HOW BUILDING INFORMATION MODELLING APPLICATIONS BENEFIT DESIGN TEAMS INTO ACHIEVING BREEAM ACCREDITATION

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The current construction industry demands lean construction. The idea behind building information modelling is to eliminate in-efficient processes in terms of designing, constructing and managing buildings. One of the advantages to BIM is its ability to produce beneficial data-sets, this data could potentially be used to achieve Building Research Establishment Environmental Assessment Methodology (BREEAM) credits, which is the leading environmental assessment organisation in the United Kingdom. Using BIM within a design team allows for integration of sustainability analysis such as daylighting analysis, water harvesting and thermal assessment whilst capturing the data which can be used for BREEAM assessment as it has been marked very much a tick box process. Therefore the availability of data compared to traditional methods can be used to design teams, stakeholders and Environmental assessment bodies' advantage. Since BIM boasts extensive building performance analysis capabilities, design teams should be provided with standard methodologies and guidance into successfully achieving certain BREEAM criteria. Leading to this studies objective is to highlight gaps in existing theory to develop a solid understanding for further research in order to achieve BIM integrated BREEAM design team protocol.

Keywords: Building information modelling (BIM), BREEAM, Sustainability analysis, BIM Design teams, BIM model

INTRODUCTION

The UK government has singled out the built environment as an essential influence in helping the UK economy accelerate out of the recession. Statistics from the government industrial strategy show that the construction sector accounts for 7% of GDP (Gross domestic product). In addition the UK government construction strategy 2011 indicates a 20% reduction in the cost of assets by 2016 in the public sector as the areas costs accounts for 40% of construction sector spending (Government Construction strategy 2011).

Recent investigations into sustainability are increasing due to requirement for low embodied energy buildings required by employers, clients, governments and organisations. Azhar and Brown 2010, Autodesk 2009, and Biwas 2008 indicate that as a result Local authorities, clients and Green building bodies are demanding low carbon energy efficient buildings from the construction industry due to 40% of the EU energy consumption is used in the construction sector (Schlueter and Thessling 2009). This is seen as a major opportunity to implement sustainability practice with effective tools such as BIM to deliver an energy efficient structure.

The construction industry is experiencing rapid modification in the methods buildings are designed and as a result project teams and constructors face the difficult task of adapting to these new methods whilst still applying sustainable systems to designs (Beserick and Kensek, 2010)

By 2016 all government procured projects are required to supply the design works using BIM. As a result building information modelling (BIM) has been one of the most talked about topics in the construction industry, increasingly in the last 5 years due to its attributes such as improved project quality and delivery methods by means of important data and analysis. The tool provides accurate real time estimations to the construction works and can generate the information needed by facilities managers in the running and ongoing maintenance of the building after handover (BIM webinar Take up BIM now, 2014).

In the UK environmental assessments such as the Building Research Establishment Environmental Assessment Methodology are used to align the sustainable practices with the building design building works along with the use of the construction in the buildings lifecycle.

BREEAM is used with projects to assess the performance of buildings and is used as a benchmarking tool in order for a rating to be specified by a qualified BREEAM assessor (BREEAM Accredited Professional). The code for sustainable homes (CSH) has similar criteria for housing only and is compulsory to achieve a certain level of the code on new builds in Wales particularly. (BRE 2014) Some criteria identified in the guidelines provided by these two documents could be achieved and managed more easily through the incorporation of BIM with sustainability criteria required from sustainability assessments.

Documents BS1192 and PAS1192-2:2013 (publicly available specification) identify the approaches and standards to implement and exploit during a BIM project. Both documents set certain standards that must be met and contains best practice guidance to design teams. There has yet to be solid protocol or guidance for the integrated immersion of sustainable design through BIM for use in design teams adopting BIM.

