COMPUTATIONAL SIMULATION TOOLS FOR BUILDING SERVICES DESIGN – PROFESSIONAL'S PRACTICE AND WISHES

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ABSTRACT

This paper describes interviews conducted to understand the use of computational tools in daily design practice.

The interviews form one part of a research project aimed at better informed design decision. This project also includes a review of state of the art building design support software and design process observations.

A group of 15 world leading building services professionals were interviewed about their individual experience with computational tools during the design process.

The outcome of the interviews was used to identify potential shortcomings of state of the art computational tools and causes for the limited success of integrating computational support to the daily design practice.

Finally, guided by the importance of the early design stages, the paper argues that the use of appropriate computational tools has the potential to more effectively support the decision making process.

INTRODUCTION

The use of simulation tools in the building design process is currently limited to a number of design stages. It is assumed that by practicing building performance simulation at an earlier point in time during the design process reduces the design iterations.

To investigate the capabilities of simulation tools, several tools dedicated to the conceptual design stage were tested on their efficiency and usefulness, interviews were carried out and people in practice were observed during a design team meeting.

The interviews focused on obtaining cross disciplinary personal expert knowledge regarding the conceptual design stage. The following key questions were answered.

- Introduction and definition of project involvement.

- Problems repeatedly encountered during the early design stages.

- Experiences using computational tools to support building design, in particular the conceptual design stage.

- List of issues future design support tools should address.

METHODOLOGY

It was assessed important to not only gain an impression about the tools capabilities for the conceptual design stage but to for receive feedback about their application in project work.

Therefore this research was divided into two parts. The first part was characterized by a critical software review which was achieved by surveying software related literature and testing tools on two case studies. During the second part, 15 interviews with international building services professionals were performed to gain an insight into their experience and knowledge concerning the design process. The research was finalized with a design team meeting observation.

CRITICAL SOFTWARE REVIEW

A software review was carried out investigating the applicability of building performance simulation tools for the conceptual design stage. Six tools, Orca, MIT Design Advisor, h.e.n.k., Energy-10, Building Design Advisor and e-QUEST were therefore considered. A review of software related literature was conducted as well as hands on case studies performed.

The perspective of the tool review was equal to the perspective of an integrated design team at a design problem.

It was assumed that an integrated design team follows a holistic design approach, allowing other engineering disciplines to influence their design concepts in order to find the most favourable compromise (design solution) by complying with performance criteria defined in the program of requirements. Furthermore, it was idealizes that the design disciplines were synchronized with regards to simultaneously working on the conceptual design.

The tools considered can be used for the following applications: energy calculation, comfort assessment, life cycle costing, artificial and day lighting assessment and code compliance checking. Traditionally, the six applications/ services listed above are provided by mechanical engineers.

It was found that the six tools address different value drivers. A value driver can be understood as a

responsive value, which when changed, has a significant impact on the design process (Hopfe et. al., 2005). The tested tools only address value driver like energy consumption, life-cycle- and investment costs, thermal and acoustic comfort etc. related to the consequences of the interaction between building structure and (a number of) building systems. Value drivers related to architectural and/or structural concepts were not specifically addressed.

The use of vocabulary and level of detail required for the representation of systems for four of six packages soon identified their origin as being developed for mechanical engineers from the perspective of mechanical engineers. The addressed value drivers are subsequently related to energy, comfort, system performance etc. One package was specifically dedicated to the performance assessment of one building component – the façade, whilst another tool was characterized by one for architects developed new interface to VA114.

In order to asses the tools, a number of criteria were identified and categorized using headers such as technique, general requirements and testing. The criteria identified during the early stages of the investigation were rephrased and specified based on the results of the literature review and used for the case studies.

Criteria assessed to be of great importance for the software review were applicability, geometric building representation, defaulting, calculation engine and design optimization.

Concluding the review of software related literature it can be stated, that:

- The tools reference themselves to a wide range of design stages and users.

- The range of applications does not depend on the tools status of either being commercial or free of charge.

- An even split was noticed between tools using unique application based calculation engines and tools using third party engines.

- The extent of user support depends on the range of tool application and target market.

- Five of the six programs considered were successfully tested on accuracy by either internationally or locally recognized methods such as BESTEST or EDR.

The case studies revealed that the six tools cover an even distribution of geometric resolution levels from low to high, i.e. from one room to an entire building space layout representation.

Limit's could be identified concerning the representation of building types apart from office buildings as well as special features such as double

façade, atrium, other than flat roofs and double height spaces.

- A number of three out of six tools were able to by default represent building types apart from office buildings.

- Two of six tools were able to consider the performance of double skin facades.

