environmental performance. In order to address this it is important to explicitly explore the relations between the architectural expression and its impact on the environmental performance.

- The use of digital tools and applications can help, but need to be used critically. The tools do not work by themselves, but only do what they are asked to. Therefore it is important to make ones knowledge about how the environmental performance is related to the expression of the building operational and through that possibly use the digital tools and applications to explore how best to inform the design process.

It is important to be aware of that the design process cannot be a set of specified procedures to follow and that there are no specific things that should be done. Each project is seen as its own unique project. This is not something that it is necessary to change, but because each project is unique it does not mean we start from scratch in the design process every time. Neither does it mean that the experiences from one project are impossible to transfer to another project. These recommendations do not

attempt to setup a recipe or specify specific steps for the design process. They point towards areas that need focus in the design process to help define which steps and which procedures to follow in the specific design process in a project. Furthermore the recommendations points towards that it is the combined expert knowledge of the design team that can help to define this frame in order to move towards achieving architecture with a high environmental performance. This is not achieved by a single person in the design team, whether it is an architect or engineer, or by adding new professions or roles to the design team, but by focusing how we collaborate and how the combined experiences and knowledge of the design team can inform the design process. So what we see is that the important issue now is to explore the boundaries between the professions involved in the design process and possibly start to move within hybrid professions to move beyond the experiences that drives the design process today.

7.2 FUTURE RESEARCH

The research on which the present PhD is based is not an end in itself. It is merely a step on the way. It does state that knowledge about the experiences architects and the design team have with the design process can be used to form a more analytical approach to the design process and it does suggest how this could be done, but how it will work and what more specifically what is required is not evident from this. For me a main question is how the knowledge and experiences are made operational in the design process. The four English offices do suggest their own individual ways through checklists and matrixes that suggests strategies that can address the different issues related to the environmental concerns in the design process. But can a more generic approach be used to gather and make the experiences operational? In the literature review case-based design was mentioned, however it is not something that is seen in practice, but can it be made operational, thus fusing the experiences more closely into the design process.

If this is extended to also encompass the use of digital tools and applications in the design process it starts to raise questions of if digital tools and applications can be used to implement the experiences in the design process. Can sketching in digital media for exampled be coupled with a project database?

So from the research there is a new line of questions that starts to emerge that can be an outline of future research. Questions that aims at developing this field of research further and clarify uncertainties in the present research. In connection with the term experiences the following questions can be raised:

-       What kind of experiences is it actually the architects and design teams use? In this research it is just mentioned as experiences they use to address the issues, but there is no explicit dealing with the kind of experiences.

-       How can they gather the experiences from the design process and make them more operational. The four English offices do it, but how did they do it? Was there anything specific they aimed for or was it just something that happened?

-       How the experiences are made an integrated and explicit part of the design process? The English offices use them, but what how have they implemented it and how does it actually work beyond the mentioning of checklists and matrixes?

Another range of questions can be found when looking at the design process:

- At what stage are the different participants introduced to the design process? In the work here the focus has been on the collaboration from the beginning, but it is mentioned that it is not what happens most of the time. So when does it happen and what is the reason for this? Can it be changed?

- There are evidently also a range of barriers in the design process between the professions as all the participants in the interviews expresses in various degrees. How can this problem be addressed to improve the collaboration that is needed to address the environmental issues that are in focus here and possible other issues that will emerge in the future?

To focus bit on questions within the realm of the digital tools and applications especially with focusing on BIM, interesting issues could be:

- How do architectural offices, considered as being among the leaders within sustainable architecture, structure their design process, especially in relation to address environmental issues during the early conceptual stages of the design process?

- How can the work with experiences through checklists or matrixes be used to develop databases based on previous projects that allow informing the design process directly as sketching happens on the computer?

- Can BIM be used in connection with case-based design so previous cases are derived from the modeling process? Which can then be used expanded to the question of if and how BIM can become an integrated part of the very first stages of the design process where the first ideas to the concept are developed.

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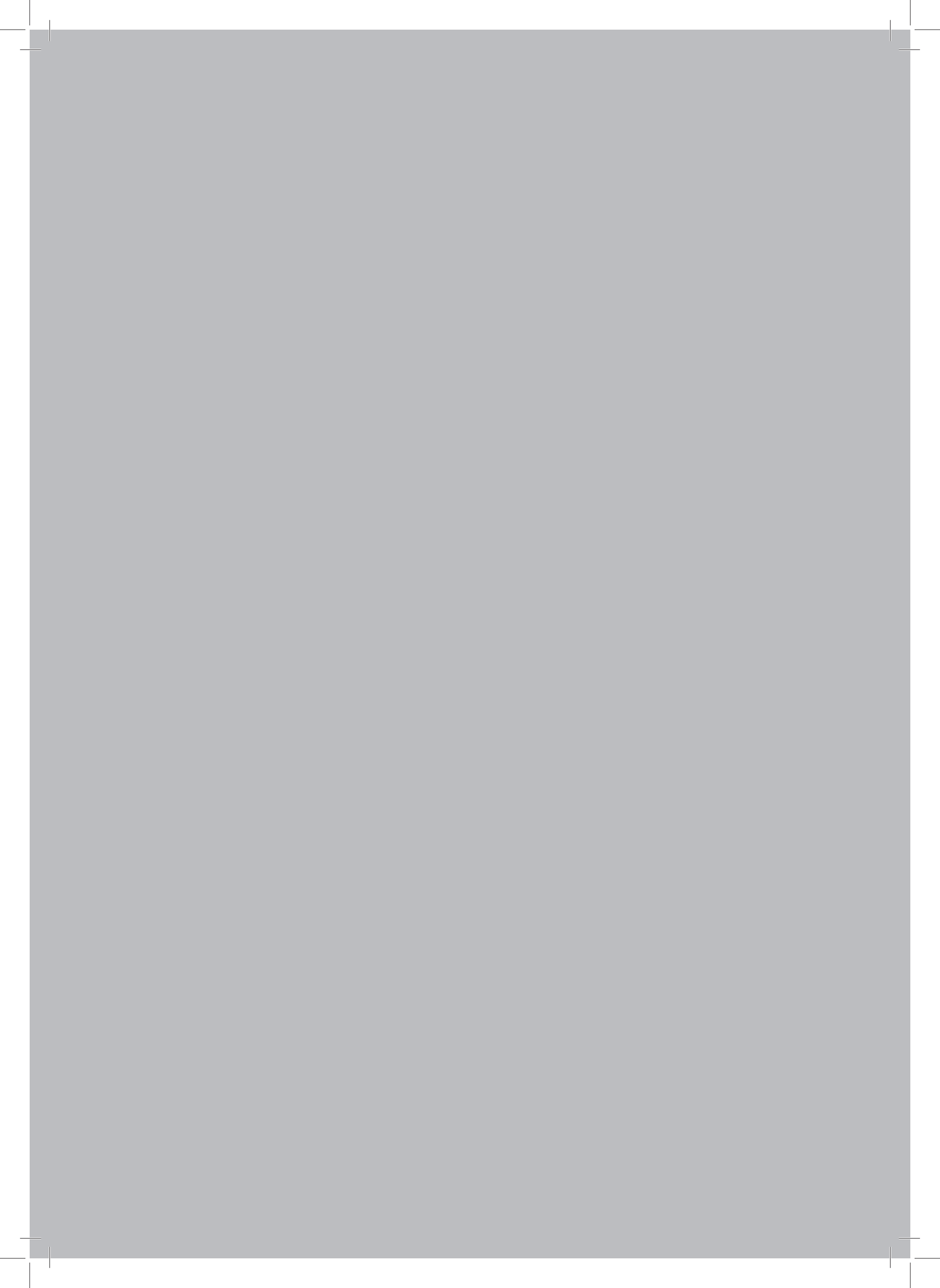
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APPENDIX 2 - INTERVIEW GUIDE

Interview guide for the competition stage

Let's start with talking about what happens during a competition project and which considerations that have an impact on the progression of a competition. We will more specifically talk about how you work with sustainability and which procedures you use.

Let us start with the progression of the competition in itself.

1. Can you describe how you approach the design process? For example from how it is decided that you should participate and when is a project interesting for you? When do you get involved in the projects? Is there a better time than others? How do you decide who should be on the team? What part do you play as a consultant during the initial stage? Can you try to describe if there are any specific steps you go through in such a design process?

2. How do the first ideas to the project appear or how are they generated? Who comes with the first ideas in your experience? How can you influence these ideas as a consultant? When do the first sketches start to appear and how are they developed throughout the project? Who in the design team does sketching?

3. Is there anything specific that relates to different phases or steps in the design process? Is there any specific progression or set procedure you use? Can you try to elaborate on that? Is there for example a specific formal language that defines what happens in the design process? What would you say in general defines the progression during the design process?

4. How do you work with the different issues that appears during the design process that are a part of working in architecture, like structure, materials, functionality, light etc? Do you have any specific approaches to the different things involved? What does it mean for the way you think and work during the design process? How is such an approach helpful for you?

Let's try to focus on how you more specifically work with sustainable issues in the design process

1. How do you work with sustainable issues during the design process? What impact does it have on your design process in your experience? Can you give some examples of what you do? Looking at the entire design team who would you say should have knowledge about sustainable issues and to what extent? At what stage during the design process are these things introduced? When are they ideally introduced?

2. Does your involvement in projects have an impact on other stakeholders in terms of passing on experiences? What do you do in order to pass these experiences on in other projects? How do you keep up to date on these issues? How do you work with implementing new knowledge and experiences into the projects? What are your experiences with implementing new knowledge? What is of interest for you in relation to the way you work and your general approach to the design and your goals?

3. Are there anything you specifically focus on in relation to sustainable architecture? Any specific agendas? What? What are then incentives to design sustainable solutions in your experience? What does that mean in relation to the way you approach the design process? How do you implement these issues during the design process?

4. Are there other parties involved in relation to the work with sustainability? What is your experience with the co-operation between you and them? What do you do in order to make

2

such a co-operation work? Are there any special considerations you need to take in relation to that?

Let's move on and talk about which challenges you meet during the design process in relation to the procedures you use and the way you co-operate with others

1. In relation to sustainability are there anything that limits you in the design process and how you have worked earlier? Is that something that can be seen? How? How does it limit you in your work? What do you do to move beyond such limitations?
2. In your mind what could you imagine of initiatives within architecture to make it easier to cope with these things during the design process? How would that help you? How do you see the role of different kinds of software during the very early stages that we have just discussed in terms of informing the design process through simulations and calculations?

As a last thing, do you have any further comments or anything that is of importance to you that haven't been mentioned?

3

APPENDIX 3 - PAPER 1

Petersen, MD & Knudstrup, M 2009, 'Performance based parameters as generators in digital architecture: An environmental approach', in K Hans (red.), Architecture and stages in the experience city, Architecture and Stages in the Experience City, nr. 30, Institut for Arkitektur og Medieteknologi, s. 115-122.

Performance based parameters as generators in digital architecture
An environmental approach

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This paper revolves around the discussion about sustainable architecture; the parameters related to it and how these parameters can be used in relation to generate architecture where the energy consumption during operation is in focus. A topic which is of interest in today's architectural world because of the high energy use buildings have. It calls for a rethinking of our approach to architecture and for an implementation architectural and technical demands from the beginning of the design process. The term generating in relation to this article is focused on algorithms and parametric descriptions, but can also encompass a more analogue process.

1.0   Background

Working with performance based parameters in architecture is not a pristine field of study as it has been of interest since the emergence of computers in the sixties where the possibility for using them in the design process were explored (Negroponte, 1970). Performance based in this context is meant as quantifiable data used in relation to simulations of e.g. structural and mechanical engineering. Today this subject is still interesting because the demands for simulations and documentation of the technical performance in architecture stated in the building regulations are increasing. Furthermore the discussions about humans impact on the global environment is by now omni-present and affects architecture as buildings are one of the most energy consuming products today (OECD, 2003). In a Danish context this is becoming more and more evident in the building regulations where the energy consumption during operation of the building has been significantly lowered during the last couple of years. In order to achieve and document performance within the limits of the legislation, it is becoming important to implement knowledge about the specific parameters in architecture affecting the energy consumption during operations during the early design phases as it is here the biggest effect of decisions are achieved (Chaszar, et al., 2006).

The discussion about how simulations of energy consumption during operation are important. Some states that the evaluation of the performance is done as post-evaluations (Hensel, Menges, 2006), whereas others argue that the knowledge implemented in the design process is gained through years of experience and the simulations at the end of the process is merely a confirmation of this knowledge (Hagan, 2008; Yannas, 2008). However the tools used for these calculations and simulations are developed for post-evaluation by engineers. Implementing these tools in the early design processes requires knowledge about what specific parameters to work with, in the given tools and knowledge about how these tools can be used to inform the design team during the early design

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phases and differentiate between the architectural performance and the system performance (Chaszar, et al., 2006). A problem in relation to these tools is the lack of interface between the traditional tools used for architectural design and the tools used to perform the simulations of the energy performance (Penttilä, 2007), which can make such a process rather tedious.

As mentioned the work with making performance based simulations started during the sixties (Negroponte, 1970; Hagan, 2008). These explorations, even though limited by the present technology, still are the basis for today's approach in architectural circles. During the past decades there have been remarkable developments within the use of digital tools. Most of these developments have been focused on the formal expression of architecture and has focused on how digital tools can challenge the traditional formal expressions in architecture (Lynn, 1999), but has turned into explorations related to structural as well as manufacturing considerations of the building (Kloft, 2005; Whitehead, 2003). These explorations and further developments in terms of using generative algorithms, parametric and associative modeling creates a basis for discussions about today's avant-garde architecture (Hagan, 2008). The possibility for using the knowledge about relations between building and site and the impact they have on the energy consumption during operation can help to explore architecture further – a thing that is currently being explored in different projects (Charron, Athienitis, 2006; Grobman, et al., 2008).

This technological development is pushing the boundaries for architecture and our perception of it. Projects using this digital technology have been realized and ideas about implementing real physical parameters in the design process proposed in the sixties are present today. This discussion about the implementation and understanding of such physically based parameters is the basis for the present research project. The focus in this research is on the relations between building envelope, climate on the site and the energy consumption of the building during operation can be used in order to generate form through the physically based parameters and discusses this in relation to moving beyond the often purely instrumental performativity discussed in relation to these matters.

This paper presents an initial discussion about how physical parameters related to the building envelope, the climatic conditions and the energy consumption during operations can be used to generate form through digital tools. It takes its starting point in the discussions about the developments in sustainable architecture and relates these parameters to the discussions about digital architecture and through that create an understanding of how these two directions in architecture can interact with each other and help to push the discussions and understanding of them further. Through this discussion a proposal for a generative approach to environmentally sustainable architecture is made.

2.0   Method

The framework for this discussion is related to the Integrated Design Process (IDP) (Knudstrup, 2004), where an iterative process is used in order to develop architectural demands and technical demands simultaneously from the early stages of the design process. There are a variety of different approaches related to the IDP used here spanning from the technical based focused on attaining a quantitative optimized result (Petersen, 2008) to methods mainly focused on environmental issues (Synnefa, et al., 2008; Luebkeman, 2003). What is important to note here is that the IDP is an architectural methodology where the synthesis between architectural and technical demands is the aim

and it aims at exploring the relations between these two sides, working with a broad selection of parameters that can be chosen or in focus depending on the project.

3.0   State-of-the-art

Discussions about sustainability in architecture are omni-present today. In a Danish context most discussions in this field are aimed at energy consumption and how to reduce it, which is focused on avoiding overheating thereby reducing cooling requirements – a discussion mainly driven by legislative demands today, whereas it previously have been driven by ideology especially during the oil crisis in the seventies (Williamson, et al., 2003). The demands in the building regulations also require that the actual performance of the building is assessed before erection. The tools provided for this purpose are all highly specialized and not initially designed to provide the design team with information during the design process but as tools for documenting the performance at the end of the process (Chaszar, et al., 2006).

Today the assessment of the different sustainable or environmental issues is often performed through assessment schemes where the different categories are checked. If the design complies with it, it is checked of and gives a point or a grade (Hyde, et al., 2007). This is a good way of communicating the final result to authorities or clients and furthermore can be used to see what the design team needs to address to get a high score, but again the assessment of the parameters are made after the design to some extend is finished. The categories used in relation to these assessment schemes can also be seen in elaborate studies of how architects are, and have been, working with sustainable architecture. What these studies also reveal is that the different notions used within sustainable architecture are using a common toolbox when they work with the sustainable issues as seen in figure 1. These tools are the ones used in relation to the integrated design process (IDP) (Knudstrup, 2004) when working with environmental architecture at Architecture & Design, Aalborg University.

As it is seen in figure 1 the different parameters used are things like orientation, window area etc. These are not specific to sustainable architecture but are general to architecture and have influence on how a building is experienced where e.g. the work with natural light and the compactness of the building can be of interest in order to create an environment habitable to people in the building (Hawkes, 2008). Of course with an increased focus on the energy consumption these parameters become more important in relation to the quantitative performance of the building and through that, the assessment of the performance throughout the design process becomes important, though without losing the balance between the quantitative and qualitative performance of the. Previous research in this field has shown that the understanding of the tools used and how they are applied during the design process is important as well as a differentiation between architectural and system performance (Chaszar, et al., 2006). The application of such knowledge is seen in different iconic projects realized within the last decade. An example of this is GLA headquarter by Foster + Partners. One of the major design parameters was to minimize the solar load on the building, which was first attempted through assumptions from the design team. On a later stage simulations showed that these assumptions were not sufficient and the design was altered in order to accommodate the results from the simulation and still maintain the architectural idea that was the starting point for the design (Whitehead, 2003)

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Figure 1. Mapping of different approaches to sustainable architecture and their design principles and dominating concerns (Knudstrup, et al., 2009).

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3.1.   Application of the digital in terms of performance based parameters

In relation to the GLA headquarter, seen in photo 1, a fairly simple use of parameters is seen. Furthermore the graphical representation was easy for the architects to understand. Generally speaking the approach seen in this case is similar to a "traditional" design approach where the design is finished and afterwards the simulations are made, though this example highlights a few interesting things. First of all the initial shape was based on studies of the solar path and responding to it with its south façade sloping inwards shadowing for itself, whereas the northern façade is sloped gently towards the sky using the natural light here without having any direct solar gains (Whitehead, 2003). The second point is that the simulation results and their effect on the design are visible, making this a good explanatory example for the application of performance based parameters.

Photo 1. GLA Headquarter by Foster + Partners (Own photo)

This is a very analogue application of performance based parameters even though it is used within a process driven by digital tools for design, simulations and manufacturing. Today research is pointing in a direction where automated processes are used and genetic algorithms generate the design solutions, based on inspirations from the natural world both in terms of structures and skin. The use of parametric algorithms is creating a solution space for the design (Terzidis, 2006). In relation to a more strictly sustainable strategy, experiments have been made where factors such as light and materiality have played a major role in the generation of the form (Hensel, Menges, 2006). These experiments have created interesting results where the parameters and the qualities they possess have had

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great influence in the generation of the form. The key to doing this is to break the design in to a series of different problems that can be described and solved or evaluated individually. This is basically what is done in the traditional design approach, though some specific parameters are in focus and the evaluation of these are often focused on the qualitative side of them (Negroponte, 1970). The work was continued during the nineties and today it is starting to gain more attention again among researchers exploring the possibility of using generative algorithms to utilize environmental factors in the design (Grobman, et al., 2008). Furthermore if the focus on the issues about sustainability is abandoned for a moment, similar developments are seen when structural issues are discussed. Here projects utilizing generative algorithms have been realized (Shea, 2006). This focus on the relations between form and structure have been explored for decades and helped to rethink architectures relation to materials and structures. As mentioned the computation of environmental parameters were attempted during the seventies (Hagan, 2008). Despite of this it is only very recently that it has started to be of interest in architectural design

In relation to the traditional tools in the before mentioned toolbox used within sustainable architecture many of the tools related to the building envelope can relatively easily be evaluated through simple calculations and simulations, and that these parameters have very big influence on the architectural expression of the building in the early design phases (Chaszar, et al., 2006). This is a very important issue, because the understanding and utilization of the parameters in architecture requires they are assessed in terms of both their technical importance as well as their importance for the architectural expression.

