Future direction for effective sustainable design: a survey on the extent and the format of a decision support tool

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ABSTRACT: This paper – as part of a broader research - summarizes the key findings of a survey based on an online questionnaire which has investigated existing insights, needs and expectations of architects about decision support tools (DSTs) to assess sustainability of buildings. The survey is conducted in Dutch context with architectural professionals. Furthermore, this paper underlines the major requirements for future improvement and development of support tools for architects in a sustainable design process. With the results we aimed to gather information that would help us to have an insight on current use of DSTs in several stages of the design process, preferred level of breadth and detail of information and knowledge by architects throughout the process of designing a high performance green building and the preferred format of information and knowledge presentation about sustainable design – extent and format of a possible decision support tool.

1 INTRODUCTION

1.1 Background information

Recently, sustainable development receives worldwide attention due to human activities compromising future generations' ability to meet their own needs. Architects are aware of their responsibility in changing the current approaches of the building practice to reach more sustainable environments.

This awareness resulted in a paradigm shift in design thinking. This new way of thinking continues challenging the existing architectural practices and has constituted the underlying driver for a change towards new design processes; in which – instead of prescriptive approaches - performance has become the guiding principle. This type of transformation towards a performance based design process entailed the question of what performance means in architectural design and how to build high performing buildings to achieve sustainability. In this regard, the means and the tools play a significant role in the way architects deal with the information which will ensure high performance/sustainable solutions.

This increasing awareness on the issue of performance in terms of environmental impacts of building activities brought the development of Building Sustainability Assessment (BSA) tools with which mainly the evaluating the level of sustainability is aimed. Architects have started to use these tools as design guidelines or checklists to have better performance results.

The need for building sustainability assessment has brought along rating and labeling systems for identification and classification of sustainable buildings. These systems have become significant tools for the stakeholders in the construction industry both to guide projects and benchmark their performances.

Starting by the release of BREEAM in 1990s, quite a number of building environmental assessment methods has been developed. The idea behind these methods was mainly to frame the existing environmental knowledge and bring it into a practical format. Followed by LEED in mid-1990s these tools served as checklists for reducing environmental impacts of mainly commercial buildings. Further methods are developed with a growing interest towards performance assessment (Cole et al., 2005). Since then, designers have been utilizing these methods to achieve results with high performance and to learn further about the issues related with sustainability.

However, the format of the tools and the information provided by them do not fully enable the architects to explore and find the most effective solution among several possibilities. Neither it allows for a (rational) decision making process. Such a process to provide rigorous evaluation and comparison of design options under uncertainty is given by Augenbroe (2001) as one of the tool functions to be developed. This is stated to be based on ontology of unambiguously defined performance requirements and their assessments through quantifiable indicators.

Also looking at the other currently available tools such as CAD/BIM or simulation tools, we need to question whether existing tools are capable of being easily reconfigured to fulfill the new environmentally-conscious agenda.

Since the awareness of the environment and importance of sustainable design increases, so does our knowledge of factors that can influence a sustainable design. This challenges existing tools in their flexibility to adjust to these rapidly changing conditions and still being able to present results that are expected from them and easy to grasp (Cole, 2005).

Besides the format and the content of the tools, there are other limitations in the architectural practice to realize sustainability goals. Often due to limited time and budget, architects are restricted in terms of having instant access to the necessary information that will guide them reaching the goals. This restriction occurs because the resources are scattered and the provided information is considerably disintegrative. As a result architects are hampered in finding the optimal solutions while dealing with different sustainability dimensions simultaneously. Starting from this point, we can argue that architects need to have sufficient and continuous support to make informed decisions in terms of high performance green design.

1.2 Relation to whole-systems thinking

During the design decision making, from early stage to detailed stage, architects need instant feedback in order to satisfy certain performance requirements towards a sustainable environment. Therefore we can assert that building performance assessment is a significant component in a decision making tool. In order to fulfill design integration of performance assessment, a systematic identification of indicators and parameters relevant to the concept of sustainability in building designs is essential.

There are quite a number of researches in the literature about overall sustainability issues in design but not sufficient tools to be integrated with the design process, design tools. In general, these researches take one aspect of sustainability into account. For example, there are several studies looking at the integration of building energy performance simulation tools to design process (Attia, 2011; Weytjens et al 2009).

