BUILDING INFORMATION MODELLING: EMPOWERING ENERGY CONSCIOUS DESIGN

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Abstract. The increasing awareness of climate change and carbon dioxide emissions from the built environment is resulting in the need to visualize the environmental performance of buildings. One of the recent drivers in the UK has been the tightening of building regulations relating to energy consumption in buildings, mandating all buildings to be performance evaluated by accredited environmental simulation tools to test their carbon dioxide emission against set targets.

Currently there is major confusion on all levels from architects to building control officers and contractors on how to engrain energy consciousness principles in the design and construction of buildings. Within this context, 'Building Information Modelling' that is linked to 'Building Performance Modelling' is increasingly being looked upon as a tool to facilitate the communication between the design team and contractors and to provide a transparent information model on the specification and targeted energy consumption of all new/ refurbished buildings to all parties involved. In this paper, analysis of the benefits and drawbacks of current efforts to combine those two comprehensive databases will be investigated. A sample of main software development companies, architects and contractors, using semi-structured interviews is undertaken to find out how Building Integrated Modelling (BIM) and Building Performance Modelling (BPM) can support the design and construction teams to deliver energy conscious buildings.

1. The Need for Building Information Modelling (BIM)

The interest in creating media for collaboration underpinned the development of Building Information Modelling (BIM). Collaboration in the design phase arose from the need to facilitate and document the various social and professional interactions that leads to the realization of architectural design projects. The recognition that various team members (architects, engineers, owners etc) communicate and process information differently pushed forward the development of a variety of visual aids, animations and simulations to help facilitate communication. 3D modelling was seen as an opportunity to remove communication and language barriers among teams (sometimes global teams) working on large scale projects (Raman, 2007). The term ‘Building Information Modelling’ was coined to describe a 3D building model that can be used as a single repository for information linked to the design and construction phases. In this paper ‘BIM’ is used to describe a single platform that allows for visualization in 3D of aspects of design, structure, visualization of materials and quantities that are linked to the building model.

In the construction industry, efforts to use Building Information Modelling (BIM) to decrease the fragmentation of information and inaccuracies of 2D drawings led to embedding intelligent conflict detection systems in a BIM. This radically reduced the inefficiencies and coordination difficulties in communication, data exchange and design analysis experienced between design and construction teams (Dawood, et al 2002).

BIM research prototypes started in the mid 1970s in an endeavour to create integrated design systems that utilize a number of applications working together – rather than individually – to create the project. But it was not until late 1990s that a trend emerged to commercialize computational environments and technologies supporting BIM. During early 2000 there was a slow pick up in adopting BIM in design practices and construction companies. It is advocated as a crucial paradigm shift from traditional ways of drawing in 2D and then creating the 3D model and finding out inaccuracies in interfaces due to multiple teams and data sources involved in created the project (commonly discrepancies between structure, detailing etc and architectural plans). BIM applications support designing in 3D then a process of ‘slicing 2D’ drawings takes place which reduces inaccuracies. Research includes development of interoperable applications based on shared products that create high levels of communication among participating design and construction teams in order to develop collaborative design environments where professionals can exchange information and decision making even when they are separated spatially and temporally (Figure 1).

The term ‘Building Information Modelling’ is also referred to as Virtual building Environments (VBE), Virtual Building, Integrated Practice and Virtual design and construction (VDC). (Khemlani, 2007) reports on the uptake and use of BIM in one of the US based, international practices. The company (Walter P. Moore and Associates) report that there is a slow uptake of BIM within practice as only one third of the architects they work with use BIM applications and it is not sought after by building owners either.

Generally it is found that applications used within BIM framework tend to be used to resolve structural and civil engineering coordination. This facilitates reviewing drawings and conflict detection is used for structural analysis and project quantity surveying. As the 2D drawings are extracted from the 3D model there is an increased opportunity of capturing design intentions with fewer inaccuracies in the process and more team collaboration. Figure 1: explains the BIM philosophy as a shared project model database.

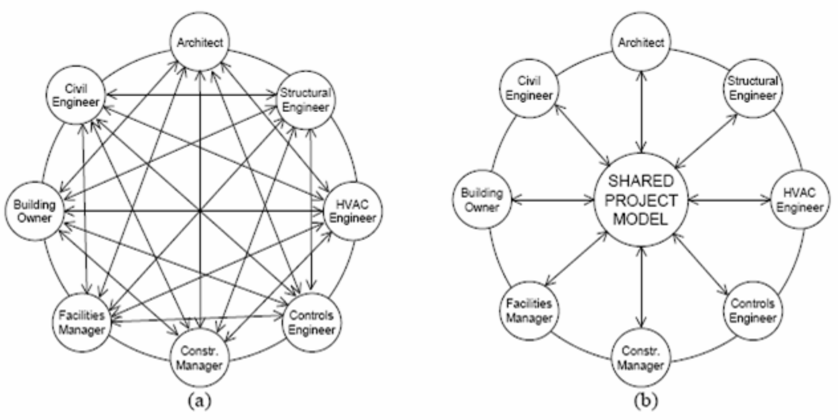

Figure 1: (a) presents current information flows within the design team, *(b)* the promise of interoperability. Source: IAI, 1997.IFC end user guide. Industry Foundation classes-International Alliance for Interoperability, Washington DC, USA

