Future direction for effective sustainable design: a preliminary study on utilisation of existing tools in the architectural practice

S. van Dijk
Delft University of Technology, Delft, the Netherlands

I. Erbas
Delft University of Technology, Delft, the Netherlands

ABSTRACT: Architects need continuous support in their sustainability choices for building design because of the excessive amount and dispersal of information on sustainability. Currently architects utilize BSA tools that provide them general information with a checklist of sustainability measures. However, it is observed that these tools do not fully support a design process; they are mainly developed for assessing a finished design. In that respect, improvements of the existing tools or developing new ones become inevitable to supply architects with more sufficient design support. In this paper, as a part of a diptych, we discuss issues involving the architect's needs for support in designing a high-performance green building, such as the current support tool, the interconnectedness of performance criteria and the architectural design process. Furthermore, it presents a method for a survey, from which the results are presented in our second paper.

1 INTRODUCTION

Computational support in building design is a continuously growing field. It allows dealing with a increasing complexity of building construction and makes way for non-standard, virtual and interactive architecture. Furthermore, it provides opportunities to deal with complex issues that occur during the design process. For example, considering the need for transition to a healthy and comfortable environment, architects have to deal with excessive information about several sustainability issues during all stages of their design process. Although they need to incorporate sustainability in their designs, they hardly know which decisions to take and which criteria to consider for achieving a high performance green design.

Several buildings show high sustainability performance on a variety of criteria ranging from energy, comfort, materials and water to biodiversity and social issues. Example projects are Villa Flora in Venlo (NL), Ford Rouge Center in Dearborn Michigan (USA), EVA Lanxmeer in Culemborg (NL), Park 20|20 in Hoofddorp (NL), TransPort in Schiphol (NL) and the Watertower project in Bussum (NL). Although these examples show that it is possible to design and construct a highly sustainable building, the majority of recently erected buildings hardly perform better than the imposed building regulations.

Although the large number of Building Performance Simulation (BPS) tools available suggests ample support for players in the field of the building sector, the development of proper architectural design support lags behind. As an example, research shows that the availability of building energy software (BES) tools for engineers in the USA is tremendously high compared to BES tools provided to architects (Figure 1). Simultaneously, several scholars assert that effective support for the early design phase is poorly provided by most of the contemporary BPS tools (Lam, 2004; Riether et al. 2008; Weyntjens et al., 2010; Attia, 2011a).

Moreover, many BPS tools aim at design assessment at the end of the design process or even after construction. Several of these Building Sustainability Assessment (BSA) tools claim to be

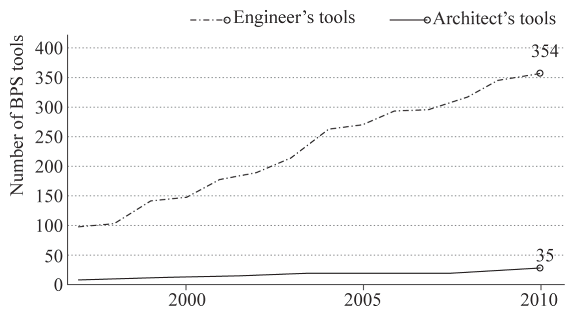

Figure 1. Number of BPS tools available for engineers versus architects 1997-2010 (adapted from Attia, 2011)

supporting the architect in his design decision-making during the early design phase. However, since these tools assess buildings at a high level of detail – aiming at assessment of a finalised design or building –, they have difficulty coping with the actual needed design support during the early design phase.

Furthermore, previous research hardly questions whether BPS tools would be the optimal support to architects in the first place. Most research in the field of BPS regards its current tools as proper guidance for architects. But do these tools really fit the architect's general creative process of designing? Is it not a limited comprehension of the architect's information processing by BPS-tool developers that contributes to the slow adoption of BPS tools by architects? For example, previous studies have identified criteria that BPS tools should meet to effectively support architects in the early design phase, such as usability, inter-operability, accuracy, intelligence and process adaptability (Lam, 2004; Attia, 2011b). However, they lack insight into the architect's general preferences concerning information collection and processing in the early design phase.

