Sustainable BIM-driven post-occupancy evaluation for buildings

CIC Start Online feasibility study

June 2012

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Acknowledgement

This feasibility study is funded by CIC Start Online. CIC (Construction Improvement Club) Start Online supports innovation for sustainable building design and refurbishment in Scotland. It is a joint project of Glasgow Caledonian University (lead partner), Edinburgh Napier University, Heriot Watt University, Glasgow School of Art, The Robert Gordon University, University of Edinburgh and University of Strathclyde Glasgow. CIC Start Online is funded by European Regional Development Fund and Scottish Government SEEKIT programme.

CIC Start Online aims to embed sustainable building design and refurbishment into practice. The project will assist Scottish small and medium sized enterprises (SMEs) to develop and test innovations at testing facilities of the project partners' institutions.

The project runs a scheme for joint industry/academic feasibility studies and a competition for free academic consultancy. An independent panel assesses applications submitted jointly by researchers and businesses for feasibility studies and applications submitted by businesses for academic consultancy

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Executive summary

The achievement of zero-carbon buildings requires monitoring and sharing the information of building performance from the time the building is handed over to occupants. Therefore, there is a need to facilitate this sharing of information among the stakeholders and supply chain. It becomes evident that BIM technology pioneers the discipline of sharing accurate information.

Despite the growing interest in using BIM in construction, BIM technology has not been fully utilised in the current procurement strategies. Practical implementations of BIM are mostly during the design and construction stage. There is limited research that links knowledge gained from energy practices and BIM models to improve the overall operations and energy efficiency of buildings. This feasibility study identified the key operational and carbon performance variables for Scottish public buildings needed for monitoring building performance, which are required to adopt BIM approach for better informing the stakeholders on the performance. This outcome will help in developing a smarter procurement strategy based on consistent information to be shared by all stakeholders. The conducted interviews also helped in testing the feasibility of using BIM approach to monitor building performance and in mapping the requirements for a smart procurement strategy for the post-occupancy stage. This will enable stakeholders to monitor building performance using unified language to achieve the CO_2 emission targets. Benefits to the SME include the development of a greater understanding of this emergent technology, allowing the delivery of an improved service to future clients and increased competitiveness within the market place.

On the other hand, sharing accurate information about the use of energy-efficient technologies will improve the means to reach occupants expectations and improve their working conditions. The output will also help in developing an ontology for Energy Management in buildings which will form common language within the industry about the terms relating to carbon reduction. The ontology of EM will also help improve the process of energy savings and the quality of thermal comfort in buildings. The ontology will be linked to the BIM model of the building. The ontology will ensure that relevant information for energy use and assessment is recorded throughout the lifecycle of the building. Using BIM technology to monitor building performance can also be used in designing suitable scenarios to maximise energy savings in order to match design and performance of buildings.

The Scottish economy will benefit from the proposed BIM-driven procurement as a smarter approach for the Government client to cope with the low carbon economy where reductions in operational costs and carbon emissions are targeted.

Introduction:

The national regulation on energy performance and 'carbon' accounting emphasis the need for a greater consistency of construction information to achieve the CO_2 emission target. Therefore, clients (especially the major one "Government") and Industry should work closely together in developing plans to make the transition to low carbon buildings feasible in order to meet the CO_2 emission target over the identified time horizon. Achieving so requires the development and/or refinement of alternative approaches to the procurement of integrated teams to deliver zero carbon building.

In this context, Building Information Modelling (BIM) can play a key role in addition to its capability to create more homogenisation of the construction supply-chain. In a recent study[1], Government (as a prime client to lead the change in the built environment) were advised to mandate the use of BIM for all central projects with a value greater than £50m. The industry was also advised to work, through a collaborative forum, to identify when the use of BIM is appropriate (in terms of the type or scale of project), what the barriers to its more widespread take-up are, and how those barriers might be surpassed, leading to an outline protocol for future ways of working. Despite the significant savings derived from adopting the BIM approach, BIM adoption should be considered within an overall improvement strategy for the industry sectors, especially governmental clients.

