DECISION SUPPORT FRAMEWORK FOR LOW IMPACT HOUSING DESIGN IN THE UK

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There is an increasing drive to achieve sustainability agenda, as well as climate change challenges. For UK buildings, design is believed to be the key in delivering the low impact agenda. Hence, a fundamental change to designers' approach in designing for low impact buildings is needed. However, existing design- decision support tools had not addressed in full the expectation of architects to design such buildings. The tools, specifically the Building Performance Energy Simulation (BPES) tools are not fully integrated into the design process, to enable UK architects to make informed decision at the early stage of the design process. Thus, this study seeks to provide a decision support framework that defines the required characteristics of BPES tools for architects to achieve low carbon housing (LCHs) design in United Kingdom (UK). It sets out to determine how UK architects can achieve the design; what the needs of architects are in BPES tools to deliver the design; and what design decision tasks are required, towards development of the framework. Consequently, the research examined low impact housing design. Existing statutory and non-statutory regulations, as well as design and decision support tools, which relate to the design and its delivery, were identified. These were used to frame the questions for the qualitative semi structured, face-to-face and in-depth interviews with architects in practice and in the academia. Data analysis revealed that there is lack of fitness between existing decision support tools, in form of Building Performance Energy Simulation (BPES) tools, and the various stages of the design process. It emerged that architects use BPES tools, primarily at the later stage of the process. Support for the early design stage remains poor, especially at the conceptual stage of the design process. The findings confirmed that design decisions for low impact housing design vary significantly in terms of level of accuracy, flexibility, and detail. At the earlier stages of the process, as relatively little information is available, flexibility and approximation in BPES tools is more relevant to support design decisions. As the design develops, and more information becomes available, precision and higher level of detail is required in BPES tools.

Keywords: architect, building performance, energy simulation, early design stage, design decision, low impact housing.

INTRODUCTION

Buildings account for approximately forty per cent of carbon emissions in the UK and across the European Union (Carbon Trust, 2010). They have been described as complex entities involving a wide range of stakeholders drawn from a large number of disciplines (Dibley et al., 2012). Within the building industry, the housing sector alone was responsible for over a quarter (twenty-eight per cent) of the total carbon emission (DEFRA, 2005). The current trend is that this will increase due to new technologies, such as digital radios, plasma TVs, and air conditioning requiring higher energy inputs

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(CLG, 2007; Seyfang, 2008). Forbes (2007) posits the existence of environmental concerns in light of anthropogenic climate change have impact on the housing sector, because it is the major energy-consuming, and carbon dioxide producing sectors. Despite some buildings having green credentials, Scofield (2002) observed, they were found to be responsible for as much energy consumption and pollution as comparable to conventional buildings.

This is because, environmental design decisions are taken late in the design process to validate design after critical decisions have already been made (Dunsdon et al., 2006). Early in the design, architects often make decisions regarding the building form, orientation, fenestrations and construction materials with little or no support (Hong et al., 2000). These issues have been observed to have important implications in achieving the low impact building agenda. The way design decisions are made have great influence on the outcome of the design. Fundamental design decisions taken early in the design process have far reaching environmental impacts later on. Better informed design, from the earliest conceptual stage, will improve the design of individual buildings, and help achieve low impact buildings. For this reason, tools have become a necessity for the early and on-going consideration of environmental performance and an important delivery mechanism to aid architects' design and decision making to deliver the low impact buildings.

However, in the traditional design process, it is the energy engineer who uses simulation tools for equipment sizing and code compliance, after the architect has completed the architectural design (Ellis et al., 2008). This is because; existing decision support tools had not addressed in full, the expectation of architects. Design-decision support tools, specifically the Building Performance Energy Simulation (BPES) tools are not fully integrated into the design process, to enable the UK architects make informed decision necessary at the early stage of the design process. From the RIBA Climate Change Toolkit 05, all design tools, from simple calculation procedures to complex simulation models, are means of estimating the approximate performance of a given design (RIBA, 2009). Hence, BPES tools for architects' decision making should complement the designer's own knowledge by quickly confirming whether proposed changes to a design are likely to make the performance of the design better or worse, and by indicating the relative effects on performance of different design features (Royal Institute of British Architects, 2009). They should provide different degrees of confidence, depending on the quality and amount of the input data as well as the complexity of the calculations. Canada Mortgage and Housing Corporation (2004) defined; Decision Support Tools (DSTs) as any tool(s) used as part of a formal or informal decision process or that, which informs the decision-making process by helping to understand the consequences of different choices. Decision makers such as the architects, need the right tools and data at the right time to identify and assess potential low energy design solutions (Dunsdon et al., 2006).