Concurrently, most of the above studies review tools that focus on one aspect only – often that of energy performance, including the concepts of Passive House and Nearly Zero Energy Buildings. There is no research that studies effective sustainable design support for the early design phase considering multiple sustainability aspect. However, the difficulty lies in supporting the architect in providing insight into the interrelatedness of sustainability criteria and guiding them in carefully weighing these criteria and effectively merging them into one design.

Consequently, in their effort to reach for a sustainable building design, architects collect information from the available BSA tools that cover multiple criteria. They combine this information by drawing up checklists of sustainable measures and use these as a support when designing. However, these checklists provide incoherent sustainability information and do not show insight into the detailed interconnectedness of the various measures. This lack of insight usually leads to non-cohesive, disconnected design measures and will negatively affect the overall "green" performance of the building.

Furthermore, collecting and processing information on sustainable measures is time-consuming because of the vastness combined with the diversity of this information and its diffusion across different kinds of media. Whilst willing to develop knowledge and skills on eco-effective design, architects are not able to spend significant time and budget on doing so; unfortunately, the competitiveness in the building sector hinders this progression. Moreover, architects can no longer rely merely upon their own experience (Weytjens et al., 2010).

This raises the question: how can architects be properly guided to achieve a high performance green building concerning the above mentioned? In addressing this question, this study as a part of a comprehensive research composes the outlines for a survey among architects. First, chapter 3 presents the method for the survey, followed by chapter 4, which discusses relevant terminology for this inquiry and poses questions as a basis for the questionnaire. Chapter 5 presents the sample selection. Finally, conclusions and recommendations are presented in Chapter 6.

2 RESEARCH QUESTIONS AND METHODOLOGY

As elaborated on in the introduction, a great number of architects continue being unable to design a high-performance green building. This research aims at identifying reasons for this limitation by gaining insight into the architect's way of dealing with sustainability in the design process: What guidance do architects need to attain high performance green building design?

In addressing this question, this paper – as a part of a comprehensive research – offers a methodology and composes the outlines for a survey among architects. The study specifically focuses on the current use and support of sustainability tools in the architect's design process. Furthermore, it considers their preferences concerning the level of detail and breadth of information and the format in which this information is to be presented.

Consequently, the sub-questions formulated for this research are as followed:

1. (To what extent) does the currently available design-support guide the architect in designing a high-performance green building?
2. What level of breadth and detail of information and knowledge do architects find appropriate throughout the process of designing a high performance green building?
3. In what kind of environment –inputs and outputs – and in what format should the information and knowledge on sustainable design be presented to the architect?

First, this paper presents a method for a survey among architects to obtain data from architects and manifest their practice and preferences concerning sustainable design. Second, it defines the terminology of "sustainable", "green" and "high-performance" for building design, based on literature. Moreover, it presents and discusses relevant terminology for this inquiry based on de aspects mentioned in the sub-questions; it discusses literature on these aspects and shows implications for the set-up of the survey. Third, it analyses the population of architects who consider sustainability and selects a representative sample. Finally, conclusions are drawn and recommendations for the survey are given. This paper forms the basis for a follow-up paper, which presents and discusses the results of the survey (Erbas & Dijk, 2012).

3 METHOD OF INQUIRY

We have made a distinction between two groups of architects: those who have a thorough mastery over sustainability and who are training to master sustainability. Since we want to find out what hampers architects in sustainable design, we are mainly interested in the latter group – group A. A survey with closed-ended questions will be presented to this group; the survey will be analysed using statistics. The first group of architect is, however, of great value and we can learn from their practice. Therefore, this group – group B – will be interviewed with open-ended questions as inspiration for the questionnaire of group A. Furthermore, some of the closed-ended questions from the survey will be posed for a comparison with the results retrieved from group A.

The content of the questionnaire embodies the aspects that have been discussed in chapter 3 and are based on three sub-questions, posed in chapter 2.