On the other hand, existing building sustainability assessment (BSA) tools such as BREEAM, LEED, etc are more comprehensive in terms of incorporating all the sustainability criteria. However these tools consider them as separate entities and the dynamic relationships among the aspects are not clear enough for the users. There is a need to reveal the relationships among the aspects. Moreover, due to lack of transparent relationships between the aspects and building elements, in such tools usually translation of the scored results back to design for improvement is difficult. Issue of rapid evaluation of alternative designs and translation and communication of the results to the design team is another tool function given by Augenbroe (2001) to be developed.

Disassembling sustainability related issues in design into individual pieces is significant in order to solve specific problems. However if such an approach remains without considering the interactions among the parts, the overall results can not be successful. As Hawken et al. (1999) stated, "Optimizing components in isolation tends to pessimize the whole system — and hence the bottom line. You can actually make a system less efficient while making each of its parts more efficient, simply by not properly linking up those components. If they're not designed to work with one another, they'll tend to work against one another."

This approach of understanding how individual aspects work together as a system is known as whole systems thinking. Whole systems thinking supports integrated design approaches.

Similarly, Cole et al. (2005) have emphasized whole systems thinking as an important feature from the perspective of assessment methods evolvement. According to him, finding the correct parameters to measure the performance is critical but what matters more is to realize the possible relations of these parameters. He continued that right now the parameters are being treated as individual elements to avoid "double counting" which results in a checklist approach. This approach leads to less effective designs from high performance, sustainability point of view. To create successful tools it is important that this system thinking concept is well understood and incorporated.

The better and more complete the incorporation is, the more successful and sustainable the solutions would be. Therefore, we assert that a tool outline is needed to be based on revealed aspect relationships and interactions as well as seeing the impacts in the overall system.

In light of these arguments, as part of a broader research, we conducted a survey on the current Dutch architectural practice. This survey is based on interviews and an online questionnaire which have investigated existing insights, needs and expectations of architects about decision support to assess sustainability of buildings. A brief description of the population is given in the next chapter. The survey method is described in more detail in the previous paper (Dijk & Erbas, 2012).

Regarding the questions, first we intended to explore the extent that existing BSA (and other existing support) tools, resources provide sufficient guidance. Second we wanted to explore the level of breadth and detail of information and knowledge which architects find appropriate throughout the process of designing a high performance green building. Consequently the type of environment and the format of the presentation of information and knowledge on sustainable design were questioned. The purpose of this paper is after giving background information about the state of the art in this issue, and briefly describing the survey population, to present three main results of this survey. It is concluded with a discussion about the findings and their possible contribution for support tool improvements.

2 BRIEF DESCRIPTION OF THE POPULATION

For this survey we composed a convenient population sample of 149 from three different groups: guest-teacher architects at the Faculty of Architecture of Delft University of Technology who attained a master class in building sustainably (104), a group of architect that followed a course on sustainability in the built environment (31) and a group of young architects drawn from our own network (14).

We had a response rate of 41%; from the 61 respondents 48 indicated to be an architect. 32 of the respondents completed the survey. For the first question we collected data from 38 participants, from 34 for the second question, and from 32 participants for the final question.

Although the participation rate does not reach the required population sample size, we still can draw some statistical conclusions from them, since the number of respondents that finished the survey exceeds the minimum of 30; the results can be considered as reasonably representative.

3 RESULTS AND KEY FINDINGS

3.1 Resources as decision support tools, use frequency and design phases

Previous research has shown that architects use an average of nine resources as decision support tools (DSTs) for their design process (Weytjens et al., 2009). These are ranging from more official channels like laws, scientific sources, to own personal experiences and rules of thumb. We asked our participants to mention the resources they commonly use as a decision support for comfort enhancing and reducing environmental impacts.

Figure 1 illustrates the use frequency of the DSTs – (almost) never, sometimes, regularly, often and (almost) always. Figure 2 presents the use of DSTs for the five or six stages of the design process as discussed by the first paper (Dijk & Erbas, 2012). The most visible outcomes of these questions were the following.

Most participants seem to rely on their own personal experiences and rules of thumb. Combined around 60-70% of the participants often uses (30-35%) or (almost) always uses (30-35%) from knowledge based on their own experiences.

Software solutions seem not to be used often to gain more information. Between 40-45% of the participants said they almost never used CAD instruments to gain more information. 30-35% sometimes used CAD tools. Between 0-5% said they (almost) always use CAD tools to gain more information. Digital analysis or evaluation tools also do not get used frequently. 40-45% of the participants selected that they almost never use these tools either.

The resources discussed above are commonly used in different design stages. We raised the question in what phase of the design process architects use the resources that were listed in the previous question. In the initiation phase the participants mostly rely on own experience, the client and good practice projects, whereas they hardly to never consult digital analysis and assessment tools, manufacturers and CAD instruments.

