Architects’ Approaches to Early Stage Design Energy Modelling – an Organisational Perspective

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Abstract
Energy modelling practices have been mainly studied from energy modellers’ and/or building services engineers’ perspectives. In addition, most discussions have focused attention on analysis parameters and tool features, with less attention devoted to organisational and social processes involved. This paper discusses how architects in leading UK and USA firms approach the adoption and implementation of recently developed early stage energy modelling with a focus on organisational processes across 9 large firms. Findings suggest differing facilitating conditions, social influences and attitudes contributed towards architects either temporarily adapting or adopting energy modelling in their organisational and design practices.

Introduction
Building energy performance is defined as the amount of energy actually consumed or estimated to meet the different needs associated with a standardised use of the building, which may include heating, cooling, hot water, ventilation and lighting (de Wilde 2014). Discrepancies of over 100 per cent in the energy performance of buildings have been reported, with factors related both to the simulation process as well as to the physical buildings identified as possible sources for this discrepancy (Ruyssevelt (2014); Robertson and Mumovic (2013)).

Whilst improvements in energy performance are recognised to have a large impact on national energy savings (Zero Carbon Hub 2014) and though increasing research has focused on addressing the issue via tool improvement and development (de Wilde 2014), understanding the design processes that lead to early building conceptualisation carried out by architects, that have inherent effects on energy use prediction and enable its simulation are poorly studied and overlooked.

Although many interrelated issues have been highlighted as the cause of the discrepancies, the most significant challenge lies in complexity of data exchanges between architectural design outputs and building energy simulation components. Interoperability between early stage design and subsequent modelling is not well understood. In addition, related workflows, suggested to be problematic, are under examined.

Building geometry and associated spatial properties in a cad file characterise architects ‘spatial and aesthetic’ view of the building; not its ‘performance’ view (Attia et al., 2012). Drawing on a large survey, Attia et al., (2012) document the typical differences between architects and engineers as main operators of a simulation model. Though some scholars suggest, predicting emerging phenomena lie largely in new computational methodologies, there is an emerging agenda that asks for ways to understand ‘designers’ imagination and experience’ (Hölscher and Brosamle 2007).

Emerging insights gained by Oliveira et al., (2017) suggest architects’ focus and approach to planning for energy efficiency and use is often overshadowed by other design priorities such as the aesthetic appearance of buildings and users’ spatial experience - all of which have shown to have an impact on building performance
(Simeone et al., 2013). Zapata-Lancaster and Tweed (2016) draw on an ethnographic study of architecture firms in England and Wales to examine how simulation tools such as IES and TAS are experienced by design professionals. They suggest designers tend to initially rely on experiential knowledge rather than simulation tools, viewed mainly as validation mechanisms rather than exploration tools.

General site conditions and constraints as well as the building potential tend to be explored initially during early stages of design with modelling viewed as a way to evidence achievement of targets. Soebarto et al., (2015) conducted surveys with architecture firms in the USA, the UK, Australia and India finding that in most cases architects recognised the importance of early stage energy modelling, however, largely did not implement it in their design practice. According to Soebarto et al., (2015) most architects did not perceive energy modelling as their responsibility, viewing all the technological advancements on energy modelling as largely outside their domain and the responsibility of other experts. Their study suggests greater emphasis needs to be placed on energy performance within architecture education and professional development of architects.

Though buildings impact upon sustainability in a range of ways, energy performance is a ‘reasonable proxy for overall sustainability’ (Mashford and Reason 2017); making for a compelling and urgent argument to provide innovative novel approaches to addressing and analysing the ‘performance gap’. Though above discussed studies provide initial scope and understanding into architects approaches, there is a growing need for cross-disciplinary methods that take account of a range of designers’ work processes (often viewed as intuitive and reflexive) enabling new understandings on key characteristics of energy analysis that are largely unexamined and overlooked.

While it is assumed that architects undertake some type of early stage energy analysis, it is unclear what range of processes are applied and how they inform or not the energy modelling carried out mostly by the engineer. Leading architectural firms are, however, starting to promote use of in-house early design simulation (such as Sefaira) to help make energy design decisions at conceptual stages.

Most of research analysing architects’ approaches to energy modelling do not rely on qualitative empirical data basing discussion on objective reviews and comparison of tool features. In addition, most studies do not base analysis on theoretical insights that may offer new observations as discussed in section below. The following sections outline the research methods and findings. The final section discusses implications of the research and contributions to practice, policy and academia.

