Green BIM and Green Star certification practices: Case studies in commercial high-rise office design

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ABSTRACT

With the goal of reducing a building’s environmental footprint, environmental sustainable design (ESD) and green building certification (GBC) is having an increasing influence on design practice. The application of building information modelling (BIM) is also affecting traditional ways of working. Whilst sustainability is a key underpinning of both initiatives, the consequences to design practices of their combined implementation are not well understood. Projects looking to realise the value of their collective benefit persist against an array of implementation challenges and unspecified management requirements. Using a qualitative case study approach, the authors explore the application of BIM from the point of view of ESD consultants and a GBC certification authority. Case study interviews reveal a range of new design workflow and management requirements relating to the communication and coordination of model datasets. The paper closes with a discussion of these management requirements and presents a strategy for future work.

Keywords: Environmentally sustainable design, Green building certification, Green Star, Building Information Modelling.

1. INTRODUCTION

The benefits of green buildings are widely recognised. Consequently, the practices of today’s AEC practitioners (architecture engineering and construction) have had to respond to a range of new design requirements. Green building certification, or GBC, has in the past decade gained traction in the assessment of building performance throughout their lifecycle. A key aspect of practitioner response surrounds the application of ESD information technologies (ITs) to model building systems and their dependencies. Complex building projects, such as commercial office buildings, with ambitious ESD and GBC objectives are increasingly utilising ESD modelling, simulation and analysis ITs within a wider strategy known as the BIM methodology. BIM is defined by Eastman et al. (2008) as a ‘modelling technology and associated set of processes to produce, communicate, and analyse building models’. BIM is not simply a technology; it involves strategies relating processes and people that allow its use. It is therefore more accurate to refer to BIM as a methodology (Jupp 2013).
BIM authoring and analysis tools represent the latest generation of object-oriented CAD systems in which all of the intelligent building objects of a design can coexist in a single ‘project database’ or ‘virtual building’ that captures everything known about the building (Howell and Batcheler, 2005). The coordinated or federated building information model provides a single, logical, consistent source for all information associated with the building. The application of the BIM methodology therefore represents a paradigm shift. Single building model environments enable the integration of multiple discipline-specific 3D models, providing an authoritative semantic definition of building elements, their properties and interrelationships. Thus the BIM methodology forces higher levels of collaboration across the entire project delivery team and can influence project delivery and governance mechanisms. ‘Green BIM’ has been coined to describe the convergence of green building design and BIM. Projects following the ‘Green BIM’ approach are reportedly able to support higher levels of life-cycle cost savings, proving the approach to be economically viable (ACG, 2010). The benefits of working in collaboration with a broader range of design disciplines for increasing building system efficiencies and achieving higher levels of ESD performance are well documented (Azhar, 2010, Eastman et al., 2011, Geyer, 2012, Kiviniemi, 2011).

In this frame, this paper investigates a research gap that exists in relation to the practices surrounding Green BIM, in particular the model coordination and workflow management challenges surrounding ESD and GBC objectives. Existing case studies on BIM often target the principal design team members (architects and structural engineers) and therefore present a limited perspective of the problems surround ESD and accreditation. The perspectives of ESD consultants are therefore rarely heard. This research seeks to address this by focusing on the perspectives of ESD consultants in order to describe the challenges and requirements of Green BIM and Green Star certification. The remainder of the paper presents a literature review, before describing the case study research method and findings. The case study investigates three Australian commercial office building developments that have been awarded 6 Star Green Star ratings. The findings of the case study interviews highlight interdependencies in the modelling of building systems between all consultants and the importance of data generated via model simulation and analysis of environmental performance to certification outcomes. The authors then discuss conclusions that can be drawn from this study and future research requirements.

2. BACKGROUND

The Green Building Council of Australia (GBCA) was founded in 2002 and in 2003, a decision was made to base the first Green Star assessment tool on the ‘new office buildings’ sector (GBCA 2012) due to the major growth
occurring at the time. The sector provided a ‘master’ framework that was then leveraged for other building types. Green Star certification is therefore a relatively recent and evolving program. With the uptake of BIM, increasingly sophisticated ESD simulation and analysis software have been used to provide the data inputs for a range of certification criteria. In managing a Green Star certification process, it is essential for projects to have clearly defined ESD goals and an understanding of their implications; in particular those that relate to the early engagement of wider range of expertise and the financial implications (Gandhi and Jupp, 2013). Higher levels of integration and collaboration throughout the design stages are required. This is mainly due to the emphasis on the entire building’s performance over individual building systems. Highest rated Green Star building design processes requires collaboration between stakeholders from the early planning stages.