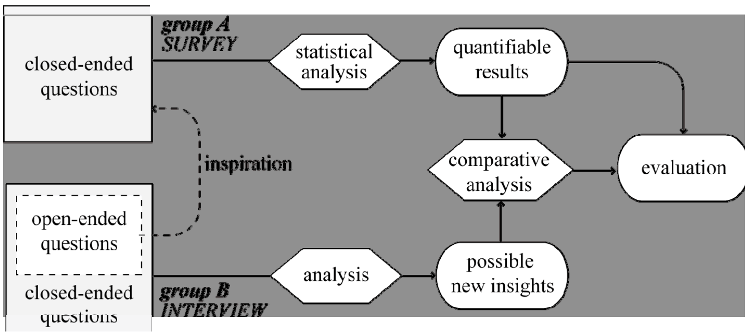

Figure 2. Visualisation of the method of inquiry

4 TERMINOLOGY

4.1 "Sustainable", "Green" and "High Performance" buildings

There is no common agreement on the definition of a "sustainable", "green" or "high performance" building. The most commonly used definition of sustainability is that of the Brundtland report: "Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland et al., 1987). The generality of Brundtland's definition expresses the confusion that often arises concerning the terminology of sustainability. Over time a wide range of literature showed "a bewildering array of contrasting building types, employing a great variety of different technologies and design approaches, each justified by a highly diverse set of interpretations of what a sustainable place might represent" (Guy & Farmer, 2006).

Kohler (1999) however refers to both a sustainable and green building and categorises it into three dimensions of sustainability: ecological sustainability, economic sustainability and Social & Cultural sustainability (Kohler, 1999). This is commonly known as people, planet and prosperity, which originates from the term Triple Bottom Line (Elkington, 1998); in brief, "people" represents social consequences of actions, "planet" represents the quality of the environment as the effects on ecology and "prosperity" represents the economic viability. According to Kohler "green buildings are supposed to have something additional to normal buildings and this additional quality must create a supplement in cost".

The US Environmental Protection Agency gives a following definition:

"Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building." (US EPA, 2012)

The term "(high-)performance" suggests a focus on the ability to evaluate aspect of building performance ranging from energy use, illuminance distribution and air quality to economic performance and maintainability. However, the term is – as stated before – used as equipollent to sustainability. For example, the American Institute of Architecture defines a high performance green building as a building that has life enhancement as a goal for both humanity and ecology. A building's indoor climate should provide healthy, comfortable spaces that improve inhabitant's wellbeing and performance; moreover, building development should prevent disruption of the balance in nature. Within the goal of wellbeing and productivity enhancement a more comprehensive variety of aspects – including sustainability – are considered in the building design, such as accessibility, cost-effectiveness, function and operation, historic preservation, productivity and safety & security (AIA, 2012).

Although above definitions claim equality between "green", "sustainable" and "high performance" buildings, other discussions about the difference between "green" and "sustainable" suggest that a "green" building serves to limit its negative impacts on the environment and its inhabitants, whereas a "sustainable" building balances the triple P dimensions. For example, bamboo regenerates itself within 5 years and could therefore be considered as a "green" building material. However, utilising this material in a Dutch building for e.g. flooring is not sustainable because of its long travel distances from its land of origin– the orient. Contradictory, if it is used in the land of origin it could be regarded as sustainable. Furthermore, labour circumstances could be poor, which would affect the sustainability of the material. Therefore, green design is regarded as a subset of sustainable design.

Because of the suggested measurability of in the term high-performance and because of the research's focus on environmental issues, we use the term "high-performance green building" and will be used throughout this paper.

4.2 Interconnectedness

At the basis of sustainable design lies incorporation of vital aspects such as the flows of air, light, energy, water, sound, matter and occupants (Pauli, 2010). Just as the systems of nature are interconnected, a building contains systems in which flows to a certain extent are interconnected; water contains potential energy (heat/cold), occupants provide heat, occupants inhale air, water transports matter's effluents, (sun)light can cause overheating, etc..

