BUILDING THE FUTURE: INTEGRATING BUILDING INFORMATION MODELLING AND ENVIRONMENTAL ASSESSMENT METHODOLOGIES

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The demand for sustainable buildings is increasing driven in part by legislation, rising energy costs and growing environmental concerns amongst consumers. As a result clients and developers are increasingly seeking to incorporate environmental attributes into buildings and demonstrate these sustainability credentials by certifying a development using an environmental assessment methodology such as BREEAM or LEED. One of the major issues in delivering sustainable buildings is ensuring that measures incorporated into a building at design stage are translated into action during building construction. This disconnect between design and construction phases of a project often results in the need to undertake costly remedial measures to achieve a targeted sustainability rating, or the building failing the assessment. This paper suggests that by integrating BIM with Environmental Assessment Methodologies decisions made with regard to sustainability attributes at the design stage can be clearly communicated and understood by all involved in the buildings specification and construction. It introduces a conceptual framework that seeks to define the relationship between BIM and EAMs.

Keywords: BIM, Environmental Assessment Methodologies, Sustainable development, Environmental Management

INTRODUCTION

The drive to reduce carbon emissions, reduce the amount of energy consumed by buildings and to create high quality, sustainable places, is changing the ways in which buildings are designed, built and operated. Government targets have set out the intention that all new housing be zero carbon by 2016, and non-domestic buildings zero carbon by 2019 (Great Britain: Department for Communities and Local Government, 2007). These targets, alongside changing legislative requirements, and an increasing recognition of the benefits of sustainable construction amongst clients and developers, have led to an increase in the use of Environmental Assessment Methodologies (EAMs) such as BREEAM, LEED, CASBEE and the Code for Sustainable Homes. At the same time the advent of Building Information Modelling (BIM) is set to revolutionise the way in which the construction industry operates. BIM is viewed as having the potential to offer significant improvements to the construction industry, particularly in the areas of collaboration and design integration (Capper, Matthews, & Lockley, 2012). Such is the promise of BIM, the UK Governments

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construction strategy requires fully collaborative BIM as a minimum on government projects by 2016 (Cabinet Office, 2011).

It has been suggested that integrating sustainability metrics into a BIM model addresses difficulties in making design decisions earlier in the design/build process and allows measures to be incorporated based on actual building conditions and attributes. However the authors suggest that from a sustainability assessment perspective, the power of BIM centres on its ability to store information about the entire building, and a complete set of design documents in an integrated database. Whilst the technical capabilities of BIM with regard to sustainable building have garnered some attention over the last few years, less thought has been given as to how the collaborative aspects of BIM may be better used to ensure that the sustainability aspects of a building design are communicated throughout the project team and beyond.

MEASURING SUSTAINABILITY

Measuring the sustainability of buildings is an increasingly complex task considering the wide range and diversity of issues to be addressed. The complexity of the task is growing alongside the challenge of tackling carbon emissions and other associated environmental, social and economic issues. Understanding of the stresses that buildings can place on natural systems has increased rapidly over the last couple of decades, as has knowledge of how to design and construct sustainable buildings. However, such knowledge is useless if not translated into effective decision making, whether at political level, or in the procurement, design and construction of buildings.

Over the last two decades, a considerable amount of work has gone into developing tools and methods designed to measure a buildings environmental performance over its life (Ding, 2008). Such tools are usually referred to as Environmental Assessment Methods (EAMs) and the term is used here to describe a technique that has building environmental assessment as one of its core functions, and which may be accompanied by third party verification. These tools have been developed in order to evaluate how successful at design stage and post construction stage a development is in balancing energy, the environmental and ecology with respect to both the social and technological aspects of projects (Clements-Croome, 2004; Kawazu, Shimada, Yokoo, & Oka, 2005). Parallel to this there has been considerable training to produce EAM evaluators and assessors. Design teams are getting better at designing buildings that meet sustainability principles and achieve targeted design stage certification with the chosen EAM. However problems still occur at the construction stage where design decisions made during the early stages of the project are not implemented correctly or changed completely. The result may be that a target assessment level is downgraded. This can be the result of various elements, which will discussed further in the following sections