Research methods

The research method draws on a qualitative multiple case comparative analysis design in order to explore how different settings approach a similar issue (Ragin 1989). Nine case studies represented by large UK and USA architecture firms: Studio ‘A’, ‘B’, ‘C’, ‘D’ and ‘E’ in the UK and Studio, ‘F’, ‘G’, ‘H’ and ‘I’ in the USA participated in the study. The cases were selected as they were all in the process of recent implementation of early stage energy modelling tools (including Sefaira, Green Building Studio as well as Ladybug tools) across their projects. All firms were large and employed between 125 to over 300 staff across a range of international locations.

To date 72 participants have contributed to semi-structured interviews and focus group sessions in the UK and in the USA. Interviews and focus group sessions conducted by the first author were semi-structured and addressed the following themes: the role and background of participant within the organization, learning approaches to using the modelling tools, reasons for using the tool and methods for sharing ‘modelling’ knowledge with client and building services engineer. In most instances, the technology referred to by participants is Sefaira. See also Table 1 for participant characteristics.
Table 1: Participant Characteristics

<table>
<thead>
<tr>
<th></th>
<th>UK</th>
<th>USA</th>
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</thead>
<tbody>
<tr>
<td><strong>Firms</strong></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><strong>Participants</strong></td>
<td>52</td>
<td>20</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Bristol, Manchester, London</td>
<td>New York</td>
</tr>
<tr>
<td><strong>Tools Discussed</strong></td>
<td>Sefaira, Green Building Studio, Open Studio</td>
<td>Sefaira, Ladybug tools</td>
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Data collected was analysed in NVivo using a combination of descriptive and analytic themes. Three initial descriptive categories included: 1) Organisation, 2) Learning methods and 3) Energy relationships. Within the categories further sub-themes were examined including: hierarchical loops, motivational blockages, client dependence, existing design drivers, uncertain effects. In a second phase data were re-coded drawing on Davies' and Harty (2013) categorisation of the Technology Acceptance Model (TAM) theory as illustrated in Table 2.

Table 2: Categories of TAM Theory

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>Performance Expectancy</td>
<td>the degree to which an individual believes that using the system will help him or her to attain gains in job performance</td>
</tr>
<tr>
<td>Effort Expectancy</td>
<td>the degree of ease of use associated with the system</td>
</tr>
<tr>
<td>Facilitating conditions</td>
<td>the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system</td>
</tr>
<tr>
<td>Social influence</td>
<td>The degree to which an individual perceives that important others believe he or she should use the new system</td>
</tr>
<tr>
<td>Attitude</td>
<td>toward using technology, an individual’s overall affective reaction to using a system</td>
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The purpose of drawing on TAM was not to measure or quantify using scales. Following qualitative work carried out by Peansupap and Walker (2006) and Miller et al., (2009) constructs from TAM were used in the analysis in order to derive an extended understanding into technology adoption.

There is a developing research agenda on ways construction organizations implement new ICT technologies within their practice drawing on diverse theoretical concepts (Linderoth 2010). In most cases studies draw on established bodies of knowledge applied in other domains such as information management and systems disciplines (Linderoth 2010). Examples include the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Actor Network Theory (ANT), and Diffusion of Innovations (DOI).

Hjelt and Bjork (2007) propose the use UTAUT to study user attitudes towards electronic document management systems in construction. A combination of TAM and UTAUT has been deployed in a study on inter-organizational information technology in the US construction industry (Adriaanse et al., 2010). The technology acceptance model (TAM) has informed research on the user acceptance of building management systems as well as research on individual beliefs about the outcomes of BIM use in construction organizations (Davies and Harty 2013).
energy modelling tools within their design work processes including how they viewed the performance and ease of use; as well as what if any facilitating conditions they viewed as key; in addition to the attitudes and social influence they reflected upon when discussing the learning and use of the technology.