- Only one of six packages allows the defining roof geometries different to flat roofs.

- The double height space and atrium definition is possible in two of six tools. However, calculating bulk airflow problems and the interaction between open plan office areas and atria is only possible in one of six programs.

PEOPLE IN PRACTICE

The reason for conducting interviews was to gain an better understanding of the design process. Important aspects considered were: feedback from practitioners, experience the design process structure, design team synchronisation, integration and hierarchy.

The results of 15 conducted interviews are condensed summarized below. (Note: for more detailed description see (Hopfe, Struck, Ulukavak, 2005), (Hopfe, Struck, 2005) and (Ulukavak et. al., 2005). The questionnaire was discussed with 15 building design professionals: nine mechanical engineers, three building physicists, two architects and one civil engineer. 12 of the interviewees can be references too as practitioners having extensive industrial experience whilst the remaining three are working in academia.

Interviewee classification

- The interviewees were categorized as innovators, early adopters or conservatives taking into account the role they adopt during the design process.

- The categorization was linked to different key aspects like computational tools, design team integration and communication.

- It was found that people can be conservatives as well as innovators at the same time regarding the different aspects.

- The Classification doesn't depend on profession: a civil engineer as well as a building physicist could be innovator, early adopter or conservative.

- More of relevance was found their position in the company.

Value driver and frameworks

- A great variety of design assessment criteria dominates.

- There exist different/ varying value drivers like energy consumption, thermal and acoustic comfort.

- Value drivers are project depending and have therefore a variable influence on the project.

- The frameworks - arising from the different professions of the design team members - can overlap or differ.

Design process

- There exists a varying understanding of process structure. Some interviewees saw the design process as one phase, whilst others were confident that there are no design phases as the process was apprehended as highly unstructured.

- Altogether there is a great importance allocated to the conceptual stage, because of the impact of decisions taken during this time.

- The order, weighting and number of value drivers/ frameworks are project specific.

- Prescriptive design solutions in the program of requirements can hinder the design process.

Practice

- An integrated design team is most suitable to find integrated design solutions.

- Non - synchronized processes hinder the design progress communication.

- The number of the produced concepts depends on the project complexity.

- Value drivers are used to scale the success of projects and can be project and/or discipline specific.

Computational support

The first impression of the interviewers was that the interpretation of the word "Simulation" differs. For some interviewees, simulation is sketching concepts, whilst for others, a simulation is conducted by using a computational tool (Hopfe et. al., 2005).The detail required for representing a design problem increases according to the design progress, although most of the tools for the conceptual design stage only address one value driver.

It was stated that the use of simulation tools enable an impact assessment of different design parameters. However, the use of simulation tools without having an idea of building performance simulation does not bring the necessary benefit (Hopfe et. al., 2005).

Nevertheless the interviewers came across the fact that available tools for the conceptual design stage are too basic for experts.

The interviewees manifested the request of an easy to use tool, which acts intuitive dependent on the user's needs, background and experience.

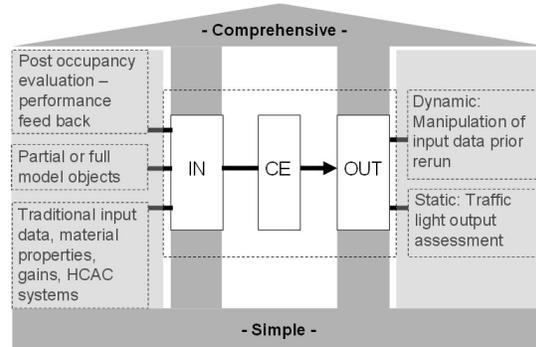Based on feedback from the interviews, the schematic in graphic 1 was developed.

Figure 1, Ordered dynamic input/output boundaries dependent on user level

Therefore the idea was formulated of a contingent upon the user level reacting tool with the scale simple to comprehensive. On the input site this gives several opportunities like traditional data input of material properties etc. (low user level) reaching to the higher user level with post occupancy evaluation; in between the less comprehensive input of partial or full concepts models.

The same procedure applies on the output site: a static traffic light output (low level) and the possibility to manipulate dynamically the input data prior rerun.

Thus, other wishes like a copy and paste function of old concepts as the chance of reuse parts of old projects would be fulfilled.

Design Team Observation

In order to check the theory obtained from the interviews with experts, one design team observation was carried out.

The aim was to follow several design team observations. But because of the exchange of information which could be confidential, the authors had only the possibility to participate on one meeting.

The results of this meeting combined with the experience of two experts gives an early impression of the current practice of Building Performance Simulation.

