Loughborough University
Institutional Repository

Building Information Modelling and offsite construction in civil engineering

This item was submitted to Loughborough University's Institutional Repository by the/an author.


Metadata Record: https://dspace.lboro.ac.uk/2134/14483

Version: Accepted for publication

Publisher: ARCOM (© ARCOM and the authors)

Please cite the published version.
This item was submitted to Loughborough’s Institutional Repository (https://dspace.lboro.ac.uk/) by the author and is made available under the following Creative Commons Licence conditions.

For the full text of this licence, please go to: http://creativecommons.org/licenses/by-nc-nd/2.5/
BUILDING INFORMATION MODELLING AND OFFSITE CONSTRUCTION IN CIVIL ENGINEERING

V.K. Vernikos¹, C.I. Goodier² and A.G.F. Gibb³

¹ School of Civil and Building Engineering, Loughborough University, Loughborough, LE11 3TU, UK

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, Latham, 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 2015 (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.

BARRIER AND DRIVERS


Offsite has been seen to improve efficiency and productivity in construction (Blismas and Wakefield 2007). Drivers of offsite include time, quality, cost and health and safety (Blismas et al. 2006, Gibb and Isack 2003). Despite the existing literature, advantages related to offsite are poorly understood therefore there is reluctance in employing such methods (Pasquire and Gibb 2002). Barriers for offsite are process, value, conservatism and knowledge related (Blismas et al. 2005). Two major issues are the complete understanding of the process and the cooperation throughout the supply-chain (Pan and Sidwell, 2011). According to Nadim and Goulding (2009) improved communication, teamwork and problem solving in critical for increasing the usage of offsite. Many will argue that the construction industry is focused on initial construction cost rather than value, hindering offsite as it is not equitably evaluated (Blismas et al. 2006, Pasquire and Gibb 2002).

<table>
<thead>
<tr>
<th>BIM</th>
<th>Drivers and Advantages</th>
<th>Offsite</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBS BIM report, 2013</td>
<td>Profitability</td>
<td>Pasquire and Gibb, 2002</td>
</tr>
<tr>
<td>NBS BIM report, 2013</td>
<td>Time</td>
<td>Pan and Sindell, 2011</td>
</tr>
<tr>
<td>Kriegel and Nies, 2008</td>
<td>Sustainability (e.g. Reduce waste)</td>
<td>Pasquire and Gibb, 2002</td>
</tr>
</tbody>
</table>

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, Bernstein and Pittman, 2005) that believe BIM improves communication indirectly through its 3-D elements and visualisations, effectively communicating information on 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.

<table>
<thead>
<tr>
<th>BIM</th>
<th>Barriers and Disadvantages</th>
<th>Offsite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bernstein and Pittman, 2005</td>
<td>Initial cost</td>
<td>Blismaz et al, 2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goodier and Gibb, 2007</td>
</tr>
<tr>
<td>Howard and Bjork, 2008</td>
<td>Process and Management</td>
<td>Blismaz et al, 2005</td>
</tr>
<tr>
<td>Moun et al, 2009</td>
<td>Lead-times</td>
<td>Blismaz et al, 2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gibb and Isack, 2003</td>
</tr>
<tr>
<td>Ashawi and Faraj, 2002</td>
<td>Coordination/Cooperation</td>
<td>Pan and Sindell, 2011</td>
</tr>
<tr>
<td>Verheji and Augenbore, 2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nisbet and Dinesen 2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taylor, 2007</td>
<td>Lack of knowledge</td>
<td>Blismaz et al, 2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blismaz and Wakefield, 2007</td>
</tr>
</tbody>
</table>

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 Quann, 2005). Nevertheless, structures are complex entities formed by various subs-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 staffs’ attitude toward the technology, the firms’ structure and culture, the level cooperation between the supply chain partners, leadership and senior management support and the firm’s ability to change (Jacovou 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 PrOSSPa. Avanti’s core aim was to encourage the use of Computer Aided Design (CAD) by arguing that managing information databases was more
efficient 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, PwOSPA aimed to encourage offsite solutions across the construction sector (Goodier and Gibb, 2007). PwOSPA 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 by combining 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 how other industries approached similar challenges therefore the automotive industry was explored. Traditionally, the construction industry has ‘trouble with precision and efficiency’, not as much with regards to structural design but with time, cost, material usage, man-hours, etc. Model based information such as model driven scheduling and costing was the solution to address 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 frictions. 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 their predominately 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 subcontractors 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)’.

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 adoption and, using BIM as an opportunity to achieve greater efficiencies, not as much with regards to structural design but with time, cost, material costing was the solution to address 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 frictions. 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).

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...
many parameters that determine where and how to use offsite but ‘BIM helps
designers take into account all these factors and make a more informed decision’. 
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 
part 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 
sufficiency 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. Economics 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.

REFERENCES

implementation. Construction Innovation, 2, 33–51
Banwell, H. (1964) The placing and management of contracts for building and civil 
engineering works. HMSO, London
Modeling in the Building Industry”. Autodesk Building Solutions Whitepaper, 
Autodesk Inc., CA.
research on building information modelling and construction informatics: concepts 
and technologies. IGI-Global, New York, 30-64
Use of Off-site Production on Construction Projects, Architectural Engineering and 
Design Management, 1(3), 153-162
BSI (2007) BS 1192:2007. Collaborate production of architectural, engineering and 
construction information – Code of practice. British Standards Institute, UK
Identification and classification - Code of practice, British Standards Institute, UK
BuildingSMART. (2011) Constructing the business case for BIM. International Alliance for 
Interoperability, 1-20
States for On-Site and Off-Site Activities. Journal of Construction Engineering 
Management,134(7), 517–526
Information Modeling for Owners, Managers, Designers, Engineers and Contractors. 2nd. John Wiley & Sons, USA
Environment, Transport and the Regions, London
Emmerson Report (1962) Survey of the problems before the construction industries (The 
buildings: pre-configuration and re-configuration - two case studies. IN: M. Sharp 
ed., Manubuild - Proceedings of the 1st International Conference, The 
Transformation of the Industry - Open Building Manufacturing. Doelen Congress 
Centre, Rotterdam, Netherlands, 25th-26th April 2007, 149-159
Expectations and Drivers. “Building Research and Information”, 31(2), 146-160.