Thus, the study seeks to provide a decision support framework for architects to achieve low impact design in the United Kingdom (UK). It sets out to determine how architects in the UK can achieve the design; what the needs of architects are, in BPES tools characteristics, to fit their design and decision making. It finally maps out a Decision Support Framework (DSF) that includes the use of Building Performance Energy Simulation (BPES) tools, fit for architects' design and decision making to deliver the low impact housing design in the UK.

BPES Tools and Approach adopted for the Decision Support Framework

Application of computer based tools in building design can be broadly categorised as computer-based drafting and design tools such as AutoCad and computer-based Building Performance Energy Simulation (BPES) tools such as Autodesk Green Building Studio, Building Design Advisor, Design Advisor, DOE-2, ECOTECT, ESP-r, Energy 10, Energy plus, eQUEST, and Integrated Environmental Solutions (IES). BPES tools, according to Hong et al. (2000), are tools that are used to simulate: Energy performance analysis for design and retrofitting; Compliance with building regulations, codes, and standards; Passive energy saving options; Building Energy Management and Control System (BEMCS) design; Cost analysis; and Computational Fluid Dynamics (CFD)

A brief summary of ten different building performance simulation tools were described and compared in Attia et al (2009). A more extended report on different energy performance simulation programs can also be found in Crawley et al. (2005). Another overview is accessible on the building energy software tools directory from the U.S Department of Energy (2012). Building Performance Simulation (BPS) in general is supposed to calculate, through predictive simulation, a variety of outcomes of the proposed design, such as energy consumption, performance of heating and cooling systems, visual and acoustic comfort, dynamic control scenarios for smart building technologies, smoke and fire safety, distribution of air borne contaminants and others (Augenbroe et al. 2004).

However, Morbitzer (2003) stated that the best established use of simulation for architects in design of low impact housing in the UK, is after finalising the design, hence it is for performance verification and commissioning (Morbitzer, 2003). This is not supposed to be the case, as building design is perceived to be the key to deliver the low carbon agenda. Design decisions made at the early design stages, especially at the conceptual stage of the process, have greater benefits for the construction industry to achieve low impact building design and delivery in the UK. Thus, this research, from the architects' perspective becomes necessary towards contribution to achieve the low impact housing design agenda in the UK.

Strategic decision-making in the design and construction of buildings is a knowledge and information intensive process. Some related reviews in the United States (US), which influence this particular study, include Canada Mortgage and Housing Corporation (CMHC, 2004) from the International Energy Agency (IEA, 2001). They organised tools by stage in the building life cycle and developed the Green Matrix website, which combines the LEED categories with the phase in the design/build process. Keysar and Pearce (2007) also developed Decision Support Tools (DSTs) for green building to facilitate selection among new adopters on public sector project for architects and engineers working for United States Army Corps of Engineers (USACE). Other influencing reviews include Dunsdon et al., (2006), who proposed a computerised framework to map the design process, which integrate energy analysis at the appropriate decision points. A process framework for building design was further proposed in Loh et al., (2010). They developed an ICT system to support multi stakeholder decision-making which facilitates inclusion of energy issues in the early design phase of buildings.

Consequently, the approach adopted in this study involves the integration of simulation, in form of BPES tools fit for architects’ decision making, with design-decision tasks of architects from the early to the technical design stage of the Royal

Institute of British Architects (RIBA) outline plan of work. This is towards contribution to reduce carbon usage in buildings, especially from the onset of the design process for architects to deliver the low impact housing design in the UK. The RIBA Outline Plan of Work was established over fifty years ago in the form of Plan of Work for Design Team Operation (Royal Institute of British Architects, 1963). It is widely used by those in the building industry (Royal Institute of British Architects, 2008) and has been referred to by several publications (Mackinder and Marvin, 1982; Imrie, 2007 and Adeyeye et al., 2007) within the scope of this study. The stages of design in the RIBA Outline Plan of Work are familiar to architects, as well as being widely recognised by the general construction industry in the UK. It is a model with set of procedures for building project administration. Hence, it is used in this study towards achieving the low-impact housing design because of its familiarity to architects and the general construction industry in the UK.

RESEARCH METHODOLOGY

Achieving the decision support framework and implication of the research, towards recommending the findings to software developers as well as the research communities necessitates the qualitative elements to answer the following research questions: Why are UK architects not using the existing design -decision support tools? What are the requirements of architects in decision support tools, at the different stage of the design process?

Thus, qualitative in-depth, semi structured interviews; desk study of literature review and analysis of case- based documents on integrated design processes (IDP) on low energy/sustainable housing designs were used. The logic of qualitative research defined by Henn et al. (2008) is not so much to test out given theories about what guides human behaviour, but to develop an appreciation of the underlying motivation that people have for doing what they do. In relation to this particular research, it involves interviewing experts (see Table 1) in the field. Pilot interview was carried out, to assess whether questions were clear, understandable and whether the structure and flow were acceptable. A sample of ten architects was finally interviewed. The interviewees were with diverse qualifications, years of experiences, and past sustainable housing projects in UK. Details of their profiles and years of experience are shown in Table 1.