Buildings cannot be considered as solely aesthetic compositions that meet regulations and functional goals (Pauli, 2010). Furthermore, disassembling sustainability related issues in design into individual pieces is essential in order to solve specific problems. However if such an approach remains without considering the interactions among the parts, the overall results cannot be successful. As it is stated in the book Natural Capitalism (Hawken et al., 2010) "Optimizing components in isolation tends to pessimise 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."

As mentioned in the introduction, either BPS or BSA tools hardly display interrelatedness between the various sustainability aspects; this counts for tools considering both a single and multiple criteria. This is mainly because of the risk of double counting an effect of a sustainable measure. If these tools cannot provide knowledge on or insight into these connections, how do architects go about it in practice? Do architects take this interaction into consideration?

4.3 Currently available tool support and the design process

Sub-question number one:

> (To what extent) does the currently available design support guide the architect in designing a high-performance green building?

4.3.1 Support of current tools

Considering the needed emphasis on early design decision to deal with sustainability in building design, we need to provide an overview to understand the architect's preferences on collecting information for building design. Most of the current sustainability support does not speak the language of the designer; they have divergent focus, methods and values. Science searches for a correct answer, design searches for an appropriate answer (Cross, 1982).

Recent research provides insight into some aspects of design support. For example, Weytjens et al. (2009) defined six aspects of support – as knowledge base, for evaluation and analysis, for modeling, for structuring, for presentation, and for communication – and concludes that architects require additional support for evaluation and analysis in the early design phase, for communication in the building permission phase and more knowledge-based decision support evenly distributed over all phases of the design process.

But what kind of information sources do architects use in the early phases of the design process? What kind of support might fit their general information-collection and solution-oriented design approach? Does this support comply with the current guidance provided by decision support tools (DST)? Therefore, we will present a list of information sources to architects and ask them to select the sources they deploy for every phase of the design process.

4.3.2 Design process for a high-performance green building

The majority of the current architectural design support focuses on quantitatively assessing buildings after design or construction. The availability of this type of tools is vast and building assessment extremely useful for the evaluation of the success of the design in practice. However, it is common knowledge that most influential decisions for building design are taken in the early stages of the architectural design process (Yannas, 1989; Brown & DeKay, 2001), illustrated by Figure 3.

Subsequently, design support in the early stages does hardly allow quantifiable assessment. The great uncertainties that appear during the early design process complicate a detailed calculation and evaluation of the concept or scheme design. Therefore it can be stated that most the current IT sustainability support conflicts with the early stages of the architectural design process.

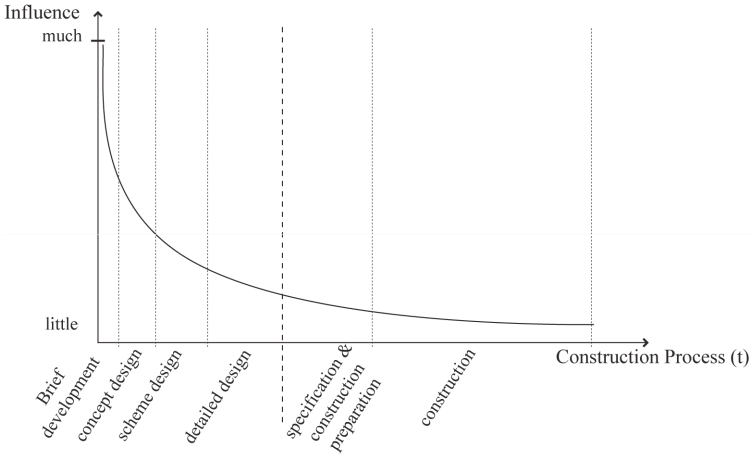

Figure 3. Declining influence in the process of building design and construction

Gray & Hughes (2001) describe the following work stages for architects: (1) inception; (2) feasibility – outline proposal – scheme design; (3) detailed design – production information – bill of quantities; (4) tender action – project planning; (5) operations on site – completion. The term early design phase refers to the design stages in which the architect conceptualises his/her first ideas, in accordance with the formulated project requirements (Mahdavi & Lam, 1993).