Findings

Three key categories emerged in the analysis in the UK and USA including 1) expectancies (performance and effort); 2) facilitating conditions and 3) influence and attitudes (see Table 3). Across the firms in the UK emphasis in particular categories varied from the USA as discussed in detail below.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Performance and Effort</th>
<th>Facilitating Conditions</th>
<th>Influence and Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of learning</td>
<td>Senior management</td>
<td>Greater good</td>
<td></td>
</tr>
<tr>
<td>Uneasy application</td>
<td>Client dependence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficult interoperability</td>
<td>Project/Time dependence</td>
<td>Liabilities and compliance</td>
<td></td>
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<tr>
<td>Uneasy sharing</td>
<td>Frequency of use</td>
<td>Risk</td>
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Due to restrictions in size, this paper focuses on two of the categories (Facilitating conditions and Influence and Attitudes) that reflect mostly upon the organisational and social issues involved as discussed below.

Facilitating conditions - client interests and project types

Within ‘facilitating conditions’ six themes were found including: senior management dependence, client dependence, project specific use, time, design team buy in and frequency of use.

Architects in the UK discussed how use of the new tool depended on a number of issues including client interests, project types and suitability as well as availability of resource and time. For many architects, undertaking energy analysis and modelling in a project depended primarily on client interests.

“Depending on the type of client and what the design drivers are, the typology of building, the client and I suppose the site as well, to an extent…” Participant Studio A, UK

In addition to depending on clients’ interests and drivers, many discussed how use of the tool was intrinsically linked to type of project. In some instances, projects were described as predetermined. A participant in Studio A observes how very often there isn’t “the choice on building orientation of the site, even window sizes, (there isn’t) much choice sometimes”. In the USA, clients’ willingness to invest in energy analysis and ultimately an environmental design played a big part in how and if architects were able to use tools in projects.

“…Yes, it takes time, it changes things, it becomes more cost kind of impact on the project- Im not talking about the soft cost- Im talking about the actual façade cost going up and then sometimes its driven by clients where its hard to sell a 30%/40% when the wall ratio which is 70%, so there are challenges that exist, but we often find a way round it, we find solutions that we can deal with all these requirements. Its usually, I think getting clients more excited, that’s a bigger challenge…” Participant Studio F, USA

In addition to being dependent on clients’ interests and willingness to fund energy analysis, most architects in the UK and USA discussed how use of the tool
depended on the project stages. In the UK, participants noted that particular projects were predetermined either by a set of pre-established constraints or programme, making exploration and energy modelling less appropriate.

“Yeah, it wasn’t bad, and we were constrained by planning application, so we already had 40 per cent glazing ratio and windows and specific places, we could move them a bit, but not a huge amount, not suddenly glazing a tower elevation, or suddenly shade a tower elevation, so we kind of used it to test and refine a little bit.” Participant Studio C, UK

Interest and understanding of senior management was also found to be a stumbling block. In the UK, most architects reflected upon being ‘in the hands of senior managers’ who had ‘certain agendas’ whereby design fee time could not be taken up by exploratory energy modelling work. In the USA, reference was mostly made to leadership ‘not understanding what is needed’ or how best to ‘train and up-skill staff’.

Influence and attitudes—reluctance, distrust and potential empowerment

The ‘influence and attitude’ category included six themes: personal interests, moral obligation, greater importance, liabilities and risk, compliance drivers and insecurity.

Whilst facilitating conditions were found to be a large factor in how and when particular new energy modelling tools were used and or shared, social influence and attitude towards energy analysis played a critical role in continuity of take up and eventual adoption or adaptation. For many architects in the UK, there was a reluctance and perceived lack of trust in ‘what engineers do’ and the assumptions they may make when carrying out in-depth energy modelling.

For the most part, architects in the UK discussed using tools such as Sefaira and Green Studio to ‘see what engineers have done in a model’ as they ‘don’t believe their results’.

...I think it’s something where, as things become more onerous, I think for the architect to have power to test things and actually work things out because at the moment, even Part L at the moment is a bit complicated…” Participant Studio B, UK

Whilst in the UK the tool was seen as a way to exert influence over a project, in the USA, the process of energy modelling was viewed as adding edge and providing compliance and leadership in an emerging field. For many firms in the USA, showing that ‘energy modelling is done here’ means we have ‘high performing teams and designs’. Very often high performing buildings were conflated with high performance teams. Also in the USA, distinctions were made between ‘design’ architects and ‘technical’ architects; with most ‘design’ architects perceived to not focus on energy analysis other than when it is integral to their existing workflow process.