BIM application for energy analysis has special interest to the industry, but mostly at the design stage. The energy analysis packages allow the designers to receive feedback on their design; such as how much energy the building will use, what are the anticipated CO_2 emissions and whether the building will pass performance criteria (based on certain standard, LEED or BREEAM). However, for the Post-Occupancy Evaluation (POE) of building, clients should find a proper and systematic methodology to monitor the behaviour of the building and make critical decisions to ensure that the energy criteria of the design are really met in practice.

Achieving the CO_2 emission target requires better monitoring of building performance and the sharing of accurate information among the stakeholders. This study aims to investigate the feasibility of using BIM approach within the Scottish public departments to adopt a more efficient POE methodology. For the purpose of this study, the Scottish Government Construction clients are capable of achieving significant step changes in helping the market to respond to the requirement of BIM utilisation. A structured and consistent approach can drive a mass improvement in BIM taking-up over a well defined horizon to improve the performance of the government estate in terms of its cost, value and carbon performance. The general aim is to transform the current procurement strategy into a new BIM-driven approach to deliver an environment whereby the Government client would have an estate smarter enough to face a low carbon economy where reductions in operational costs and carbon emissions are targeted.

[1] Low Carbon Construction, Innovation & Growth Team, Department for Business, Innovation and Skills, November 2010, BIS/11/10/NP.

From this identified general aim, this particular feasibility study has the following objectives:

1. To identify the key variables of operational and carbon performance affect on the decision process, especially within the Scottish Government as a client, that should be embedded in BIM applications
2. To identify the information at key stages to ensure consistency of clarity to the supply chain for a new BIM-driven procurement approach

This will help investigate the use of BIM to gather and utilise information and knowledge for POE of buildings to better maintain and operate the lifecycle of buildings.

Methodology:
The methodology adopted to achieve these objectives was to interview a number of professionals within the Scottish public departments and industry practitioners. The main purpose of the interviews is to collect data on the current process of POE in buildings. Data will be also collected on the current use of BIM technology, the view on transforming the current procurement strategy into BIM-driven approach, what/how technologies including BIM technology are used to assess operational and carbon performance, and how the supply chain should be engaged in this process. A list of the interview participants is shown in Appendix A.

Energy Management in public buildings:
The current process of Energy Management in public buildings can be represented as shown in Figure 1. As Post-Occupancy Evaluation (POE) is the main target of this study, further details of the information sources and exchange at each level will be investigated in the following sections and as shown in Figure 2.