During the early design phase, architects highly rely on their own experience; furthermore, they frequently consult non-scientific publications, books, clients, websites, perform cost analysis, and consult good practice projects and experts. They seldom use digital analysis & assessment tools. Moreover, further on in the design process the use of digital analysis & assessment tools grows to a moderate to frequent use in the final design stage after which utilization diminishes again to a seldom use in the specification phase.

In relation to these questions, we asked the architects if they would like to use a decision support tool when designing with sustainability issues. We indicated that this decision support aims to guide the architect in his design choices to achieve a highly sustainable building. 87, 2% responded that they have a desire for a tool to assist them during the design process to create more sustainable designs. 7,7% said no and 5,1% had no idea. Later on we asked about the design phase in which they require a decision support tool. Two phases stood out, 70-75% of the respondents had a high need while around 25% indicated an average need to use such a tool while creating the scheme design phase in which 80-85% of the respondents indicated a strong need while 15-20% indicated an average need.

3.2 Level of breadth and detail of information and knowledge

Figure 3 illustrates the preferred level of breadth and detail for six stages of the design process. The numbers horizontal axis indicates how much detailed information they need (1: little detail -9: great detail). It also indicates to which extent they want a broad selection of performance criteria to consider (1: little breadth -9: high level of breadth). Here the level of information represents how much detailed information they need, and the breadth represents the broadness of sustainability criteria - from single to multiple aspects.

As stated in the other paper (Dijk & Erbas, 2012) results show that preferences on the level of breadth and detail of information correspond with the suggested relation of the level of breadth and depth during the design process. During initiation phase there is a clear preference for a broad set of topics. This preference becomes less pronounced and shows reducing consensus as the design process progresses.

Nevertheless, distributions on the level of detail show clear preferences. During the earliest stages of the design process architects express a clear preference for little detail. As the design process continues the graphs show a shift in detail levels; it displays an average wish for detail during scheme design and final design and an articulation of preference for a high level of detail in the building permission and specification phase.

3.3 Possible outputs and format of a decision support tool

We are interested in more detailed preferences of architects concerning decision support and formulated the following five possible output types for a DST. Figure 4 illustrates the architects' preferences by presenting these outputs provided by DST (Dijk & Erbas, 2012).

The charts show that architects give priority to all types of outputs, although they least prefer a DST providing information on other than aspired performance criteria still with 50% high rating. The highest rated DST output is providing options for improvement (81,6%), closely followed by assessment of design alternatives (75%), interpretation and evaluation of predicted performance (74,2%) and information on aspired performance criteria (68,8%).

Design tools can come in all kinds of formats. To get a picture on what our participants would prefer we presented them with several options. They were able to rate each suggested format with a degree of preference from 1 to 9 (1: least preferred - 9: most preferred). In our final results we divided the rating from 1-3 as a low preference, from 4-6 as average preference and 7-9 to high preference. Figure 5 visualizes the results.

Of these presented options the preference for detailed simulations (CAD plug-ins), 62,4% of the respondents had a high preference for this type of tool. 15,7% has a low preference for this tool.

A digital library or database of successful projects was preferred as second; 59,3% of the respondents would prefer to use such a tool. 9,4% said they would have a low preference for this tool.

Computer aid with more complexity but showing the relationships among the several criteria is rated as 54,7% with third highest preference. 19,5% of the respondents has a low preference for this tool.

Educational games however scored very low. Most participants did not see the benefit of such a tool to assist them.



Figure 1. Resources as DSTs and their frequency of use.





Figure 3. Preferred level of breadth and detail of information and knowledge for six stages of the design process.



Figure 4. Possible outputs of a DST.



Figure 5. Format of a DST.

4 DISCUSSION OF THE RESULTS

4.1 Discussion of first results

The results tell us that architects seldom use BSA tools in their early design phases. However, they do indicate that they want decision support to meet high sustainability performance. The results also show that architects prefer consulting websites, good practice projects, using rules of thumb, and consulting non-scientific publications and books aside from relying on their own experience. This suggests that they preferably consult knowledge-based support in the early design phases. However, the lack of experience with analysis and assessment support could be a reason for this preference. In addition, based on these conclusions, we can assert that a possible DST would be capable of incorporating a dynamic knowledge base.

Overall the participants seem to rely mostly on their own experiences (and gut feelings; even though not given in the list, this response has been given strongly in another question which we excluded in the context of this paper) to complete a project.

Even though they use of digital analysis & assessment tools more frequently in the final design stage, they still rate a higher need of a decision support tool during the same stage. We interpret this finding as verification that digital analysis & assessment tools are needed to be improved so that they can inform architects in their decisions even in the final stage.