Great effort has been applied in the use of BIM within a design team however implementation of sustainability methods using the BIM process compared to traditional design and sustainability measures is a grey area for design teams. According to Bynum et al, (2013) sustainability was not thought to be the main use of the BIM tool and instead the virtual building model and the 3D visuals it can create along with the collaborative workflow and simultaneous working mind-sets within design teams. This highlights the need for structured guidance to design teams.

An investigation into how BIM will support sustainable design and systems is essential in this thesis to deliver useful information to design teams and green design bodies to demonstrate how the two systems integrate with each other from review of desk study literature and exploratory research. To do this various objectives must be aims and objectives must be identified from the following desk study research. Further to this literature review the sustainability organization must be critically analysed and the relationship between BIM and the BREEAM criteria must be evaluated to develop standardised methodologies to be adopted by design teams.

Current studies have suggested areas of enquiry due to the emerging development of techniques such as BIM and the existing government objectives in sustainable design. The purpose of the research was to investigate the current implementation of BIM with the application of sustainable design methods. As a result reviewing and evaluating BIM's capabilities as a tool for project delivery, incorporating sustainable systems and policies and testing the software used to produce building performance analyses. (Gerber and Kensek 2010)

BUILDING INFORMATION MODELING OVERIEW

BIM is a method that involves the management and input of data utilizing an integrated design process.

Using BIM allows for 3D representations compared to traditional methods of 2D drawings that have no real meaning or construction specific information contained in the building elements (Krygiel and Nies, 2008) From the 3D parametric model documents are automatically prepared as the model is federated to enable for quicker more efficient decision making between clients and design teams at early conceptual stages. Azhar (2009) identifies that AEC's using BIM for sustainability analysis are noticing considerable time and cost savings utilizing BIM based sustainability analysis.

The information is issued using data drops at certain points in the project cycle as shown in the information delivery cycle diagram in PAS 1192. This information is required by the government for Construction operations building information exchange (COBie) data drops and can be used to support the management of the facility through detailed information provided by the design team such as equipment locations and spaces. (COBie UK, 2012 and RIBA BIM overlay, 2012)

There are considerable advantages to design teams utilizing the BIM process including the ability to create 3D visuals for presentation and supporting information to deliver schedules for quantity take off and 4D models. Additionally to using the 3D model for building performance analysis, structural design and cost estimating from building component areas (Khemlani 2007). Figure 1 shows the most popular uses of BIM.

These advantages overall allow for shorter programmes to delivery of a project, one reason for this is use the Common data environment (CDE) which is a central store for any project files for use by multi-disciplinary teams to transfer information to facilities managers from design teams (BSI,PAS-1192-2 2013).

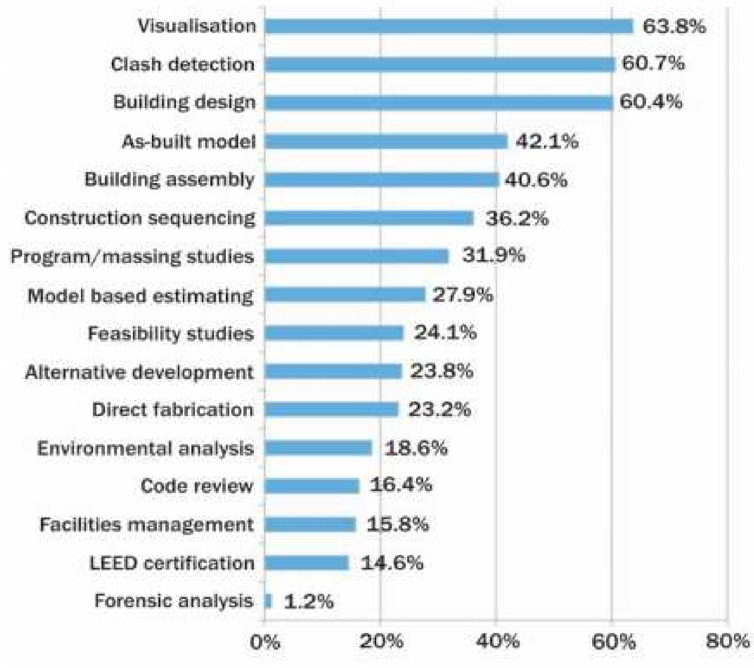

Figure 1- Most popular tasks using BIM (Gerber and Rice 2010)