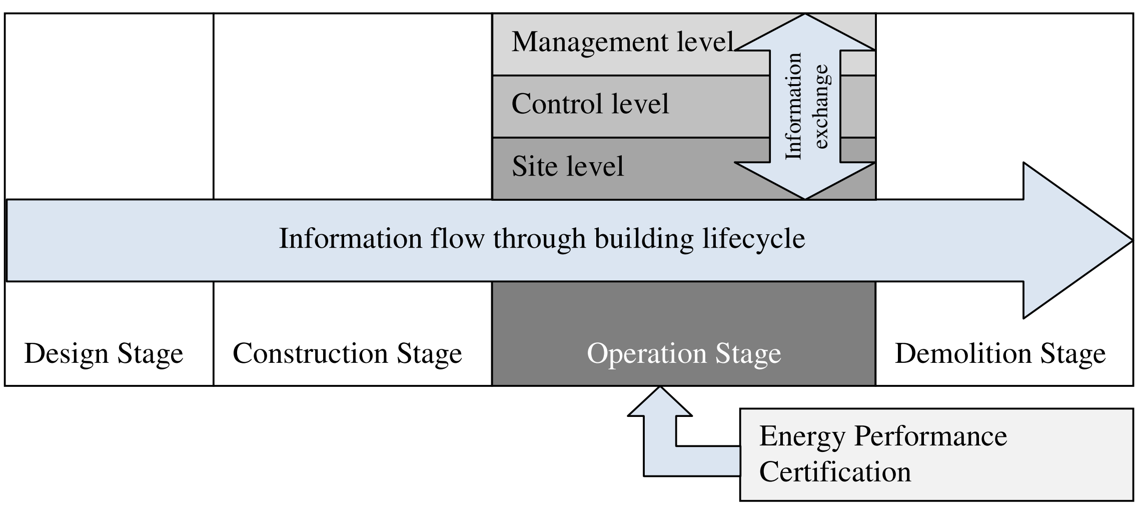

Figure 1: Information flow through building lifecycle

Site level:
The recent developments in building technologies and control strategies including the new building codes have improved the energy performance in buildings. For the majority of the public departments participated in this study, an average of 250 – 300

buildings are to be monitored by an energy team. A holistic approach to monitor building performance requires consistent and simultaneous access to data from different sources. The majority of the buildings are now equipped with Automatic Meter Readings (AMR). There are few buildings that are monitored by manual meter readings, suppliers' files, or sensors.

Energy teams usually include a representative (e.g. caretaker) on sites to supervise the process and in majority of cases to take meters reading. The team size and structure varies from department to another. There are also a number of roles identified within these teams such as: Energy Manager/Adviser and Carbon Manager. Their roles are mainly to collect site data and undertake further analysis then report the results to management teams for decisions.

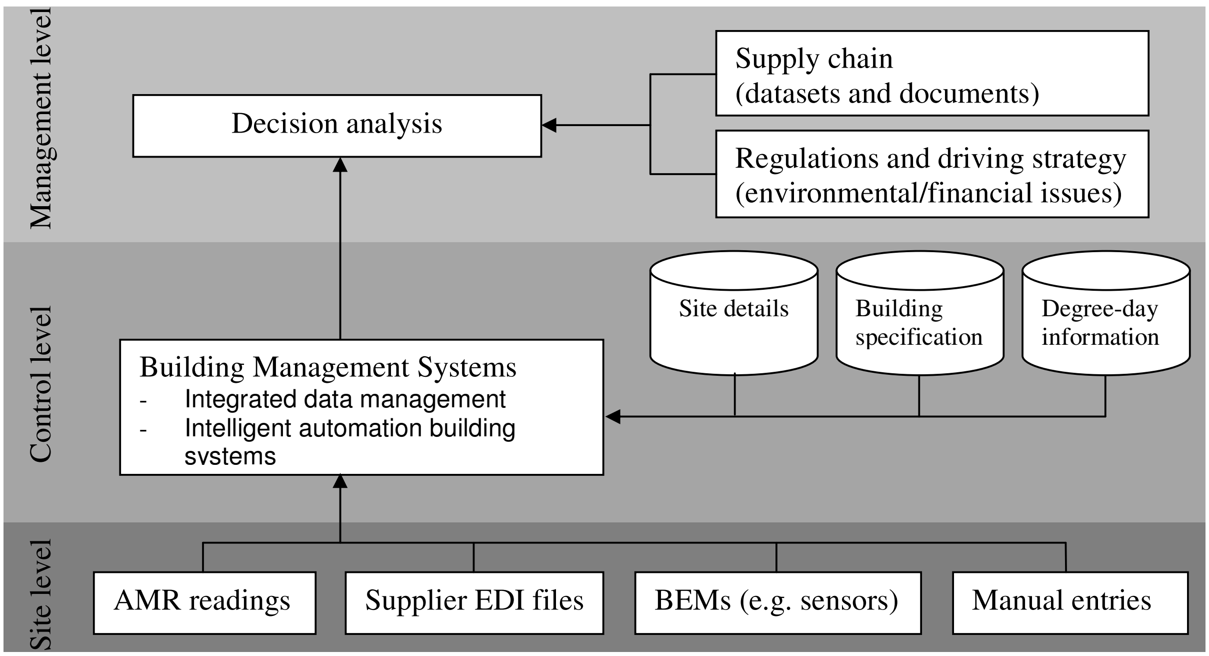

Figure 2: Framework of the data flow for Energy Management in Buildings during the operation stage.