4.0   Future directions

As it is seen in the previous, research is going on within this field and has been going on for the past 40 years. That it is a continuing research does not make it less interesting. One of the key issues in relation to this field is that the communication between the different participants on the design team is made easier, and that the "language" is becoming common – both in terms of the actual participants' as well as the language between the different tools. This is a key issue in relation to research into Building Intelligent Models (BIM) which today is obligatory in public projects in Denmark of a certain size. The problem here is that this approach is very badly supported by today's programs (Penttilä, 2007). In order to cross this hurdle it is important that the design teams knows how the different parameters affects the energy consumption during operation as well as the architectural idea in the building – both of which have to be considered. One way to do it is to use the traditional programs already available where different parameters are evaluated individually on a conceptual level (Chaszar, et al., 2006).

However a different way to approach this problem is to generate architecture as discussed previously. As it was seen parameters related to the energy consumption are relatively clearly defined, and presently are evaluated as an integral part of the design process in some projects through the use of existing programs (Chaszar, et al., 2006; Hagan, 2008; Yannas, 2008). But it can be argued that the complexities in working with different parameters individually can cause a narrow focus and not explore the full potential of architectural form. A matter discussed forty years ago by Negroponte (Negroponte, 1970) and still discussed today (Hensel, Menges, 2006). This is one of the major arguments in the current discussion about why digital architecture should be approached more broadly and why architects in general should be more aware of the possibilities inherent in digital tools. On the other side there is the more common discussion about technology's influence

on architecture – a discussion that has existed for a very long time and where the relation between architecture and technology is in focus (Mumford, 1961). One of the main questions in relation to this is how the experience or the immeasurable, as Kahn says (Kahn, 2003), is described in an algorithm.

This being said one can challenge the argument for using digital tools in relation to generating architecture and "just" stay with the old methods of working with architecture. But at the current state architecture generated with the help of parameters describing the relations between the building envelope, climate on the site and the energy consumption of the building during operation can be a way of challenging the perception of sustainable architecture. In order to achieve a synthesis between these issues and gain more time to develop the design, the instrumental performance an understanding of how these relations can be described and used in a generative process is needed.

5.0   Conclusion

What is seen in this paper is that parameters concerning the environmental performance of the building can be used to generate architecture. In fact the thought is not new, but the idea has not gained further ground since the seventies. The difference from forty years ago is that we have the tools to do it today, both in terms of generating, simulating and manufacturing. Furthermore it is seen that there are attempts to generate architecture in this way. One can challenge some of these attempts though. Where are the simulations or the factors used to generate the form, and what do these factors give to the form or the experience of architecture? Other attempts or proposals for generating such architecture are solely based on the technical issues and then architecture can be put on top of the technical solution (Petersen, 2008).

So the knowledge in the different fields as well as the technology is present. The tools needed are also present today, though still not streamlined to support the design process fully, but specially developed tools are used on projects around the world. To push this further several things are needed. A major issue is the design process generally speaking. As mentioned an integrated design process is needed, where both technical and architectural considerations are made and create a synthesis. In order to obtain this it is important to be able to assess the design and the decisions made along the way both in terms of its technical performance as well as in terms of the architectural performance. In the end this a more digital approach that can encompass both a generative approach, but also based in a more traditional architectural approach. In other words it is important to maintain the creativity in the form-finding process.

In order for any of these to work it is important that actual knowledge about the parameters that affects the architecture is present. What in the building envelope has an effect on the energy performance of the building during operation both summer and winter and how can it play a part in the design process? Furthermore how can it be assessed and give a feedback to the architect or the program generating the form?

A last issue that is not to be forgotten in this discussion is what architecture is and should be – the balance between art and technology (Mumford, 1961). This is an important discussion as architecture is more than quantifiable data. The measurable part of architecture is only a servant to the immeasurable (Kahn, 2003). Therefore the discussion about what architecture should be is important to have in relation to the discussion about the generation of architecture and the parameters affecting it.

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APPENDIX 4 - PAPER 2

Petersen, MD & Knudstrup, M 2009, 'Implementing calculations of solar gains in parametric models', in C Gengnagel (red.), Design Modelling Symposium Berlin. Concepts Beyond Geometry., Universität der Künste Berlin, s. 167-176.

Implementing calculations of solar gains in parametric models

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INTRODUCTION

Working with environmentally sustainable architecture is becoming more challenging because of increasing focus on the environmental impact (Hyde et al. 2007). This demands a design process, where parameters affecting the environmental impact are considered from the beginning. In Denmark this is discussed as the building's energy consumption during operation, making the relations between architectural form, building envelope and climatic conditions on the site an area of focus in order to lower the energy consumption. The focus on energy consumption is a theme at Architecture & Design's, Aalborg University, 8th semester architecture specialization where students work with environmental architecture. The basic model used is developed through studies of parameters used in sustainable architecture in general as seen in Fig. 1 and studies of how the Integrated Design Process (IDP) can be used to address such issues (Knudstrup 2004).
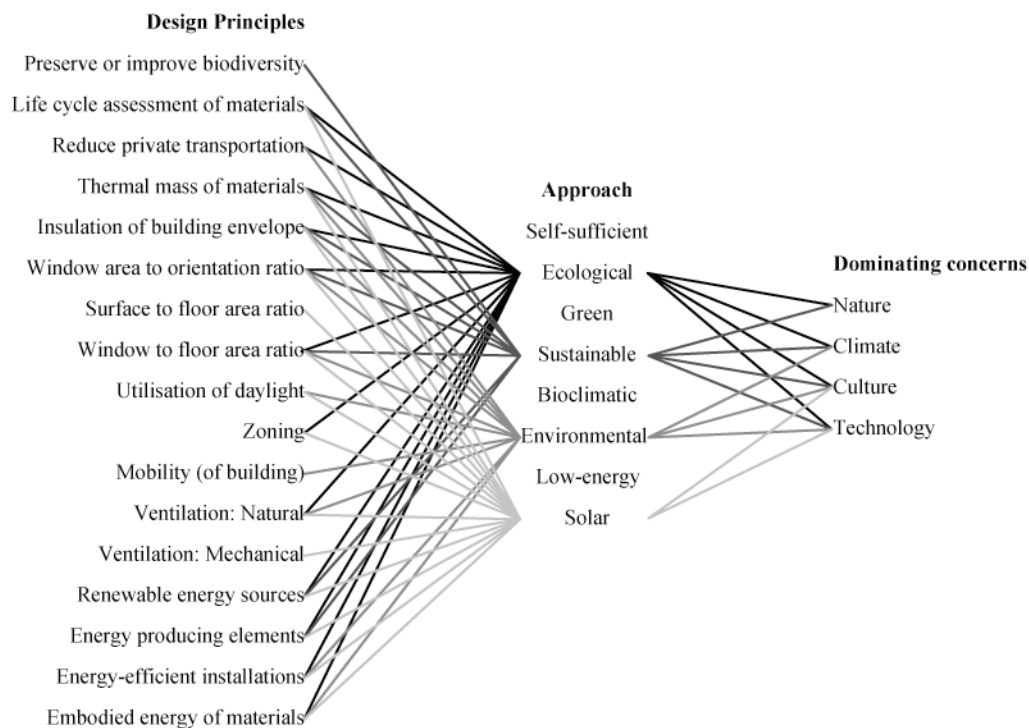

Figure 1: Diagrams showing the different directions within sustainable architecture and the tools they use (Knudstrup et al. 2009).

Today the assessment of these issues is done with software designed for documentation through calculations and simulations. The tools are designed for documenting the performance of the design and become difficult to work with during the early design phases as well as the level of detail needed in them is high (Chaszar et al. 2006). However Building Information Modelling (BIM) is addressing such problems, but is lacking the efficiency during the early design phases (Penttilä 2007).

Present research focuses on how digital tools can be used to inform the design process about the effect decisions about form; orientation etc. can have on the energy consumption during operation. The focus in the research is to use the parameters identified in previous research about parameters related directly to the architectural expression and study how existing simulation tools and modelling tools can inform the design process, not focusing on a specific tool or approach but on how tools can help to inform the design process.

Present paper focuses on how parametric tools can be utilized to implement data about solar radiation in a parametric model and studies how this can inform the design process. In this case Grashopper for Rhino. The solar radiation is used here, as it is the basis for expanding into studies of the buildings energy consumption. It presents a possible way to implement Design Reference Year (DRY) data in a parametric model and get feedback of the solar radiation on a surface and discusses the possible application of this.

METHODOLOGY

The approach to the research is based on implementing data from the DRY into a parametric model that creates feedback to the architect or design team. It is done by focusing on how data can be implemented with simple functions in a parametric modelling application.

The first part describes the geometry itself where a basic description is used in order to keep focus on the implementation of the data. The geometry in this experiment is a horizontal plane allowing for a simple relation between the geometry and solar radiation.

The second part focuses on implementing data from the DRY database - in this case for Denmark. It is concerned with importing the DRY data and relating it to the geometry. Tab. 1 shows the data imported compared to the data in EcoTect used for comparison

Table 1 : Comparison of diffuse and direct radiation in EcoTect and the DRYdata

	EcoTect diffuse Wh/m^2	EcoTect direct Wh/m^2	DRY diffuse Wh/m^2	DRY direct Wh/m^2
January	8565	3937	10149	30880
February	16277	15728	19580	45221
March	35079	23318	36469	71113
April	55248	62890	56979	111090
May	73734	81035	73220	154972
June	78657	107117	82682	135665
July	79233	81115	82076	130367
August	61621	74020	64334	122612
September	44359	39918	42947	87101
October	24183	20243	23135	56830
November	11370	7636	11603	32202
December	6446	5375	7283	19089

The third step in this experiment is the feedback to the model. In this case a numerical feedback has been chosen, but a feedback based on colours is also possible.

Parameters

The parameters used in the description in this experiment are orientation and solar radiation. There are two things that are needed here. The angle between the surface and the direct solar radiation as well as the angle between the surface and the ground for calculating the amount of diffuse radiation as seen in Fig. 2.
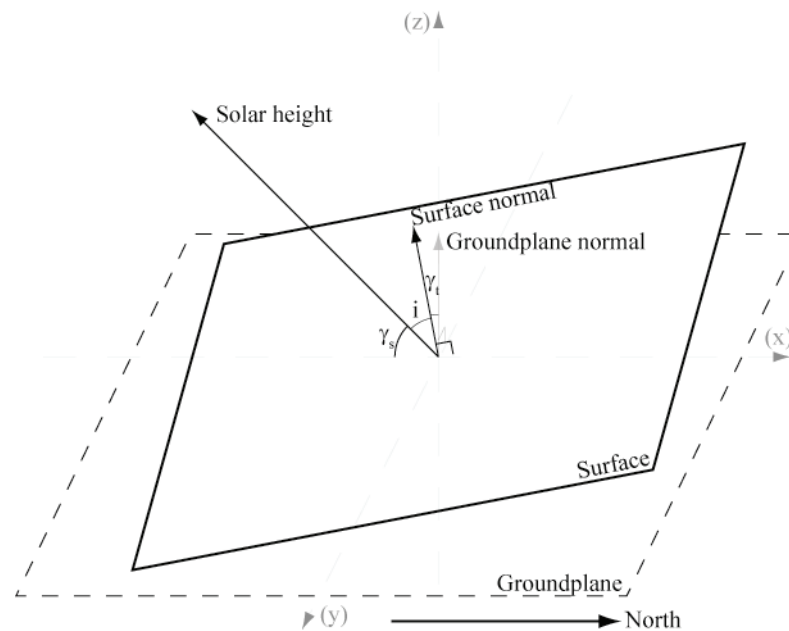
Figure 2: Figure showing how the relation between the model and the sun is made in this experiment where the x, y and z-axis are the basis of the modelling program. The sun is then located within this system.

First the equation used to calculate the direct radiation as it was seen in Tab. 1.

$$E_{est} = E_{es} \cdot \cos(i) \qquad (1)$$

where E_{est} = radiation on a given surface, E_{es} = radiation on a surface perpendicular to solar radiation, i= angle between the solar radiation and the surface (Petersen 1982, p. 44).

The diffuse radiation is as mentioned above the radiation that comes from the entire sky except from the sun and is described in this equation:

$$E_{eocv} = f_{oct} \cdot E_{eoc} \qquad (2)$$

where E_{eocv} = diffuse radiation on the given surface, f_{oct} = amount of the sky that the surface is facing, E_{eoc} = diffuse radiation on a horizontal surface (Petersen 1982, p. 46).

The amount of the sky the surface is facing is described through the following equation.

$$f_{oct} = 0{,}182 \cdot (1{,}178 \cdot (1 + \cos(\gamma t)) + (\pi - \gamma t) \cdot \cos(\gamma t) + \sin(\gamma t)) \qquad (3)$$

where f_{oct} = amount of the sky the surface is facing, γ_t = angle between the horizontal ground plane and the surface (Petersen 1982, p. 46).

Process

In order to implement the DRY data a VB.script was used where the data is imported and sorted in order to integrate relevant data, meaning that the datasets without radiation are left out. Fig. 3 shows a diagram of the links, whereas Fig. 4 shows the actual setup in Grasshopper.
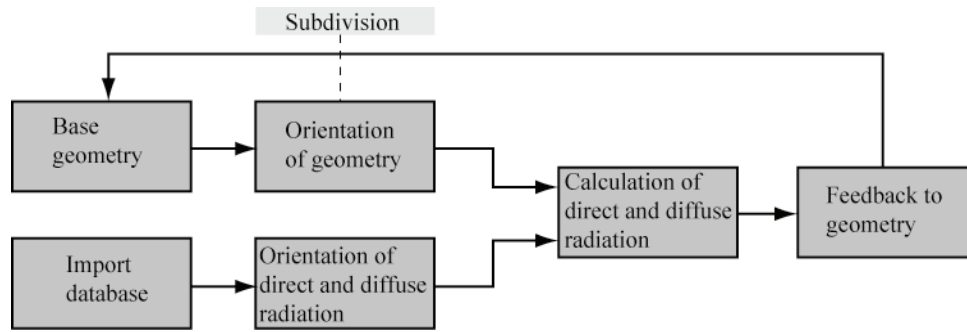
Figure 3: relations between the parts in the parametric model. The feedback is not changing the base geometry it is only a visual feedback. The subdivision box is an input that allows the architect to refine the geometrical description for more accurate feedback.
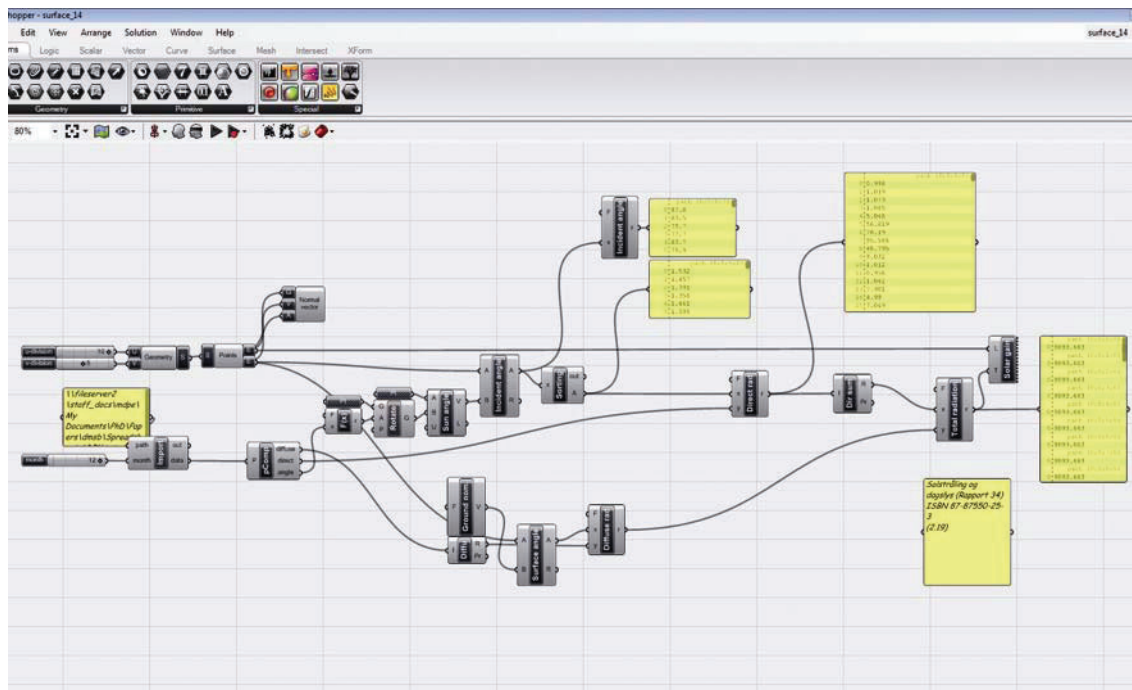

Figure 4: The actual setup in Grasshopper showing the links between the different parts.

RESULTS

In Tab.2 the results for each month compared to EcoTect is seen and Fig. 5 shows an example of the feedback given in Rhino.

Table 2 : Comparison of results from EcoTect and the experiment.

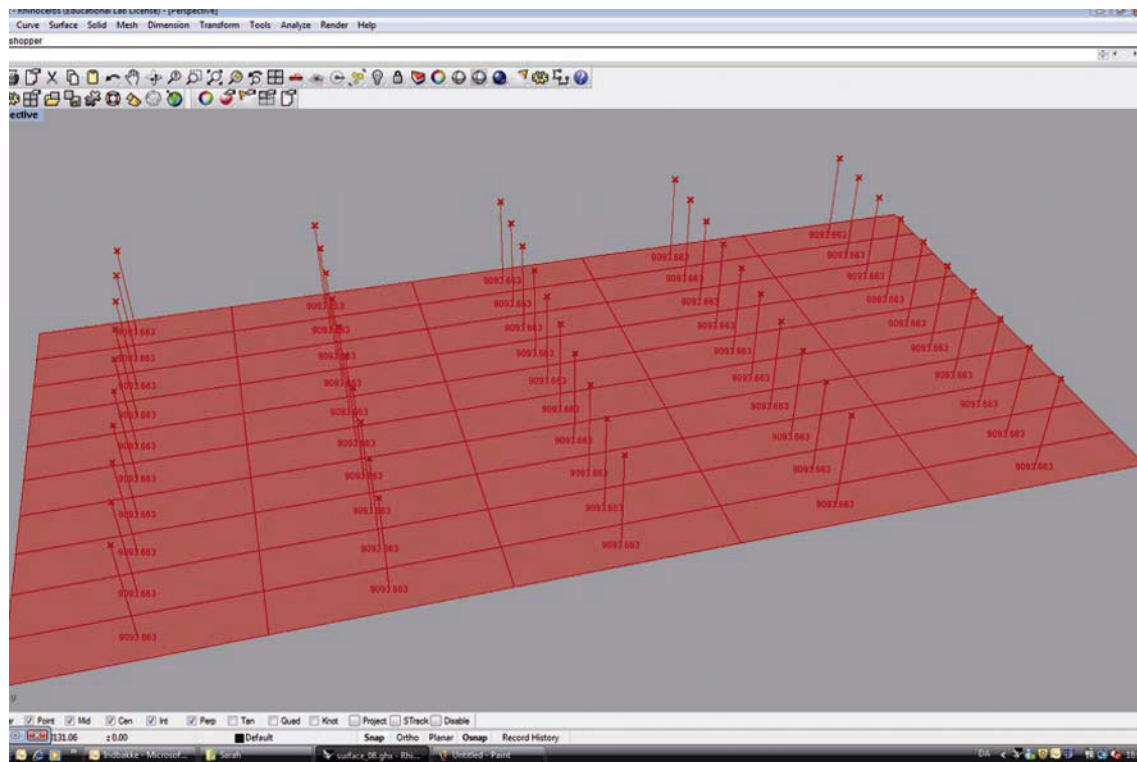|	EcoTect diffuse Wh/m^2	Experiment 2 Wh/m^2
January	10369	10960
February	23420	31200
March	50740	52780
April	101580	113640
May	139587	162490
June	163665	164390
July	147382	152010
August	116840	122740
September	71566	72140
October	35588	34300
November	14929	14610
December	8041	9090

Figure 5: Graphical feedback showing the amount on each subsurface.

