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BUILDING INFORMATION MODELLING AND OFFSITE CONSTRUCTION IN CIVIL ENGINEERING

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In 2011, the UK Government mandated that all construction projects (buildings and infrastructure) that they procured would be undertaken within a 3-D BIM (Building Information Model) environment by March 2016. This has caused both construction procurers and providers to embark on a journey towards universal BIM adoption, including the integration of BIM within a revised construction process. Offsite construction has also seen significant development in the building sector in the past decade; in infrastructure however, offsite exploitation has been more limited. This paper presents research regarding how innovation initiatives such as BIM and offsite can and need to be considered together, thus allowing leaner design, a greater integration of lifetime project data and more novel technical solutions. The analysis outlines the benefits of utilising offsite within a BIM environment, the challenges currently facing the supply chain, and recommendations are made as to how best to implement the emergent benefits.

Key words: Building Information Modelling (BIM), Civil Engineering, Infrastructure, Offsite Construction, Innovation

INTRODUCTION

Improving efficiency in construction has been on the UK government industry agenda for many years (Wolstenholme, 2009). Various initiatives have been documented, addressing different aspects of the construction industry (Simon, 1944, Emmerson, 1962, Banwell, 1964, Lawn, 1994, Egan, 1998). Recent initiatives – such as BIM, lean construction and offsite – aim to reduce costs through improved resources and enhanced data management (Vernikos et al, 2011) with BIM becoming increasingly applied within the UK construction industry in recent years. BIM implementation is occurring via a ‘push–pull’ process and BIM is slowly becoming embedded in various forms and methods in many current construction projects (National BIM Report, 2013).

The UK government wants to achieve a total of 20% savings of construction costs and aims to implement BIM in all government construction procurement contracts by 2013 (Morrell, 2011) hoping to contribute to the savings target. Many would consider this target to be a real challenge, solely through the implementation of a single innovative initiative, in such a short time. The paper presents drivers and barrier documented and discusses past research initiatives on BIM and Offsite (i.e. Avanti, PrOSpa, Manubuild). Through the analysis of 12 interviews, the research explores how the industry currently defines BIM and Offsite current BIM development their effects on Offsite construction.

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<tr>
<th>BIM</th>
<th>Drivers and Advantages</th>
<th>Offsite</th>
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<tr>
<td>NBS BIM report, 2013</td>
<td>Profitability</td>
<td>Pasquire and Gibb, 2002</td>
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<td>NBS BIM report, 2013</td>
<td>Time</td>
<td>Pan and Sindell, 2011</td>
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<td>Pasquire and Gibb, 2002</td>
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<td>Goodier and Gibb, 2007</td>
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<td>Kriegel and Nies, 2008</td>
<td>Sustainability (e.g. Reduce waste)</td>
<td>Pasquire and Gibb, 2002</td>
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<td>Nisbet and Dinesen 2010</td>
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Table 1: Research summary of drivers and advantages for BIM and offsite

Many of the aforementioned statements can be applied to BIM and its implementation. The drivers and barriers for BIM however, are not as thoroughly documented as offsite, possibly due to the more recent nature of the innovation. Table 1 and Table 2 include some of the most critical advantages and disadvantages of BIM currently documented. Recent industry surveys in the UK an USA (McGraw-Hill, 2010; NBS BIM report, 2013) claim that productivity is one of the greatest advantages.
of BIM. Nevertheless, there is very little evidence, in the literature, for these productivity improvements to have been realised (Whyte et al., 1999, Taylor, 2007). One may argue that the surveys are more recent and the published literature is outdated. Amongst many barriers documented in the literature the most debated in its effects on cooperation and general communication. There are many (Succar, 2009, Sacks et al 2010) that believe BIM improves communication indirectly through its 3-D elements and visualisations, effectively communicating information on r spatial, logistical and material requirements. However, there are others (Ashawi and Faraj, 2002, Nisbet and Dinesen 2010) that argue that BIM does not foster collaboration.