The approach was informed by three major publications (Mackinder and Marvin, 1982; Imrie 2007; Isiadinso et al. 2011). Mackinder and Marvin (1982) used interviews with architects to understand the role of information, experience and other influences on the design process. Open-ended questions were used at intervals in the interview process and architects were encouraged to lead the discussion. Imrie (2007) involved a sample of practicing architects from the Royal Institute of British Architects (RIBA) database and combined the analysis from the interview with other web-based information of a sample of architectural practices primarily based in London. Finally, Isiadinso et al. (2011) conducted an online survey and interviewed experts who were construction professionals with substantial records of accomplishment or linking expertise in sustainable design in both industry and academia.

Table 1: Interview Profile

Interviewee	Academia	Practitioners
A		A practicing architect in the UK. He has 20 years of experience and a wide knowledge of different areas of sustainability issues especially as related to low impact housing design in the UK
B	An architect in academia with 18 years of experience	
C	An architect in academia with 10 years of experience and vast knowledge of sustainable practices.	
D	A practicing architect but is now in academia. He has 16 years of experience and participated in design of a notable low carbon energy village.	
E		An international architect in practice. He has thirty (30) years of experience and a world record of sustainable past projects using sustainable materials.
F		A practising architect with 25 years of experience in design of sustainable housing.
G		A young, dynamic, and enthusiastic architect with strong ideas and innovation on sustainability. He has three (3) years of experience.
H		An international architect with a dynamic record of past sustainable projects and publications. He has thirty-(30) years of experience.
I		A practicing architects of 10 years' experience.
J		A practicing architect of 15 years' experience.

Hence, the following issues were investigated in the study: Design and decision support tools to deliver low impact housing design in the UK; Characteristics/requirements of BPES tools, fit for architects design-decision making at the various stages of the design process; and Presentation of the Decision Support Framework (DSF) in a manner that will enable UK architects to achieve the design.

RESULTS AND DISCUSSION

Architects' Perceptions of existing BPES tools

The interviews show the diverse nature and experience of the architects who participated in the process. All subjects acknowledged the importance of design and decision support tools in the delivery of low impact design. Interviewee E specified 'Integrated Environmental Solutions (IES) tools'. Although, he does not believe the tool will necessarily deliver the design. However, in his opinion, 'This is the best at the moment'.

To know the architects' perception about existing design-decision support tools and the importance of using them during design stages, calculation; simulation; energy calculator; carbon embodiment; code compliance; and checking tools /software were all confirmed by more than half of the interviewees as being necessary to the design and delivery of low impact design in the UK. Interviewee B stated, ‘The tools, at various stages of the design process, should link with ventilation strategy, air tightness, energy calculator, carbon embodiment, code compliance and checking of results’. Interviewee C further stated, ‘Tools for decision support should be easily accessible and less complex’.

Interviewee E specifically said, ‘It will be good to have a tool that starts from when the client writes a brief to the management level, and it should include health and safety issues.’ Interviewee D stated, ‘Architects understand U-Value Calculator, since it is the basic thing, it is therefore definite. However, carbon embodiment is useful but there is not enough data to produce reliable prediction’. He further said, ‘Code compliance and checking tools are okay, but it will be good if confidence can be tested against post occupancy evaluation. Hence, a degree of prediction against reality of the design and confidence in the use of tools for decision support were added to the list of requirements for recommending tools that fit into the way architects work.

Nevertheless, Interviewee A categorically made this statement in response to his own general view on low impact design and delivery of housing in the UK. He stated, ‘We are the clients' servants: we can only do what we are asked. Very few clients want to have low carbon homes. Those that do, (owner-occupiers, by and large, and how many 'self-builders' are there in the UK?) frequently stop wanting them as soon as the additional costs become apparent. Developers and I include many social housing providers here, unfortunately, only want to do an elegant sufficiency to comply with statutory requirements. How many 'tools' can you be using when the total fee for designing a dwelling is frequently only a couple or three hundred pounds?’

Required Characteristics of BPES Tools for Architects

In relation to requirements of architects’ friendly BPES tools, to deliver the low impact housing design in the UK, the following were acknowledged from the interview analysis, for the early and detail stages of the design process.

Degree of approximation /accuracy as related to design stages

Early Design Stages: As minimal details are available; Approximation and flexibility are paramount; Accuracy is less important; Low input to avoid hampering creativity and design thinking; Quick output in a language understood by architects.