DISCUSSION

Present example shows that implementation of such parameters is possible and can help to create feedback in a modelling program with parametric capabilities. As it is seen the method seems to be accurate, but it is important to remember that it does not replace the calculations and simulations on later stages. The purpose is to inform the design team about how changes affect the energy consumption during operation. With results like this there is a possibility to expand it into actually assessing the energy consumption and add parameters that allows for quick changes in the assessment. It also points towards a generative approach where the information is used to generate form.

In relation to teaching, this can be a powerful tool, because the students have to describe relations between the form and the technical design parameters they wish to investigate. Furthermore the focus is limited to parameters related to the architectural expression, whereas parameters related to the building systems becomes irrelevant in this limited context. Approaching the design in this way can help students to gain a better understanding of how their design decisions affects the energy consumption and develop their skills working with such parameters in order to discuss relations between quantitative and qualitative issues.

Implementing technical parameters in the design is seen before especially in relation to structural and manufacturing issues (Whitehead 2003). Working within the field of sustainable architecture requires knowledge about the intrinsic relations between site and building and knowledge about how they can be explored in order to work with the architectural expression and move this work beyond a merely quantitative analysis of the architecture (Yannas 2008). The parametric approach can help to explore these relations and increase the understanding of how different technical parameters can be implemented. Through this the approach to, especially the early design phases, can be more thorough integrating evaluations of technical issues along with discussions about the development of the architectural expression, as described in the IDP (Knudstrup 2004).

CONCLUSION

What is evident in this paper is that utilizing a parametric approach has the potential as a mean of exploring how basic parameters affect the energy consumption during the early design phases. It shows that different studies are possible and that it can be expanded in order to get more detailed feedback. However it is also evident that when using it one has to be critical towards the results its application and to what extend it is used. Furthermore the experiment shows a great potential for students to explore how form, orientation and energy consumption are related and how this relation can be described in order to assess the issues related outside the normal programs used forcing them to take into consideration what is important to know and what kind of feedback they want from it.

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APPENDIX 5 - PAPER 3

Petersen, MD & Knudstrup, M 2010, 'Tools for environmental simulations and calculations in an Integrated Design Process', i B Goodwin & J Kinnard (red), Re.building. 98th Annual Meeting., ACSA Press, Washington, s. 202-209.

Tools for Environmental Simulations and Calculations in an Integrated Design Process

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INTRODUCTION

Working with environmental simulations in architecture today is crucial in order to design buildings that fulfill the requirements set up in legislation and to send a signal to potential clients and the world that we as architects care about the environment. This requires an increased focus on how to implement knowledge about environmental and sustainable issues in the design process and knowledge about how to assess it during the design process, without over emphasizing the focus on such issues and losing focus of the development of the qualities that are aimed for in the architectural developments during the design process.

At Architecture & Design, Aalborg University in Denmark, this is in focus during the 8th semester of the architectural specialization. Here the students are introduced to environmental architecture and the assignment is to consider environmental concerns as a part of the design process and integrating them with their architectural ideas in order to create a synthesis between environmental concerns and architectural ideas. The methodology used in relation to this is the Integrated Design Process (IDP) (Knudstrup 2004, 221-234) where the aim is to integrate technical considerations into an architectural design process creating an inter-disciplinary approach where analysis of the different parameters creates a synthesis as seen in Fig. 1.

The education at Architecture & Design, Aalborg University, gives there candidates' a profile located in the gap between the traditional Danish architectural education and the traditional engineering education. Using the IDP and teaching the students both architectural and engineering subjects is a way to bridge the gap that can be seen between the two traditional professions in praxis and through that, possible problems or contradictions can be assessed earlier in the design process than normally possible through what is an inter-disciplinary approach (Knudstrup, Eriksen, and Petersen 2009).

The present research is focused on how digital 3d object based tools can be used from the very early stages of the design process in order to inform it and integrate solutions related to the environmental performance in the design process. This is tools where information about components, manufacturing, materiality etc. is used as seen in Building Information Modeling (BIM). Especially with a focus on energy consumption during operation which is crucial in relation to the building regulations in Denmark. It evolves around the gab there is between the theoretical knowledge present at Architecture & Design, Aalborg University, where students' work show that it is possible to implement such knowledge in the design process and research into the application of such programs in the early parts of the design process in a practical environment where problems seems to appear (Schmitt 2004, 31-41; Penttilä 2007, 291-
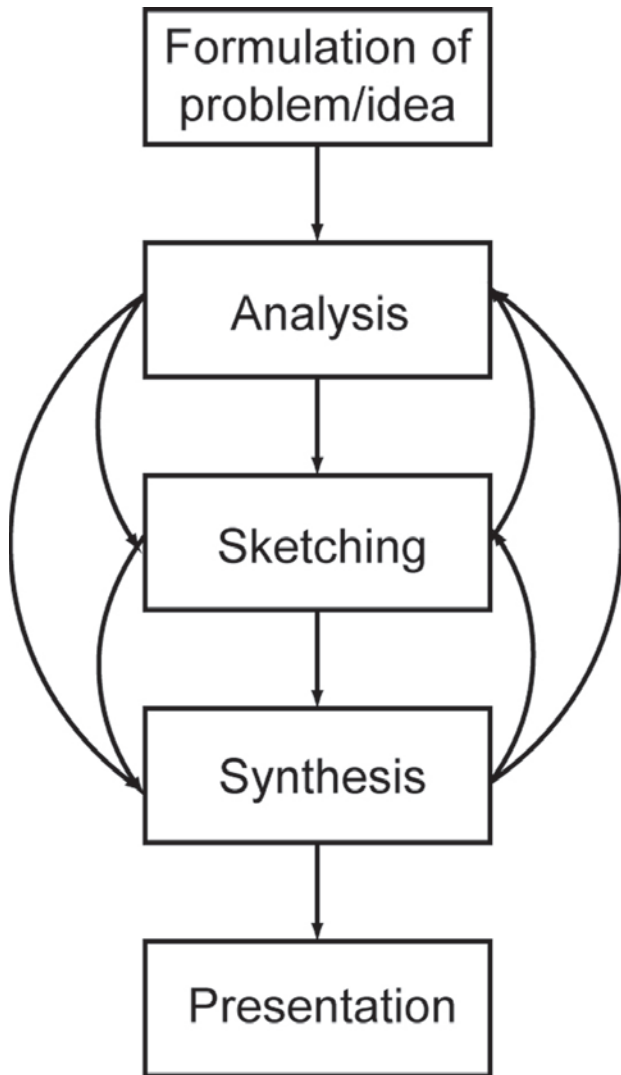
Figure 1: Diagram of the different steps in the IDP and their connections showing the iterative process (Knudstrup 2004, 221-234).

302). With this in mind it aims at studying how knowledge from the theoretical environment at Aalborg University can be used to inform the practical design process encountered in a "real world" environment.

This paper presents the view of a student working with the inter-disciplinary approach where the student's work with environmental architecture focuses on fulfilling the requirements for the passive house standard. The paper focuses on the process and the way it utilizes different tools to identify and assess the effect of different parameters in the early stages of the design process and through that obtains

a result where architectural and technical considerations have helped to inform the design process and the final result. It suggests that knowledge about which parameters to work with and knowledge about how different modeling, simulation and calculation tools can help to inform the design process if one is aware of the possibilities and are able to integrate this into the design process.

PROJECT BRIEF

The brief for the project described here was to design a building complex on the edge of the dense city in Aalborg. It had to fulfill the Passive House requirements and had to fuse the qualities of the traditional Danish single family house with its garden, with the more compact and dense living of the building complex. Furthermore the project had to have a minimum height of three stories and had to be located on an old train area in close proximity to public transport, the city center and shopping possibilities. On the site an old train depot is located as well. Finally it had to be located within an environmental approach to architecture and it was (Lauring 2009)

The student here, chose to expand the site in order to get a solution that integrated the city and the open land and green area closer, as well as keeping the old train depot and integrate it as a part of the area, keeping a historical reminiscence implementing different functions in it allowing it to be an active part of the area referring to its previous central role as a workshop.

The work with the Passive House standard (Passivhaus Institute 2007) in the description of this project was initiated in order to give the students a very specific focus where the utilization of the building's passive gains and losses were explored as an "optimization" of these has a great effect on the energy consumption of the building during operation - especially in a temperate climate like the Danish. There are three demands that need to be fulfilled in order to get a Passive House certification - the heating demand must be below 15 kWh/m^2 per year; the total energy demand for the building cannot exceed 120 kWh/m^2 per year and the air change cannot exceed 0.6 h^{-1}. The last two demands though require a post occupancy test of the building making them relatively insignificant for the students' design process.
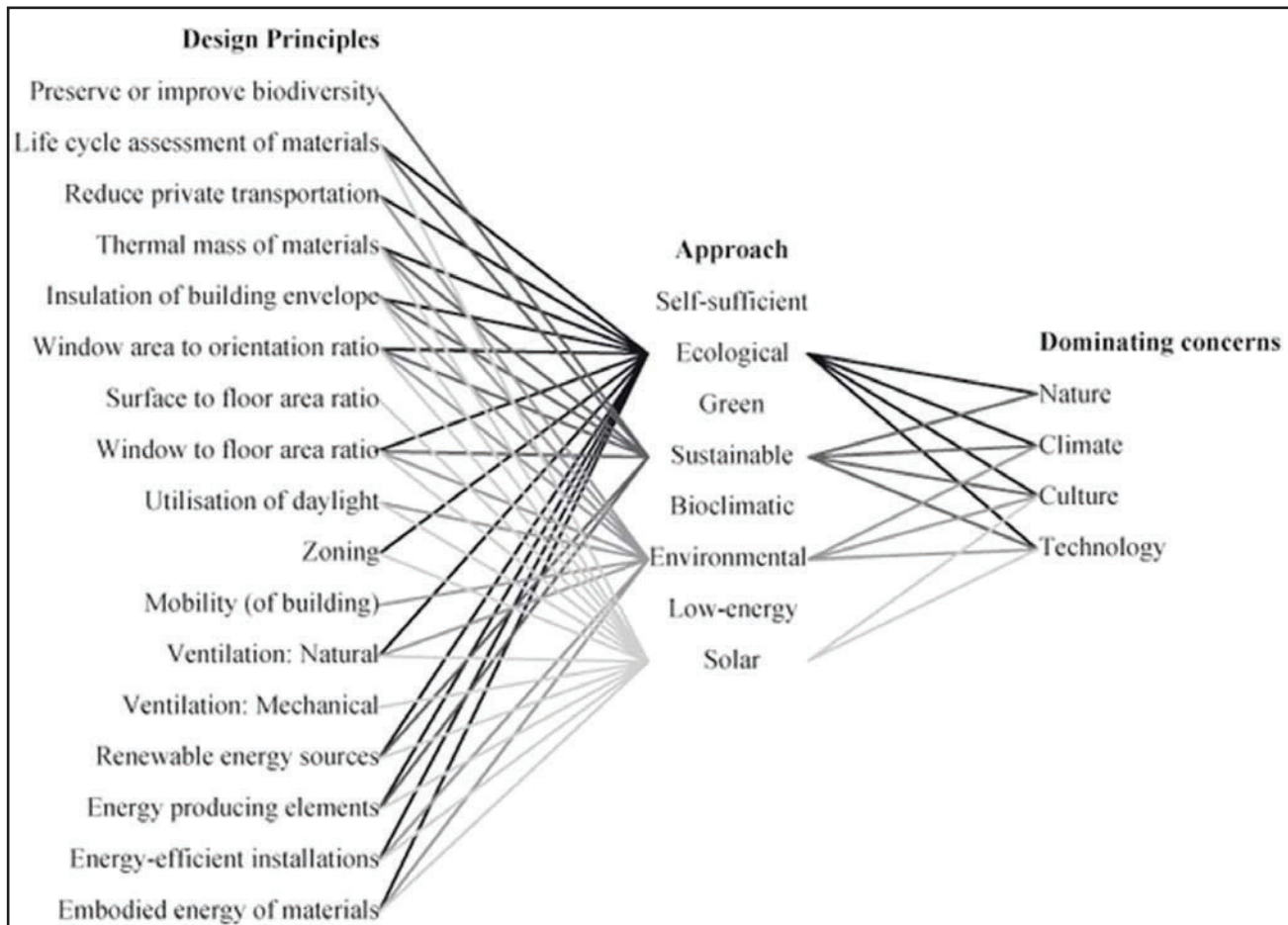
Figure 2: Diagram showing the relations between the different directions covered by the general use of the term sustainable architecture and the tools they employ during the design process (Knudstrup M-A et al., 2009).

Tools for simulations and calculations

The students are introduced to different tools for simulation and calculation during their education. On the 8th semester the tools can be split into two categories. Tools based on spreadsheets and simulation tools based on what are traditionally used in the Danish building industry for documentation of the energy performance and comfort in the building. Besides that BIM tools are now being introduced as this is beginning to be a demand in projects in Denmark, however it is not the primary focus yet.

As for the spreadsheet based programs there are two basic spreadsheets introduced designed by the supervisors at Architecture & Design and there is the Passive House Planning Package (PHPP) which is used to certify passive houses and is developed

in Germany (Passivhaus Institute 2007). However the project presented here did not use PHPP but instead used BE06 which is the program used for documenting buildings' energy performance in Denmark. The basis of the two models of calculation is different, making direct comparison difficult; however research has been done in order to make comparison possible (Ellehauge and Kildemoes 2008, 4). As for the simulation the students are using Building Simulation (Bsim) developed by the Danish Building Research Institute, for simulating the comfort levels and energy performance of the building. In this project Ecotect™ was used for studying the solar insolation on the building and to optimize the passive solar gains in the building.

As a general digital design tool for exploring the formal issues Rhino™ has been used because the student sees it as a versatile tool supporting an

intuitive approach and interoperability with other programs and CAD/CAM technologies.

DESIGN PROCESS

The methodology used in projects at the 8th semester architectural specialization at Architecture & Design, Aalborg University, is the IDP (Knudstrup 2004, 221-234). Using the IDP the aim is to develop the project from the beginning using both architectural and engineering assessments in order to achieve a synthesis between them. The methodology is in some respect similar to what Lawson's later research into how architects approach the design where analysis precedes the design and an iterative design process is formed pointing towards achieving a synthesis shows (Lawson 2006). From there it has developed into a methodology taught to the students at Architecture & Design where both architects and engineers serve as supervisors and lecturers during the semester and students are familiarized with both professions perspective. Through this design process solutions to possible problems are integrated in the design or one could say that the design process helps to avoid problems in the design (Knudstrup 2006, 14-19). Using this approach, it moves beyond a traditional design process based on previous experiences where ideas come from these experiences and are developed through negotiations with different parameters (Trebilcock 2009).

The assessment of the technical issues can be difficult for the students as it requires knowledge about which parameters to assess and how these parameters affect the architecture. In order to inform them about these issues the starting point is research where different parameters used in sustainable architecture are identified as seen in Fig. 2. In order to assess the different parameters, though, the students are introduced to the different programs to get quantifiable data about their buildings from early in the design process and add another layer in their argumentation and support the design process. The programs traditionally introduced are mainly selected because they are certified to make assessments in the Danish building industry and therefore are the ones students are likely to be facing when finished with their master degree. There is however a few very simple spreadsheets introduced as well in order to make it possible for the students to assess different

possible solutions from a more diagrammatic stage as well and already from there let information about energy consumption inform the design process.

In search of the form

The above mentioned tools and the direction acts as the students' starting point in the design process. However it is important to mention that the students are developing the project simultaneously with being introduced to some of these tools. The idea introduced in this project used to exemplify the work done at Architecture & Design, Aalborg University, is guided by the student's aim for "a right to light" meaning that everybody, including the inhabitants in the old buildings, has a right to good natural light conditions. It is not a novel idea but an important statement to keep in mind working with passive houses and trying to utilize passive gains and lower the energy consumption. With that he defines a primary driver to the design process (Lawson 2006).

The initial step in the design process was to make brief studies of the relations between energy consumption in the building and the volume to floor area ratio both in a horizontal and a vertical development. This was done briefly in order to get an idea about how the relations affected the energy consumption and was immediately translated in to an actual design idea based on the statement "a right to light". The initial discussion was then set into the context located on the edge of the city center with the open land towards south and the site with its building blocks with court yards towards north. This served as the guide for the lay-out of the master plan for the area where the combination of arcs and the orientation towards south creates the dynamic form in the plan with contrasts between the private court yards and the public paths through the area. This development was also based on the recommendations made by the Passivhaus Institute regarding the orientation of buildings (Passivhaus Institute 2007).

From these initial investigations the design started to take a more detailed direction where the overall plan is evaluated through the use of simple spreadsheets concerning the monthly average energy balance for the individual units as seen in Fig 3. Here the initial volume studies are combined with the overall plan, and with the spreadsheets

the technical parameters are evaluated as well as the formal parameters in order to integrate possible solutions if any problems seem to appear at these early stages of the design process. This was studied through diagrams of volumes in the building complex related to analyses of the functional program. The representation of these results is made in Rhino™. In order to get results that can be used for comparison and give an idea about the performance of the building different parameters needs to be determined such as ventilation rates, use of buildings and u-values, which at these early stages are based on previous experiences and standard values from different literature or other programs.
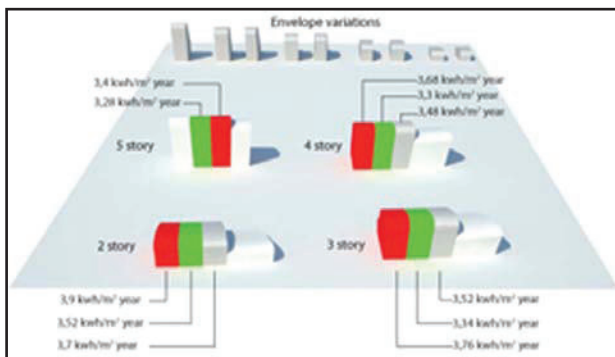

Figure 3: Diagrammatic representation of the results obtained in a simple spreadsheet in Rhino (Larsen 2009).

Because the student worked with passive houses the project actually needed to use the PHPP for documentation of the performance. Students are advised to use it from the early stages as it can ease the final documentation and make them familiar with the program, but in this case the use of PHPP was discarded because one in a Danish context has to use a different program for documentation. In order to switch between the two programs for documentation it is important to be aware of the differences in their calculations that make immediate comparison impossible. However research has been made to deal with this meaning that the energy demand of 15 kWh/m^2 per year heating required in the passive house guide is 9 kWh/m^2 per year in Be06 that the student used (Ellehauge and Kildemoes 2008, 4).

The last step in the student's process was to determine how much passive gains the buildings received from the sun as well as investigating how that related to the experience of light in the building. This was done through a variety of programs. In order to investigate how many passive gains were needed the monthly average spreadsheet was used. In order to study the amount of passive gains through the window openings Ecotect™ was used and in relation to the light analysis DialEurope™ was used for daylight factor whereas Ecotect™ and Radiance was used for qualitative assessments compared to quantitative simulations in order to investigate how the technical demands corresponded with the experiences the student wanted to promote as it is seen in Fig. 4.
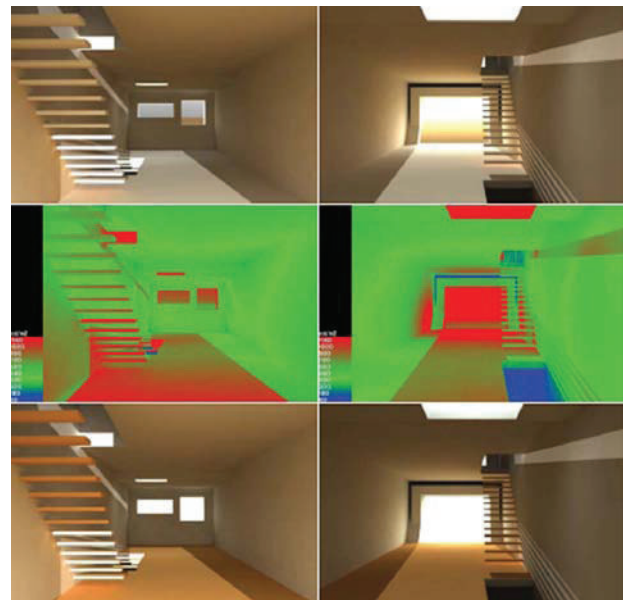
Figure 4: Images from Radiance simulations through EcoTect where the top pictures are the human perception of the space, the middle is measures of the actual light levels and the bottom is the illuminance renderings (Larsen 2009).

