BIM in the Water Industry: Addressing Challenges to improve the project delivery process

Suresh Renukappa[1,*], Subashini Suresh[1] and Andrew Kamunda[1]
[1]University of Wolverhampton
* email: Suresh.Renukappa@wlv.ac.uk

Abstract

The UK Government BIM implementation 2016 target for all public projects formed the major driver for the construction industry to upskill and learn new ways of working. The water industry is a private sector that has no mandate to implement BIM and would also benefit from its use. Research has identified that fragmentation and inefficiency still existed in the water industry project delivery processes. These issues can be addressed by harnessing the collaboration that BIM brings by using emerging information technology. The UK water industry has had little research in the use of BIM in the project delivery processes over the years. Therefore, the aim of the research is to explore and examine BIM use in the water construction industry, as well as understand the challenges faced and how they are being addressed to improve project delivery processes. The qualitative case study approach was adopted for the collection and analysis of data which was carried out by undertaking observations, document reviews and semi structured interviews. A water company and a design and build contractor on a framework formed the research sample. The design and build contractor was also part of other water industry frameworks. The research findings identified that there are similarities between the water industry and the other infrastructure sectors in the use of BIM realizing benefits of collaborative working. These benefits included improved information quality, cost reductions, shorter programme durations and greater collaboration. However, BIM was yet to be fully understood and used which led to challenges of overcoming and changing organizational cultures, developing levels of BIM expertise, data and information control, interoperability and data entry. The research also identified that the water company was lagging in BIM use despite noticeable benefits shown by its supply chain. The paper concludes by identifying that the water industry supply chain has taken positive steps and started to benefit from BIM use. However, more needs to be done as BIM is still in its infancy facing challenges associated with changing organizational cultures. The research recommends that the water industry and its supply chain should continue to invest more resources in implementing BIM to achieve the benefits realized by other sectors with NBS and CITB becoming more visible. This should include staff training, creating standardized approaches, processes to harness the collaborative nature of BIM.

Keywords: BIM, water industry, challenges

1. Introduction

The UK water industry has been undergoing significant changes which have impacted on water companies and its supply chain. Since the water industry's privatization 25 years ago, over £100 billion have been spent (NCE, 2014a). The National Audit Office (NAO, 2015) expects a capital expenditure of £44 billion in Asset Management Period (AMP) 6 (2015-2020) whereas Hackett (2018) predicts an expenditure of £50 billion in the next AMP7 (2020 to 2025) which is a 13% uplift from AMP6. However, there have been calls for infrastructure investments to be based on sustainable and efficient solutions to meet an increase in population, climate change and technological changes. Most of the existing water infrastructure is the creation of engineering innovations from Victorian times. Although this is an incredible legacy, it has not been nurtured as it should be particularly over the last forty years. Until recently, capital investment programmes have been undertaken to varying degrees by the water companies to upgrade its infrastructure (CST, 2009).

Back in 2006, Rezgui and Zarli (2006) highlighted that the construction industry was moving from using traditional physical elements to information technology software with intelligence. This was supported by Hardin and McCool (2015) who pointed out that the construction industry was in the midst of a technology renaissance; however, the new technology did not fit into the previous project delivery processes. The NCE (2014) further ruled the processes as inefficient needing more collaboration and integration. These processes were also deemed broken in 2017 leading to delivering expensive assets, poor performance and failed to make best use of emerging technology (ICE, 2017). The use of collaborative Building Information Modelling (BIM) presents opportunities to remove these inefficiencies (Owen, et al, 2010). Using BIM involves sharing of information and presents diversity of risk areas hence there is a need to identify challenges and barriers which becomes a prerequisite to its application (Khosrowshahi and Arayici 2012).

The UK Government mandate for use of BIM for all public projects starting in 2016 formed the major driver for the construction industry to upskill and learn new ways of working. Big organizations tend to undertake most capital work due to stronger financial positions and likely face more difficulty in the use of BIM (Miller, 2012). However, financial implications and skills shortages on BIM implementation were cited by Sinclair (2012) as barriers. Azhar et al, (2008) identified model ownership as the first barrier for BIM use. These challenges might become hindrances to project progression if not addressed.

The UK Government has stated a key aspiration for the construction industry to be efficient and technologically advanced through the Construction Strategy 2025 (HM Government, 2013). There is emphasis on the use of BIM being able to form a basis for meeting efficiency and technological 2025 targets. These targets include achieving 33% cost efficiency, delivering 50% faster and achieve 50% reduction in greenhouse gases emissions. However, there is a realization that there is a great challenge to fully embrace and implement BIM (HM Government, 2013). This provides a significant driver for this research project for water industry projects.

