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-

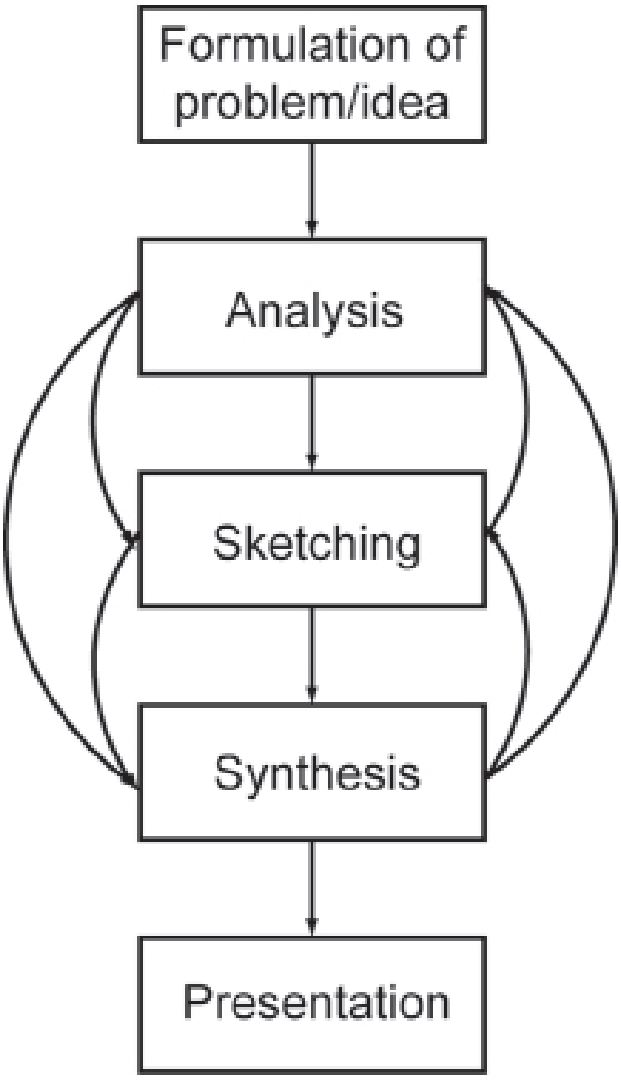

Figure 1: Diagram of the different steps in the IDP and their connections showing the iterative process (Knudstrup 2004, 221-234).

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.