DISCUSSION

The question in a design process like the one outlined above is how to navigate between the technical parameters that can be measured and compared to one another and the more formal parameters that by nature are more elusive and argumentative. How can these two worlds interact and how can the technical parameters be used in a way so they inform the design process instead of controlling and dominating it and remove the

discussions about the qualities of the architecture from the design process (Knudstrup 2006, 14-19). Here Fig. 5 shows the results of the student's work. One could describe it in the words of Louis Kahn who talks about the measurable being a servant to the immeasurable (Kahn 2003).

Figure 5: From inside one of the apartments of the building and from one of the courtyards in between showing how the characteristics was developed (Larsen 2009)

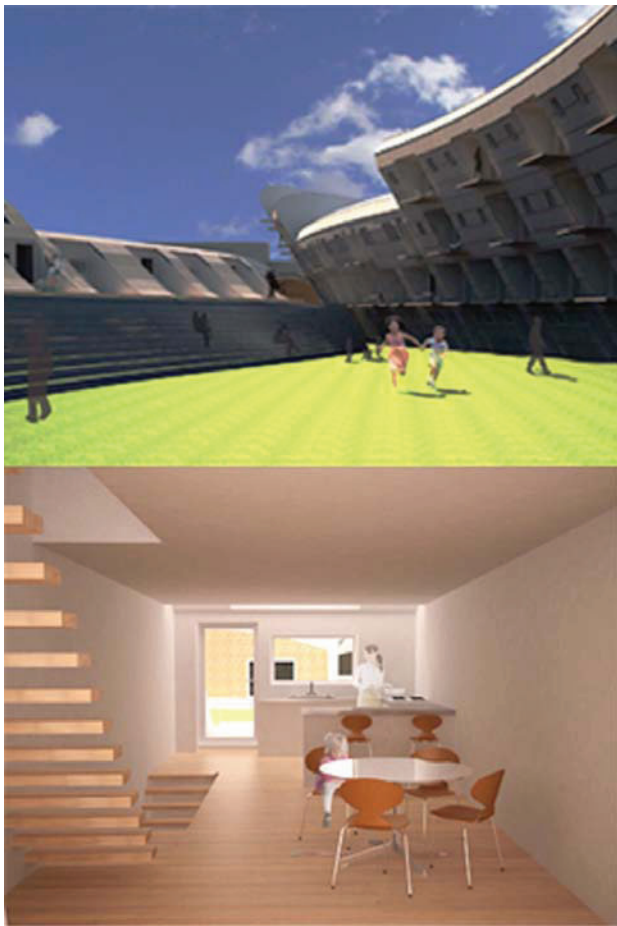What is seen in this project is that the student is using a very strong statement to drive the design as well as very strong idea about how the different programs used in relation to simulations and calculations can be used to address issues that are of importance. At the same time it is evident that the student is aware of the limited accuracy at the early stages of the design process and uses different abstractions and different tools to help guide the process which is seen in for example the volume studies and the

diagrammatic investigations of the building heights and how that affects the access to light. In connection with that this is also affected by the investigations about what qualities that is of interest in this project. This is achieved through using different tools on very specific issues and assessing these issues in a conceptual way as it is seen in relation with the initial studies of volumes and their energy consumption and the diagrammatic approach to the studies of volumes in the master plan for the area. By doing this the student reveals tendencies and uses this knowledge in the design process.

The design process used in this project and in general at Architecture & Design, Aalborg University, is the IDP (Knudstrup 2004, 221-234) where technical and architectural considerations are fused into the process very early through analysis of different requirements creating an inter-disciplinary approach which is similar to the descriptions made of the design process by Lawson (Lawson 2006). Even though the design process used is the IDP the tools used do not support such an approach fully. One of the major issues is the lack of interoperability between the programs. Looking at the programs the following can be seen. The main modeling program is Rhino™ which is a NURBS modeling program and even though it is considered to have a good interface with other CAD/CAM programs it does not contain any information about the different elements or objects in the building. This information must be defined in other programs. The spreadsheets are another widely used tool in this project. Even though they are simple, they are developed specially for the education at Architecture & Design, Aalborg University. Again there is no interoperability between spreadsheets and Rhino™ or any other programs used, meaning that the inputs need to be made manually. The only program that actually supports interoperability in this project is Ecotect™ and it can be claimed that because none of the other tools supports it, it is not used to its full potential. In order to achieve a full potential for the integrated design process it is crucial that one dives into the questions about programs and how to use them during the design process. The student in this case does it by applying the knowledge present, but how does it relate to the practical approach one encounters in an architectural office?

Research shows that there seems to be a gap between the theoretical approach such as the

"family" of approaches to which the IDP belongs and the approach to the design process encountered in architectural offices (Trebilcock 2009). Here it is seen that the gap between the "theoretical" design process and the "real world" design process is significant which is caused by a number of reasons also identified in different research projects, but some of the major issues are the professional boundaries, time and economical restraints. This is a very important issue to point out as the students needs to be prepared for what they might encounter when they are finished and needs to utilize their skills in a more traditional setting in an architectural office. Today there is a progression towards architectural and engineering offices working closer together during the early stages of the design process to obtain sustainable projects. However as it is pointed out here it is important that someone can help to close the gap between the professions and explore the possibilities inherent in implementing parameters early in the design process in order to let them inform the design process and from the project here it is seen that the tools can help to do this, but also that it is important to start with it on a very conceptual level.

What this discussion highlights is how these tools with interoperability can play a bigger part in the early stages of the design process and through that help to create a design process where the flow of information becomes more fluent between the different programs and where the manual inputs to spreadsheets during the design process is minimized. Even though the use of these programs in this example is limited to the work with natural light in the building it is seen that it is useful as it allows for quick tests of the viability of the different design solutions. If expanded to also be used during earlier stages in a diagrammatic way like the spreadsheets are used in the early phases the flow of information can be increased creating a tighter link between the early investigations and the final product, though it requires an ability to create a certain level of abstraction during the early stages of the design process as seen used with the spreadsheets in this project.

CONCLUSION

What is seen in this paper is that the implementation of simulation tools and a methodology supporting and creating a framework for the use of them in the design process can help students in their work

and it can help to expand the range and depth of arguments for design decisions by giving them quantitative data that supports the ideas about qualities they wish to promote in the design. This points as mentioned towards a design process where the measurable becomes a servant for the measurable (Kahn 2003).

What is important to notice is that the students working with simulations and calculations in the early stages of the design process has a tool that can help to move and support the design process in the architectural and engineering offices, because they are able to move and communicate between the two professions, helping the architect to gather more hardcore quantifiable arguments that supports the ideas and developments related to the more elusive qualities discussed during the design process and that often are the drivers of the design process along with the functional requirements. Through this the architects can develop another layer of arguments in the process and it can also help the engineers to understand the arguments brought up by the architects and through that move the design process further. However it is also seen that it is important to be aware of which tools are used and how they are used.

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APPENDIX 6 - PAPER 4

Petersen, MD & Knudstrup, M 2010, 'An Integrated Design Process: One Step Further?', SB10 Finland. Sustainable Community – buildingSMART., SB10 Finland Conference Secretariat, Espoo, s. 520-528.

An Integrated Design Process: One step further?

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Summary

Present paper is placed in the discussion about how sustainable measures are integrated in the design process by architectural offices. It presents results from interviews with four leading Danish architectural offices working with sustainable architecture and their experiences with it, as well as the requirements they meet in terms of how to approach the design process – especially focused on the early stages like a competition. The interviews focus on their experiences with working in multidisciplinary teams and using digital tools to support their work with sustainable issues. The interviews show that there is a difference in the experiences of the different offices. Architects taking an active part in the development of projects and tools in general have a better understanding of how to approach this. It is of course not surprising, because of a focused strategy towards this. However the most important thing it shows, is the importance of being able to understand the relations between architecture and its impact on environmental issues like energy consumption. Through an understanding of these relations the architects will be able to link energy consumption to building geometry and create solutions where the environmental measures cannot be discarded due to extra costs.

Keywords: Environmental architecture, energy simulations, design process

1. Introduction

Working with sustainable or environmental architecture today is becoming more and more important, as the requirements in the legislation are increasing. This is for example seen in a Danish context where the demands for reducing the energy consumption are increasing [1]. The increase of these demands are having an effect on the design process and makes it important to study what it means in terms of the architects' approach to the design process and how architects work with these increasing demands – especially in terms of using new technologies such as Building Information Modeling (BIM) and the possibilities it potentially has to support the design process in terms of sustainable issues. This is of importance during the early stages of the design process, because of the impact on the final results, both in terms of architectural expression and energy consumption such decisions have.

Currently the work with environmental or sustainable architecture, in an international context, is maintained primarily through the use of different assessment schemes [2] or by using simulation programs to address specific issues about performance [3] all of which in the end is based on previous experiences [4]. However with the current discussions about BIM it is seen that through a variety of different tools sustainable and environmental solutions can be achieved [5]. However in the Danish context the focus on BIM and the integration of it in the offices [6] suggests that there is a potential for developing the work with these issues in a.

The use of BIM in the design process is seen as a great potential for having a more lean design process and suggesting it as the technology of the future [7]. However there are still problems in using it from the very early stages of the design process [8,9] as international research shows. This point towards the real potential is in understanding how the early stages of the design process works and how architects think and work and relate that to the information in BIM.
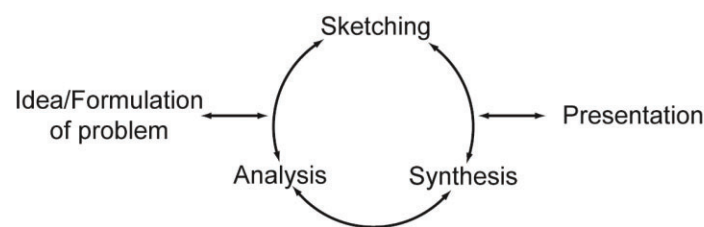
This is where present research is taking its point of departure. The question about how "hard" information related to simulations and the general use of BIM tools can be used in the design process. The particular interest is in how this information can be used by the architects in their development of concepts based on their work with spatial and experiential concerns during the early stages in a way that allows it to become a support and or a to guide the design process.

Present paper is focused on the architect's experience of the current work with sustainable and environmental architecture in a Danish context. Here with a special focus on energy consumption. It presents the results from interviews with four leading Danish architectural offices and their experiences with this work. In the interviews it is seen that the design process today is mostly a co-operation between architects and their consultants which of course makes the use of BIM tools an obvious solution, because they aim at interoperability and creating a common platform for information between different professions. Present paper suggests a stronger focus on communication and understanding relations between the architectural form and the energy consumption of the building as the first step to getting this information into the design process and designing architecture with an inherited sustainable agenda.

2. Methods

As mentioned in the introduction the aim of the present paper is to investigate how architects see their work with sustainable architecture and investigate how they work with it. It points towards describing and analyzing the work from their point of view and to gain an understanding of what they experience as important in relation to this work. Furthermore it is framing this work within the early stages of their design process as seen in for example a competition where the first sketches starts to appear and through that gaining an understanding of what the architects use as a starting point for the design process.

To discuss the design process the interviews are related to previous research into the design process. The overall framework is an understanding of how architects work which can be described as conjecture/analysis. Here the first solutions are suggested from previous knowledge and not the full information for the current project but where the analysis of these first suggestions are helping to inform the architecture [10]. This is described more thoroughly by Lawson and the progression and interaction between problem and solution through analysis, synthesis and evaluation [11]. In terms of environmental architecture this is defined more thoroughly through the Integrated Design Process (IDP) [12]. Here the concern is the integration of technical issues from the beginning to address the environmental as seen in figure 1.

Fig 1. Representation of the IDP and the interaction between problem and representation where technical issues are already implemented in the first ideas to address sustainable and environmental issues

2.1 Interviews

Present research is conducted as interviews with four leading architectural offices in Denmark as examples on how architects work in a Danish context. All of the interviews have explored three

main topics. Their approach to the design process in a competition, their work with sustainable issues in the design process and possible barriers they encounter. These interviews are used as basis for further research where the knowledge from the interviews as well as knowledge from experiences working with simulations and calculations during these early stages of the design process is used in an actual design process in an architectural office.

The interviews are conducted as conversations in the form of semi structured interviews where the architects are interviewed in a conversational setting and the architects reflect upon what they do through the questions – An approach that could be described in the terms of Kvale as a traveller's description [13]. It is through the conversations that their knowledge is revealed and they can reflect upon it. The interviews merely give an understanding of how these four architectural offices think and how they implement sustainable issues in the design process. Through that and reflections on previous research into the design process the analysis investigates these topics to discuss possibilities for implementing knowledge about sustainable issues in the design process and how BIM tools can be used in relation to that.

Besides the relations to previous research into the design process a comparative analysis between the different offices is made in order to highlight different stages and problems that can occur when sustainable issues starts to play a more significant part in the design process.

3. Results

In the interviews it is seen that the awareness of one's design process is very important to be able to address sustainable issues in architecture. Especially through an understanding of the relations between architecture and its impact on environmental issues like energy consumption. Furthermore the office's approach towards developing their work in terms of addressing these issues is important and how active they are in doing it and finally the importance of being able to integrate the solutions in a way so they cannot be discarded because of cost savings.

3.1 Setting the context

Before starting the actual discussion the context, in which this is set and should be understood, is outlined in the following quote:

"The classical way from the eighties' environmental planning was the architect drawing a building they found beautiful and then afterwards in text described that materials should be environmental friendly and it should save energy" (office 3)

This quote confirms previous research into the work with sustainable architecture in a Danish context [14], where sustainable issues are mostly described in text by the architect and when the project has to be realized the engineer has to solve problems arising from a lack of knowledge from the architect. However today there is an increased awareness of what is required in the building industry in order to design architecture where the sustainable solutions are integrated in the first proposals, though it still is a time of transition as the interviews show.

3.2 Contemporary architects and their work with sustainable architecture

Today contemporary architects see the work with sustainable architecture and the challenges embedded in this work as important. In the following quotes from the four different offices are used to explain these issues and to discuss the differences that can be seen between them. The starting point is quotes that focus on how they see the current work with sustainable architecture and how they work with it in a forward pointing way. The offices are arranged starting with the one with the emerging awareness ending with the one with a more well-defined approach. The quotes for each office focuses first on when the sketching starts, then on how they work with sustainable or environmental issues ending with quotes related to the use of BIM.

3.2.1 Office 1

"…you sit and draw diagrams for how you will draw what the program says… It starts by generating images and spatial ideas; it defines some structures when you read the program" (office 1)

Here the sketching starts when the reading of the program starts. The sketch is used to interpret the program and to make diagrams that point towards solutions to some of the problems or demands listed in the program. In this quote the focus is on the traditional drawing as sketching but modeling programs and physical models are also used. In terms of sustainable issues and how they address them during the design process is not expressed directly, but in the following quote it becomes evident that this might be a new area for them to work with.

"It can be frustrating that the tool you need, the tool that can show if the orientation of the house should be one way or the other or how open the facades should be, is missing. It is someone else that deals with it and you are told that you cannot get the answer immediately." (office 1)

In terms of designing sustainable or environmental architecture these are basic parameters to assess. The question is how a tool will help if they don't have the knowledge about the relations between the architectural expression and the energy consumption as the parameters they mention have great influence on these issues. However as it is seen in the following quote they are trying to investigate the possibilities of what different tools can give them in relation to the implementation of BIM as the platform for working in the office.

"We are currently looking into Revit that we are using to see if any of the analysis programs or plug-ins can help us" (office 1)

Overall this office can be described as still being in a phase of searching for not just technical solutions but also general knowledge about the subject in a broad sense. There are a few key persons that have the knowledge, but it is not something that is widely spread in the office. Furthermore there does not seem to be an overall strategy for what they should achieve in terms of working with sustainable issues and it points towards working in the traditional way mentioned before where the engineers solve the problems in the end, though with an awareness of that this can be changed.

3.2.2 Office 2

"You can say that there are two main tracks… during a competition. They both start at the same time for full speed. One will be an analytical approach to the project... A thorough analysis of what has to do with the program and the assignment. At the same time another track is running where physical models are used to test and study formal consequences of the analysis and volume studies of the program and how the different functions relate" (office 2)

Again it is seen that analysis and sketching are starting simultaneously. With this office there is a very well defined approach to the beginning of the design process. It is very clear that formal studies are conducted along with the analysis and during the progression of a project it becomes more detailed and the analysis informs more and more of the form. Furthermore it expresses what appears to be a very open mind towards being influenced by new things creating an evolution which is also expressed in the following quote outlining the work they did on a project where sustainability and energy consumption were in focus.

"It's a tower where we were asked to make a combined office and apartment tower… the offices typically suffers from overheating but still wants the views but without getting direct sunlight… apartments can use the passive solar heating… so when you arrive at home in the evening it's

good that the apartment has been heated by the sun during the day and you will feel compelled to sit and enjoy the sun… It has made this tower a folded or bended version… where the apartments points towards south and up to the sky, and the offices… gets light in from high in the sky and deep into the offices… and is orientated towards north to avoid the direct sunlight." (office 2)

This quote illustrates how they implement certain parameters into the design and lets them inform the design directly. Even though the knowledge implemented here is very basic in terms of designing sustainable or environmental architecture the result is different from what is traditional seen. What is not seen in the quote is how they have worked with the engineers to verify that it is possible. Even though the idea is based on simple knowledge and sound principles it is difficult to make work. In relation to this it is relevant to discuss how they see the use of BIM as a way to achieve better co-operation and a more fluent process – however as the following quote shows they do not see the biggest potential of BIM in the early stages.

"It is especially during the planning phase, but also during the sketching phase that the expertise in calculating energy consumption is getting more developed. So I think that it is during all the different phases, but particularly during the phases after the competition something will happen when the planning becomes completely 3d based" (office 2)

This second office does not have an elaborate strategy towards working with sustainable or environmental architecture, but sees it more as something that will become more and more integrated in their design process. However they have a strong concept about their design process where they allow the different things analyzed to have a direct effect on the project. It is open for different influences and ideas. Furthermore they seem to have a good co-operation with engineers that knows them well and can help to inform the design process during the conceptual developments.

3.2.3 Office 3

"Typically within the first week or two about ten to twenty different concepts are developed that are then evaluated in relation to the criteria's that we set up... Then there can be others where we say there is something to it. In terms of energy we can make it. It's compact, good orientation and functions are related in the right way" (office 3)

Again the approach to the process is clear cut. Here the focus is on models and the criteria's set up during an analysis phase and reading of the program. It starts out by testing different ideas against these criteria's. Again the analysis seems to inform the form and the form the analysis. Furthermore it is seen that in order to address the different issues they have to be a part of the base knowledge that the design team has. Otherwise they will not be able to discuss and assess the different solutions in relation to that

 "Then there are…, PHPP and BE06 calculations. They will be defining for what we can do as architects when we design passive houses or zero energy buildings… Instead of seeing it as an obstacle for what is possible; we see it as parameter for how we can generate new values…. We have actually tried to reverse the process and starting by defining the technical… we tried to design a house where the surface area couldn't exceed a certain size, the surface should be like that and the main part of windows towards south and very limited towards north…" (office 3)

This quote shows that there is an interest in exploring some of the basic calculation tools originally developed for documentation of energy consumption in buildings and how they can be used to inform the design process. They express that they have tried to define limits they can work within and developed their design from this starting point. It shows a very active approach from the architects where they can make some of the basic calculations in order to inform the design process without relying on engineers that would normally make such calculations.