Recent research in this field has identified a range of factors that hamper the adoption of BIM (Geyer, 2012, Jupp and Gandhi, 2012, Succar, 2009, Jupp, 2013). These factors can be classified in to three broad areas: technical-, policy-, and process-based. A growing body of research is being undertaken to address all aspects of these adoption barriers, with a large portion of the research focusing on BIM technologies, including software and hardware issues that range for example from integration and interoperability issues (Clark and Bettin, 2012, Fisher, 2012) to naming conventions and code checking (Laakso and Kiviniemi, 2012) to semantics and modelling tools (Zhong et al., 2012). The process and policy-based requirements for individual professional disciplines are also being explored yet are dominated by architecture discipline perspectives (Coates and Arayici, 2012). A gap in research exists in understanding BIM-enabled design processes and configurations management protocols that are relevant to ‘non-lead’ design team members. Those investigations that do address the requirements of lead design team members (London et al., 2008, Reefman and van Nederveen, 2012) often only refer to supporting consultants as a ‘byline’. The impact of process- and policy-based challenges to Green BIM implementation are therefore just beginning to be understood (see for example (Azhar, 2010, London et al., 2008, Luthra, 2010, Singh et al., 2011).

In previous research Gandhi and Jupp (2013) define a design management framework specific to coupling Green BIM with GBC processes. The framework is a simple roadmap that includes three project stages: conceptualisation, criteria design, and detailed design. It identifies general guidelines across these stages and can be summarised as: 1) Conceptualisation - including the definition of project type and procurement methods, in conjunction with development of green building specifications and documentation so as to identify and evaluate resources to achieve GBC targets; 2) Criteria Design – including the development of a framework for GREEN BIM, developing an ESD activity plan which consists of informational dependencies, information exchange protocols
and interoperability requirements specific to ESD and GBC, as well as developing an ESD and GBC criteria matrix; 3) **Detailed Design** - consisting of developing a ‘GREEN BIM configuration management system’ and definition of GBC coordination map, identification of ESD stage gates, activity modelling and information management plans. Whilst the framework accounts for general coordination and management issues it is lacking in details concerning new workflow and management functions. This research therefore tries to understand the nature of new requirements arising from Green BIM and Green Star objectives.

### 3. RESEARCH SETTING AND METHOD

The literature reviewed suggests that a Green BIM management methodology that enables higher levels of integration and collaboration throughout the design process for the purposes of improving sustainability and attaining high rating GBC outcomes does not yet exist. In exploring this gap an empirical case study approach is utilised, following the principles of hermeneutics (Gummesson, 2003); the adopted approach is therefore aimed at supporting development of new theories. Three 6 Star Green Star projects, rated by the GBCA and based in Sydney, Australia, were identified as Green BIM projects and therefore qualified as case studies for investigation. Table 1 describes details of each case.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Details</th>
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<tr>
<td><strong>Cases</strong></td>
<td>Case 1: 44887m² 30 storey commercial high-rise; completed Feb 2012</td>
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<tr>
<td></td>
<td>Case 2: 42863m² 27 storey commercial high-rise; completed July 2011</td>
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<tr>
<td></td>
<td>Case 3: 58000m² commercial office space; completed November 2012</td>
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<tr>
<td><strong>Participants</strong></td>
<td>7 interview participants: ESD consultants, Green Star accredited professionals, project and design managers.</td>
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<tr>
<td><strong>Procedure</strong></td>
<td>Semi-structured interviews, project documents, modelling guidelines.</td>
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A semi-structured interview approach was adopted and ESD consultants and GBCA authorities and GBC accredited professionals were the main interviewee group. This focus group was targeted so as to build a description of project-based experiences in Green BIM-enabled multi-disciplinary working environments. Supplementary interviews were also undertaken with project managers and design managers. Data collection also involved analysis of project documents including design management plans, contract documents, project correspondence and reports, and documents defining modelling specifications. Each interview took approximately one hour and recordings were transcribed and verified.

#### 3.1 Interview Design

The design of research questions was based on the premise that the perspective of the ESD discipline has been neglected. BIM execution plan
templates developed by leading authorities such as NATPECT (REF) provide only a short reference to key consulting services, including energy and environmental analysis. Interview questions therefore covered three focus areas of a combined Green BIM and Green Star approach: (1) benefits of a combined approach, (2) challenges to collaborative working and information management practices; and (3) identification of process and protocol requirements. Questions were also structured according to three parts: main topic questions, ‘prompt’ questions (to elicit additional insights), and closing questions. Socio-demographic data was collected based on gender, age group, level of experience, and professional background prior to the main topic stage of questioning.

4. RESEARCH FINDINGS

Findings are presented in relation to (1) general findings relative to the nature of the industry and (2) specific project-based findings relative to process- and policy-based issues.