Schefer in the NCE (2014) stated that there is a need to think differently. Water companies and its supply chains must be more integrated and collaborative. Inherently, most water companies are set up around planning, delivery and operations as different departments with a breakage somewhere between the two components. BIM would solve the above stated issues if BIM is used correctly (Kemp, 2014). Furthermore, significant efficiencies, cost savings and improved delivery of client's value in construction can be achieved by correctly utilizing BIM (ICE, 2015). It was expected that BIM will advance its importance in the UK water sector AMP6 period (NCE, 2015a).

Rezgui et al, (2009) stated that despite the advantages that follow BIM utilization, there are several issues that have derailed its adoption. The concerns include trust, authentication, security, validation, quality, ownership and other related issues. By addressing these concerns and challenges construction projects would yield the benefits associated with effective BIM use. In addition, UK water projects will meet the objectives set by Ofwat and address the shortfalls identified by Latham (1994) and Egan (1998).

2. The UK Water Industry: Then and Now

2.1 The Water Industry History

The water industry was disjointed up to and through the Second World War, with development required due to an increase in water demand, industrial revolution, economic growth and population increase. A drought in 1959 and flooding in 1960 led to the recognition of the importance of collaborative planning and to the creation of the Water Resources Act in 1963. However, planning challenges continued in the 1960s and 1970s which resulted in the restructuring of the water industry; ten water regional authorities were established to manage water resources & supply and water & sewerage services on a full-time basis in adherence to the Water Act, 1973. Economic challenges in the 1970s and 1980s led to changes in the legislation with the Water Act, 1983 reducing the government's decision making whilst local authorities could seek private investment (Ofwat and Defra, 2006).

However, these approaches and changes failed to yield the intended benefits and led to the privation of the water companies in 1989 to access private funding. The privatization led to the creation of three regulatory bodies which represented the public interests, The National Rivers Authority (superseded by the Environment Agency), Office of Water Services and Drinking Water Inspectorate (Ofwat and Defra, 2006).

2.2 The Water Industry Today

The industrial revolutions, urbanization, increasing economic demands and increasing environmental requirements shaped the status (Ofwat and Defra, 2006). The UK water industry's key purpose is to provide safe drinking water and effective wastewater management (CIWEM, 2010). It consists of relatively small Water Only Companies (WOCs), and Water and Sewerage Companies (WaSCs), which are larger and offer water supply and sewerage services (Hainworth and Salvi, 2017). These can be regional or local companies, (a) water supply and (b) water supply & sewerage licensees and infrastructure providers delivering large infrastructure projects. Most customers are served by monopoly water companies for their water and sewerage services (Ofwat, 2019). See Table 1 below.

Table 1: UK WOCs and WaSCs (Hainworth and Salvi, 2017)

<table>
<tr><th>Water and Sewerage Companies</th><th>Customer (millions)</th><th>Water Only Companies</th><th>Customer (millions)</th></tr>
<tr><td>Anglian</td><td>6.7</td><td>Affinity</td><td>3.5</td></tr>
<tr><td>Dwr Cymru (Welsh Water)</td><td>4.1</td><td>Bristol</td><td>1.1</td></tr>
<tr><td>Northern Ireland</td><td>1.8</td><td>Dee Valley</td><td>0.3</td></tr>
<tr><td>Northumbrian (inc Essex & suffolk)</td><td>3.6</td><td>Portsmouth</td><td>0.7</td></tr>
<tr><td>Scottish</td><td>6.7</td><td>Bournemouth</td><td>0.5</td></tr>
<tr><td>Severn Trent</td><td>10.4</td><td>South East</td><td>2.1</td></tr>
<tr><td>South West</td><td>1.6</td><td>Sutton & East Surrey</td><td>0.7</td></tr>
<tr><td>Southern</td><td>4.6</td><td rowspan="5">South Staffordshire (including Cambridge)</td><td rowspan="5">1.6</td></tr>
<tr><td>Thames</td><td>14.9</td></tr>
<tr><td>United Utilities</td><td>8.5</td></tr>
<tr><td>Wessex</td><td>3.1</td></tr>
<tr><td>Yorkshire</td><td>6.0</td></tr>
</table>

he UK water industry operates on five-year cycles, called Asset Management Planning periods (AMP) where projects are planned, and budgets set. Under the regulation of Ofwat, (The Water Services Regulation Authority) water companies submit price reviews (PR) to Ofwat which detail their proposals on how they intend to deliver customer needs and wants, the latest being PR19, i.e. Price Review 2019.