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<tr>
<th>BIM</th>
<th>Barriers and Disadvantages</th>
<th>Offsite</th>
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<td>Bernstein et al, 2005</td>
<td>Initial cost</td>
<td>Blismer et al, 2005</td>
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<td>Gooder and Gibb, 2007</td>
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<td>Howard and Bjork, 2008</td>
<td>Process and Management</td>
<td>Blismaz et al, 2005</td>
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<td>Moun et al, 2009</td>
<td>Lead-times</td>
<td>Blismaz et al, 2005</td>
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<td>Gibb and Isack, 2003</td>
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<td>Ashawi et al, 2006</td>
<td>Coordination/Cooperation</td>
<td>Pan and Sindell, 2011</td>
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<td>Nisbet and Dinesen, 2010</td>
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<td>Taylor, 2007</td>
<td>Lack of knowledge</td>
<td>Blismaz et al, 2005</td>
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<td>Blismaz and Wakefield, 2007</td>
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Table 2: Research summary of barriers and disadvantages for BIM and offsite

The civil engineering sector is moving towards a multi-dimensional object-oriented design in a similar way to the building sector. Many believe that this will inherently encourage the production of ‘objects’ designed for manufacturing, especially if data can be sent directly to the fabricators. Construction is a ‘low information intensity’ industry compared to banking or finance (Hu and Quinn, 2005). Nevertheless, structures are complex entities formed by various sub-systems and diverse components. The continued reliance of the civil engineering industry on using paper-based drawings as a means of recording designs and fabrication data is inhibiting offsite innovation. Theoretically, with the ‘digitalisation’ of construction data it is expected that advanced automation in design, manufacturing and erection through BIM will increase offsite (Eastman and Sacks, 2008). BIM is the technology that allows construction data to be ‘machine readable’ and manufacturing of components without human intervention possible (Eastman and Sacks, 2008). Nevertheless, for any technology to be implemented in the industry there is a series of factors to be considered including staff’s attitude toward the technology, the firm’s structure and culture, the level cooperation between the supply chain partners, leadership and senior management support and the firm’s ability to change (Iacouvou et al, 1995 Irani and Love, 2008)

METHODOLOGY

Grounded theory was applied in this research to allow for insights into investigating the emerging industry processes while avoiding adjusting or steering the data towards previous theoretical frameworks (Glaser, 1998). The grounded theory used focused on a phenomenological approach and deductive derived theory (Strauss and Corbin, 1990). Unlike other qualitative approaches, grounded theory begins focusing on the conceptual scheme through a contextual way avoiding any predetermined theory (Cassell and Symons, 2004). This investigation did not intend to focus on a distinct area but rather to allow the research to unravel through a continuous comparative analysis of incoming data that enabled a conceptual development. The data collection period lasted six months and data was considered sufficient when ‘theoretical saturation’ occurred (Glaser and Strauss, 1967). The conceptual theory was initially established through a series of discussions with industry experts. When the exact research question was identified, a thorough and focussed literature review was conducted including published research, industry reports and government regulations. Twelve semi-structured interviews were conducted with BIM leaders and directors from leading UK construction contractors and consultants, software vendors, industry institutions and the UK Government. The interviews were thematically analysed.

FINDINGS

For this research, twelve experts first explained what each term meant to their organisation. BIM was seen by all as a platform for communication and collaboration. Although the focus is on data and information, attention was drawn to the way the design or modelling processes are managed and controlled. Recurring terms such as ‘correct’ or ‘improve’ show a positive attitude and enthusiasm towards this innovation. In summary, in this research, BIM is an umbrella term for object-oriented modelling that relates to both vertical (i.e. buildings) and horizontal (i.e. railway, highways, etc) infrastructure where the objects have extended attributes that can be leveraged to understand the content of a design and allow for a consistent platform of communication throughout the supply chain.

In contrast, the offsite definitions were more diverse. Contractors saw offsite as a construction process, where components are fabricated in a factory or somewhere near-to-site and are transported to site for installation. For consultants, offsite is more of a means to achieve increased efficiency where products, bespoke or off a catalogue, that are manufactured in a controlled factory environment are assembled on-site. There was confusion between the terms standardisation, prefabrication and preassembly.