COMMON ISSUES WITH EAMS

The construction industry, usually resistant to change and acceptance of new ideas, has embraced many EAMs in their various forms in a remarkable way. This is due to a variety of direct and indirect interventions from within the sector and externally, these include financial, commercial and legislative. However the development of effective communication, data storage and reporting procedures have so far been neglected. The result is that an EAM which should be fully integrated into the design process in order to best achieve its specific aim, more often run separate and parallel to the design process. This in turn leads to the a number of issues and conflicts such as:

- Design teams lack understanding of what is required to achieve EAM rating
- Lack of, or inconsistent detailed data supplied, this can include drawing specification
- Required sustainability documentation divorced from project documentation
- Breakdown in communication
- Appointment of a assessor at a late stage to influence the development
- Considerable variation in terms of implementation of sustainability options during construction

The majority of the existing environmental assessment methods of buildings evaluate environmental performance of buildings relative to explicitly declared or implicit benchmarks (Häkkinen & Kiviniemi, 2008). An accredited EAM assessor then assesses the design and construction specifications against these benchmarks. This process currently relies on an assessor managing large portfolios of information in different formats. Such a process places enormous amount of pressure on assessor, design team and the projects document storage and retrieval systems. Typically, the required documentation takes the form of both digital and paper-based material stored in multiple locations under the control of many different individuals. Whilst most EAM assessment bodies such as the BRE have established a quality and assurance procedure for scoring green credentials of a building, they have failed to produce an effective data handling and communication approach. Such is the need for an improved process design teams and EAM assessors are turning to third party communication providers such as South Facing's Tracker Plus service (Tracker Plus 2012) to verify information and better manage reporting of data for EAM certification.

Many of these issues described above may be attributed to poor communication between different members of the design team, construction and project managers, contractors and suppliers. It is suggested that here BIM can contribute to the successful completion of sustainable buildings.

BIM AND SUSAINABLE BUILDING

BIM has a number of attributes that may be used to improve sustainability within a building design, construction and operation. Firstly, BIM may be used as a decision making tool to reduce the amount of work involved in evaluating multiple design options early on in the design process (Bank, McCarthy, Thompson, & Menassa, 2010). BIM models can easily be exported to software programs such as Ecotect or Green building studio for energy or daylghting analysis. Products such as Revit MEP and the IES virtual environmental allow for bi-directional interaction between BIM and environmental software (Bank et al., 2010), which may result in improved outcomes against sustainability criteria. It has also been suggested that BIM can be used to evaluate both operational and embodied CO_2 emissions over the life cycle of a project (Capper et al., 2012).

BIM is being used by some professionals to provide the information required to demonstrate compliance with environmental assessment criteria within an EAM such as calculating travel distances, proof of energy demand or solar calculations (Sheth, Price, & Glass, 2010). A fully collaborative BIM data library model will store a great deal of information both in 2D and 3D, as well as component and material specifications. For example information on specific material and wall structures can be easily extracted and aligned with a sustainability rating or grade, such as that contained in the BRE Green book. Currently such a process can be extremely time consuming using more traditional CAD models.

Another key strength of using BIM for sustainable buildings is its strength as a visualisation tool. BIM models can be used to quickly generate high quality rendered images for visualisation purposes as well as create walkthroughs for clients and stakeholders (Sheth et al., 2010). The benefit here for sustainable buildings is in the visualisation of low and zero carbon energy systems such as solar photovoltaic panels. Many stakeholders such as local residents and planning authorities are often nervous of how a particular development will 'fit' in the surrounding area. Good, early visualisations of a proposed development can go a long way to ease a developments path through the planning process.

Finally, BIM can be used as a powerful tool to aid and improve communication during the design and construction process. As already discussed, one of the key reasons for a building not achieving its targeted assessment rating is that a design feature or other specification articulated at the early stage of the project is not implemented on-site. There are many possible reasons for this – the contractor misread the instructions, the specification was amended or downgraded or simply a specification was not correctly written down. BIM can be used to ensure that all necessary component and contextual information is communicated throughout the design and construction phases of a development.

INTEGRATING BIM AND EAMS

BIM and EAMs integration has been the subject of some development over the last few years. It has been previously recognised that the benchmarks and information required to satisfy the requirements of a specific EAM may be included in a BIM model. Consequently, such a model would allow for multi-disciplinary information to be superimposed thus creating an opportunity to conduct an evaluation much more accurately and efficiently than traditional assessment methods (Azhar, Carlton, Olsen, & Ahmad, 2011). Through the advancements and power of Revit, work has been done on the integration of the documentation of a LEED assessment with in the BIM Model, however some specific technical and metrics specifications are needed and not all the credits can be assessed in this manner (Patel, 2012).