Ofwat reviews them and provides water companies with feedback on either approval, rejection, requirement for more information or revision of proposals (Ofwat, 2019).

Bailey (2003) stated that the water industry's significant capital works is carried out and provided by the construction industry engineering and construction organizations. These organizations form the supply chain which has technical expertise that allows them to undertake capital works as delivery partners to the private water companies. To date, creation of frameworks, with fewer partners in a settled supply chain have been undertaken in response to the publication of the Egan and Latham reports which highlighted the need for greater collaboration between clients and the supply chain (Cabinet Office, 2011). Anglian Water named its framework partners for the current and future AMP in 2014 with contracts that span 15 years (Anglian Water, 2014). Back in 2013, Thames Water's Asset Director Lawrence Gosden, stated that "*the decision to deliver the investment programme using an alliance marked a complete transformation in the way the company delivers capital investments*" (Thames Water, 2013). United Utilities, Wessex Water, Severn Trent Water, Southern Water, Yorkshire Water and Welsh Water are other companies that have also created frameworks (Construction Enquirer, 2015).

2.3 The Water Project Delivery Process

Most UK construction projects are delivered following the model developed by the Royal Institute of British Architects (RIBA) called the Plan of Work. The Plan of Work is a process model for delivering building and construction projects which provides a shared framework for organization and management. It is widely used as a process map and a management tool providing work stage reference points, in a multitude of contractual, appointment documents and best practice guidance (RIBA, 2012).

Stage 0 is developing of strategies which define project descriptions (RIBA, 2012). Water companies' Project Reviews submission to Ofwat form Stage 0 for some projects, which are prepared carried out their internal teams (Ofwat, 2015). The project is strategically appraised and defined before preparing a detailed project brief. The strategic definition stage which is also called the inception stage, is where the decision to invest in a construction or development project is made (CIOB, 2010).

During Stages 0 and 1, the Project Brief is developed which is a description of the project scope. Stage 2 is for Concept Design development and includes preparing outline designs, specifications, proposals, strategies and cost data whereas Stages 3 and 4 are for design development which lead into construction i.e. Stage 5. The next stages 6, and 7 are handover, and operation and maintenance respectively (RIBA, 2012 and Anglian Water, 2014).

2.4 BIM in the Water Industry Project Delivery Process

The Construction Project Information Committee (CPIC) (2015) defines BIM as "*digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition*". BIM itself is not a technology but a data rich model-centric business process with the power to transform project delivery. This transformation adds value across the full lifecycle of infrastructure assets – plan, design, build and manage. It is a knowledge process about the way to build things (Autodesk, 2015a) and involves creating and utilizing intelligent 3D models (Autodesk 2015b). For the purposes of this paper, the BIM definition by CPIC (2015) will be adopted.

The UK Government BIM Task Group established the BIM4Water Group after publication of the Construction Strategy (BIM4Water, 2015). This is a cross industry group open for all organizations involved in the delivery and management of water and wastewater projects in order to support adoption of BIM. The BIM4Water (2017) Task Group highlighted that BIM is already changing how capital projects are being delivered and how asset information is created and exchanged; this has been delivered benefits and created value opportunities throughout the asset management cycle. These opportunities are driven by use of digital technologies in capital projects.

BIM4Water (2017) regarded BIM as a business change that will take years to fully embed requiring investment in processes, people and systems to yield long term benefits. There is a need to align BIM with data, information, digital strategies and security though there is exists practices across the water industry. This will lead to BIM evolving to become more aligned with national BIM standards to deliver aspirations set out in the UK Government Construction 2025 Strategy. BIM4Water (2017) has called the water industry players to be part of the Digital Britain to enable accessing new efficient ways of working as in the case studies below.

The Anglian Water Recycling Centre Extension project was carried out using BIM which showed significant improvements in business processes yielding delivery time and cost savings. The Semer Water Treatment Works, an Anglian Water project used 3D modelling aligned with programme and the associated commissioning plan which led to removal of significant business risk associated with an old unreliable borehole source. Severn Trent Water use of BIM on the Minworth wastewater treatment facility project led to a £5 million and 13.5% cost saving (BIM4Water, 2019). According to NCE (2014), BIM real benefits go to the client as it can reduce whole life costs of the asset during operations. There is the recognition by clients, contractors and consultants that the significant benefits of BIM use stem from sharing of data throughout the project lifecycle, optimising design performance, reducing errors and reduced project durations. BIM offers a unique opportunity (RIBA, 2012) and is regarded as the driver to revolutionize construction projects delivery. This is a shift from the traditional inefficient paper-based processes with fragmented project teams to a more integrated, seamless transfer of data between collaborators who are incentivized to deliver whole life cost savings (Building, 2014).