4.2 Discussion of second results

As predicted, preferences for more detailed levels grow as the design progresses. However, the suggested decline of preferences in breadth levels does not occur; it does show a more evenly distribution across the scope of little and high levels of breadth. This might suggest that architects want to be able to evaluate a selection of the initially adopted performance criteria instead of assessing a single performance criterion. This finding can be correlated with the assumption made in the introduction: importance of revealing performance aspect relationships.

4.3 Discussion of third results

Looking at the results about possible outputs, respondents show no significant preferences for a single type of DST among the options for improvement, design alternatives, interpretation and evaluation and information on aspired performance criteria. This can be interpreted as they need a tool which can deliver all of these outputs with a more priority on providing improvement options, assessment of design alternatives, interpretation and evaluation of predicted performance and information on aspired performance criteria. These findings are in line with the tool function wishlist of Augenbroe (2001): rapid evaluation of alternative designs and comparison of design options.

For the format of DST, it is found striking that architects highly prefer detailed simulations by CAD plug-in. The previous section – level of breadth and detail of information and knowledge – found that architects prefer detailed information at the end of the design process. This suggests that the format of detailed simulation by CAD plug-in would fit the architect for the advanced stages of the design process.

In the first section of results discussion, we suggested that architects preferably consult their own experiences and knowledge-based support in the early design phases. Furthermore, in the last section, architects express their high preference for a digital library/database as well. Computer aid with more complexity but showing the relationships among the several criteria is also very significantly rated. This might indicate that a digital library/database integrated to a computer tool would best fit to the architects.

5 CONCLUSIONS

There are several barriers to adoption of high performance (sustainable) building practices. Within the scope of this paper, referring to Larsson (2009) three major barriers have been taken

into account. These are, difficulty in measuring performance in an objective and reliable way, increasing requirements for specialized skills and knowledge in the design process (expert knowledge) and making wrong decisions at the early design stage due to lack of instant feedback.

According to Larsson (2009), if a different approach could be followed it would be possible to reach sustainable building designs. For example, if it was possible to "make use of the experience and knowledge of engineers, building operators and even users, early enough to influence the design", and tools are used to predict how the designs and possible design alternatives will perform for every project, building solutions would be more sustainable.

We believe that intuitive process of designing should be supported by analytical techniques in order to achieve high performing solutions in an architectural way rather than purely relying on consultants. Because designers can only have a limited grasp of the consequences of the decisions made during the design process. Especially at the beginning of the design process there are often too many factors to take into account while in this part of a project very important decisions are being made. To make these decisions efficiently the designer will then most likely use the most readily available knowledge, which is his or her intuition, own experience and rule of thumb. The results of choices made early in the design process become clear later in the project. (Janssen, 2004). If then there is a desire to adjust or revert some of the earlier choices the project is usually too far ahead to justify the costs. Even if costs are not a problem the design is by then usually so deeply thought out that it is difficult to investigate and revert to other options that can bring an even more satisfactory result, leaving the designer with limited options to create a more sustainable design.

This can be solved only with providing a reliable check to the architect if a design is performing good or not before certain early design decisions are made. Assessing the impact of design strategies and technologies is significant part of achieving high performance, in the sense that, assessment would inform and guide architects. And a better informed architect is a better designer.

Augenbroe (2001) also discusses that in some cases decisions about implementing environmental technologies were made without adequate knowledge and evidence of the actual performance. Referring to a study by de Wilde et al. (2001) a group of design projects revealed a clear absence of building performance analysis experts at the early stages of the design process. Often the consultants' knowledge was only implemented later to fine-tune the project. By then the design decisions that form the fundamental base of the design were already made, usually based on grounds of overall design, requirements of the owner and cost effectiveness. This situation narrows down the improvement of the design in the later stage.

Based on our findings presented in this paper, we draw the following conclusions:

- A possible decision support tool would have;
- A knowledge base in which such expert knowledge, and in addition, best practice examples and dynamic relationships among sustainability aspects are represented,
- Outputs with a more priority on providing improvement options, assessment of design alternatives, interpretation and evaluation of predicted performance and information on aspired performance criteria, and
- The format of detailed simulations as CAD Plug-in, digital library/database (preferably early stage) or computer aid with more complexity but showing the relationships among the several criteria.
- A possible decision support tool would respond;
- Differently at different design stages due to different needs of information level and broadness of the performance/sustainability criteria.
- Comprehensively incorporating the whole systems thinking.

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