Control level:
In general, Building Management Systems store, integrate, analyse complex data sets from multiple data sources such as wired/wireless sensing devices and meters. In addition, other data about the site and location information of a particular building including all the individual zones, building specification, and weather data is also required to perform multi-dimensional analysis of building performance and to support decision-making process. This shows the potential use of technology such as BIM to help manage and process this data.

As energy efficiency reports should be accessible to energy managers and relevant stakeholders, there are many off-shelf systems in use for data management and for intelligent automatic energy control. Improved building control systems can contribute to the reduction of energy-consumption. In addition, using automatic building systems is often faster and less costly than insulating building shells. Few buildings were found using these automatic energy control technologies especially within the PFI projects. For the studied public departments, Systemlinks is the most widely used, and allows all data collected from sites to be classified and reported for management decisions. However, for any further analysis using additional data such as building specification and weather data, different tools such as spreadsheets have to be used with the need to manually handle data entry.

From the current practices, there are good potentials to use BIM at this level. BIM models can collaborate with manufacturers data systems to automatically generate execution details of the building systems with construction guidelines provided by the manufacturers. This will provide the information needed for quantity take offs and products used for various simulators and assessment tools. The collaboration and interoperability features of BIM applications can help the integration of analysis tasks which will improve the outcome at this level of control.

Management level:
Decisions made at this level are based on data aggregation from lower levels in addition to open and extensible information exchange with the supply chain. Decisions made at this level consider many factors such as: the strategy adopted by the department in terms of achieving the emission targets and the financial implications of any managerial and technical solutions for energy savings. The integration with the suppliers and other stakeholders such as buildings' staff/occupiers is an essential element of the decision. This could be to fix site problems or liaise with occupiers for better use of the buildings. It was addressed that building occupiers play a key role in the process; therefore special programmes were set in place for such issue.

Energy Performance Certification:
The methodology of the National Calculation Method (NCM) is used for the assessment of buildings to be certified. While there are many criticisms of the accuracy of this methodology, it is still the only mandatory method for building assessment. The methodology utilises certain parameters such as daylighting or external temperature and uses building models (usually a 2D model generated by an energy assessor, especially for existing buildings). All required data is then manually transcribed into spreadsheet format prior to uploading into an Energy Performance program, such as the iSBEM program or other accredited interface program. Errors in the transcription process are expected and considerable time is spent on the multiple handling of data prior to final data capture by these programs. Even if there is an electronic building model (2D or 3D), there is no direct facility to import design data into SBEM. One key issue that becomes a problem in using programs such as SBEM is the format of data storage under object tree structure which allows only basic representation of the building and makes the software incompatible with any other possible integrated environment such as BIM. There are other issues about SBEM in terms of inaccuracy with respect to historic buildings, the limited range of input options available for fabric elements, and the poor ability to model Heating, Ventilation, and Air Conditioning (HVAC) systems or modern low-energy lighting.

There are other programs that offer streamlined data entry and can import a building model directly from a CAD based system. However, these programs are still constrained by the capability of the NCM algorithms and the object tree storage structure that makes the integration with BIM products impossible. More advanced programs (such as: TAS and IES Virtual Environment) which are based on Dynamic Simulation Modelling (DSM) have also been developed with different algorithms to undertake dynamic assessment of a 3D non-abstract building model and apply hourly or sub-hourly analysis. These models also allow advanced analysis of micro-generation technologies and factors such as solar shading. The DSM programs can also utilise direct data import from the CAD systems for a building without the restriction of the object tree structure. While the data from DSM is not currently specifically configured for external use in a BIM environment, these systems can be easily adopted for BIM. On the other hand, considering the rapid development in COBie methodology(1) to facilitate the compilation and structured integration of consistent and compatible building datasets, the use of such COBie BIM methodology will help better management of energy use.