ENVIRONMENTAL ASSESSMENT METHOD

Environmental assessment boards are primarily put in place to set standards to design teams on new and existing construction projects to responsibly design there buildings, by a set of obtainable standards for assessment at design stage and post construction (Cam and Ong 2005).

The non-domestic building account for 18% of the total carbon emissions in the UK(Carbon trust). BREEAM is the pioneer sustainability assessment used in the UK for sustainable design practice following through to the construction and life cycle of the building (BRE 2014).

The method of the assessment is as follows; an overall percentage is given to the building at design stage and then re-assessed post construction. The percentages are classified as follows, less than 30% unclassified, pass 30% or more, good 45%, very good 55%, excellent 70% and outstanding 85% (BRE 2014).

The categories of the assessment criteria include management, health & well-being, transport, water, materials, energy and waste, pollution and land use and ecology. Credits are scored in each section for example ENE 1 there are 15 credits available. To achieve a BREEAM rating the minimum percentage must be achieved if that particular credit requires minimum standard see appendix A, therefore the minimum amount from the 15 credits available from ENE 1 must be achieved (Roderick et al 2009).

The assessment criteria is split into 9 weighted sections and one additional section for innovation, see table 1

Table 1- BREEAM Credits and weighting overview

Section Topic	*No. of Credits Available*	*Section Weighting*	*No. of Minimum Standard BREEAM issue*
Management	22	12	3
Health & Wellbeing	10	15	2
Energy	30	19	3
Transport	9	8	0
Water	9	6	2
Materials	12	12.5	1
Waste	7	7.5	2
Land Use & Ecology	10	10	1
Pollution	13	10	0
Innovation (additional)	10	10	N/A

BUILDING INFORMATION MODELLING IN DESIGN TEAMS

Using BIM in design teams is the most effective way to fulfil the tools potential. AEC's may choose to work alone however this works against BIM's integrated design strategy. Deutsch 2011 conveys the idea to use the time to learn and advance skills in the technicality of the software, the application of analysis upon construction and BIM theory so users equipped for integrated project delivery (IPD).

Deutsch (2011) advises pilot projects for design teams new for BIM and integrated project delivery. This method allows for sustainable design techniques to be analysed along with sustainability analysis tools compatible with BIM software.

Information and data collected by the AEC's is managed and integrated by the design team into the BIM model. Through successful collaboration that information is used starting at design phase, over construction and the on-going maintenance of the building providing the quality of documentation is accurate (Krygiel and Nies 2008). The process allows the design team and anyone involved in the phasing to extract product information, parametric statistics and details of construction to build up the BIM model. In addition the model can be used to assess the buildings structure and flag up any construction defects during the design process (Bynum and Issa 2013). The diagram below (Figure 2) taken from PAS 1192-2:2013 shows the BIM design workflow.