For the survey we categorised the design process into five design phases; in these phases architects are able to influence their design. Furthermore we have distinguished the process of renovation from new development, which leads to an additional phase in the design process: inventory and documentation phase. This leads to the following six design phases: (1) initiation, (2) inventory and documentation, (3) scheme design, (4) final design, (5) building permit and (6) specifications.

In our research we define the early stages of design as the period within the process of designing that starts with initiation and ends with the finalisation of the scheme design.

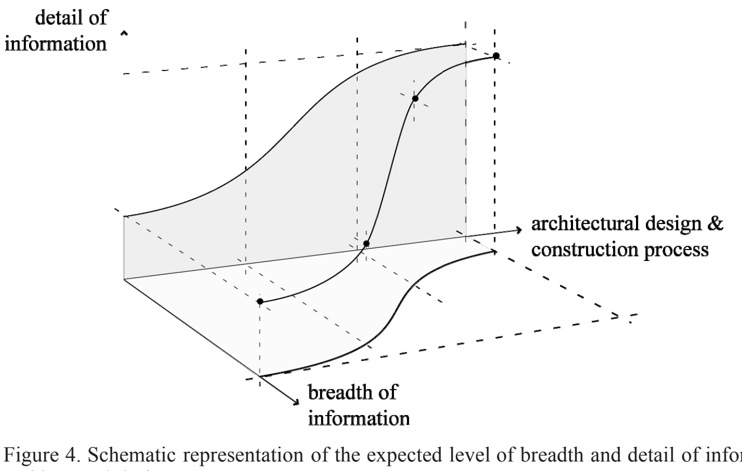

Figure 4. Schematic representation of the expected level of breadth and detail of information for the architectural design process

4.4 Level of breadth versus level of detail of information

Sub-question number 2:

What level of breadth and detail of information and knowledge do architects find appropriate throughout the process of designing a high performance green building?

There is general agreement that architects do not need very detailed information at the beginning of the design process (Brown & DeKay, 2001). However, at the end of the building process detailed information about the design decision should be available to facilitate BSA. Furthermore, the interconnectedness of sustainability measures asks for inclusion of a vast share of sustainability criteria. Within this research we presume that Figure 4 includes a graphical representation of the required level of breadth and detail during the multiple stages of the design process. Does this representation correspond architects wishes concerning the level of breadth and detail requirements throughout the design process?

4.5 Environment and format of design support

Sub-question number 3:

In what kind of environment –inputs and outputs – and in what format should the information and knowledge on sustainable design be presented to meet the architect's preferences?

Literature concluded that architects require additional support for evaluation and analysis and knowledge-based decision support in the early phases of the design process. We are interested in more detailed preferences of architects concerning this support and formulated the following five possible inputs-outputs types for a decision support tool (DST).

The first type DTS provides information on potential measures, techniques and technologies for selected performance criteria. It serves as a so-called knowledge-based decision support.

However, a tool could also provide information on performance criteria that have not been selected by the architect. This could lead to adoption of other criteria during the process of design and would stimulate architect to fully exploit the interconnectedness between performance criteria.

An other type of support could be offered by presenting – project specific – options for improvement for an existing design. This type of support would not be beneficial for the earliest stages of the design process; however, it would be profitable for optimisation of sustainability for renovation objects.

A tool could also support an architect by assessing design alternatives, considering the interactions between the various performance criteria. An architect could provide multiple designs and selects the best design by evaluating sustainability performance and for example functionality, which provides room for synthesis and creativity.

The last proposed type of support is a type that could offer evaluation and interpretation of predicted performance. It would help interpret and evaluate calculated performance delivered by BSA and guide the architect to translate provided results on performance into design measures.

Furthermore, research has shown which tools architects use during the design process. However, little research questioned which kind of DST would they prefer to present relevant information to them. In other words, what format do architects favour when they search for information on sustainability?