Detail Design Stages: As much details are available; Precision and specification are paramount; Higher level of Accuracy is required; Higher level of detail input required; To produce ‘Realistic’ or ‘as built’ output.

DISCUSSION

Thus, the first major finding of this study suggests, within the design process, architects are more concerned with design issues, such as : geometry; orientation; comfort; aesthetic; natural ventilation and day lighting, while engineers are more concerned with mechanical systems and control, hence, the difference in the type of tools important to each profession and in their requirements.

The state-of - the-art on design and decision support tools such as environmental assessment and BPES tools is that these tools are used at the later stage of the design process. It specifically reveals how the tools are used in only one discipline such as engineering or one design phase by majority of the architects, despite the attribute to cater for the whole design process specified by software developers and the various marketers. Emphasized in this study is that most BPES tools are easier to use by architects in only one phase, which is: the design development phase. Thus, the function becomes to help designers in improvement of their basic concepts but not to create the basic concepts towards the design of low impact housing design.

In relation to building modelling software, this study revealed that all software are not created equal; some simulation software is not even intended for design. However, design decisions stem from building simulation by which the right tool must be chosen to optimize the design from the early stage of the design process. Hence, discovered in this study is that: existing BPES tools claim to perform one or too many functions by which the required geometrical detail are not allowing the tools to perform the required function for architects in terms of required flexibility and other characteristics for the various stages of the design process. Consequently, this study made some recommendations for characteristics required of architects' friendly BPES tools in Figure 1.

Presentation of the Decision Support Framework (DSF)

Based on the reviews within the scope of this study and the analysis from the interview findings, a holistic approach was adopted to develop a DSF for UK architects to achieve the low impact housing design. It cross references the RIBA Outline Plan of Work (being the most familiar to architects and the general construction industry in the UK) with sustainability and environmental design decision tasks and the required characteristics of BPES tools that fit the intrinsic way of architects’ decision- making for the different stages of the design process (Figure 1).

Stages of design		Some Design Decision Tasks		Characteristics of BPES Tools
Earlier Design Stages	A and B	Building orientation (appraisal); Topography (appraisal); Site usage (appraisal); Sun path (appraisal); Air change rate (appraisal); Building Shape; Insulation of building envelope; and glazing (optional)	A typical site analysis in the design process, the interplay of the building mass and natural features, such as trees, sun path, wind patterns, and the form of the land are important items to consider. It helps to ensure that the site is utilized to maximum advantage. 	Flexibility of BPES tools to accommodate rapid design changes, and to avoid hampering design creativity; Low input to minimise disruption to design creativity; Fast output in a language that designers understand primarily based on approximation; Interoperability to seamlessly integrate BPES tools with design tools; Interactive to enable designers to interrogate the design model performance; Intuitive and easy to use
	C	Shape of building; Orientation (small adjustment); Insulation and mass; Attribution of building zone; Window size in different façade and orientation; Solar control requirements; Summer ventilation requirements; Glazing and Types (detailed analysis); Air change rate (detailed analysis); Materials selection and adjustment; Artificial lighting strategy, daylight utilisation, visual comfort and cooling; and Fuel Type/ Renewable Considerations	During this early stage, designers rapidly explore and refine ideas by engaging in free-flowing, collaborative brainstorming sessions, during which a wide range of designs- in the form of sketches, 2D drawings and layouts, 3D models and renderings- are considered and evaluated until a final concept design is chosen 	
Later Design Stages	D, E	Finalised material definition; Finalised building orientation; Finalised ventilation strategy; Finalised window properties (size, type, solar control); Lighting strategy, daylight utilisation, visual comfort and cooling. Detailed technical analysis such as: Assessment of passive cooling system (Ground cooling); Assessment of passive heating systems (solar preheat of air); Ventilation studies; and Test and refinement of heating and cooling control strategies		Higher level of detail and precision from detailed and accurate design information input; Detailed Output to meet detailed needs of the architects in accordance with high standard of design input; Realistic to produce ‘as built’ output, without attempt to conceal any feature; and Training, but not an intensive one for architects’ use

Figure 11: Decision Support Framework

CONCLUSIONS

This paper has led to some practical results (especially from the interview analysis) towards making recommendations for software developers to develop architect-friendly tools that fit the intrinsic way of architects' design-decision tasks. At the early design stage, as minimal details are available, approximation and flexibility are paramount while accuracy is less important. At the detail design stage, as much details become available, precision and specifications are paramount while higher level of accuracy is required. Thus, the framework was developed. It defines the sustainability and environmental design decision support tasks along with the required characteristics of BPES tools, for architects to achieve the low carbon housing design in the UK. It is different from the RIBA Green Overlay, because it integrates the use of simulation tools into the whole design process, and especially from the early design stage.

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