Implementing BIM has not been without its challenges as it is a new way of working. Khosrowshahi and Arayici (2012) and RIBA (2012) stated that the main challenges to the use of BIM has been firms not being familiar to its use, unwillingness to train staff, or initiate culture changes or new processes or workflows, unwilling to procure respective software and technology. BIM4Water (2015) goes on further to state there is a need raise BIM awareness through training people on how to manage and using asset data. Other challenges and barriers to BIM adoption include (a) higher expectations from the supply chain, (b) inconsistent or multiple protocols, (c) significant culture change to adopt BIM, (d) lack of informed clients and (e) the need to define new roles. It is apparent that challenges stem from the need to change from business as usual organizational cultures which comes with progression into the unknown BIM environment (BIM4Water, 2017). Hence there is a need to explore and examine use of BIM in a project delivery setting, to understand the challenges and thus identify solutions to solve them. This would enable water projects achieve the cost and programme benefits of using BIM. There is also little research in the area addressing BIM challenges at project delivery team level and this study aims to fill some of these gaps.

3. Research Methodology

A research should be conducted to correspond with the availability of needed data (Neuman, 2014). The research aims, and objectives point towards investigative work as BIM has not fully matured in the water industry despite making some progress and there are limited study findings in the subject (BIM4Water, 2017). Hence, there is a requirement to understand perceptions and experience the project delivery processes in relation to BIM. A qualitative research approach was selected for the research as it is a method of discovering and understanding the meaning of individuals or groups ascribed to a social or human issue (Creswell, 2009) which met the research aim and objectives of understanding what is going on, by what people say or what they do with BIM in the water industry projects.

The study required an in-depth analysis of the water companies and the supply chain's BIM implementation to support the literature findings on benefits achieved by addressing challenges. This pointed towards a case study approach which can elaborate on an entire process holistically and allow incorporation of multiple perspectives (Neuman, 2014). A case study's ability to incorporate multiple data sources and provide detailed account of complex research phenomena in real life context made it suitable. It is regarded as a viable way of carrying out qualitative research and involve in-depth exploration and to supports use arguments with conclusions related to a related topic. Hence the data was collected from the review of two water companies and its supply chain, review of intranets to understand project delivery processes and documents, observing organizations' cultures, behaviors and undertaking selected interviews of five project participants based on theoretical sampling methodology. Two interviewees were BIM technicians, two were project designers and one was a project leader. This sample represented the design team involved in project delivery.

4. BIM in Practice

4.1 Organizational Culture Support for BIM

BIM is regarded as a shift from the traditional way of delivering projects and requires organizational culture process acceptance and changes to implement it. According to Aranda-Mena *et al*, (2009), BIM facilitates integration of fragmented practices and acts as a catalyst for changing business processes. Autodesk (2015a) pointed out that the use of cloud-based technology in BIM allows carrying out multiple iterations of very complex analyses in near real time versus minutes, hours, or days.

The study identified that BIM has already changed how projects are carried out by the two water companies and the supply chain. The organizations had set up information technology systems that allow hosting BIM technology and processes. This includes rolling out of ProjectWise, a collaborative file saving and sharing cloud-based platform and training staff in its use. Project delivery management took the lead in prompting project managers to use BIM, or its elements, during project inception or reviews. One of the study organisations had prepared and implemented a BIM Execution Plan as part of the water company framework, making it a reference document for project delivery. This stated the provided information technology that needed to be used to support BIM (Autodesk Revit, Civil 3D, Navisworks, Piping & Instrumentation Diagrams and Revit to Excel links). The organisation put in place measures to support BIM, as they had identified this as an enabler for realising BIM benefits. This addressed the challenge of procuring the respective BIM software (Khosrowshahi and Arayici, 2012).

BIM4Water (2015) points out that there is a need raise BIM awareness on the need for people training and that upcoming designers and contractors should embrace the new collaborative working methods (RIBA, 2012). During an interview, an individual stated that BIM was in its infancy and is being gradually developed within their organisation. Training support was offered by all the organisations within the study cohort, however some interviewed think that more can be done as this is restricted by organisations allocated budgets. However, in one organisation, BIM Technicians were allocated training budget associated with their skill level and regular training was encouraged by management to ensure that experience was passed onto their respective projects.

The study also observed that none of the two water companies themselves had processes and information technology that supported BIM. BIM4Water (2015) highlighted that the construction industry broadly agrees with BIM intended benefits; however, challenges to be overcome are associated with measuring the benefits and costs consistently and identify recipients of the benefits and justifications. For clients, they would want to identify the problems and what they need to do to meet their regulatory requirements, at the cheapest cost. The study observed that this was the approach for the research cohort as the water companies left BIM use to the supply chain as they deemed them best suited to use it. However, the water companies carried out relatively very small projects which did not justify investing in BIM processes from their own perspective.