4.1 General findings

Reported experiences of working on a BIM-enabled project aiming for 6 Green Star GBC rating were overall positive. Interviewees reported similar opinions about the nature of the benefits and barriers to BIM-enabled projects with ESD and GBC objectives. Participants suggested that Green Star rating tools assisted in the process of sustainable design, but that these tools were more often used as validation tools, rather than drivers of ESD decisions. One of the ESD consultants emphasised that GBC was not necessary for generating sustainable building designs. Another point emphasised by interviewees was that the New South Wales property market did not provide incentives for developing 6 Green Star rated buildings, and that it is only the willingness of clients, developers and project management consultancies to target high Green Star ratings.

Fundamental revision to the planning and organisation of projects was another common theme identified. Changes not only to certain design activities and processes that support GBC accreditation were mentioned, but also changes to traditional approaches to project delivery, including tendering, contracts, and construction project management methodologies. Interviewees identified how BIM technologies drive these changes and can also assist in managing this change. Overall the ESD consultants and council representatives interviewed believed that the local construction sector is ‘BIM ready’ with regard to addressing the information technological requirements of ESD and GBC criteria; however, the main sentiment expressed was that the process and policy based management issues needed to be resolved.

Another common theme identified related to socio-demographic characteristics of the Australian AEC industries concerning the availability
of professionals with appropriate skills and experience in BIM and ESD. One interviewee pointed out that: “People working in industry for more than ten years with adequate construction project experience are not skilled in the use of the latest technologies. Skilled technicians are usually recent graduates with less than five years’ experience”.

4.2 Workflow and management findings

An analysis of interview responses categorised findings into three groups which related to workflow issues, identified as workflow and process management, (2) data management, and (3) protocol management.

4.2.1 Workflow and process management

A common theme highlighted by all interviewees was the lack of integration of design processes and effective process management methods. One interviewee explained that whilst the industry has advanced towards a Design–Construct delivery method (from the traditional Design-Bid-Construct) a gap in process integration persists between design team participants and manufacturers, and from the design team to the main contractor. It was also suggested that the sector follow more closely and adapt the design processes and management practices of the automotive sector, moving towards a lifecycle approach to realise broader ESD and GBC rating goals.

Another process management issue identified related to difficulties surrounding the early involvement of a range of design expertise that can support ESD issues and decision making, which was thought to be a major benefit to achieving GBC goals. In particular the expertise of facilities managers and trade contractors were seen to be most often neglected in the ESD process due to the increase in upfront investment costs to contract required consultants. Implementing the BIM methodology requires considerable investment in process integration and its management. Most interviewees believed that developers were often unwilling to invest unless assurances could be given from councils about development approvals (DA). The DA procedure was perceived to be time consuming and a decisive factor for progression to the next project stage. As one interviewee expressed it, the potential for rejection at the DA stage “creates financial insecurities hampering BIM implementation and investment in early energy and environmental modelling.”

Mechanical, electrical and plumbing (MEP) service consultants were also seen to play a significant role in the design process, particularly in relation to translating ESD strategies during design development. Timely information and revision of building system models is required for ESD consultants to conduct various sustainability analyses and complete documentation. However, it was claimed by the ESD consultants interviewed that MEP services consultants usually failed to provide valuable information concerning the specification of building systems in a
timely way, resulting in design changes that sometimes negatively affected building performance. The knock-on effect then caused rework and raised new management problems for process coordination. One of the reasons for delays or failures to provide information during the design process was attributed to shortages of MEP service professionals in the sector as compared to the increasing demand.

4.2.2 Workflow and data management

Experiences with BIM ITs were considered by most interviewees to be appropriate and all reported to be working with state-of-the art software, hardware and supporting technologies. It was emphasised by all ESD consultants interviewed that their level of understanding of BIM, its use and capabilities were equal to or greater than the main design team participants. All interviewees expressed a similar perspective and approach to BIM software as being “just a tool that helps achieve more efficient and effective design and delivery”. Various software applications exist for conducting sustainability analysis and the main software identified by interviewees included: IES, Autodesk Ecotect, EnergyPlus, and TransSolar. However, IES and Autodesk Ecotect Analysis were by far the most popular amongst ESD consultants. Both these application were considered more expensive than other options but were simpler to use and this was seen as a “driving factor of adopting software applications”.