Past Government Initiatives

Whilst offsite has been promoted by the UK government for generations, albeit using different terms such as prefabrication (Murray and Langford, 2008), the focus on high-powered information and communications technology has been somewhat more recent. In 2002, The Department for Trade and Industry (DTI) combined with the Engineering Physics and Science Research Council (EPSRC) to develop a programme of works, the Innovative Manufacturing Initiative (IMI). The IMI funded a theme called Meeting Clients Needs through Standardisation (MCNS) which orchestrated a group of focused calls for research programmes. The last two programmes funded were Avanti and PrO2SpA. Avanti’s core aim was to encourage the use of Computer Aided Design (CAD) by arguing that managing information databases was more
effort than managing 'drawings in a cabinet'. Avanti supported early access to information from all parties of the supply chain and work protocols promoting improved communication and common information models. Similarly, ProSPa aimed to encourage offsite solutions across the construction sector (Goodier and Gibb, 2007). ProSPa was the predecessor to the industry-focused organisation BuildOffsite and Avanti developed into the BIM initiative.

**ManuBuild**

ManuBuild was a good example of European funded research on combining BIM type technologies with offsite prefabrication. Briefly, the research team included 22 partners from 8 countries focusing on building concepts from a design perspective and production technology from a construction perspective. The aim of the research was to combine the two processes to achieve an increase sustainability, quality and durability without increasing costs. Some participants interviewed would define the project as 'one-system-manufacturing, that required standards and component catalogues, automated factories and manufacturing'. Participants in ManuBuild believed that to achieve these efficiencies it was critical to explore other industries and similar challenges therefore the automotive industry was used as a comparison. Traditionally, the construction industry has 'trouble with precision and efficiency', not as much with regards to structural design but with time, cost, materials, etc. Model-based information such as model driven scheduling and costing was the solution to the problem. Some issues occurred with large corporate software firms, 'although they say there are keen to collaborate they do not want to be limited by standards because they see this as making their customer base available to the competition'. Other issues focused on the project management of the research project. The participants interviewed claimed that there are examples of large R&D projects funded from the European Union that have serious issues with project management. The claim that when research in conducted in the construction industry, at least from an industry perspective, the exact outcome or output of the research is 'unsure'. There is a continuous change of data therefore different targets and expectations. Conventional project managers, which have work of research projects find it exceptionally difficult to work in such a 'fluid' research environment. Rigid ideas of industrial partners in research projects create friction. In cases where there are many partners from the supply chain working on the same research project, the situation becomes even more complex from a project management perspective. There are examples of partners, when under pressure, they become 'disillusioned and back off'. Partners who are running into difficulties need a particular handling in order to maintain focus and continue to work collaboratively. Participants interviewed concluded that ManuBuild did not have the desired impact to the industry nevertheless there are few publications available (Gibb et al, 2007, Long et al, 2007).

**BIM and offsite in the Civil and Building Sector**

Both the Avanti and ProSPa programmes focused on this primarily on the building sector rather than infrastructure or civil engineering. Despite the downturn in the current financial situation in the UK, offsite is employed in many large scale building projects varying from hotels and hospitals to prisons and student accommodation. Certain aspects, such as precast concrete elements, have also been widely employed in the civil engineering sector, but other applications have had little deployment (Gibb, 2001, Goodier and Pan, 2010) and this view was supported by the interviewees in this current survey. Some claimed that the civil engineering sector 'thinks less of their process and data possibly due to the size and duration of the projects'. Others debated that, in the building sector, learning from project comparison is less challenging as you can analyse, for example, the cost on a functional breakdown and compare the cost of a system from one project to another. Whereas, in civil engineering projects, one cannot compare the contractor’s breakdown neither at a project-by-project basis nor a contractor-by-contractor basis because of its arbitrary nature due to the work breakdown and the different tasks delegated to different sub-contractors on site. Some consultants claimed that offsite was easier to develop for the building sector due to 'object libraries' and 'catalogues of components'.

With regards to BIM, and similarly to offsite, most participants agreed that the building sector is currently leading in its implementation. The main reason was due to the software available being more focused on vertical construction. The software providers interviewed claim that 'the building sector has instant gratification from BIM and it is less challenging compared to horizontal infrastructure where segmenting the model is a complex process'. Consultants argue that despite software for the building sector being 'more mature', the real challenges occur when large geographical areas demand the combined utilisation of Geographic Information Systems (GIS) and BIM. Government experts claim that less research on processes and data transfers is undertaken by the civil engineering sector which 'lacks comprehensive data systems, such as Industry Foundation Classes (IFCs)'. Although most firms contributing to this research are involved in large scale infrastructure projects, only one participant claimed that 'some key civil projects (i.e. CrossRail) are using much more superior BIM techniques than any building project'. To conclude, it was evident that the building sector is utilising BIM on a wider scale and it is more aware of BIM processes (National BIM Report, 2013), however, in civil engineering there are some best practice examples demonstrating the applicability of BIM within a complex infrastructure environment.