This third company has a more investigating strategy when it comes to sustainable and environmental issues and it allows them to test different things. They are open to use some of the existing programs developed for final documentation of projects and investigate what they can give to the design process. However this is work done in relation with physical and digital models as well as sketching and the calculation creates another layer of information in the project that can help to create relations between the technical issues and the architectural expression

3.2.4 Office 4

"But it is about early in the process to figure out what the prerequisites for this competition and define not only the program, but also what the prerequisites for the climate and the infrastructures are for the competition and it has to be more thorough than usually."

It is seen that the understanding of the demands in the program is important. Besides that, when working with sustainable and environmental architecture, it is seen that they are focusing on climate and infrastructure in the area. They define the targets and address these issues with different approaches when they design in order to implement solutions in the design. This approach seems focused on understanding how architecture and sustainable or environmental issues relates, which is also seen in the next quote where their strategy towards it is outlined very clearly.

"We have a strategy that says reducing, optimizing, producing energy. It's the part about reducing that is the difficult and cross disciplinary one" (office 4)

This is a very clear strategy in three steps starting with exploring the relations between the geometry of the building and its impact on the energy consumption, because they see reductions there as the best. That way their solutions cannot be discarded because of expenses. After that one can start to optimize the building in terms of insulation, windows, ventilation etc. Things that can be changed, because of costs and in the end there is the energy producing elements. However there is also an awareness of that the focus on reducing through geometrical developments is difficult. It requires focus on the multidisciplinary work and a strong co-operation between architects and engineers. Besides the awareness of the work on the team and the influence of different professions there is also the awareness of the tool as seen in the quote below.

"We do not want to be a part of making a program that works as trial and error. This is what most of the new eco plug-ins for different programs are based on. They do not teach you anything. Only by making mistakes and finding out what does not work and then you have to guess what works yourself." (office 4)

Here it is seen that there is an awareness of that tools have no meaning unless the knowledge to use them and interpret the results are present. This raises the question about how knowledge is implemented in the design process or how architects obtain this information so they can start to use tools in a conceptual way or use the knowledge more intuitively in the design process both in the sketching but also in the dialogues with engineers.

This office has a very clear strategy and approach to the work with sustainable and environmental issues. They use this knowledge to make a very close relation between architecture and sustainable solutions. Furthermore they to do it in a way so builders cannot change them because of expenses. If the architecture and the space they design have the main savings in itself, they believe that is the best. They are, as it is seen, also focused on how they get the knowledge in and are focused on that it should be something that the architect possesses and can bring into the sketching without relying on calculations and simulations.

4. Discussion

In these interviews it is seen that there is a difference in the offices awareness and approach, ranging from the basic, and to some extend almost unknowledgeable, to the very clear cut strategy and from the classical approach working with the spatial developments and their relation to the energy consumption to a more diagrammatic and holistic approach where the information about relations between the architectural expression and energy consumption informs the form directly, creating examples of architecture where this can easily be seen.

However there are also similarities between the four offices and how they experience the work. One of the important things in terms of similarities is that the sketching and analysis happens simultaneously. Some of the offices do some kind of analysis first, when they read the program and try to pinpoint what the focus should be, but during this stage sketching is also happening. This is a very important thing to notice, because it points towards the architects using previous knowledge to generate the first solutions [10] and then uses the demands and criteria from the program and the ongoing analysis to inform the architectural form as the diagram in figure 2 shows. This is especially evident in the quote from the third office where they generate maybe 20 models in the first two weeks and then assess them through the demands in the program and discuss which ones could be possible. But this also raises a question to how knowledge about sustainable and environmental issues can become a more integrated part, because if this knowledge is not present during this part of the design process it can become more difficult to solve the problem set up in the program.

Conjecture/Idea ⟷ Analysis ⟷ Presentation

Fig 2. Representation of conjecture analysis where the analysis part here is consistent with the analysis, sketching and synthesis phase from the IDP where the increasing amount of information informs the development

Another similarity between the offices is that they all see the calculations as being the engineers' job. Even though the third office is using calculation programs they use it in a very conceptual way. This can be said to be a slightly old fashioned approach to the design process especially as the demands to documentation during competitions are increasing, however this demands that an increased co-operation and communication between the different professions participating in the design process.

This is exactly what the fourth office points at in their last quote – that the multidisciplinary work is important to move further in terms of designing sustainable and environmental solutions in a Danish context. All of the offices interviewed in general have good examples and experiences from this work, but there seems to be a tendency towards that the offices with most existing knowledge about the sustainable issues are able to move further. Both if the team work is good but also if it does not work. In that case they have the knowledge to push the work further and they have knowledge they can use to do some of the basic work that an engineer might have done. However none of the offices sees this as a good solution.

4.1   One step further?

This raises the question about what is needed to take a step further in terms of working with sustainable and environmental architecture. The first thing to be aware of is the progression in the design process. As it was seen the sketching and the analysis was two more or less parallel paths informing each other where the first ideas are based on previous knowledge [10]. This means that if the knowledge is not present in the sketching phase, it can be something that is "applied" later. This means that there is a difference between the actual design process and the IDP [12], as it is seen in an educational context where the integration of the technical knowledge concerning sustainable and environmental parameters are dependent on the engineers bringing it in to the design process from the beginning if the architects does not have the knowledge. In the educational context where the IDP is developed the students work with all the parameters during the process and implement the environmental concerns from the beginning [15].

This means one can point at two immediate solutions that will help to move this work one step further. One is that the architects have the basic knowledge about these issues and when they work with the first sketches are able to bring that basic knowledge into the design as it is seen some of the offices are trying. The other solution is that the engineers becomes "designers" in the design process and work along with the architects during these early stages taking an active part in the design process. But neither of these will work alone. From the experiences the offices brings forward it is seen that the architects needs the basic knowledge but the engineers also needs to take active part in the design process and bring their knowledge forward. In the end it becomes a question about communication on the design team.

This points towards BIM as a solution to make the communication in information between models better and more streamlined allowing for making simulations of for example energy consumption quicker with an increased interoperability. However in order to take the full advantage of this, the fourth office points at something crucial, namely that in order for this to make sense and stay efficient the models should already have been informed by some very basic considerations related to environmental or sustainable issues in order not to spent time on assessing solutions that could have been discarded because it was evident that it would not be possible to solve, just by looking at it. BIM is merely a platform that allows for increased interoperability between professions and sharing information and the results in terms of more sustainable or environmental architecture will not change unless the right information has been implemented in the very first stages so the basic considerations have been made

5. Conclusion

What is seen in present paper is that knowledge about the relations between the form and architectural expression of the building and its energy consumption is important to move further, which is confirmed by the interviews. Even though there is an increasing amount of programs to calculate and simulate energy performance and other sustainable parameters during the design process the interviews shows that it is more important to be able to implement this knowledge before the programs are introduced. Today it is often the engineers that have this knowledge, which means that they need to become a more integrated and active partaker in the design process than has traditionally been seen in a Danish context. There is a need for closer co-operation between the architect and engineer. In a longer perspective the architect should start to posses more of this knowledge. Not to take over the job of the engineer, but to push the architecture further in terms of challenging the perception of what architecture can be. One of the important tools here can be BIM, but it is important to remember that it is a platform that can help to create a leaner and more effective design process. It does not solve problems without the participants in the design team using their combined knowledge in a dialogue where this knowledge is used to form the building.

Present paper is focused on the competition stage and in the interviews discussions about other projects have been avoided. However there is basis for expanding the conclusions into these fields. The aim in any project these architects work on is to design a building for the client that meets the standard of what the office do. In order to achieve these standards it is important that they have the ability to implement this knowledge whether it is a competition or any other kind of project.

6. Acknowledgement

We would like to thank the offices that participated in the interviews for taking the time to discuss their design process and their view and experiences of working with sustainable issues in their projects.

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APPENDIX 7 - PAPER 5

Petersen, MD & Knudstrup, M 2011, 'Environmental Challenges in the Design Process: Qualitative Interviews with Eight Offices', Architectural Science Review.

Environmental Challenges in the Design Process: Qualitative interviews with eight offices

Abstract
Present article is based on qualitative interviews with eight offices involved in the early conceptual stages of the design process. It investigates what experiences they have with their design process especially in relation to address environmental issues. The data from the interviews are analyzed through a coding scheme that focuses on what experiences they have in the early stages of the design process with the brief, the environmental concerns and the challenges they meet in their work. From the interviews it is seen that the direction today is to have an increased focus on a multidisciplinary design process. Here the collaboration and broad field of experiences the participants have is needed to be able to address and inform the design process in connection with the environmental concerns from the beginning.

Introduction

In the strive towards designing environmental architecture, the focus in the past decade has been on the notion of an integrated design process. This is directed towards the implementation of technical knowledge into the early conceptual stages of the design process, as a means to achieve high environmental performance. This is for example seen in IEA Task 23's notion of "Integrated Design" and the notion of "Integrated Energy Design" (Löhnert, Dalkowski & Sutter 2003, Synnefa, Karlessi & Santamouris 2008). Both of these are focusing on "Integrated Design" as a multi-disciplinary process where all participants join the team from the beginning. Furthermore a continuous evaluation of the different parameters related to environmental issues in architecture is in focus.

In a Danish context the focus is primarily energy efficiency when discussing environmental architecture. A matter that is outlined in the building regulations and has been since the oil crisis during the seventies (Erhvervs- og byggestyrelsen). Today we are moving towards designing passive houses and zero energy buildings in Denmark inspired by the experiences from Germany, Austria and Switzerland. This increases the need to be able to address the environmental issues from the very beginning to succeed in this. However some of the first experiments with designing these in Denmark show that there are problems with the ability to predict the performance of these buildings as well as addressing issues related to energy performance as a part of the design process (Brunsgaard, Knudstrup & Heiselberg 2009).
Looking at how the design process is approached traditionally, it is seen that it is based on previous experiences. It is described from a theoretical point of view in connection with conjectures in the design process (Hillier, Musgrove & O'Sullivan 1972). Other research shows that the design process is based on precedents or previous cases (Oxman, Oxman 1993, Agnar, Enric 1994). Furthermore it is seen that architects are focused on their solutions and not understanding the problem at hand as research with students shows (Lawson 2006). The core of the problem in architecture is what can be described as ill-defined or wicked problems where there is no clear right or wrong, but where it is the arguments and interpretation of the problem that is important (Rittel, Webber 1973). Addressing such problems requires experience within the field the problem is located in, to address such a problem and be able to structure and respond to the problem.

The present research investigates how architects working with environmental architecture approach this in the design process and how they structure the design process. Through interviews with architects and environmental design consultants and case studies this is
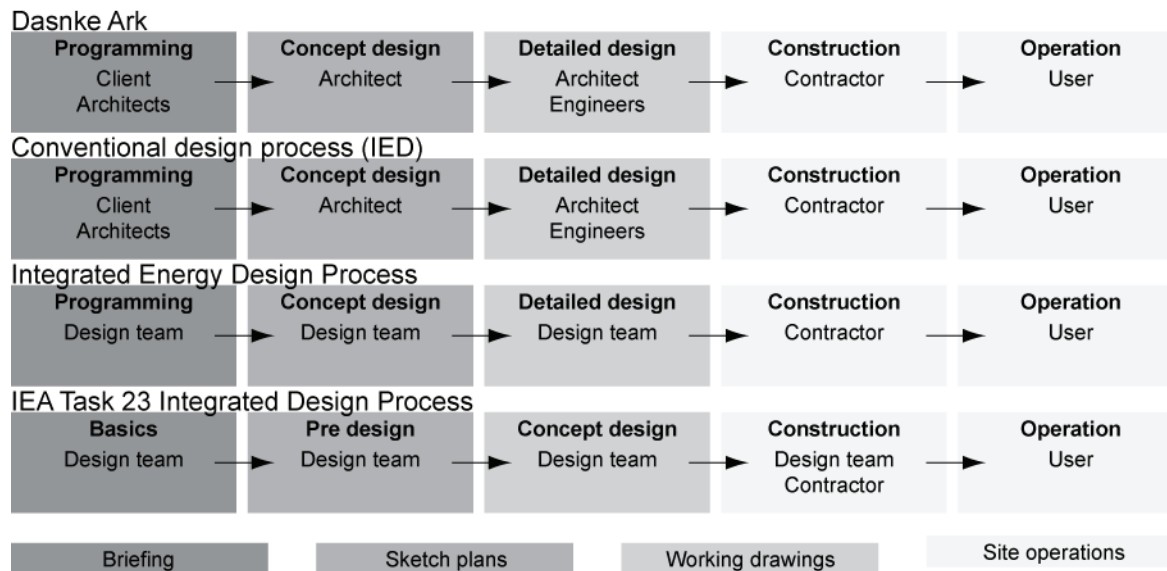
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investigated. Here the focus is especially on the very early stages of the design process before the concept emerges.

Present article takes its point of departure in qualitative interviews with eight offices involved in the first conceptual stages in the design process. The interviews focuses on the experiences they have with addressing environmental issues during the design process and how they structure their work in relation to this. The interviews show that the design process does not differ from others in the respect that they completely restructure it. Where it differs is their experience in addressing environmental issues as a part of the design process and their ability to address that as an integrated part of the design process. But it also shows differences in how these experiences are used. Here the most experienced have a very structured approach that can help to improve communication between the participants involved whereas others have a more freely structured process. From the interviews it is seen that collaboration between architects and engineers are needed from the beginning and the experiences from all professions are needed to be able to address the problems related to environmental issues in the design process, thus having expertise to address the environmental issues from the beginning of the design process.

1 Background

The background for present research is located within the design process and how architects approach the design problem. A problem that is defined as a ill defined or wicked (Rittel, Webber 1973). The focus on designing environmental architecture is often focused on the notion of integrated design. Today there exists a variety of definitions of integrated design process, such as IEA Task 23 and Integrated Energy Design (Löhnert, Dalkowski & Sutter 2003, Synnefa, Karlessi & Santamouris 2008). Both of these focuses on the iterations and information that is developed during the progression of the design process in a multidisciplinary design team and where this design team questions and evaluates the different design solutions during the design process. Here they are seen to focus on addressing small parts of the problem and then from there develop the solution. This is similar to what is described in relation to approaching ill-structured problems (Simon 1973). In a Danish context the description of tasks in the design process by professional organizations is outlining a different division of tasks where the engineers are not introduced to the project until later stages in the design process (Fri, Danske Ark 2006). The different processes and the composition of the design team throughout the design process are seen in figure 1. So the integrated design process focuses on the team and how to approach the design problem and it differs from how the design process traditionally is approached.

Figure 1: The different participants at the different stages of the design process according to different descriptions

Dasnke Ark

Programming	Concept design	Detailed design	Construction	Operation
Client Architects	Architect	Architect Engineers	Contractor	User

Conventional design process (IED)

Programming	Concept design	Detailed design	Construction	Operation
Client Architects	Architect	Architect Engineers	Contractor	User

Integrated Energy Design Process

Programming	Concept design	Detailed design	Construction	Operation
Design team	Design team	Design team	Contractor	User

IEA Task 23 Integrated Design Process

Basics	Pre design	Concept design	Construction	Operation
Design team	Design team	Design team	Design team Contractor	User

Briefing	Sketch plans	Working drawings	Site operations

Architects works from previous experiences as theoretical descriptions show (Hillier, Musgrove & O'Sullivan 1972). This is also seen in research, where it is the precedent experiences architects have that plays a part or previous cases that helps to direct the design process and is an important part of approaching the design problem (Oxman, Oxman 1993, Agnar, Enric 1994). Furthermore research shows that architects often select specific parameters to help drive the design process and make their conjecture from (Darke 1979). So the traditional approach to the work is based on the previous experiences and driving the design process through that. From this it is seen that specific issues are identified based on the architects' experiences. Other research shows that the point of departure for the design process is a series of interrelated stages from identifying the problem to developing the details of an idea (Macmillan et al. 2001).

With specific focus on the approach to environmental architecture it is seen that many publications are based on the architects' own experiences and takes their projects as point of departure in developing an approach such as Yeang and Feilden, Clegg and Bradley (Yeang 2006, Clegg 2007). Other publications are focused around analyzing build projects and deriving experiences from them in connection with how they respond to the environmental agenda (Sassi 2006, Baird 2010). Others again have tried to describe the approach to designing environmental architecture with new technologies such as Building Information Modeling (BIM) (Krygiel, Nies 2008). However there is very little focus on the first steps and what the architects or design team actually do and how they approach the design, which is where present article takes its point of departure, where it is the study of how architects considered as being among the leaders within environmental architecture experience and structure their design process.

2 Methods

In order to explore the experiences architects have of their design process, it has been chosen to interview them about how they work during the design process in relation to a competition and their experiences with it. Focusing on the competition is due to the compactness of this part of the process where the design team needs to address the first issues and convince the client that this is what they want. During this stage the design team sets out the concept of the building and creates an image that the client "buys". Later this image still needs to fulfill a large range of demands that might not have been an explicit part of the brief, thus it needs to

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be clear enough for further development and detailing. Furthermore it demands that some of these demands already have been considered in order to be able to respond to them. Especially when it comes to demands that are related to the geometry or overall expression of the building as environmental issues can be.

These interviews have the form of conversations with the architects in order to gain knowledge about how they work with these issues and what their experiences are. They are designed as qualitative interviews (Kvale 1994) where the aim is to provide a qualitative account for their work and extract their expert knowledge in the field. They revolve around three main themes.

1. How do they approach the design process in a competition?
2. How is the work with environmental issues affecting this and what are their experiences?
3. What barriers do they encounter with them during the design process and how do they work their way around them?

2.1 Subjects

The data for the eight offices interviewed can be seen in figure 2. Here it is seen that they range from small offices to large offices with different profiles both national and international. The selection of these offices is to get a range of experiences and have a broad base of data for the discussion and analysis. Furthermore the interviewees in the offices have different professional backgrounds ranging from engineers over architectural technicians to architects. What they have in common is that they all have extensive experiences working with environmental issues from the very beginning of the design process and develop their designs in connection with the environmental issues. The interviews are spread between four Danish offices, because it is where the research primarily is directed towards and four English offices as references, because these four offices have extensive experiences within environmental architecture.

Figure 2: The offices interviewed in the research and the data about them.

Office	Office type	Nationality	Profile	Emp.	Interviewee positions
1	Architectural	Denmark	National	11-50	Partner, Architect
2	Architectural	Denmark	National	51-200	Associate partner, Architect Architect Sustainability comptency leader
3	Architectural	Denmark	International	51-200	Partner, Architect
4	Architectural	Denmark	International	51-200	Associate partner, Design & Sustainability man., Architect
5	Consultancy	England	International	51-200	Principal
6	Architectural	England	National	1-10	Director, Architect
7	Architectural	England	International	51-200	Senior partner, Architect
8	Architectural	England	International	1001+	Urban designer, Sustainability researcher Environmental design analyst, Associate partner Head of info & design systems

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2.2 Procedure

All the interviews were conducted in the participants' offices using an interview guide in order to help direct the conversation and ensure that the three main themes were addressed during the interviews. The guide helped to direct the conversation, but the questions were not necessarily phrased as written in the guide, nor were they necessarily asked in the same order as written. It was not sent to the interviewee and therefore they had no possibility of preparing them for the more specific questions that would be asked.

The only information the offices had before the interviews were made, was a brief mail explaining why it was interesting to interview them about these themes. This was an introductory presentation of what the focus of the research was, then a phone conversation to follow up on the initial mail where they also agreed to do the interview. Finally a mail was sent with a further elaboration of the three themes. This model was chosen due to the fact that it was important that the interviewees did not have the possibility to prepare specific answers to the questions, but instead, as outlined above, had to reflect upon their own design process and through the questions asked reveal their knowledge in the different fields. It also, to some extent, prevented them from preparing answers they thought that would be good for the research.

All of the offices were interviewed once and it was just one person from the office that had been part of the correspondence. However Office 8 had three people participating and afterwards a short very loosely structured interview was conducted with a senior partner, because there were some further comments to one of the themes in the interview. Also office two differed because they were interviewed twice with different people due to unforeseen circumstances. The persons interviewed were key members of the staff with status as at least project architect or responsible for sustainable issues, which meant that all of them had a broad insight into the offices procedures and as well as knowledge about a broad range of their project catalogue.