The authors had the possibility to participate in one design meeting consisting of eight participants. The projects aim is to redevelop an area in Amsterdam where listed warehouses are located. A number of variably sized and structured offices (100m² – 5000m²), several parking places and restaurants are planned to be build within these warehouses. The preliminary discussions run now for 12 month with no project proposal agreed upon.

The aim of this observation was to

1. Understand the structure of the design process.

2. Experience the difficulties of the decision making process.

3. Find out how soon or late BPS is used to support design.

The authors participate on only one meeting which took place around one year after the project start. Still the procedure is not clear nor is the distribution of responsibilities and the partitioning of the building. The participating parties are in the process of producing a design brief. Based on the brief the decision will be made to either proceed with the redevelopment or to abandon the project. This means the design process had not started. During the two hours lasting meeting no decision was made. However, the discussion allowed the clients to learn from other engineering disciplines about the potential projects opportunities and limits. Despite the fact the future energy consumption was discussed as well as, façade glazing life-cycling costs and room dimensions. No simulation tool was used to support the development of ideas. The arguments were based on design experience. As a preliminary conclusion it can be said that simulation did not support the inventive process. The overall aim should be to make it more creative and therefore usable during design team meetings.

Literature review

The experience from experts concerning the design process is represented in figures 2 to 4.
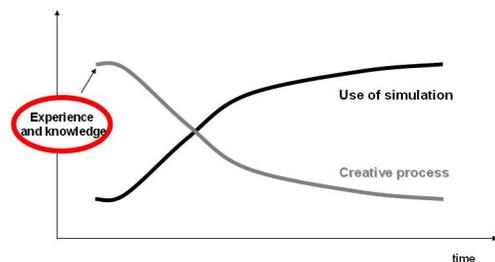

Figure 2, Use of Building Performance Simulation versus creative process

Itard (Itard, 2005) concludes simulation as a not creative process. (see figure 2) The use of simulation tools is rather put into practice at the beginning of the design process. Its use arises depending on the project progress. In the beginning of the conceptual design stage, where most of the decisions are taken, design experience and knowledge have the biggest impact.

Stoelinga (Stoelinga, 2005) divided the communication taking place during the design process into informative and specifying communication: Informative communication meaning enhancing the quality and specifying increasing the quantity of the design.
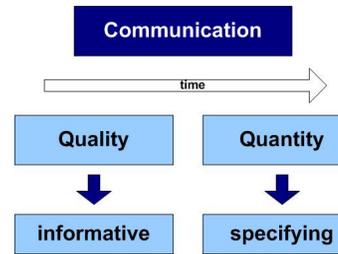

Figure 3, Design quality and quantity dependent on communication time

The comparison of the information expressed in figure 3 and figure 4, results in a similar behaviour. There exits a high degree of informative communication in each design process and another peak value of specifying communication which is also not covered by the use of simulation tools.
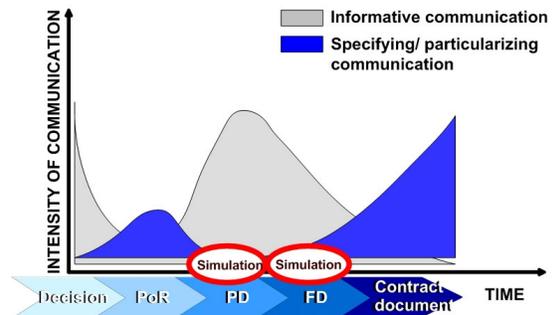

Figure 4, Relationship between communication and simulation during the design process

CONCLUSIONS AND FUTURE WORK

As explained the interpretation of the word "simulation" was experienced to be different and depending on the interviewee. The authors concentrate on numerical simulation.

There are a number of simulation tools for the conceptual design stage available. The problem why they aren't currently used is that they don't match the user needs. For experts the tools are too simple whilst for beginners the tools hold too many possibilities to make mistakes.

In spite of the fact that there is a great need for simulation tools and people seeing a great benefit in using tools during the whole design process, it is not transferred into practice. Currently simulation tools are being used during the later or final stages of the design process.

Many of the professionals interviewed see an immense benefit in bringing the first use of simulation tools forward and therefore improving the communication between the different engineering perspectives.

The design process the authors came across during the design team observation is highly unstructured and not tackled effective. People mostly follow their own aim depending on their value framework.

The communication isn't sufficient as it could be.

FUTURE WORK

The authors will progress with observing design team meetings to substantiate the demonstrated theory.

Next steps will include further literature reviews to get an idea how to make the process more creative, to look for alternatives and how to put them into practice.

Therefore the authors will focus two different directions. One will have a deeper look at the informative communication in perspective to the concept generation; the other in specifying, means quantity in direction of optimisation.

ACKNOWLEDGEMENTS

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