All participants agreed that consultants used to lead the way in BIM technologies and methods, 'starting from a position of strength', predominately because of 'their familiarity with the visual aspect of the software and the rapid production of drawings'. During the last few years contractors however have been accelerating their BIM awareness and using BIM as an opportunity to achieve greater efficiencies. In addition, large UK contractors’ main client is the UK government, therefore contractors are ‘forced into rapid BIM implementation’ in order to maintain a competitive advantage. Nevertheless, consultants interviewed claim that contractors use BIM to focus more on the detailed design and the construction phases of the project and less on the operational and the maintenance phases. The UK government representative interviewed highlights the importance of BIM for the lifecycle of the project and claims that the benefits of BIM in the design and construction phases are minimal in comparison.

**ANALYSIS**

Considering BIM’s effects on offsite, most participants thought that by the UK Government mandating BIM by 2016, the usage of offsite in the civil engineering sector will increase. Some were very enthusiastic, claiming that offsite is the missing link without which there are no easy mechanisms to ensure that design intent is translated into a fabrication intent that is manufactured affectively. In addition, it was claimed that only through BIM ‘one that designs precise digital objects can then fabricate them in factory conditions’. Others were more cautious, stating that there are
BIM has the potential to improve the quality of existing offsite methods and solutions. Notwithstanding, it was made clear that it all depends on how organisations implement BIM and offsite in the model that they operate. Despite the uniform opinion of most participants that BIM will positively affect offsite, one consultant claimed that BIM does not enable nor hinder offsite because BIM applies equally to on- and off-site work. The consultant believed that ‘offsite is on an upward curve and I don’t think that curve will become steeper since BIM was formally introduced to the industry’.

**CONCLUSION**

Both BIM and offsite as concepts are not fundamentally new, but terms referring to the ideas have changed over the decades to reflect industry trends. During the past few years a number of successful case studies of offsite within a BIM environment have been published (BIM Handbook, 2011). The majority of them are focused on the building sector with the United States leading BIM implementation. Within the UK, early adopters such as the Ministry of Justice are using BIM with offsite for prison blocks and some ‘best practice’ examples are producing promising results (MoJ, 2013). Despite all the high expectations from the literature and some practical success in the building sector, very limited application of offsite through BIM is witnessed in civil engineering. The participants in this research attempted to identify evidentiary examples to prove that BIM enables, promotes, increases or improves offsite, but apart from some aspects of ‘key infrastructure projects’, no evidence could be provided. The UK Government provided examples where ‘projects started using BIM from the RIBA-Stage C phase and this was deemed fundamentally flawed’. Therefore, based on this principle; some participants’ examples were dismissed as their ‘BIM elements were merely 3D visuals or the BIM implementation was encouraged not for its efficiencies but for commercial reasons. When participants were not able to provide evidence they claimed that the statements were going to materialise during BIM level 3. Nevertheless, as the UK Government confirmed during the interview, currently BIM level 3 is yet to be clearly defined.

Offsite is a more ‘familiar’ concept to the civil engineering sector, with precast concrete elements and bridge construction or tunnelling often employing offsite (Vernikos et al, 2012). However, throughout the data collection process many participants confused the terms ‘standardisation’ with ‘prefabrication’ and the term ‘offsite’ was not clearly understood. Economies of scale are achievable through standardising offsite elements and BIM may influence the process drastically, yet one does not automatically lead to the other. One contractor emphasised the distinction, claiming that ‘standardisation is an aspect of BIM, but a minor percentage of civil engineering works is standardised’, as parametric and logistical flexibility is needed. With consultants saying that ‘contractors don’t know what they want’ and contractors claiming that consultants give them ‘empty models’ the confusion is not limited to offsite terminology but also to BIM implementation.

After analysing the responses of twelve of the BIM and innovation directors representing leading UK consultants, contractors, software vendors and construction industry institutions, it is evident that there is a clear belief that BIM will improve and increase offsite construction in civil engineering. Nevertheless, there is still little evidence that this is currently the case. It appears from the findings presented here that BIM has the potential to improve the quality of existing offsite methods and solutions. This may raise industry confidence and therefore it could indirectly increase the overall application of offsite technologies.

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