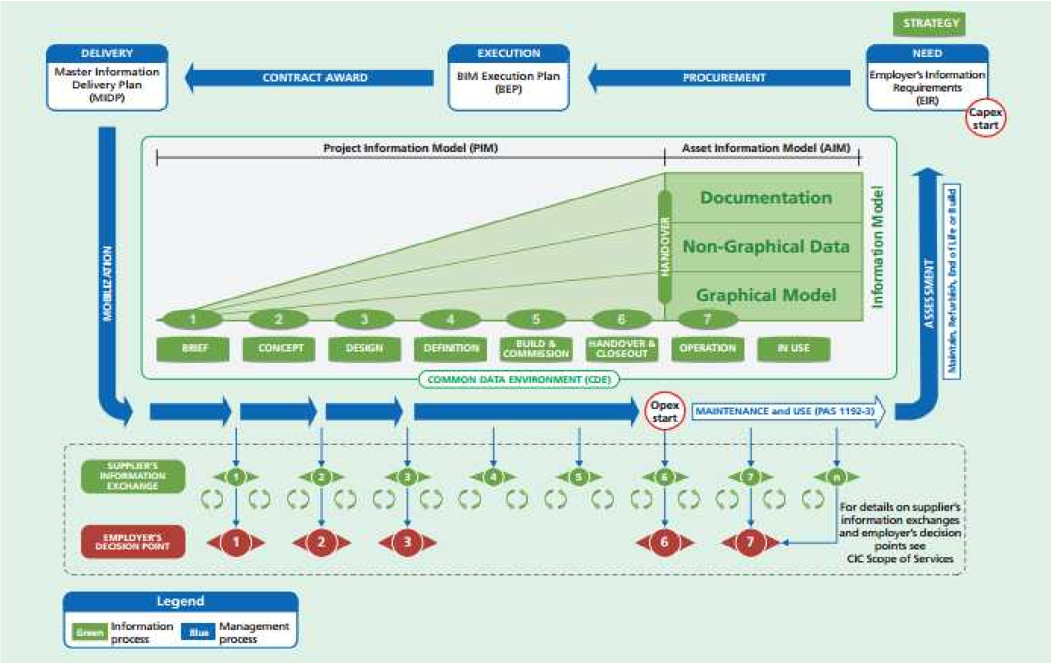

Figure 2- The information delivery cycle (PAS-2:2013)

The building information model 'BIM model' is used as the central tool and hub of data to a BIM project and is the principal instrument for design teams. BIM objects hold all the metadata and parametric information for that specific element. Manufacturer's products are available from BIM libraries dependant on their availability and competency with the BIM process (Eastman et al, 2008). Additionally design teams may produce specific custom families which can be created in a project if required. Essentially this means that any custom components can be used for future projects.

However there are possible risks and limitations. Integrating a traditional system such as sustainability theory with an advanced technological tool such as BIM that is predominantly data driven means the integration issues must be approached effectively. The method of project delivery should be agreed between organisations to ensure the design team is technically competent and has the capabilities to approach the projects integration with BIM efficiently (Grilo and Jardim-Goncalves 2010).

THE BIM MODEL APPLICATIONS TO SUSTAINABLE DESIGN

BIM allows for Architects and Engineers to produce a 3D model that contains information rich BIM objects in a computer generated model, the 3D model is the key system for use by design teams.

There are evidently clear advantages to design teams using the model. Potential shorter time scales depending on the competency with the selected BIM software. However a faster more efficient process is inoperable if the BIM model data is not accurate enough to provide valuable information. Krygiel and Nies (2008) justifies that the BIM model is dependent on data, therefore if the data input into the model is incorrect or no longer practical then this will have possible knock on effects when carrying out sustainability analysis at later stages in the design. Additionally a study by Gerber and Kensek (2010) notes that the accuracy of the as-built models is required to be of high quality to ensure a sustainable building after handover. This highlights the requirement for a working model that is up to date and informative.

The BIM model is an important factor from as early as the conceptual stage in the design. Outlined in the RIBA BIM overlay to the plan of work, the concept design stage requires outline proposals for environmental strategies. The guidance recommends the consideration and initial development of sustainable design strategies at the earliest possible stage once the massing model has been produced (RIBA 2012).

The massing model as described in Krygiel and Nies (2008) and Cho et al (2010) can be used to incorporate several sustainable design criteria from an early stage. These include volume and areas allowing stakeholders to compare materials properties, and estimate the potential cost of the design. Moreover, the positioning and orientation on the site to establish site specific co-ordinates. Sun paths for analysis of the conceptual mass in relation to the world co-ordinates to assess solar gain inside buildings. Together with assessing the suitability of Heating Ventilation and Air Conditioning (HVAC) systems for design consideration.