BIM utilisation in current procurement practice and potential barriers:
The potential utilisation of BIM for POE of buildings develops further the capability of BIM to enable a holistic and fully integrated process, from the building inception to the end of its useful life, rather than be merely a sophisticated 3D drafting tool. Although BIM software has been around for some time, it is, as yet, not widely used within the construction sector. The move from 2D to 3D CAD is considered by many professionals to be as significant in terms of financial investment and change to working practice as the progression from the drawing board to the computer in the 1980's and '90's, however the commitment to all government projects over £50m being procured by BIM by 2016 is driving this change. However key concerns – which are applicable both to the use of BIM generally, but also specifically to the use of BIM for POE – can be summarised as cost, control (and therefore liability), communication, and compatibility.

Cost. Construction professionals are concerned about the cost of buying in to BIM, in terms of capital investment, training, and the inevitable down time in productivity, particularly in the current economic climate.

Control. Although one of the key benefits of using BIM is the promotion of collaborative working, a key stakeholder must take ultimate responsibility for the model, and the criteria that are to take priority must be established and agreed early on to avoid conflicts of interest. An architect may prioritise the building aesthetic where as the M&E engineer is likely to be more concerned with the building performance and therefore require changes to be made to, say, the building fenestration to meet defined performance targets.

It is common at the moment for an architect to produce general building layouts and other design consultants to overlay their information on to these base drawings, whilst still ensuring that there is clarity regarding who has produced the information, therefore who is responsible for its content, and ultimately is liable for it. This clarity must be retained, even with a collaborative model.

Control of the model post occupancy must also be established, perhaps with personnel retained contractually to update the BIM, either as the building is modified in response to changing user requirements, or as technological or legislative advances are made that necessitate change.

Communication. It is important that both the public and the private sector are prepared for this change, to ensure not only that stakeholders are involved at the appropriate stages in the design process to ensure that the design team are correctly briefed by relevant people at appropriate stages, but also to ensure that the model is used effectively post building occupation. Public sector client bodies should ensure that training is available to ensure that stakeholders are aware of BIM, its potential value including both strengths and shortcomings, to ensure realistic expectations and effective use. Consideration should also be given to the development of national guidelines by the Scottish Executive that would give direction towards the type of monitoring required, perhaps standardisation of equipment, and any energy targets that are to be achieved that are over and above the legislative requirements.

Compatibility. At present there are a number of providers of BIM software and, much like with the VHS 'v' Betamax video formats, there is a fear that by becoming an 'early adopter' of this technology, there is a risk of buying in to a system which may become obsolete.

BIM utilisation in POE of buildings:

The Building Information Model (BIM) includes ICT frameworks and technologies that can support stakeholders' collaboration over projects life-cycle by facilities to insert, extract, update or modify information in the BIM model. BIM applications produce more usable data and information for visualizations and simulations than the traditional and separate project application tools (e.g. technical 2D drawings and documents). Studies connected to BIM have moved from basically the functions to store, link and exchange the project based technical information to cover all data/information/knowledge analysis of the whole project lifecycle that benefits all stakeholders. For BIM applications, different BIM exchange formats, such as IFC (Industry Foundation Classes) (ISO 16793) and aecXML, have been developed to ensure consistent data exchange between BIM tools including those for controlling energy use in buildings such as geometry modelling, HVAC design, energy analysis, and facility management.

Way forward:

As a discipline, Energy Management (EM) is about operating and maintaining many complex energy systems used by buildings' occupants. To maintain energy systems, relevant information, which comes from various phases of the building's lifecycle, should be available, as discussed in Figure 1. As the generation and collection of building information is commonly fragmented, created over the building's lifecycle by different teams with different objectives, stored in different systems, the integration of this information is essential. Therefore, an ontological framework of all types of energy-related information and where the information come from should be created and used during the design, construction, and operation phase of the building's lifecycle. The ontology can be connected to a BIM modelled environment to spatially orientate necessary information. The conceptual framework of a proposed BIM-based system for building performance evaluation is shown in Figure 3.