A study by Azhar et al (2011) indicated that BIM can facilitate the complex processes of sustainable design such as day-lighting and solar access, as well as automate activities like material takeoffs, cost estimation and construction schedules. Some Frameworks have been previously been suggested that make use of BIM software to extract data directly from a digital building model in order to support the sustainability assessment (Nguyen, Shehab, & Gao, 2010). Such studies include work on integrating BIM with EAMs has been carried out using the Industry Foundation Class (IFC) data model. IFC data can be combined with environmental properties such as total energy consumption and levels of waste (Chevalier et al., 2010), however one of the main barriers to such work is the lack of reference value for a large number of environmental indicators

Aside from direct extraction of environmental variables to be assessed in an EAM, BIM can also support the management of information needed in design for sustainable buildings. Häkkinen & Kiviniemi (2008) suggest that in addition to generating and facilitating sustainable building assessment, BIM could manage product data, energy assessment, service life design, and be used to supplement maintenance manuals and optimise building refurbishments. Lee et al (2010) suggest that BIM may be used to plan for and assess social issues such as sustainable community design. Häkkinen & Kiviniemi (2008) propose that BIM has the potential to support the supply, integration and management of information throughout the buildings lifecycle.

On one hand BIM and environmental assessment methodologies have emerged from different underlying market factors; BIM from a desire to streamline building design and documentation, to simplify construction management, and to improve on-going facilities management during building occupancy and EAMs to address social concerns for environmental issues, and demonstrate compliance with legislative and regulatory mechanisms (Golzarpoor, 2010). However the successful implementation of both relies on a deeply integrated design philosophy that requires the collaboration of all team players throughout the implementation of the project. In order to integrate EAM and BIM data, information needed includes data about properties and quantities of different components and elements (Häkkinen & Kiviniemi, 2008). Such information could be linked to a database that includes the environmental profiles of building components and elements. Häkkinen & Kiviniemi (2008) suggest that he environmental assessment of a building can be integrated to BIM similarly as cost assessment is already done at present. Such integration requires that product specific and energy related environmental profiles are available, for example, in the form of an XML database.

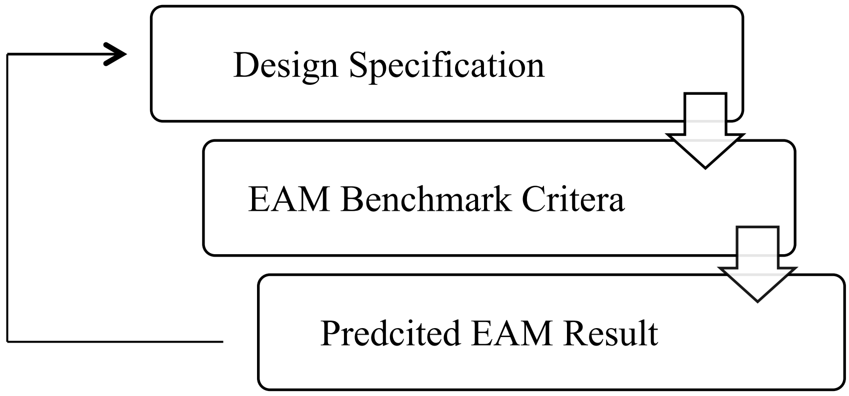
CONCEPTUAL FRAMEWORK

As previously discussed there are a number of issues associated with carrying out an EAM assessment. Here we concentrate on three such issues; integrated data provision, information management and communication, and set out BIM integrated approach that seeks to provide benefits to sustainable building design.

Integrated data provision

In relation to information gathering BIM can be useful for extracting data necessary to satisfy a specific EAM criteria. For example, PSET assesses the proposed developments' predicted Carbon Dioxide emissions, which are then compared against legislative and best practice benchmarks. Currently this is assessed using the output data from specialist energy modelling software. This usually takes the form of a printed calculations summary, the output of which has to be obtained by the EAM assessor and manually inputted into the assessment tool. If specific targets are not met the design team may need to make revisions to the building plans. The creation of an instant BIM library exported from energy modelling software, can allow instant dynamic calculation and analysis of data bypassing the current non-digital system. In a similar way additional energy assessment data such as component 'u' values and space heating energy demand in kWh/m2 can be linked to individual building components such as walls, windows and floors. Figure 1 illustrates how data may be built up in layers with BIM in order to provide the data required to satisfy EAM criteria.