Eastman et al (2008) suggests the importance of the initial energy analysis on the BIM model at the conceptual design phase determining factors such as assumptions of HVAC costs using BIM's concept building mass modelling, orientation on the site and its building shell design and volume.

BIM INTEGRATING SUSTAINABILTY PRACTICE

As more AEC practices adopt BIM and utilize the primary tools available the idea behind BIM will become more apparent (Bynum et al. 2012). In effect the areas of sustainable design will become more fundamental to design teams in key areas of the project programme.

When building up the BIM model the most important process with sustainability implementation is at the design and pre construction phase to ensure the building meets requirements post construction and during the buildings lifecycle. Relying on architects, engineers and construction managers to know how the BIM tool and green design tie together. This leads on to how BIM assists with the implementation of sustainable approaches to design (Burcin and Kensek, 2010 and Deutsch 2011).

BIM based sustainability analysis is one of the critical areas to successful integration of the two streams. Various software is available to design teams including Autodesk Ecotect, Green Building studio (GBS) and Virtual environment (IES) which all have similar building performance analysis capabilities. However Building information modelling software such as Revit only includes basic building performance analysis. Bynum et al. (2012) identifies that there is interoperability issues between the BIM software and the external performance analysis tools and suggest that BIM must improve its environmental analysis methods to establish future benchmarks for design teams to work towards.

Alternatively to exporting the data to green building analysis software such as Ecotect, simple building analysis can be performed on the conceptual mass as Revit has implemented this facility so users do not need other software packages to carry out concept design. Exporting the 3D model may result in interface issues with the user so improving on the analysis software in Revit is crucial to align BIM and sustainability methods as one operational tool (Eastman et al.2008). However energy analysis plugins such as Green building studio and integrated environmental solutions plugins (IESVE) can be directly loaded into use with Revit (Stadel and Eboli 2011).

CONNECTION BETWEEN BIM CENTRED SUSTAINABILITY ANALYSIS AND ENVIRONMENTAL ASSESSMENT CRITERIA

BIM's ability to analyse a buildings performance at design stage offers an opportunity for design teams to integrate their model data to potentially achieve certain BREEAM credits.
BIM and its ability to manipulate building data and performance statistics can influence the BREEAM assessment process. Significantly BREEAM assessments need to recognise the growing use of BIM and the advantages such as performance data and building element information have upon design teams and stakeholders to make key decisions to ensure for an efficient building prior to site handover to contractors. These evident characteristics will provide clear advantages to the BREEAM assessment process (BRE 2014).

Azhar and Carlton (2010) developed a conceptual framework of a project case study to establish any underlying links between the sustainability analysis in the BIM software and the LEED rating system which is the pioneering sustainability construction organisation in the USA with similar criteria to BREEAM.
A table was devised to enable the LEED credits to be compared against sustainable design related investigation types and at what stage of the project had direct relationship with the analysis types.
The Energy analysis was the most related to the LEED criteria at design stage, as previously discussed this verifies the importance of energy analysis by design teams at the conceptual stages to integrate data results to aim to achieve environmental assessment credits particularly in energy.
The material documentation was also a predominant successful link between the two fields. Certified wood being one of the criteria related to the sustainability analysis at construction stage (Azhar and Carlton 2010).