2.3 Analysis

The analysis of the collected data was done through coding the interviews. From the three main themes for the interviews the coding scheme was designed. The first theme that focused on the approach to the design process in a competition was named "design process"; the second focused on how they worked with environmental concerns was named "environmental concerns" and the third concerning challenges and barriers in the design process was called "challenges and barriers". In figure 3 the coding scheme is seen. First a list of keywords was made that related to the three themes, which was then the basis of a content search in the transcriptions of the interviews, which was done in both Danish and English. From the content search the different sections of the interviews were read and this created the basis for an analysis of what the eight offices interviewed focused on. This created a basis of data that can be used for further discussion of the research questions (Gill 2000). A maximum of five sections of the interviews within each office and each theme were selected and within these different discourses in the discussion were identified to elaborate on the discussion and published in an interview report. Before that the interviewees confirmed what was written in the transcriptions. All together the coding formed the starting point of the analysis and was made through the qualitative data analysis program Nvivio 8, where the process of gathering, coding and analyzing the data happened (Lewins 2007). In the following when referring and using interview quotes they will refer to the office number, as they are listed in figure 2.

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Figure 3: The coding scheme in the analysis of the interviews moving from the three themes through searching with keywords in the transcripts and to identifying the topics they find important when addressing environmental architecture.
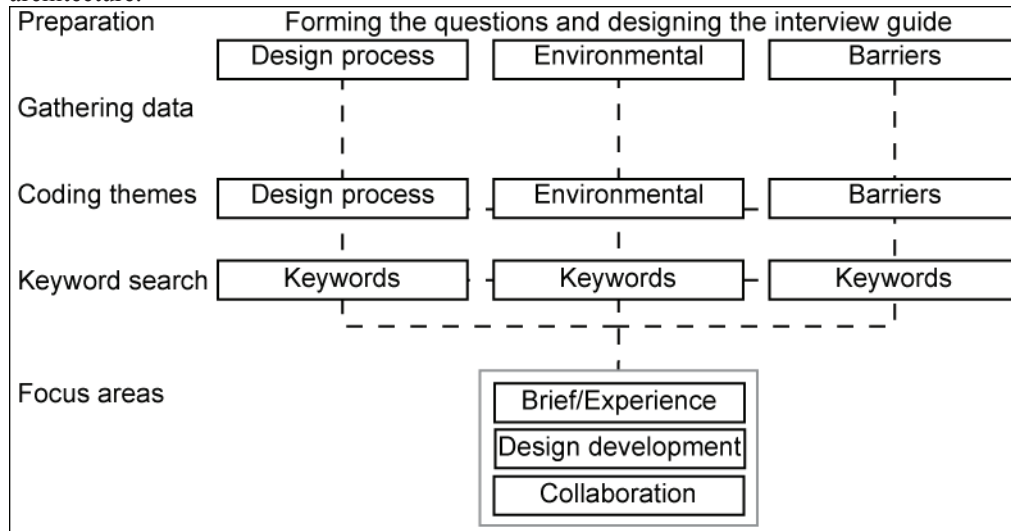
3 Results

The starting point here is also the starting point of the design process and how the design team approaches the design brief. As one of the interviewees says *"…it's about unlocking the brief. There might be other things in the brief that you are not aware of, because the people who wrote the brief aren't aware of it…"* (Office 6). This talking about the brief as the starting point is mentioned by seven of the eight offices interviewed. This was it was elaborated further by another interviewee claiming it is about *"…quickly say what it is that does that we win this competition. Afterwards you try to design your process in a way, so that you know which things need to be in focus..."* (Office 2). All the interviewees in their answers when it comes to talking about the starting point of the design process mentions the brief. This is not surprising. But when it comes to the environmental concerns it is seen that it is something they are very aware of and as one expresses it they use *"…additional criteria from a professional perspective that then becomes a part of the project. These are what you have from your own knowledge and in fact they limit the amount of possible solutions to a few models…"* (Office 1).

In approaching the brief another thing they focused on was the environmental concerns. Again seven of eight offices mentioned this as something that was important as it is for example seen in a quote where the interviewee says that *"…we have to rethink these things, because we need these contextual and climatic prerequisites actively when we design low-energy buildings today. Therefore it is important that these prerequisites are precisely defined…"* (Office 4). It is seen when they talk about addressing the environmental concerns in the design process they all mention specific parameters they focus on.

Figure 4: The offices and their talk about the approach to the design brief. Here they talked about the general importance of the brief, the way they used environmental concerns and experiences in the brief and how they actually used the experiences.

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Office	Office type	Nationality	Brief	Environment	Experience	Matrix/checklist
1	Architectural	Denmark	X	X	X	
2	Architectural	Denmark	X		X	
3	Architectural	Denmark	X	X	X	
4	Architectural	Denmark	X	X	X	
5	Consultancy	England		X	X	X
6	Architectural	England	X	X	X	X
7	Architectural	England	X	X	X	X
8	Architectural	England	X	X	X	X

This focus on the environmental concerns and identifying how to approach them in the project is also seen in the role experiences play for them. All of the interviewees expressed this. As one of them states *"...then you have all these experiences in your baggage, which is the fantastic thing about this profession. You keep on adding to your knowledge…"* (Office 2). This was also mentioned above where it was seen that the offices set additional criteria based on their professional knowledge and previous experiences. However what is interesting here is that four of the offices interviewed mentioned it as something being important for their approach to the design process. But there were also four offices that besides mentioning the importance of it also had expanded the work to design checklists or similar tools to formalize their experiences making them operational and explicit in connection with their design process. Both to determine what would be important based on previous experiences and also to communicate with clients or others involved in the design process. One of them talks about how this framework is designed in their office when saying that *"...we have something called Sustainability Health Check...we use that to collect information on each project in the office, in each stage of the design process, so once completed we go back and collect the operationally energy and feedback from the tenants and building users…that allows them to start challenging M&E's [mechanical engineers] and other consultants as well…"* (Office 8).

3.1 Approaching the work between design brief and design development

Looking further into the work with the brief it is seen that all of the offices interviewed focus on the interrelationship between the work with the brief and the sketching, modeling, or other forms of representations seen in connection with the development of the design process. This is seen in figure 5. This is clearly evident where one of the interviewees expressed that *"we follow two tracks. They will start simultaneously. One will be an analytical approach to the project where we try to map everything that has to do with the project's context, program and problems, site analyses, analyses of program and previous projects within the field, what has been done before and what hasn't been done before. A thorough analysis of what has to do with the program and assignment…".* (Office 3). This is then later in the interview elaborated with *"...at the same time we have another track where we have a physical approach to the design process and we start to test and study what the analysis means on relation to the form, studies of the form, studies of program and volumes and how they are connected. So there we*

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always build physical models..." (Office 3). So this office clearly states the procedure of the design process as it is also expressed by others. And as one of the interviewee's state *"...it's the nature of being a creative person you know. The minute after briefing, get the napkin out and start drawing something. It doesn't mean you're going to be stuck with that..."* (Office 8).

Figure 5: The offices and their talk about the relations between sketching and analyzing and what they used during the early stages of the design process.

Office	Office type	Nationality	Analysis	Sketching
1	Architectural	Denmark	X	X
2	Architectural	Denmark	X	X
3	Architectural	Denmark	X	X
4	Architectural	Denmark	X	X
5	Consultancy	England	X	X
6	Architectural	England	X	X
7	Architectural	England	X	X
8	Architectural	England	X	X

During the initial stages it is this sketching that is important for the design team. It is here they test their ideas so to speak or test how the brief can be used to inform the form of the building. As one of the interviewees say in talking about sketching *"...it can also be sketches that do not give you the solution, but we know that it is in this area it should be. We need to define an edge to the site… Now we made this solution, but it does not correspond with the first sketches in the analysis..."* (Office 2). So we see that all of the offices have an approach to the design process where they work with sketching and analyzing interchangeably during the process and they inform each other.

3.2 Collaboration between professions in the design process

Figure 6: The offices and their considerations about collaboration, their experiences in working with BIM and how they perceive BIM as a part of the design process at the early stages discussed in the interviews.

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Office	Office type	Nationality	Collaboration	Critical BIM	Worked with BIM
1	Architectural	Denmark	X		X
2	Architectural	Denmark	X		X
3	Architectural	Denmark	X		X
4	Architectural	Denmark	X	X	X
5	Consultancy	England	X	X	X
6	Architectural	England	X	X	
7	Architectural	England	X	X	X
8	Architectural	England	X	X	X

During the interviews the talk about collaboration kept returning. The importance of collaborating from the beginning was mentioned by everybody. It was especially in connection with environmental and mechanical engineers when it was about addressing the environmental issues in the design process. It was something they had mixed experiences with. A good experience is seen where an interviewee tells that *"…I experienced that in [a project] where the engineers sometimes sat down here with their energy calculations and assessments of the PV-cells' efficiency, then you would sit for half a day or an entire day and test different things…"* (Office 2). On the other hand there are the more negative experiences as seen when an interviewee says *"…if I have to look back in relation to the different processes, then we have a traditional process where we try to pull it in a direction where we have challenges. It is when we get the program and start and the first meeting with our collaborators maybe is one week into the process and the engineers maybe show up unprepared. They haven't done their homework and can't come with the contributions they should…"* (Office 4). These are representing the two extremes in the collaborative experiences. All offices had both good and bad experiences in this field. Besides these experiences they also mentioned what is important in order to have a successful collaboration today where one of them states that *"…the real trick is, and this sound very cynical, but the trick is to make it so obvious that what you're suggesting is the right solution. You make them think they thought of it. You get the best traction of people if it seems to be a collaborative decision. The minute you start to bang them on the head with a hammer you don't get that far…"* (Office 5).

In talking about collaboration the use of Building Information Modeling (BIM) was also mentioned in connection with being the platform for collaborations. Here it was seen that seven of the eight offices used it on different projects and that it was being more common. The only one that did not use it was a small company mostly working on smaller project. However in talking about BIM there were five of the offices there was very critical in their discussion. Not because they were in experienced, but because BIM in their opinion did not bring anything into the design process at the early stages that was the focus of the interviews. Even though the others used it they also admitted not to use it during the early stages of the design process.

4 Discussion

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In the results three different themes were seen. There was the approach to the initial brief and; the work with developing the design and finally there were the focus on the collaborative effort needed to achieve the results they strive to achieve in connection with environmental performance.

Starting with the initial brief it is seen that the interviewees have find the brief important as the starting point and it is here they define the benchmarks for the project. It is also evident in the approach to the brief that their experiences from previous projects are important. It is their experiences they use when they define additional criteria if there are things there are uncertain or undefined in the brief. Here it was seen that especially the English offices were very focused on using their experiences and all of them formalized these experiences to make them explicit. This also opened up for using them in communicating and discussing what they did in the process.

These experiences were especially important when it came to identify how they should approach the environmental agenda. Here the extensive experiences from the English offices and their formalized approached created a framework for the process that allowed them to focus on key issues. In the Danish offices on the other hand they still used the experiences, but it was used in a more haphazard way and was more related to individuals though also making the work with environmental issues in architecture highly dependent on a few individuals. Naturally there were individuals in the English offices that had much more experiences in environmental architecture than others, but they focused on the dissemination through their framework

So the starting point for the design process and where the key issues is the brief and the approach and work with the brief is highly dependent of the design teams previous experiences in connection with working with environmental issues and their ability to utilized them to identify the key issues for the given project.

4.1 Analyzing and sketching in the development of the design proposal

With the brief as the starting point the development of the design started. Here all offices worked more or less simultaneously with the two. What was evident was that they did not seem them as two separate things but as two interrelated parts of the design process that informed each other. As one of the offices expressed the sketch was not necessarily solution. It was also seen in connection with the models where they informed the analysis and all of the offices used this work with various representations actively in the design process as a way to develop information about the process. It could help them to reveal issues that they could not read from the brief or other documents.

Again it was evident in these parts of the interviews that the ability to address the environmental issues during the development of the design was dependent on their ability to use their experiences. So again it was seen that the English offices with their formalized framework almost had a library of possible solutions they could adapt to the given project or they could use as a starting point for developing a new solution because they could see how they had approached similar problems before. So in this respect it was seen that this formalization was very beneficial.

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In the Danish offices they appeared more searching when it came to address the environmental issues. But on the other hand it was seen that they were not afraid of trying new ways of approaching the sketching and using new information or tools to inform the design process. So in terms of informing the development of the design it was seen that experience is the key to ensure that the issues are approached, but a curiosity and will to explore new ways of approaching the design process also could prove to be valuable.

4.2 Collaborating on common ground to design environmental architecture

The last theme that was seen was the focus on the collaborative effort. Not a collaborative effort in a traditional sense where the engineers are introduced late in the process and serves as problem solvers as figure 2 suggests. But instead a collaborative effort that starts from day one. In the interviews it is seen that it is the focus on the expert knowledge from the different participants that is important. As the interviewee said it was good to have the engineers there to work with them and inform the process with their expertise. It was about having the ability to quickly address issues and being able to determine if this was viable or not.

In talking about this collaborative effort the talk about BIM also surfaced. BIM that is a collaborative platform that allows the entire design team to exchange information through the model quickly thus having all the information related to the given building in a single model (Eastman 2008). However even though all of the offices, except one, used it and had started to use it more, they did not use it early in the design process. When used it was when there was a single model and concept and then the use of BIM was a help for the collaboration. But during the early stages the design process was informed by the close collaboration between the participants in the design team through sketches and experiences the different participants had.

In terms of collaboration it cannot be stressed enough that it from the interviewees' point of view is an important factor in addressing environmental issues in the design process. Through the collaboration it becomes possible to get access to expert knowledge that can help to explore and inform the design process. This is expert knowledge that traditionally would not be accessible in the design process until later.

5 Conclusion

In the interviews it was evident that addressing environmental issues during the design process is not something that alters the design process significantly in terms of the steps they are going through as a part of the design process. This being said the interviews shows three things that are important things to be aware of when addressing environmental issues in the design process from the very beginning.

1. The identification of the prerequisites in the brief and the values the design team finds are essential to address based on their previous experiences from working with environmental issues in architecture in order to address the environmental agenda.
2. An explicit use of their experiences both to work with the brief and identify the prerequisites, but also to drive the design process forwards and develop the design solution from the first stages, both in terms of generating and evaluating ideas throughout the design process in connection with the environmental concerns.
3. The ability to work constructively in a collaborative environment where the participants together explore the how each of their knowledge and experience can be

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used to inform and develop the design proposal in a way that responds both to the architectural visions and the environmental concerns. Here BIM is not a prerequisite on the early conceptual stages but is important during the later stages of the collaboration.

What these three points have in common is the experiences as the key to working with this. And it is not only the experiences of the architect, but the entire design team to be able to explore the environmental agenda. As all of them say it is paramount that they can discuss these issues from the beginning of the design process. Furthermore the intentions need to be made explicit from the beginning. If it is not something that is mentioned in the brief it is something the design team needs to be able to focus on and add to the brief, thus increasing the focus on it.

The challenges we see when it comes to working with environmental architecture is about how we approach the design process and how we question the design solution. It is not that the process in itself and the development through sketches, models or other forms of representations used in the design process needs to change, but about the approach to use information in the design process. This is where BIM can be used at the later stages, but during the early conceptual stages where multiple models are in play experiences are much more valuable for the design team. It is about being able to use the entire base of knowledge on the design team from the beginning. This requires that there is focus on the boundaries between the professions and challenge them. It is the focus on exploring how the design team together can contribute to the design with their professional knowledge to develop the design. This also means that it is necessary to challenge our conception of the roles the participants in the design process have and move beyond what professional knowledge one have and move beyond that. Today it is a question of the entire design team contributing to the design and brings possible solutions in from the beginning. Of course with such collaboration it requires that the architect have an ability to understand and conduct the work and make everybody in the design team contribute to the design process and inform it in terms of environmental considerations from the beginning.

6 Acknowledgements

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APPENDIX 8 - PAPER 6

Petersen, MD & Knudstrup, M 2011, 'Approaching Environmental Issues in Architecture: A Single Case Study of a Design Process in Practice', Design Principles and Practices: An International Journal.

Approaching Environmental Issues in Architecture: A single case study of a design process in practice

Abstract:
The research presented here takes its point of departure in the design process with a specific focus on how it is approached when designing energy efficient architecture. This is done through a single case-study of a design process in a Danish architectural office. This study shows the importance of having a clear strategy about how to work with optimizing the energy efficiency in the building from the first stages of the design process. It is not just a task that can be addressed by the engineers when a concept has been developed and approved by the client. It requires architects and engineers to address it from the beginning and work actively with it, but it also requires the client to state it clearly in the brief. From this study it is evident that the work with energy efficiency requires us to focus on the formal framework for the design process. It must allow and support a multi-disciplinary design process from the beginning to address the challenges when designing energy efficient buildings.

Introduction

In the strive towards designing energy efficient architecture, the focus in the past decade has been on the notion of an integrated design process and the implementation of technical knowledge into the early conceptual stages of it, as a means to achieve that. This is for example seen in relation to IEA Task 23's notion of "Integrated Design" and the notion of "Integrated Energy Design" (Löhnert, Dalkowski & Sutter 2003, Synnefa, Karlessi & Santamouris 2008). Both of these are focusing on "Integrated Design" as a multi-disciplinary process where all paticipants in the process joins the team from the beginning and where a continuous evaluation of the different parameters related to energy efficiency in architecture is used.

In a Danish context the focus is primarily on energy efficiency in buildings during operation, when discussing environmental architecture. A matter that is outlined in the building regulations and has been since the oil crisis during the seventies (Erhvervs- og byggestyrelsen). Today we are moving towards designing passive houses and zero energy buildings in Denmark inspired by the experiences from Germany, Austria and

Switzerland. However some of the first experiments with these in Denmark show that there are problems with the ability to predict the performance of these buildings as well as addressing issues related to energy performance as a part of the design process (Brunsgaard, Knudstrup & Heiselberg 2009).

Looking at how the design process is approached traditionally, it is seen that it is based on previous experiences. It is described from a theoretical point of view in connection with conjectures in the design process (Hillier, Musgrove & O'Sullivan 1972). And research shows that the design process is based on precedents or previous cases (Oxman, Oxman 1993, Agnar, Enric 1994). It is also seen that architects are focused on designing solutions and not understanding the problem at hand as research with students shows (Lawson 2006). Furthermore the core of the problem in architecture is an ill-defined or wicked problem where there is no clear right or wrong, but where it is the arguments and interpreting the problem that is important (Rittel, Webber 1973). Working with energy efficiency in architecture is a new thing and the priority in Denmark is the energy performance. Therefore the precedents in the design are very limited, thus making it an important issue to study.

The present research investigates how architects working with designing energy efficient architecture approach this in the design process and how they structure the design process. Through interviews with architects and environmental design consultants and case studies this is investigated, where the focus is especially on the very early stages of the design process before the concept emerges.

Present article takes its point of departure in a single case-study of the design process in practice in an architectural office in Denmark. In this project, which was won in a tender, the task was to develop it from the conceptual sketch plans in a schematic design to site operations. The case study primarily focuses on the specific challenges the architects met in this project where they had to take a concept from another architect and develop it into construction drawings and take it to site, which is a normal procedure in a Danish context. The project followed in this case study is framed within the structure of the design process prescribed by Danske Ark seen in figure 1 (Fri, Danske Ark 2006). The case study shows that it is a challenge to design energy efficient architecture in such a structure where the architect and client develop the concept alone. It shows that even though the design team at a late stage in the process can address the issues and reduce the energy consumption, it is paramount that the thoughts about energy efficiency are a part of the project from the beginning and that all participants in the design process from the

beginning and explore the considerations about energy efficiency from a collaborative point of view.