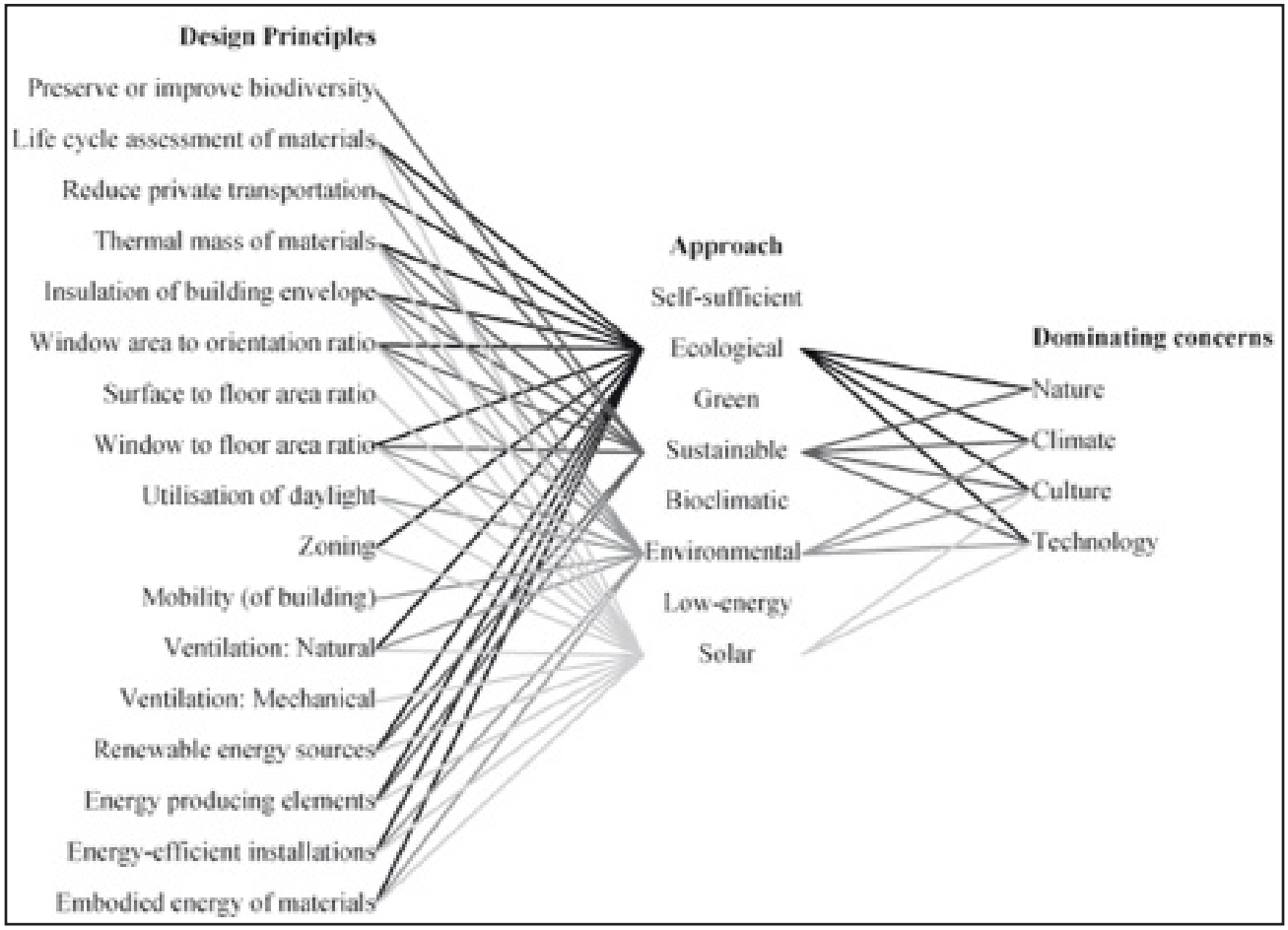

Figure 2: Diagram showing the relations between the different directions covered by the general use of the term sustainable architecture and the tools they employ during the design process (Knudstrup M-A et al., 2009).

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.

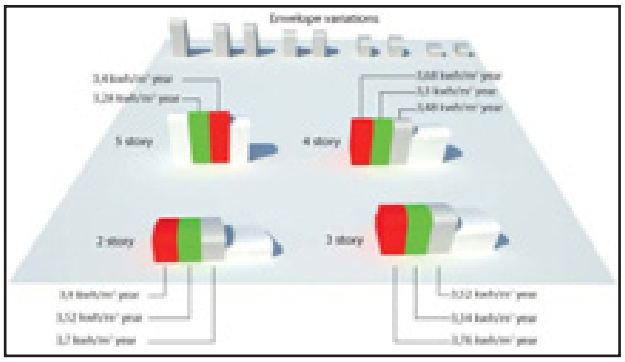

Figure 3: Diagrammatic representation of the results obtained in a simple spreadsheet in Rhino (Larsen 2009).

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.

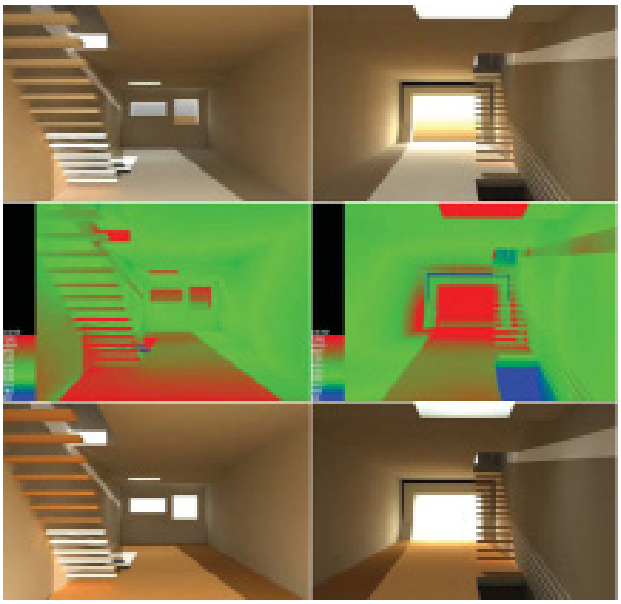

Figure 4: Images from Radiance simulations through EcoTect where the top pictures are the human perception of the space, the middle is measures of the actual light levels and the bottom is the illuminance renderings (Larsen 2009).

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).

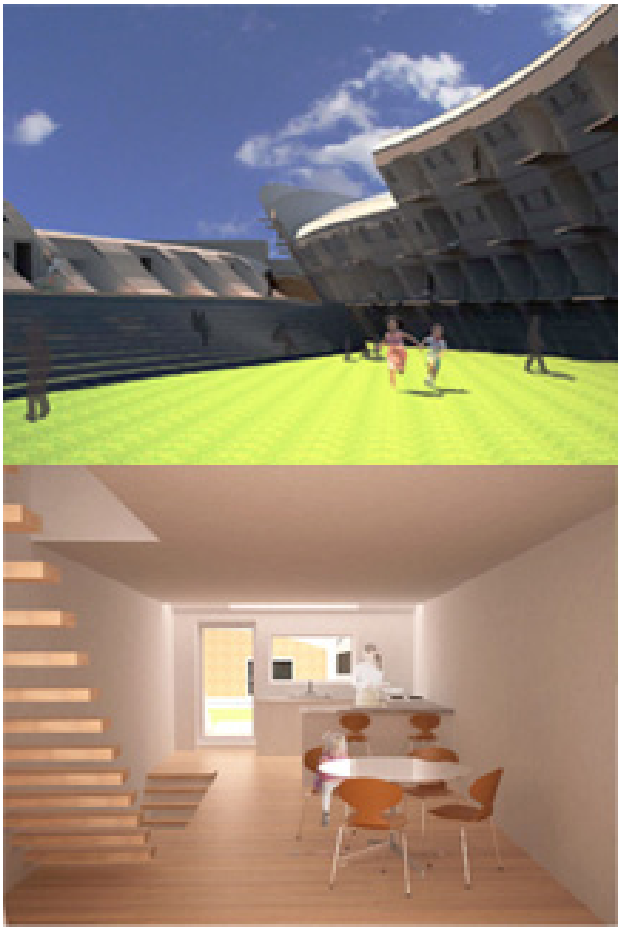

Figure 5: From inside one of the apartments of the building and from one of the courtyards in between showing how the characteristics was developed (Larsen 2009)

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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ENDNOTES

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