“…One of the things that’s a firm wide goal is to maintain our leadership in the EIA 2030 Challenge, I’m not sure if you’re aware of that, so that drives us to say all our projects have to perform a certain percentage over the database baseline from 2002 or 2003…”

In addition to enabling greater influence, for many architects in the UK and the USA, the additional abilities and knowledge gained through energy modelling was viewed as empowering architects.

“Yeah, I think it's something where, as things become more onerous, I think for the architect to have power to test things and actually work things out; if on a complex building you have to have your building energy emissions versus a target and we need engineers to do that for us. If we can actually have a tool that starts helping us do that and so the architect becomes a bit more powerful in the process, yeah, I think that would be useful…” Participant Studio D, UK

In the USA, empowerment was viewed as a route to pushing a specific energy agenda and/or steering a project in a specific ‘green’ direction. One of the architects, described how engineers are often not as
committed to a project or agenda and architects are largely the ones that ‘care about those sort of things. Greater knowledge and empowerment was also viewed as a way to market or promote a ‘sustainable’ approach that would have greater implications than a single project might have.

Discussion and conclusion

By taking a broad social science perspective and integrating technological and sociological understandings of energy modelling tools in design, this paper contributes to continued academic debate regarding the potential for integrating different perspectives in the study of energy in the built environment (Schelly 2016). Also, by furthering this debate within the UK and USA context, findings in this study help add to established research on potential characteristics of energy analysis currently excluded from discussions on building performance simulation processes.

With regards to TAM theory, findings in this study conflict with some of the theory’s key assumptions including views on facilitating conditions being primarily organisational and also as providing impetus for adoption. In this instance however, facilitating conditions included many external ‘social’ and ‘economic’ dependencies. In the UK clients’ willingness and interest in energy and sustainability wide issues prevented or enabled engagement with energy analysis. Similarly, in the USA clients’ drivers and economic interests in a particular project were described as key deciding factors. In addition to clients, wider buy-in and understanding of the role energy analysis has in projects from design team members, users and general public played a big part in architects’ engagement with the tool(s).

There are also methodological implications of this study. Most existing research in technology adoption has tended to rely on quantitative methods and use of survey questionnaires, mainly to investigate correlations between factors. However, they rarely describe the adoption/or adaptation process itself, including perceived interactions within and across organizational domains, individual views as well as social indicators. Studies that have begun to investigate the process of technology adoption in organisations so far have tended to use a case study methodology and each case study focuses on a single company and/or project and often in one country. The scarcity of studies based on large interview samples in construction and architecture specifically has resulted in less understanding of the adoption phenomenon, and so gives little guidance to firms on approaches to adoption. More actionable guidance for practitioners is needed, particularly at the context independent level (Lee et al., 2003).

Policy initiatives such as the Zero Carbon Hub in their end of term report (2014) suggest solutions need to be found in improving energy literacy amongst designers especially architects, who traditionally did not participate in energy analysis. Professional bodies such as AIA call for a broadening of energy analysis tasks earlier in design processes to include architects; tasks usually undertaken by building services engineers late in the design process (AIA 2012).

Whilst this study provides an overview of experiences in the UK and USA of particular value to policy makers and professional bodies, there is scope for further work on ways architecture firms can approach energy modelling depending on project types as well as firm set ups. Workflows within projects had a particular impact on whether and how architects decided to adopt or adapt to energy modelling processes within their design.

Further research is needed to better understand how particular design workflows and project stages shape architects and other design professionals’ engagement with energy analysis and modelling across organisational and cultural contexts.

More actionable guidance for practitioners is needed, particularly at the level of a company and within the context of a design project (Lee et al., 2013). In most instances in the USA participants discussed only training key staff who then provided in-house expertise. In many instances, the staff that received training and provided expertise often had additional ‘engineering’ skills and education. In the UK though the approach in most cases was to train most if not all staff, however, despite receiving training very few described having the opportunity within a firm or a project to fully apply new skills learnt.
New guidance is needed on how to train, apply and continually adapt new processes within project-based design firms including adopting new analysis methods such as energy modelling within a performance-driven agenda.

Whilst this study provides an overview of experiences in the UK and USA, there is scope for further work on ways architecture firms can approach energy modelling depending on project types as well as firm approaches to training and learning new energy modelling tools and processes.

References

Zero Carbon Hub, (2014), Closing the gap between design and as built performance end of term report.