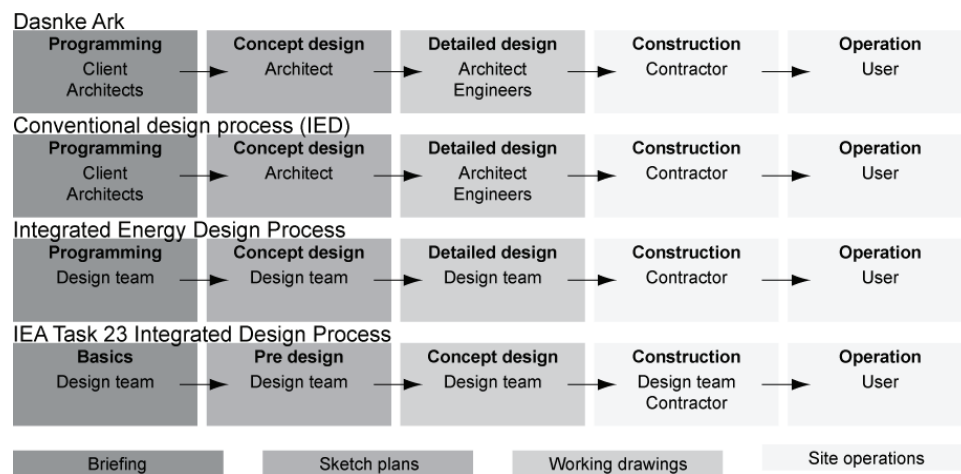**Figure 1:** The formal structure of different descriptions of the design process.

Danske Ark	Traditional design IEA task 23	Integrated design IEA task 23	Integrated energy design
Idea	Investigation of basics	Basics	Preface
Strategic briefing	Schematic design	Pre-design	Introduction to IED
Project management	Design proposal	Concept development	Communication/cooperation
It coordination	Preliminary design	Design development	The design process
Prelimenary design	Building documents	Building documents	Programming
Project proposal	Mass records/advertising	Negotiation/contracting	Concept design
Authority approval	Negogiation/contracting	Execution/commissioning	Detailed design
Detailed design	Construction management	Operation	Construction
Project clarification	Construction supervision		
Construction management	Building documentation		
Technical inspection	Supervision after 1 year		
Operation			

■ Briefing　　■ Sketch plans　　■ Working drawings　　□ Site operations

Background

The background for present research is located within the design process and how architects approach the design problem that is defined as an ill defined or wicked problem, thus being a problem with no clearly right or wrong answer to it (Rittel, Webber 1973). The focus on designing energy efficient architecture or environmental architecture is often focused on the notion of integrated design. Today there exists a variety of definitions of integrated design process, such as IEA Task 23 and Integrated Energy Design (Löhnert, Dalkowski & Sutter 2003, Synnefa, Karlessi & Santamouris 2008). Both of these focuses on the iterations and information that is developed during the progression of the design process in a multidisciplinary design team. Here the design team questions and evaluates the different design solutions and parts of them during the design process. In a Danish context, however, the description of tasks in the design process by professional organizations is outlining a different division of tasks where the engineers are not introduced to the project until later stages in the design process (Fri, Danske Ark 2006). Figure 2 shows when the different participants are involved at the different stages of the design process.

Figure 2: The participants during the different stages of the design process according to different descriptions of the design process

Dasnke Ark

Programming	Concept design	Detailed design	Construction	Operation
Client Architects	Architect	Architect Engineers	Contractor	User

Conventional design process (IED)

Programming	Concept design	Detailed design	Construction	Operation
Client Architects	Architect	Architect Engineers	Contractor	User

Integrated Energy Design Process

Programming	Concept design	Detailed design	Construction	Operation
Design team	Design team	Design team	Contractor	User

IEA Task 23 Integrated Design Process

Basics	Pre design	Concept design	Construction	Operation
Design team	Design team	Design team	Design team Contractor	User

Briefing	Sketch plans	Working drawings	Site operations

So the integrated design process focuses on the team and how to approach the design problem and it differs from how the design process traditionally is approached. When approaching the design process the architect works from experiences as theoretical descriptions show (Hillier, Musgrove & O'Sullivan 1972). This is also seen in research where it is the precedent experiences architects have that plays a part or previous cases that help to direct the design process and is an important part of addressing the design problem so knowledge from previous projects forms the basis of the development of new projects (Oxman, Oxman 1993, Agnar, Enric 1994). Furthermore research shows that architects often select specific parameters to help drive the design process and make their conjecture from (Darke 1979). So the traditional approach to the work is based on the previous experiences and driving the design process through that. Furthermore research shows that the point of departure for the design process is a series of interrelated stages from identifying the problem to developing the details of an idea (Macmillan et al. 2001).

With specific focus on environmental architecture it is seen that many publications are based on the architects' own experiences and takes their projects as a point of departure in developing an approach such as Yeang and Feilden, Clegg and Bradley (Yeang 2006, Clegg 2007). Other publications are focused around analyzing build projects and deriving experiences from them in connection with how they respond to the environmental agenda (Sassi 2006, Baird 2010). There are others that have described the approach to designing environmental architecture with new technologies such as Building Information Modeling (BIM) (Krygiel, Nies 2008). It is through these different ways of describing the work that has been done, guidelines or different issues to address have been derived. There is very little focus, however, on the first steps and what the

architects or design team actually does and how they approach the design, which is the point of departure here.

Methodology
In this single case-study different kinds of data have been collected to use multiple sources of evidence, thus making a triangulation of data (Yin 2003). As seen in figure 3 the data consists of observations of the daily work in the office; observations during meetings with consultants, clients and users; note taking and reflections during the day, as well as studies of documents in the form of mail correspondence during the process, minutes and agendas from meetings and documents from the early part of the design process where the concept was established.

Figure 4: Schematics of connection between case-study questions, data collection and analysis
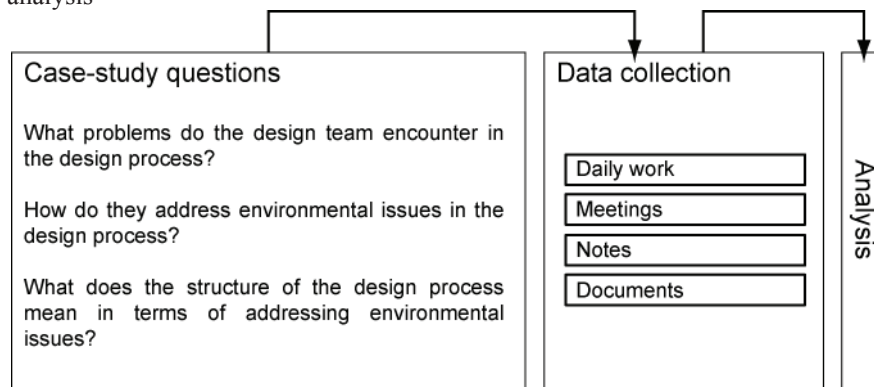
The data collected during the case study are based on the researcher being a passive observer of the events taking place and the observations are based on notes taken during the meeting and the daily life in the different settings as the work progressed (Bryman 2004). Besides these observations of the daily work and meetings, the documents produced throughout the process have also been of importance. It has been minutes and agendas from meetings where the topics discussed, and the progression of the project can be tracked as well as drawings presented and discussed during the different meetings. Furthermore the understanding of what had been important in the building concept was crucial so previous documents, such as the brief of the project, mail and document correspondences between the previous architect and the client have been collected.

The collection of data was spanning from the middle of January 2011 to the end of March 2011. Throughout the process notes have been taken from developer meetings with the developer, the users and with engineers as well as the daily work in the office and documents in the form of minutes from meetings have been collected and form the basis of the data. All data have been collected in Nvivo8 that has worked as a database. Here it has been analyzed with the aim to study how the design team has worked with designing an energy efficient building and what is of importance in this process (Lewins 2007).

Information in the process

Before looking specifically at the process and the information in it, the design project should be introduced and put into context. Figure 4 shows the stage the project was at while the case study was conducted. It was actually two projects that were followed with the same client, architect and design team and only slightly different users. Here they will be discussed as one though, as the differences were small and the challenges in the projects were similar.

Figure 4: The timeline of the project where the observations are made from January to March
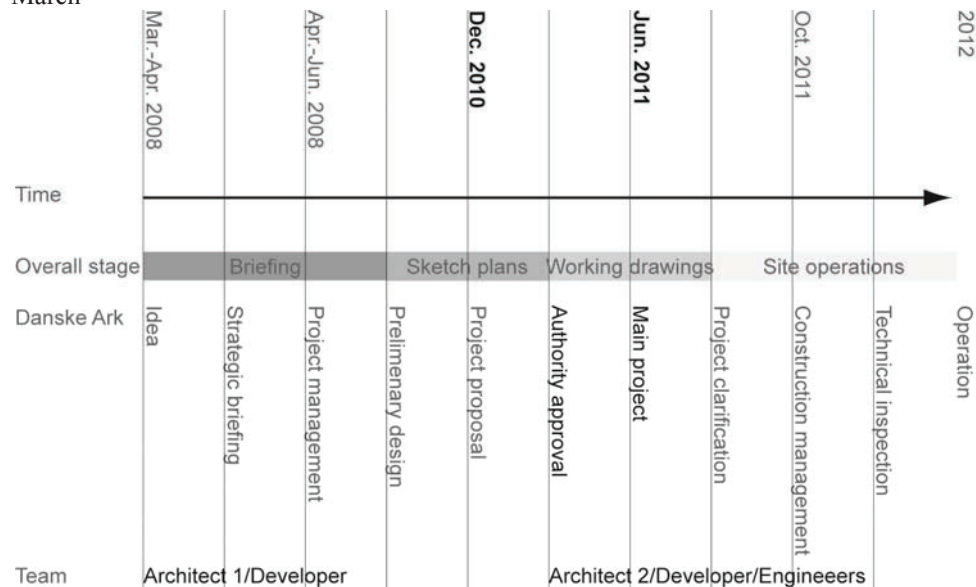

Figure 5 shows the plans for the two projects. In figure 6 the two representations of the projects made by the architect initially working on them are seen. They also show the location in a forest area and in depressions in the landscape. Already by looking at the location of the

projects in these areas, it is seen that the client's stated goal of achieving the Danish 2015 energy standard would be difficult. Another issue that is important to note in this context is that both projects are located in heritage listed areas, which, besides reducing the possibility of making changes to the site, also means that the application of renewable energy sources on the buildings is not a possibility, because the authorizations to build are based on external timber cladding as well as green roofs or roofing felt.

Figure 5: The plans of the projects as they were in the beginning of the process where the colors show the different areas as a rough outline
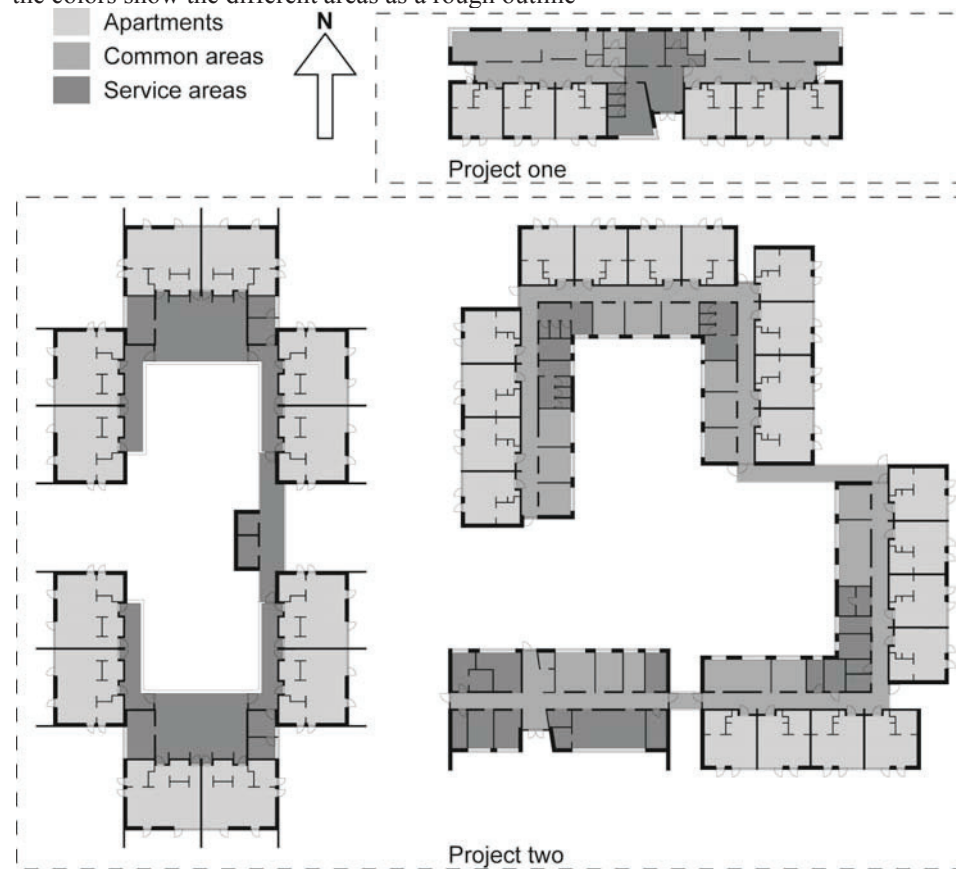
Figure 6: The perspectives of the project as they were in the beginning of the project after the tender was won. The left side is project one whereas the right side is project two
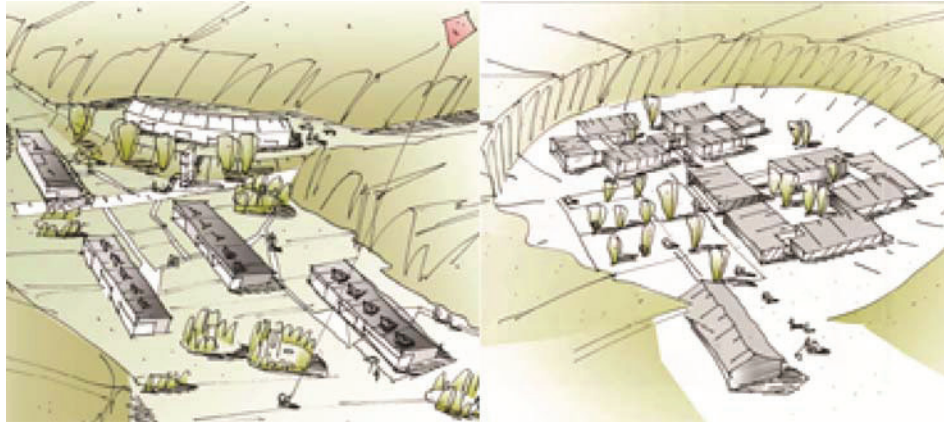
With the above the context of the project is set and as it can be seen that one has to recognize that there is a large amount of restrictions of what the architects and the rest of the design team can do in the current project.

Framework of the design process and the intentions
The starting point for this process was the material they received when they were preparing the tender. It was plan drawings, rudimentary perspectives, as seen in figure 5, and a few rudimentary sections, beside guidelines from the client outlining the demands the client had set for the user group the project was designed for. Furthermore they had the planning documents that were based on the concepts developed during the previous stages. In relation to the tender material and one of the specific points that needed to be outlined in the bid was sustainability and low energy consumption – a point that was highly regarded by the client and they aimed for achieving the Danish 2015 standard.

Looking at the process the bidding is a natural handover of information and the bid is based on the information they were provided with here. However here it is also important to note, that during some of the first meetings as well as internal discussions among the design team, that the level of detail in the project in the new architect's opinion was not high enough to the given stage of the project. Furthermore, during meetings and discussions, it proved that some of the guidelines that the client referred to were not updated or did not take the specific user group into account, thus causing confusion. More specifically looking at the energy consumption and the material that was accessible from the early parts of the process, before the tender, it was not something that had played a significant role in the conceptual design. In fact the first mentioning of it was from the summer of 2010, which was two years after the project was initially

commenced. And the notion of it at that stage was that they would need to add 5% floor area to accommodate the increased level of insulation in the walls to fulfill the standard in 2015. Besides that there was very little evidence of discussions about low energy consumption or sustainable issues in general as well as no evidence of analyses or assessments of energy are found that supports that increased insulation will be enough. This is similar to what was seen in the planning documents from authorities that had no special mentioning of that they want buildings on the site that exceeds the minimum demands in the legislation (Aalborg Kommune 2010b, Aalborg Kommune 2010a). This was in contrast to the client's wish to brand themselves as being aware of energy efficiency and environmental issues and having increased focus on this in the tender.

Challenges with information in the design process
Looking at the communication in the process itself and how it has been maintained during the process there were two distinct forms of communication. There was one that can be said to be a more informal. This was the daily conversations in the office with questions and clarifications, and phone conversations with developer, users and engineers. Then there was a more formal one at developer meetings with developer, users and engineers where design developments were discussed and decisions taken as well as mail correspondences for more formal clarifications during the time between meetings.

The communication on this stage was also dependent on what had happened earlier in the design process. During the meetings and the daily work it was seen that especially earlier decisions were questioned in order to understand what the basis was. There were uncertainties about the decisions that had been taken especially in relation to concerns about energy consumption. During meetings it was seen that the participants were uncertain about why things were as they were and users, clients, and architects were unsure about the basis, so a great amount of time was spent on understanding this and reestablishing an information level that could support the decisions needed to develop the project into the detailed stages.

With the point of departure in the discussions about energy efficiency this is where the starting point will be. Here the first thing to notice is that the architects from a meeting in December wrote that fulfilling the requirements for energy demands, the client asked for, would be difficult. The next time it was mentioned, at least as the primary focus, was at a meeting in the end of January with the engineer where the topic of energy was discussed again. Here the engineer was introduced to the project. At

that meeting the aim was to discuss the project with the engineer for the first time and give information and drawings to them, in order for them to make the first energy screening. The results of this screening are seen in figure 7. During meetings the screening was not discussed extensively and only a few issues were touched upon. In relation to this it was also seen that the client always expressed certainty that the buildings would fulfill the demands set up, however, during internal discussions between architects and engineers and in the architectural office it was seen that it was something that caused a lot of problems to fulfill and during meetings they expressed doubts about if it was possible to achieve the aim. However in the end they did meet the requirements as it was expressed in the minutes from a meeting in the beginning of April 2011.

Figure 7: The results from the first energy screening made by the engineers

General assumptions	Input to energy optimization project one	Input to energy optimization project two	Alternative solutions to achieve low-energy standard
Insulation: - Roof min. 490mm - Floor min. 450mm - walls min. 345mm - Windows max u-value 0.85; shgc 0.5 Decentralised ventilation with heat recovery of 85% Heat from districtheating to radiators Usage controlled ventilation Natural ventilation in office spaces Summer only extraction of air	Reduction of window areas: - Changing windows to parapets of same construction as walls - Reduction of windows towards north. To achieve the requirements in the building regulations a 14% reduction is required from the original - General reduction of window areas	Fulfills low-energy require-ments for example if: - Usage controlled ventilation and only extraction of air in the summertime - General reduction of window areas by 80% It appears that low energy class 1 is not achievable by passive means alone.	- PV-cells on roof - New plan solution with more compact disposition and placing more windows towards south and less towards north - Solar heating on roof

Discussion

From the present case-study it is seen that there are problems in the way we approach the design process today. Here it was seen that the work with achieving the demands were a struggle during the design process, though the project did meet the energy demands in the end. It is of course difficult to say what would have happened if a multi-disciplinary team had been used from the beginning. But it is possible that some of the basic questions that caused problems could have been addressed from the beginning. As it was seen in the environmental screening in figure 7 the engineers questioned the geometry and orientation of the building. These are basic parameters and they have to be addressed as one of the first things because they have a huge impact on the energy consumption in the building. In this case the knowledge and experience about how such parameters could have been a help to inform the concept about the environmental concerns from the beginning of the design process were not present in the beginning when it was actually needed.

So what is seen in the problem with designing energy efficient building here, is that it goes back to the brief and the first thoughts about what the project should be. Having stated that it should be an energy efficient building fulfilling the highest demands in the Danish legislation it should have been addressed from the beginning. Increasing the level of insulation as it was done after two years was a step on the way, but it was not sufficient to achieve the goal as the screening also showed. This is also seen in that the first energy screening was made after almost three years, but it could have been used to inform the design much earlier. It requires that the question is addressed throughout the process and it is not just about reducing the energy consumption to heating, but to create a comfortable environment where the temperatures are kept within the comfort zone. So it is the interplay between a variety of parameters in the design process that needs to be addressed and need to inform each other.