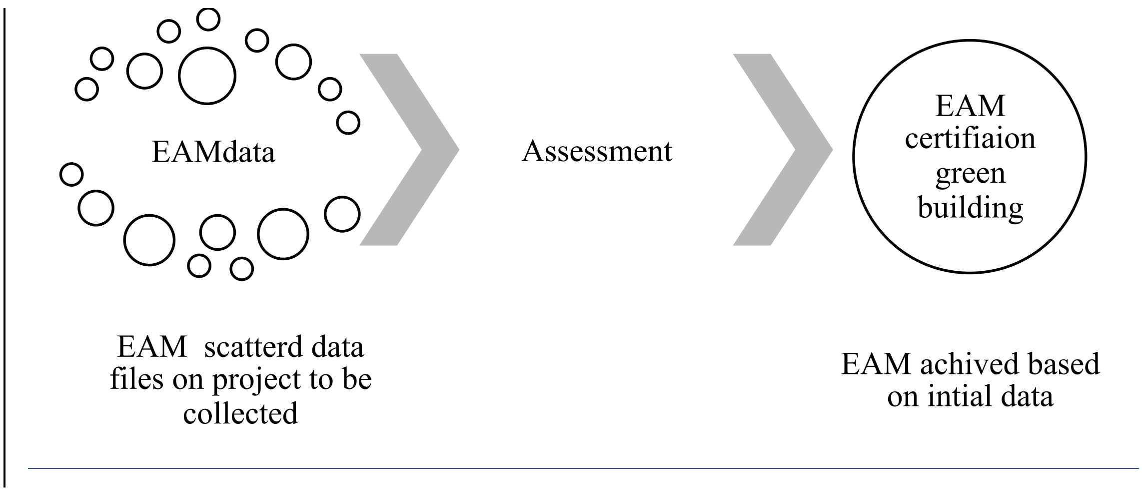
Figure 1. Data from BIM integrated into EAM



Information Management

Another of the key issues that arose during the development of the EAM was how to manage the large amount of data from multiple sources throughout the design and procurement process. At the time a simple spreadsheet database was conceived which attached key documentation via a hyperlink embedded into the EAM tool. Whilst this method allowed instant access to relevant drawings, specifications or calculations necessary to satisfy the assessment criteria, attaching and archiving this information was both time consuming and required a dedicated individual to manage it. Figure 1 demonstrates the scattered nature of information required to satisfy an EAM assessment highlighting the current challenge faced in terms of data gathering and documentation for certification. Here there is no real effective method for communication or access of data by assessor or design team.

Figure 2 EAM/BIM integrated information management



One example, which illustrates the time consuming, and troublesome aspects of environmental assessment relates to a buildings material use. PSET like many EAMs contain criteria relating to the sustainable use of materials, in terms of their environmental impact and the source of their component elements. Currently design teams are expected to produce detailed material specifications that the EAM assessor evaluates against a sustainable material database such as the Green book. The assessor manually inputs the material or designed components rating into the EAM. The assessor also needs to calculate the proportion of the material in the building design, usually by volume. This time consuming process has to be repeated if material use changes in any way. A BIM library can contain instantly generated quantitative data for materials such as type, location of use and source of supply. This can be linked to a material database such as the Green Book that would generate the necessary rating to satisfy EAM criteria. If there is a material change, the rating calculation can be instantly amended. There is also a greater degree of confidence in the amount of material use, which at present is often estimated.