Although research on BIM paints a picture of resolving project information flow errors and more accuracy in detailing and documentation, it is generally observed that the uptake of BIM systems has been slower in practice and indeed in educating future design and construction specialists. The adoption of BIM is leading to heightened interest in moving information from tools that support 'Building Information Modelling' as a repository of data, visualization of materials and rendering of the design and construction of a building to related applications to investigate energy analysis, specification of buildings.

2. Linking Building Information Modeling to Building Performance Modeling

An energy conscious building that does not compromise the perceived comfort needs of occupants is a complex task that requires close collaboration between the design and construction teams. Building performance analysis tools have been evolving with different strengths and capabilities since the 1970's. Crawley etal, (in press) contrast the capabilities of 20 mainstream Building Performance simulation tools. The availability of such tools combined with increased computational power, 3D modelling, and an increased level of tightened building regulations to reduce energy consumption and carbon dioxide emissions is having an impact on the way in which buildings are designed, analysed and constructed.

In the UK the impact of tightening of Part L: Conservation of Fuel and Power, in April 2006, had major impacts on the design, expert collaboration and procurement of buildings (Hamza and Greenwood, 2007), in which the process of compliance is extended over the life cycle of the project. In this case Building Performance Modelling (BPM) plays a major role in achieving compliance.

Several internationally renowned architectural practices have illustrated the complexity of the knowledge and expertise required to produce environmentally conscious buildings using stand alone building performance tools as decision making aids (Kolarevic and Malkawi, 2007). Research efforts in the field of building performance simulation are dominated by the idea that design is a goal oriented decision making model where goals are defined by desired performance values (Malkawi, 2004). Simulation based optimization for thermal comfort, daylight and acoustic autonomy of buildings can also be time consuming as every design iteration will involve a re-run of the environmental modelling tool with consequent changes in material, façade design, building services systems profiles.

Building Performance Modelling describes a centralized database where all performance analysis tools to predict daylight, thermal comfort, natural ventilation and acoustic performance are interoperable and linked to same data model describing the parametric aspects, occupancy and material property of the building. BPM evolved as a platform to facilitate appraisal of architectural design alternatives that influence energy consumption and human comfort in buildings.

In recent years the large corpus of research on building performance modelling was dealt with as a stand database. The research on BPM due to the complex computational demands of its component software and its large computational demands, and expertise required for data input and analysis was led in isolation from other research activities and developments of Building Information Modelling platforms.

Augenbroe, et al (2004) highlight that most past efforts in research addressed the need to achieve seamless data integration between design and analysis software applications assuming a 'perfect world' in which all information is structured and all mappings between design and analysis applications exists on a generic level. Hence the integration and interoperability efforts requires the shift from the data centric focus to a 'language' that expresses analysis and generated answers.

XML, eXtensible Markup Language, a computer language that allows software programs to communicate information with little or not human interaction was extended in 2000 to The Green Building XML schema known as ‘gbXML’ and was submitted for inclusion in aecXML. However it was not till 2004 that gbXML gained the support of the major CAD vendors (Bentley systems, Autodesk and Graphisoft) in the software industry and was developed to facilitate integrated interoperability and the transfer of building information in CAD models to a variety of engineering analysis tools (www.gbXML.org). In 2006 bgXML was further developed by only one of the three main players to transfer information to an environmental modelling tool. Only one of the main BPM companies used gbXML to provide a seamless link between the BIM 3D model into the BPM.

4. Advantages of Integrating BIM and BPM:

Figure 2, explains current efforts in the integration between BIM and BPM, it demonstrates the extensive nature of software applications involved in both platforms and the complexity of decision making in projects.

From interviews there was a general consensus among the three groups that the advantages of the integration of these two large information platforms are:

1- A single information model that holds information in a single 3D repository ensuring consistency, accuracy and accessibility of data
2- Better customer services through accurate 3D representation
3- Consistency and robustness of data and information provided by the construction drawings and detailing.
4- Beneficial technology for storage of integrated building construction, maintenance and management data.
5- Improved visualization that aids in rigorous analysis of building proposals
6- Integration with building environmental BIM leads to integrated whole life environmental data based on predictions of environmental performance and carbon dioxide emission rates over project life cycle
7- Increased productivity and ease of distilling vital information from the model
8- Representative visualization of the relationship between the detail and the whole of the building
9- Reduced cost and time for construction drawings, speeding up related activities such as planning and building control submission of projects and tendering activities.
10-Intelligent query systems through easily extracting information related to quantities required for estimation and tendering.
11-Controlled life cost and environmental data
12-The re-usability of building information for facility management purposes
13- Creating interest in the project and a visual representation of the final project to clients and involved project teams.