A number of data management issues were raised that created significant barriers that prohibited the design team from working on a single data rich semantic model. They surrounded the difficulties of managing the varying data requirements for discipline specific models due to their different analysis purposes. A common scenario reported by all three case studies surrounded each ESD firm having to develop and document their own data management and modelling guidelines (in addition to the main model management plan) for each analysis that was required for GBC. Consequently this meant that separate models for different criteria of certification were developed independently of the main architectural model. This was seen as time consuming and costly. In most cases the architectural design team were unaware of the requirements of each ESD model and therefore its scope and limitations; thus model integration was seen as an impossible task due to data management deficiencies. Most interviewees encountered interoperability issues but reported having resolved them with relative ease using IFC schemas or having established a compatible platform with the main architectural model. Investment in adopting ESD modelling software and hardware was considered nominal as compared to their capabilities and benefits.

4.2.3 Workflow and protocol management

Whilst Green Star is a voluntary rating system monitored by an independent assessment panel, the GBCA, one ESD consultant interviewed highlighted that the Green Star assessment protocols were
not a guaranteed route to sustainable design and construction: “the AEC industries need to adopt a more sustainable approach to the project organisation, sustainable ways to deliver projects and successful GBC outcomes is just part of entire concept of greener built environment”.

Misuse of checklist procedures was another common theme, where Green Star criteria were seen to promote opportunistic behaviours by developers: “Investors often want to deliver on only the basic requirements of design checklist to gain certification”. A checklist that is often misused was identified as the GBCA’s ‘Office design tools v.2’. The misuse of such design checklists was seen to be a significant challenge to developing and implementing ESD based protocols. Moreover they were seen to leave little scope for design innovation. Instead innovation was seen to be in hands of manufacturers and their ability to develop innovations in sustainable building system designs.

Whilst a number of industry-based modelling guidelines exist to support designers, ESD consultants interviewed expressed their frustration with the lack of a standard or guideline specifying modelling and data management requirements for ESD analyses and Green Star criteria. It was felt that such a protocol would help avoid time consuming and costly development of separate ESD modelling guidelines. In some cases it was found that ESD consultants who were involved in early design stages were not monetarily compensated for their time and efforts. Adding to these problems were inappropriate tendering processes, and lack of information about roles and responsibilities of ESD participants. Another important issue identified was the unwillingness to provide ESD consultants with intellectual property rights. Inadequacies in contractual arrangements were thought to be at the heart of this problem. Furthermore those contracts that mandated the development of single integrated models were also seen as a major concern to ESD consultants due to protocol and data management requirements that were not generally included. Consequently insurance and liability factors surrounding ownership and intellectual property were a concern for ESD consultants.

5. DISCUSSION AND CONCLUSION

This paper set out to understand Green BIM and Green Star certification processes and protocols in practice so as to identify barriers, benefits and new configuration management requirements. In reviewing the literature the authors identified that the principal design team members that drive design processes are often the focus of BIM case studies, and therefore their perspective is often the focus of configurations management initiatives, including the development of BIM coordination and execution plans by industry bodies. The voices of those design team members that play consultative roles, such as ESD consultants and GBC accreditation professionals are somewhat neglected. This lack of attention may be a
barrier to more meaningful management functions surrounding modelling processes and protocols that are in line with Green BIM objectives.

The study confirmed that more rigorous management and monitoring of a Green BIM methodology and guidelines defining how it can be implemented is lacking in practice. The interview findings reinforce that practical Green BIM configuration and management methods that unite these areas is necessary to advance Green BIM and Green Star practices. The case studies also identified a variety of barriers to implementing a Green BIM methodology and achieving Green Star objectives, including a: a lack of awareness about the modelling needs of sub-disciplines within the ESD domain and unwillingness of clients to invest in the early engagement of ESD consultants. The findings highlight that three broad areas of requirements that must be addressed in an integrated Green BIM/ Green Star process management plan, namely: 1) specification of data (and model-based) requirements – for ESD analyses and extracting information to input into Green Star certification tools, 2) specification of stakeholder management requirements - surrounding ESD modelling processes, and 3) specification of process management requirements - providing information exchange protocols and stage gates for outputting timely data for model coordination. Specification and management of these requirements should aim to not only enable higher levels of integration but also promote client awareness of the value of ESD consultants in the early design stages.

This research is working towards further definition of these requirements and management functions. Our case study approach is continuing to gather data from practitioners so as to build a larger dataset and a better picture of current Green BIM and Green Star modelling requirements. To complement this data, this research is also undertaking audits of existing BIM models to account for the proportion of the building dataset that can be extracted for the purposes of meeting Green Star accreditation criteria. A 6 Star commercial office high-rise completed in 2010 is the first dataset that is now being analysed for these purposes and is beginning to provide valuable information on how BIM datasets can be developed and leveraged, providing a lists of data types and mappings to the authoring and analysis tool types used as well as to the Green Star credits that can be achieved. This on-going model auditing process is also enabling a re-engineering of critical design stage gates and revealing the classes of object libraries capable of retrieving information directly from manufacturers.

REFERENCES


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