4.2 BIM and its Elements in Use

Bernstein and Pittman (2004) cited barriers to broader adoption of BIM as extending beyond the often-stated relationships between software applications to interoperability. The use of IFC is identified by as the solution to interoperability issues. IFC allows exchanging relevant data between different software and is regarded as fundamental to open BIM (NBS, 2017). GCA (2015) implemented BIM by using the Autodesk suite tools which are quite common in engineering design. The use of commonly used engineering Autodesk suite software allowed GCA (2015) to realise saving hundreds of design hours, avoiding problems, saving project time, cost and identifying engineering opportunities in design. Azhar *et al* (2008) and BIM4Water (2017) highlight that BIM can be used for purposes which primarily include *three dimensional* visualisations which are created directly from the models and contain underlying information. (Autodesk, 2015a) provide an example of a BIM water project case study which had integrated 3D model generated for the entire project.

BIM models are regarded as data and information rich with the ability to gain quicker approvals from water company client managers and site operatives. Three dimensional models are shared and present real-life representation of the asset to be built. One of the water company's solution engineers undertook an in-house presentation on a BIM delivered project stating that 3D models enabled site operatives to see what they were getting, which enabled them to recommend their preferences on access to plant and equipment for operations and maintenance activities. However, the water company did not have any information technology systems to create these models but utilised those provided by the delivery partner. To address the barrier or challenge of interoperability, 3D models were generated and embedded in Acrobat pdf software which could be accessed from most computers with free software. As data and information rich, BIM models were also used to extract schedules for procurement of respective equipment and plant. These were extracted to Microsoft Excel and Acrobat pdf files which could be accessed by most project participants. Though not used, use of open BIM would have allowed the delivery partners to share this information through IFC. Despite the young age of BIM in the Water Industry, benefits from the 3D generated views and reality has enabled greater collaboration. There is the coming of age of the ability to extract data and information quicker than before BIM use which is having positive impact on project delivery programme, cost, and quality.

4.3 BIM is here, what's next?

BIM4Water and British Water has enabled meetings of the BIM4Water Owner Operator Group formed in 2016. This group is made up of Water and Sewerage Companies in England, Scotland and Northern Ireland (BIM4Water, 2017). The water industry has been holding several workshops, seminars and events on BIM in the industry. The topics developed were being driven by the ever-increasing use of BIM in the water industry and how to reduce costs for asset owners, suppliers and contractors. It is highlighted that the water sector is beginning to reap the rewards of using BIM with an expectation that it will increase in the coming years (WIF, 2015).

Both water companies in this study form part of the BIM4Water Group and continue to support its goal of supporting the water industry to implement BIM and realize the benefits. BIM is considered to be in its infancy regardless of the years that have passed. Use of emerging technology e.g. Autodesk Revit, Civil 3D, Revizto, and virtual reality has gained traction and is leading organizations continue to invest in these areas to remain relevant. This was identified for all the organizations in this research.

5. Conclusion

The UK water industry has been lacking behind in implementing BIM as it is not mandatory. However, BIM has been adopted since other industries have been achieving positive benefits. These include achieving cost efficiencies, shorter project durations, and better-quality outputs. The water industry supply chain has started invested in procuring respective BIM software to allow them to implement it. The organizations have also put in place processes and cultures to ensure that BIM use steadily increases. However, there are challenges that continue to be faced which include lack of adequate training in some organizations due to budget constraints whereas others are doing well. The key benefits for the Water Industry on BIM implementation include visualizations in three dimensions of the assets to be built to obtain client approvals, improving collaboration as well as designing out inefficiencies. The other use is the ability to extract schedules which are then used for procurement to enable installation during construction.

There is a need for organizations to continue to review what BIM can do for them and how it can improve the way they work as its use increases and organizations continue to invest and develop led by BIM4Water. BIM definition has been explained, with BIM4Water preferring the term "Better Information Management" to make it express a better way of working which is leading to benefits being achieved in the water sector. Organizations should utilize BIM as a tool to create a competitive advantage as it is seen as being cost effective, which reduces project durations and improves quality of the end product. The open BIM platform and use of IFC for the sharing of digital information in different format should be taken advantage of and organizations like NBS & CITB should become more visible to the water industry. This research recommends that further studies are carried out to determine the effects of mandating BIM for water projects as the UK government has done for public projects.

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