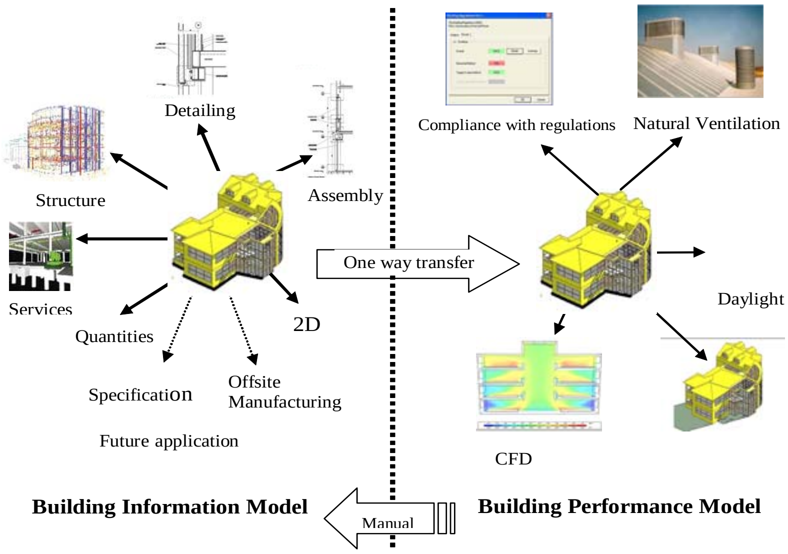

Figure 2: The Current level of integration between Building Information Modelling and Building Performance Modelling.
* Note that this is a one way transfer of the 3D model and has only been achieved by only one company.

5. Issues and Areas for Improvements:

'It is entirely practical for all members of the design team to have access to and operate on the common design model, whether or not they share a design office. The models, then, can provide a strong integrating force in design team working' (Maver, 2004). This is as general perception among advocates of collaborative working that interviewees refuted and contested.

The interviews highlighted five main areas of concern

1-The extent of coupling of tools supporting the individual platforms
2-The real extent of interoperability between the two platforms
3-The level of abstraction/detail in both modelling platforms
4-Management and training
5-Future needs

5.1 THE EXTENT OF COUPLING OF TOOLS SUPPORTING THE BIM AND BPM PLATFORMS

The definition of BIM implies that the central database in the platform is tightly coupled to all changes and transactions by all design team members while they are in the iterative process of design decision making processes.

'Inexperienced users hear about BIM and have a rosy perception. BIM is expected to automatically couple all changes and iterations in any of the supporting software into the original model and co-ordinate changes' Group A.

Experienced interviewees with BIM (Goup A&B) were against this tight coupling of data structure and indeed saw it as a limitation and unwanted complication explaining that the design process itself requires a careful mix of tightly and loosely coupled data structures.

'For example: during design architects would like to work at a strategic design level then cascade down to the detail, in this process parts of the building model are still 'fuzzy', it should not then be shared with other design team members who would be capable of introducing changes and make decisions according to the information in the model while the design itself is not fully resolved' Group A.

'You can imagine that the structural engineer is still working on the design of the structure and its dimensions…eventually changing and revisiting the drawings. While he is working on it, the quantity surveyor decides to calculate the amount of steel needed only to find out that the model is not finished yet and has been changed afterwards..if the model keeps changing who then will be responsible to manage and track those changes?' Group A.

'BIM or BPM, the most effective way of communication and for efficient work flow will always be the face to face meeting between the design team' Group A

5.2. THE REAL EXTENT OF INTEROPERABILITY BETWEEN THE TWO PLATFORMS

Before the BPM platform was founded, interoperability between a BIM product such as REVIT or Bentley Microstation, could be achieved through a laborious process. This process involved slicing through the 3D models created by these platforms to create 2D plans. To prepare the 2D model for feeding into the building simulation tool, drawings had to be imported into AutoCAD or a similar package to explode the drawing, then delete all text and dimensions thus extensively downgrading the information to a simple 2D drawing. The 2D drawing was then imported into the building performance analysis tools where it was extruded back into a 3D model based on creating rooms that were then computed as bounding elements that surrounded the air volume in a room leading to the performance analysis prediction.