The ontology and information will help Energy Managers determine and evaluate the use of energy properly and also communicate well with the suppliers and contractors. The integration of the ontology with the BIM model and the relevant energy systems will help utilising these systems and allow for a spatial organization of the modelled information.

The information collected for this feasibility study helped to identify the main clusters of this information. The study can help modify the current data flows to be more efficient and effective. Once the ontology is developed, instances of the classes will populate the taxonomy embedded in the ontology and tied to the BIM, as proposed in Figure 3. The analyzed data flow is specific to energy practices in public buildings considered for this study.

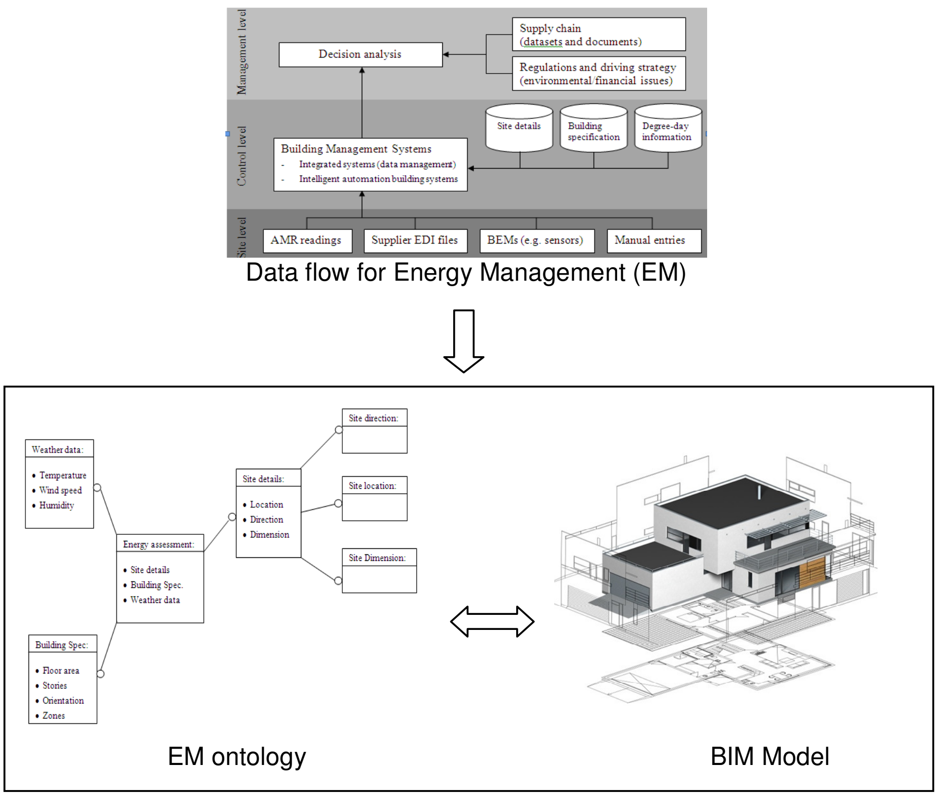

Figure 3: Proposed BIM-based system for building performance evaluation

Appendix A:

Historic Scotland
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Scott Brady | Carbon Manager
Audrey Tully | Energy Manager

HUB South East Territory
Alan Sansom
Programme Director

West Lothian Council
Douglas Evans
Energy Manager

East Ayrshire Council
Sarah Farrell
Energy Adviser

North Lanarkshire Council
Ron Hill (Scottish Energy Officers' Network)

Ingenium Archial Sustainable Futures
John Easton
Principal Sustainability Consultant
working with the Carbon Trust

Thistle Property Consulting Ltd
Philip Lovegrove
Energy Assessor
(Perth & Kinross Council framework)