In terms of the structure the process have followed here, which is a traditional structure, it has caused that addressing the concerns about energy consumption was not addressed until after the concept had been approved by the client and the plans for the area were based on that concept, because no one with the experience were a part of the early stages. This meant that changes that could do something significant in terms of reducing the energy consumption through changes in geometry and expression were impossible. It was a concept that was uniformed by the concerns about energy consumption that the client had set out. But it was not the architect that developed that concept that was the problem here, but just as much the client and the client advisor that took part in developing the project. Returning to figure 2 showing the participants in the different stages it is seen that they have just done as the descriptions prescribe. But that structure does not allow for the expertise needed to be involved from the beginning of the project. So unless the architect has the experience and knowledge it will not be addressed until later as in this case

Information and process
The communication and information used during the observed part of the process had a formal dimension in meetings and mails and a more informal through conversations. Both of which were important in the process in order to clarify and direct the design process. The communication in present project was mostly related to clarification of the project and not as much on how to solve and address the details. So the work here was focused on clarifying issues that should have been clarified previously and thus to try to understand the project in order to develop it.

Studying the minutes from the meetings it is seen that it is very often the same things that have been discussed and that the level of progression in during the time the project was observed was limited.

The focus on achieving the demands to the energy consumption was also limited. The client took it for granted that it was easily achievable and the work with it was primarily the engineers making calculations and dimensioning the ventilation system and discussing with the architects if there was space for it.

In this discussion it is important to be aware of that at the current stage of the project the problems related to energy consumption could not have been addressed in a significantly different way because there was no possibility for changes in geometry or other very basic parameters that could give a significant contribution to lowering the energy consumption.

This process points at the importance of addressing and evaluating different issues related to the building continuously throughout the design process, especially issues that are considered to be key aspects when working with energy efficient architecture.

It is seen that clear communication between the different participants is needed and that the design brief and program needs to be clear and all participants in the process including the client needs to question the design solutions about its possible ability to achieve the high energy demands asked for.

Conclusion

In this single case-study it is evident that the key to be able to address environmental issues in the design process is the brief and how it is approached. In this case it is difficult to say exactly what the intentions were from the architects' point of view in terms of energy efficiency, but from the documents in the project it does not appear to have been in focus from the beginning. In the end this had an impact on how the project was solved.

With this in mind it is the brief and the very first steps in the design process we need to focus on here in order to be work with the energy efficient concerns in architecture. In this project this concern was not addressed beyond a statement at some point and then mentioned again two years later. In between that no one questioned how the energy efficiency should be addressed. Two things are seen here.

1. Precisely described brief and intentions from both client and architects involved in the design process communicated from the beginning.

2. Describe and explore the brief through a broad collaborative process to use the experience base of all professions involved in the design process and through that understand the implications the basic decisions can have later in the design process.

With the first point it is a question of the formulation of the brief and the information the client gives. Here they formulate what it is they want and what requirements the building must fulfill. Today the environmental concerns and the focus on reducing the energy consumption are important to outline here. If they want to move beyond the minimum requirements in the legislation it needs to be stated clearly and they must be aware of how it can be achieved. If it is not stated in the brief it is the architect or others in the design team that needs to question if it is something that should be addressed or should have explicit focus.

The other point is about the collaboration and the design team's ability to address and question the brief and develop it. Even though energy efficiency was mentioned in the brief in this study it was not questioned by architect or client for two years. What is seen in this project is the problem if the architect does not have the experience to address the environmental issues from the beginning. However it is not the architect that is at fault. With a design process that is based on previous experiences it is extremely important that the design team have the experiences from the beginning. This is not supported in the formal structure of the design process. It is the ability to use the broad experience and knowledge base as an explicit part of the project and inform the project that is needed. This requires a change of the formal structure of the design process. Of course the structure is not necessarily enough. One must ask if it is not also a question of culture.

Acknowledgements

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APPENDIX 8 - PAPER 7

Petersen, MD & Knudstrup, M 2011, 'Reflections on the design process', Scroope, vol 21.

Reflections on the design process!

More than ever before, there have been discussions about the design process and the notions of integrated design[1] or integrated energy design[2] – especially in relation to the discussions about sustainable architecture. Both notions of integrated design are based on a multidisciplinary process where all involved parties contribute to the process from the very beginning under the direction of a facilitator or team leader. Ideally, this process should be interdisciplinary, meaning that the boundaries between the different professions are crossed by other professions participating in the design process, thus challenging each other. In a Danish context these discussions are mostly related to the design approach of low-energy buildings. Today, passive house is becoming an increasing inspiration for the standard requirements in Denmark.[3] It is expected in the future that the aim would be to achieve plus energy buildings. However, as a recent research project on some of the first passive house buildings in Denmark reveal, this pursuit is challenging considering the multidisciplinary nature of the process in designing such buildings.[4] However the question is how architects experience a design process, whether it is integrated or traditional, and how the experiences architects have from their own background, can be used in relation to addressing low-energy concerns in such an integrated design process.

Present research is focused on exploring the experiences architects and design teams have as they undergo the design process, especially in developing concepts for low-energy architecture. This involves exploring how they implement and work with the different issues from the very early stages of the design process. Through qualitative interviews this research explored experiences architects, considered being among the leaders within environmental architecture, have with the design process and how they structure it. The aim of this study is to understand these relations, and how these differing experiences of the architects help to inform and drive their design process.

Eight offices have been interviewed about this and present article presents a brief account of the interviews. Table 1 shows the different offices from the interviews. In the present article not all offices will be quoted, however the full range of offices is still shown in the table. The quotes used here and the general context of the interviews is about the architects experiences in working with environmental architecture, therefore all the quotes should be seen as remarks that relates to addressing environmental issues – or more specifically low-energy architecture.

Table 1: The eight offices interviewed and data about the size, their primary direction and the interviewees in the offices.

Office	Office type	Nationality	Profile	Size	Interviewee positions
1	Architectural	Denmark	National	11-50	Partner, Architect
2	Architectural	Denmark	National	51-200	Associate partner, Architect Architect Sustainability comptency leader
3	Architectural	Denmark	International	51-200	Partner, Architect
4	Architectural	Denmark	International	51-200	Associate partner, Design & Sustainability man., Architect
5	Consultancy	England	International	51-200	Principal
6	Architectural	England	National	1-10	Director, Architect
7	Architectural	England	International	51-200	Senior partner, Architect
8	Architectural	England	International	1001+	Urban designer, Sustainability researcher Environmental design analyst, Associate partner Head of info & design systems

Experiences

 "You can even pigeon hole [these architects].… [they] produce almost painterly views of buildings and then everybody tries to shoehorn in what's required into these strange blobby shapes"
(Office 5)

Even though the above statement is very blunt, it shows the consultant's occasional reaction to the design ideas handed down by the architects in a traditional design process. However looking at the structure of the design process, as seen in table 2, and the different participants in the different stages, as seen in figure 1, it can be seen why such statements might actually hold some value. The architect traditionally produces a concept for a building and then the engineers solve possible problems and 'shoehorn' solutions into it. However the interviews show that there is an increasing understanding of that it is necessary to work much more multi-disciplinarily in the design process where everybody contributes with inputs – a process that is highly dependent on the different personalities within the design team, as is expressed in the next statement.
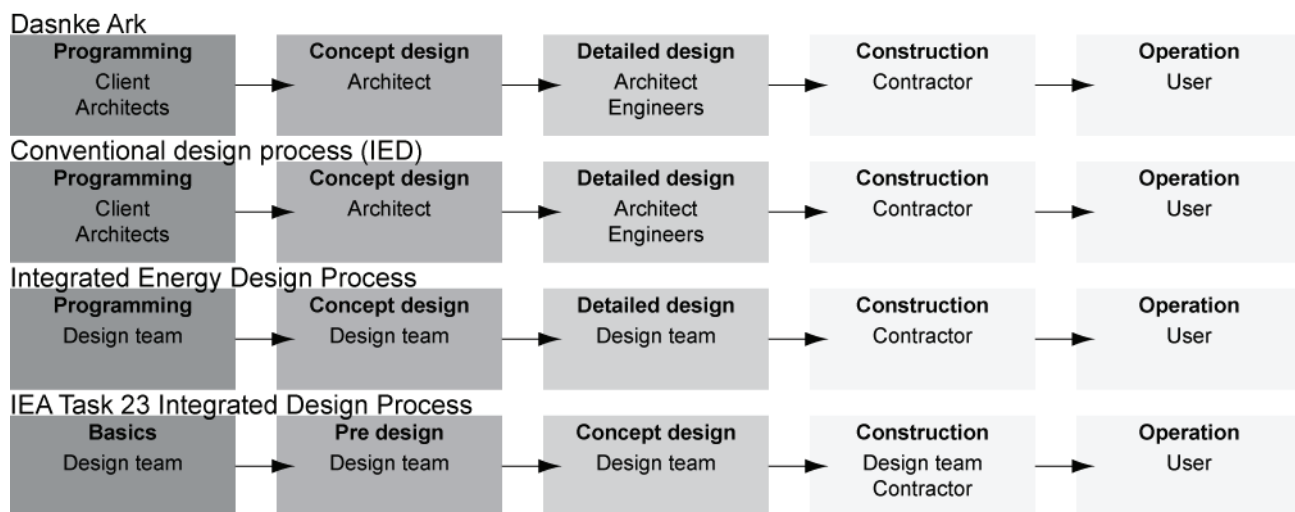
Table 2: Different formalised descriptions of the design process with the different stages and in relation to the overall aims of these stages.

RIBA/LAWSON	Danske Ark	Tradtional design IEA task 23	Integrated design IEA task 23	Integrated energy design
Inception	Idea	Investigation of basics	Basics	Preface
Feasability	Strategic briefing	Schematic design	Pre-design	Introduction to IED
Outline proposals	Project management	Design proposal	Concept development	Communication/cooperation
Scheme design	It coordination	Preliminary design	Design development	The design process
Detail design	Prelimenary design	Building documents	Building documents	Programming
Production information	Project proposal	Mass records/advertising	Negotiation/contracting	Concept design
Bills of quantities	Authority approval	Negogiation/contracting	Execution/commissioning	Detailed design
Tender action	Detailed design	Construction management	Operation	Construction
Project planning	Project clarification	Construction supervision		
Operations on site	Construction management	Building documentation		
Completion	Technical inspection	Supervision after 1 year		
Feedback	Operation			

Briefing	Sketch plans	Working drawings	Site operations

Figure 2: The different participants in a few of the above formalised processes in relation to the overall aims of the stages.

Dasnke Ark

Programming	Concept design	Detailed design	Construction	Operation
Client Architects	Architect	Architect Engineers	Contractor	User

Conventional design process (IED)

Programming	Concept design	Detailed design	Construction	Operation
Client Architects	Architect	Architect Engineers	Contractor	User

Integrated Energy Design Process

Programming	Concept design	Detailed design	Construction	Operation
Design team	Design team	Design team	Contractor	User

IEA Task 23 Integrated Design Process

Basics	Pre design	Concept design	Construction	Operation
Design team	Design team	Design team	Design team Contractor	User

"It's like a good or a bad party. It's on that level. It has to work around the table."
(Office 4)

The above statement outlines two crucial things, which are important to be aware of as a part of the context for the design process. However, the actual social interactions during the process that the quote points towards, is only in the periphery of what present research is aimed at. The first thing of interest is the design brief that states the design problem and what the client is essentially asking for. It can therefore be seen as the yardstick for the design proposal. Furthermore the design brief provides the design team or the architect with the program for the building. However, as the architects describe in the interviews the brief can easily be a folder with long and sometimes contradicting descriptions, which makes it important to find some defining criteria as described in the following statement.

"We usually find some values or criteria's for success, read the brief and try to understand the brief. However [the brief] is not always clearly formulated. Then we make a list outlining where we are going with

this and what we want to achieve."
(Office 2)

Or as another very briefly describes the beginning of the design process

"It is about finding the prerequisites for the design."
(Office 4)

So at this stage it is about defining what the design team determines to be a part of this design. From the quote above, it could be said that the design team needs to define issues that might be missing in the brief. This could refer to the key issues that can help them win if it is a competition, which may involve designing low-energy buildings, if this is not specifically addressed in the brief. A somewhat systematic approach is sometimes taken in discussing what is required to reach a certain level of energy efficiency, as shown in the following quote.

"We then said ok if this is going to be a good practice building what are the characteristics it is going to have? What are the u-values? How are we going to deal with material issues? What are the things we want to focus on? If it's going to be better practice what can we do? And if it's really going to be pushing the boundaries, if it's going to be innovative where should it be? And if it's going to be pioneering where should it be?"
(Office 7)

Where the above quote is a description of a way to find basic information about what is important in order to achieve a certain level of energy efficiency, it does not necessarily tell anything about what is happening in the actual process of developing the design or the concept for the design. In other words, it is still unclear how architects move from these guidelines or from defining these parameters, as described in the above quote, to actually working with the form. As it tends to be traditionally, the work is based on the spatial developments in the form of drawings or models, as demonstrated in the following quote:

"Our approach is that you need to understand. You need to do an awful lot of understanding of the site and brief etc. I'm part of a school of thought that says you should jump in and splash around with ideas, so you start to draw quite early on and see what emerges from it. If anything my own particular tendency is to jump to conclusions quickly. That's fair enough and those conclusions are based on all kinds of previous experiences to do with how buildings perform. So building physics is part of the initial moves you're making. Orientation is key to it and massing is key to it."
(Office 7)

Of course a more literal use of such parameters can be seen in the quote below where the building program and the concerns about light and energy are used to form the building directly, thus outlining a more holistic approach to the design process.

"It's a tower where we were asked to make a combined office and apartment tower… the offices typically suffers from overheating but still wants the views but without getting direct sunlight… apartments can use the passive solar heating… so when you arrive at home in the evening it's good that the apartment has been heated by the sun during the day and you will feel compelled to sit and enjoy the sun… It has made this tower a folded or bended version… where the apartments points towards south and up to the sky, and the

offices… get light in from high in the sky and deep into the offices… and is orientated towards north to avoid the direct sunlight."
(Office 3)

This is a very conceptual approach, taking a point of departure in simple passive approaches that connect the building program and the considerations about the environmental performance. Other architects have taken a more technical approach to define specific guidelines for the geometry of the building based on knowledge about the relations between form and energy consumption, as seen in the next quote. Their first conceptual developments will then be influenced by the guidelines, which subsequently point the design in a more energy efficient direction.

"We have actually tried to reverse the process and starting by defining the technical… we tried to design a house where the surface area couldn't exceed a certain size, the surface should be like that and the main part of windows towards south and very limited towards north…"
(Office 1)

However this approach is not as common within the field of architecture as architects and also consultants tend to use rules of thumb in the early design stages to quickly develop and test the different ideas or define guidelines to move towards designing low-energy architecture.

"And very quick sketching, almost, tools that gives them an understanding of the performance. In terms of surface to volume ratio, a few simple indicators are so important at the beginning of the design process, because that will tell you so much. This is also reflected in the before mentioned matrix, which basically is a list of "rules of thumb" to achieve a specific level of energy efficiency."
(Office 8)

This is, of course, a very brief overview of the architects' experiences with the design process and their work with low-energy architecture, through a limited range of quotes from the interviews. However the question is how these experiences are related to the discussions about an integrated design process and how these experiences can be used in relation to such a design process.

Discussion

Now with the starting point being the term integrated design or integrated energy design the question is how the experiences from the architects and consultants are related to that. It is important to remember that the two first quotes, related to the collaboration in the design team, actually frame the rest of the quotes. This means that we need to understand the quotes presented after that, not just in terms of individuals working with environmental issues in architecture, but as a collaborative effort between the different parties involved in the design process. With the integrated design or the integrated energy design the key is the implementation of different professions and the information and knowledge they can provide from the very beginning of the design process and use it in the development of the design. This happens in an iterative process. Depending on the description it can be done in a multidisciplinary team[5] or in an interdisciplinary process where the participants are more of a hybrid between the architect and engineer crossing boundaries.[6] However it is important to introduce the term conjecture in relation to the design process, which can be used to describe how the architect's first ideas are generated and what creates the starting point for the design of the building and is based on previous experiences.[7] Furthermore there is the

design brief or the design problem. As seen in the quotes, the problems are not always fully described and besides that the problems can be defined as ill-defined or wicked problems where partial aspects are revealed throughout the process.[8]

Of course the question is how the above quotations taken from the different interviews can be understood in relation to the notion of an integrated design process. During the interviews the term 'integrated design' has not been mentioned so the architects have solely reflected on how they approach the design process and the experiences they have with the changing demands to the work they do. However similarities can be seen and the experiences the architects have can be understood in terms of integrated design.

In the first two quotes it was seen that there is an increased focus on a stronger collaboration between the different parties involved in the design process. This is something all of the interviewees have elaborated on during the interviews. Everybody recognises the need for a strong collaboration between the different professions involved in the design from the beginning. However, it is not always up to the participants as, most of them explain, they are bound by the fee structures of the professional organisations, as it was also seen in figure 1 and maybe more importantly by the clients' ability to see the need for working together from such early stages of the design process. In the end the client has to pay and therefore needs to understand the possible benefits of approaching the design process from a different direction that usually where the costs in the beginning will increase. Additionally, the interviews suggest that the successful co-operations are when everybody on the design team takes ownership of the project and contributes freely to it.

By examining the design process and how the information, about parameters that can affect the energy efficiency of the building, finds its way into this process a few things become evident. First of all there is the notion of the use of matrixes where different parameters and the level one would like to achieve are used to guide the design process as it is seen in one of the quotes. This is something that is common for all the interviewed UK offices. This appears to be a condensation of their previous experiences and it allows them to set out different parameters in the design that are important. Or it can be seen as a way to make the previous experiences operational in terms of communicating with people outside the office through referencing some previous projects, by helping them visualise the potential impact of these different solutions to the project in discussion. However, another quote showed that focusing on a few specific parameters can actually also be used much more directly in the design process. Here these parameters and their relation to the program were not just used to guide the concept, but to define it.

So from a general point of view, it is seen that the architects or design teams identify key values or parameters from the very beginning and they are using them to create a guidelines for the project. As it was seen that could be from the technical point of view, the use of the matrixes based on previous experiences or it can be to inform and affect the form directly through relations between the building program and parameters affecting the energy performance through passive means in the building. Evidently, these are then evaluated primarily by 'rules of thumb' or simple applications that allow the design to explore the ideas that focus on energy consumption. Subsequently, new iterations can be made through this exploration. It is through this they refine the design proposal or possibly discard to test a new one.

Conclusion

What can we derive/learn about the design process from these interviews? First of all the interviews show that an integrated design process that starts out with a multidisciplinary team is not something that happens very often, even if it is something that everybody agrees to be beneficial. However, the experiences of the architects and consultants show the existence of the considerations about low-energy performance of the buildings and with these experiences they can achieve a design process where knowledge traditionally located within other professions in the design process, can start to be integrated. Furthermore, we see that they most certainly influence the design process. Some examples include the use of the matrix by the architects, the development of small applications that can help the architects to explore their ideas in relation to energy consumption, and the development of concepts through utilising information they gather about orientation and the functions in the program. This is all information that is used throughout the process in the quotes above.

As most mention in the interviews there is a tendency to 'jump in and splash with ideas.' They try out a range of ideas, based on the first information they get in the brief and on the key issues they define from that brief. These are conjectures based not only on that information, but also previous experiences, as it is also mentioned. And in this case experiences from their work with environmental issues play an important part. So what we see is that the previous experiences become a crucial part of finding different solutions of any following projects. So it is through applying their experiences in relation to the analysis of the brief that they start to unlock the brief and give it more direction and focus if it is not clearly defined in it.

These experiences can help to inform an integrated design process through the range of different approaches undertaken by the architects. Each of them is coming from the offices individual interests and experiences with the topic. What can be seen is that there is no single recipe for the process. Instead it is seen that adaption and interpretation to the process as well as the understanding of the individual complexities in the different design problems are important. The ability to work with these complex problems and to bring solutions forward is a natural part of the architect's job. In the interviews with these offices considered being among the leaders within sustainable architecture it is seen that their experiences play an important role. It is these experiences that allow them to explore the relations between the form of the building and the concern for reducing the buildings energy consumption already at the early conceptual stages of the design process. This is possible because the experiences to challenge and question the early design solution, thus informing them specifically in relation to their environmental agenda, which is of importance in the work towards designing low-energy architecture.

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