Although the seamless coupling between the BIM and BPM platforms is seen as an advantage in work flow and analysis only one software company went down this route. Interviews revealed that 'using gbXML now means that the 3D model from the BIM is transferred into the BPM eliminating the laborious and error prone effects of previous manual methods' but there was extensive collaboration between the BPM provider and the BIM provider in writing a gbXML file. 'We have an indirect route and a direct route to transfer 3D Models. The way that normally files are transferred is in the form of DXF or gbXML. DXF files include a lot of information that is not needed in the analysis. With the likes of gbXML Autodesk tell us that they reckon we are lucky if 50% of the file gets converted properly. We have worked with AutoDesk to improve the quality of the gbXML, I believe we have improved it to about 98%. But this is the indirect route to transfer the model. We also have a direct way to communicate between REVIT and IES to improve the transfer by a click of the button' Group B.

However, the seamless transfer between the two platforms means extra care has to be given to construct an accurate BIM, as the transfer back from the BPM model to the BIM is not feasible. This is because the intelligence used in both platforms is different. For example, curved walls are transferred into faceted walls in the BPM and therefore will not be re-imported to the BIM.

On the issue of importing the BPM information back into BIM, the response was: **'**I don't believe there will ever be a two way conversion and it's the wrong thing to do. We have lost the intelligence embodied in the BIM and it is not transferred to us. After using Environmental simulations and after all iterations are finished users have to make sure they have reconstructed the final BPM model into BIM' Group B.

'The vendors approach is a two pronged attack on the user, firstly to provide the best tool for the user but also to lock users into the software. I do not belief that this issue will ever be resolved. The commercial issues are the biggest thing in the way of interoperability and it is difficult in a way. Academia seem to be set on producing complicated systems that seem to only work on project by project basis. What is needed is a mainstream process that can be used in any project.' Group A.

The seamless transfer also entails taking care that bounding elements status and their adjacency are specified correctly. The BPM may read elevator shafts or columns as unidentified spaces and compute this as external spaces! This still involves time consuming manual operations. The danger of BPM is that it will still produce analysis results where interpretation is undertaken by the analyst. Group A

'There is also the issue that if you use environmental modelling tools do you understand the results. Every simulation uses rules of thumbs and shortcuts. The user needs to understand those. If you do not know how a piece of software arrives at a conclusion then how can you trust it?. The difficult thing is that we are coming after a generation that was strong on doing calculations on paper and effectively took part in writing these packages. Now the difficulty is that the new generations have not been involved at his level but in a way the new generation will not have the 'gut feel'. With technology comes responsibility, responsibility to check that we know what the issues are and that results make scientific sense' Group A.

The importance of an education that balances the teaching of theoretical basis and the underlying knowledge alongside introduction of new software technologies has also been asserted in previous research (Horne and Hamza, 2006)

5.3 THE LEVEL OF ABSTRACTION/DETAIL IN BIM AND BPM

As a data repository, there seems to be a trend to over populate the model with information. From an architectural design point of view it was seen that populating the model with too many unnecessary detailed construction interfaces was a waste of time and computational power.

'A curtain walling manufacturer would know much more about their products and it is pointless to cut and paste these into the BIM…We only need to show interfaces with the construction, and its effects on aesthetics of a building..such as the mullion divisions, their colour etc' Group A

'DXF files include a lot of information that is not needed in the environmental performance analyses, there has to be a level of abstraction in the model that is based on an expert's opinion' Group B.

'The model needs to be a tool to detect clashes in construction and services, a deep level of detailing is best dealt with by the sub-contractors' Group C

This indicates that there is still a need for expertise in constructing both the BIM and BPM and deciding on the level of model abstraction

5.4 MANAGEMENT AND TRAINING

Group A and Group C, respondents revealed a need for managing the initial stages of the implementation of BIM. The time savings in efficiency and accuracy were offset by the time required to learn the application and customize it for the specific firm requirements.

However, firms that had some experience with BIM have realized several un-quantified benefits such as increased productivity and better presentation of the design concept to clients. However the need for effective implementation requires profound changes in the way architects work. Adopting BIM is more is the realm of architectural and construction analysis while BPM is more in the realm of building services engineers. However, both platforms require more than learning a new application. Firms found that they need to reinvent the work flow and re-assign staff responsibilities. 'Although they do not want to invest in it, clients are impressed when we show them BIM. BPM is needed for compliance with building regulations anyway. The problem is that even building services engineers sometimes do not fully understand building performance modelling results' Group C

5.5 MORE INTEGRATION

Interviews with Group A and B revealed that integration of BIM with specification is seen as an urgent activity in the future. Managing specification libraries was a project by project activity to overcome any chances of information overload. Currently specification of both construction and services libraries are very explicit and large and this is an ongoing research that members of Group A are engaging with the UK National Building Specification (NBS).

Also the issue of lean construction and how BIM can help in sending information for prototyping and offsite construction were on the wish list of Group A.

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