The study put into perspective the link between BIM based analysis and the environmental assessment criteria, however a future system to diminish BREEAMs interoperability issues with BIM is currently being developed. The development of such frameworks will benefit design teams if a clear interface between the two is established.
Due to the demand BRE have instigated research into the development of an IT infrastructure because the input of information through use of BIM allows for opportunity to integrate the output of building data information and strategies and combine with BREEAM performance criteria to develop a clear relationship between

the exchange of BIM data and the success or failure in meeting the BREEAM objectives. (BRE 2014)

ISSUES FACED BY DESIGN TEAMS USING BIM BASED SUSTAINABILTY

Due to building information modelling being a relatively new tool, there may be some problems with compatibility with sustainable design measures (Bynum et al.2012). The current practice by design teams enabling the use of sustainable design in BIM delivered project is to export the data to external simulation packages underlined earlier in the paper. The main issue with this process is the risk for errors due to multiple data entry and the transfer of accurate information into other software platforms (Motowa and Carter, 2013).
In addition Azhar et al,(2013) suggests a possible solution to the integration issue between the two systems requires for the BIM model and the sustainability analysis to take place in a single BIM platform to reduce errors during the building performance analysis.
Additional issues being faced by design teams suggest the lack of a simple method to change the BIM model to meet the required building performance from the energy simulation results. Greater integration is needed to allow for precise elements to be highlighted that require modification in order for the criteria to be met on the next performance assessment (Ferrari et al,2008).
In relation to the above issue discussed the research of Bank and McCarthy (2010) provides a possible solution proposed by combining the BIM model from e.g. Revit with a system dynamics (SD) modelling program which is a tool for decision making. The dynamic system model integrated with the model in Revit would automatically update the BIM model from highlighted modifications shown in the SD analysis results.

CONCLUSIONS

The implementation of BIM in design teams and the process of undergoing BREEAM assessments unquestionably have a positive impact in relation to government zero carbon objectives. The frameworks devised by existing studies only provide an indicator for further research or have drawn conclusions that relate back to interoperability in existing software or lack of environmental assessment user friendly interfaces integrated into BIM software.

There are feasible methods to directly link BIM to achieve certain BREEAM criteria. As discussed many applications of BIM are highly linked to BREEAM credits especially in the Energy section, with the BIM model a key factor in achieving the credits. Therefore leaving an opportunity for guidance to be developed for use by design teams. As a result of the exploratory research it has been concluded that the main BIM input by a design team is through the BIM model such as building performance analysis. There is limited knowledge of how BIM can benefit a design team to achieve certain BREEAM credits, therefore standards are required to be implemented to standardise methods in order to apply and input data into the BIM model to directly achieve BREEAM credits.

Architectural, Engineering and construction practitioners lack best practice guidance that takes into consideration cultural and behavioural factors linked with achieving credits through BIM, if these guidelines are not put in place benefits to design teams from the use of BIM integrating sustainable design may not be recognised.

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APPENDIX A

Table - 2: Minimum BREEAM standards by rating level

	Minimum standards by BREEAM rating level				
BREEAM issue	PASS	GOOD	VERY GOOD	EXCELLENT	OUTSTANDING
Man 01: Sustainable procurement	One credit	One credit	One credit	One credit	Two credits
Man 02: Responsible construction practices	None	None	None	One credit	Two credits
Man 04: Stakeholder participation	None	None	None	One credit (Building user information)	One credit (Building user information)
Hea 01: Visual comfort	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Hea 04: Water quality	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Ene 01: Reduction of CO_2 emissions	None	None	None	Six credits1	Ten credits1
Ene 02: Energy monitoring	None	None	One credit (First sub-metering credit)	One credit (First sub-metering credit)	One credit (First sub-metering credit)
Ene 04: Low or zero carbon technologies	None	None	None	One credit	One credit
Wat 01: Water consumption	None	One credit	One credit	One credit	Two credits
Wat 02: Water monitoring	None	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Mat 03: Responsible Sourcing	Criterion 3 only	Criterion 3 only	Criterion 3 only	Criterion 3 only	Criterion 3 only
Wst 01: Construction waste management	None	None	None	None	One credit
Wst 03: Operational waste	None	None	None	One credit	One credit
LE 03: Mitigating ecological impact	None	None	One credit	One credit	One credit

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