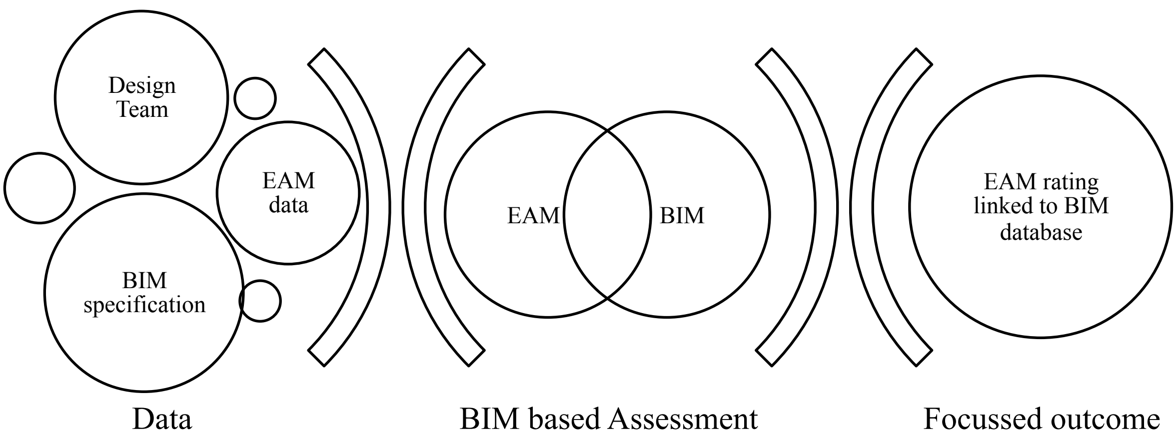
Communication

The final issue discussed here is that of communication thought the design, and procurement construction of a building to be assessed with and EAM. Often deign decisions made early on in a project to specifically meet a criteria specified by an EAM, can be reversed during the construction or procurement phases of a project. This may be due to a sub-contractor or supplier specifying an alternative product, or a construction detail amended on-site. Whilst there are may be pragmatic reasons for doing so, the knock on effect may be that a specified rating is not met. We suggest that by integrating EAM criteria within BIM can assist in communicating the importance of not changing a specification. For example, should a particular material be specified due to its environmental credentials, such as a reduced Global Warming Potential (GWP) in its manufacture, this can be flagged in the BIM as essential for the EAM rating. This flag can be included on any specifications or drawings produced from the BIM helping to raise awareness amongst suppliers or contractors that this particular material specification must be followed precisely. With the advent of BIM being utilised on-site through mobile applications such as tablet computers and smart phones, such communication can occur in real-time as the design team makes amendments to specifications or drawings.

BIM integrated approach

The approaches which we have described above set out the vision for a BIM /EAM integrated approach. Figure 3 illustrates this approach, which incorporates specific procedures for handling data, linked to a database, or file produced from BIM enable software such as Autodesk's Revit. Rather than the current de-coupled approach where BIM and EAMs are operated and managed in isolation from each other, the assessment can take place within the BIM model.

Figure 3 – BIM/EAM integrated approach



The benefits of BIM /EAM integrated approach are many. Sustainable design options can be appraised, and assessment data accessed with much greater speed and efficiency than at present saving both time and money. In addition there can be greater certainty that a building design will achieve a desired rating through improved information management and communication.

CONCLUSIONS

This paper has sought to identify the role that BIM can play in facilitating successful design and certification of sustainable buildings. It has suggested that integration of BIM and EAMs can provide benefits in terms of data provision, information management and communication. It can be concluded that from a point of view of assessor the use and adoption of an EAMs integrated with BIM, not only saves time, but is a much more dynamic and verifiable, and traceable approach in terms of building assessment. Clearly there will have to be further investigation of the transferability of individual building components, dimensions and other attributes for a whole variety of environmental elements. EAM indicators mentioned earlier such as energy and materials assessment, can not only be more easily assessed by closer BIM integration, but also assist architects and design teams to go beyond standard proactive and minimum regulations through the production of real time data and or design modifications.

There are however obstacles that the industry will have to overcome in order to facilitate the integration of EAMs and BIM. One of the most troublesome is the domination of the market by commercial assessment tools such as BREEAM and LEED that require an assessor to undertake detailed training on methods and procedures and stipulate very detailed QA systems therefore inhabiting the development of effective communication mechanisms. The closed nature of such EAM development, and the rigidity of their application make tight BIM integration tricky. Large commercial products similarly dominate the market for BIM software, which also makes integration with EAMs difficult. Perhaps in the future open-source and bespoke EAMs and the open-source BIM software xBIM will allow design teams and sustainability professionals to develop new methods for assessing and communicating sustainable design options.

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