5 SAMPLE SELECTION

Since this research tries to find answers to what guidance architects need to achieve a high performance green building, it needs to inquire architects with experience in the field of sustainable design. Architects who have no or minor experience in sustainable design will not be able to identify the difficulties arising during the sustainable-design process. This asks for a population sample that only includes architects who have a thorough mastery over sustainability and who are training to master it – "sustainable" architects (SA).

The sample size for the survey is determined by using Rogers' diffusion of innovation theory. Rogers (1995) defines the diffusion of new ideas as followed: "an innovation, which is communicated through certain channels over time among the members of a social system". This diffusion is illustrated in Figure 5. Furthermore, he describes the characteristics that determine the rate of adoption of an innovation, being: relative advantage, compatibility, complexity, trialability and observability.

We cannot exactly determine the current status of the adoption of sustainability; although sustainability – as the innovation – came in and out of vogue in the 1970s and enjoys a revival since mid-2000s, only since this revival the market endorsed sustainability. Sustainability has a growing relative advantage and compatibility due to its market value and an increasing awareness that we need to change our wasteful behaviour. However, it still encompasses a – growing – complexity. Therefore, although adoption rates are rising, sustainability remains limited to the minority of innovative architects.

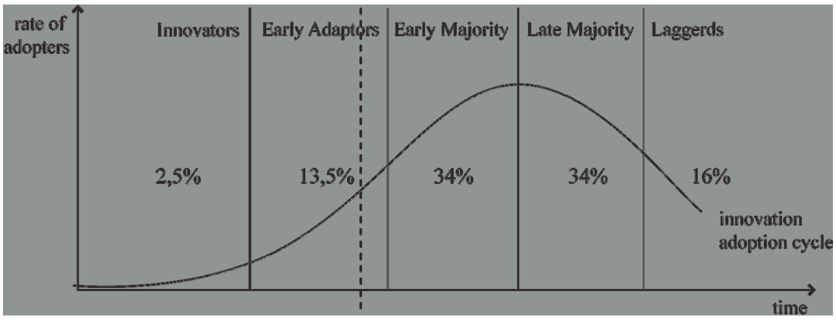

Figure 5. An adopted representation of Rogers' (1995) diffusion of innovation theory

Considering the above, we assumed that the current adoption rates would be approximately 12,5% of all architects, represented by the dashed line in Figure 5. The population sample of all architects is derived from the Dutch “Architectenregister”, which comprises all registered architects in the Netherlands. Although it is assumed that not all of the registered architects are practicing architecture – some have retired, others are practicing in consultation or education – we will use this population for this research. Other sector organizations have a significantly lower number of member architects in their database. Therefore, we use the population size offered by the “Architectenregister” which currently has a size of 9.142 architects. As a consequence, we derive a population size of 1.143 SA, which leads to a sample size of just over 200 SA.

6 CONCLUSIONS & RECOMMENDATIONS

This paper describes the preliminary research that was done for the set-up of a survey among Dutch architects who are skilled or are training their skills in sustainable design. The survey was set up to gain insight into what guidance architects need to attain high performance green building design. The research formulated a series of three sub-questions, covering aspects of the issue and that continues on previous research on the topic (Weytjens et al., 2009).

1. (To what extent) does the currently available design support guide the architect in designing a high-performance green building?
2. What level of breadth and detail of information and knowledge do architects find appropriate throughout the process of designing a high performance green building?
3. In what kind of environment –inputs and outputs – and in what format should the information and knowledge on sustainable design be presented to the architect?

The following questions have been derived from the discussion on the sub-questions and have been taken up as survey questions.

For sub-question 1 we going to ask architects which sources they consult when they want information on comfort enhancement and environmental impact reduction. Furthermore, we are going to ask them to select the sources they deploy and categorise them for the several phases of the design process. We are going to pose sub-question 2 as it is. Finally, we are going to present them with five possible inputs-outputs types for a decision support tool (DST) and ask them to rate them by preference. Furthermore, we are going to ask what DST format they favour when they search for information on sustainability. Results are presented and discussed in a second paper (Erbas & Dijk, 2012).

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