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An Evaluation of BIM for the Water Sector in Ireland

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Abstract – The level of BIM adoption is increasing within the AEC industry as a whole. However, some industries have been slower to adopt BIM than others, the water sector being one of these. This paper focuses on the use of BIM for water network distribution networks. If BIM is to be promoted within the water sector in Ireland, it is important to first understand why the industry is not choosing to adopt it. This study will aim to determine if it is because BIM is not suitable for their projects or if it is other factors like an unwillingness to change their methods. This paper investigates the benefits and barriers for implementing BIM on water supply projects. This will be achieved by carrying out stakeholder analysis in the form of interviews with industry professionals. The findings of the stakeholder analysis will then be used to develop an assessment model to evaluate if BIM is being implemented successfully. This assessment model was tailored for use by a Client in the water sector. This paper shows that BIM is suitable for use on some water network distribution projects. However, there are a number of considerations to be taken into account when deciding if BIM is suitable for a particular project.

Keywords – BIM, Distribution Network, Watermains, SLAM BIM, Water.

I Introduction

Building Information Modelling (BIM) technologies are used to deliver data and information collated over the life of an asset. BIM is responsible for a digital upheaval to the traditional way of constructing and managing an asset [1]. BIM provides interoperability to the Architectural, Engineering and Construction (AEC) industry by providing information throughout a building's lifespan. BIM focuses on the creation, storage and management of information relating to an asset from concept design all the way to demolition [2]. BIM is more than just a change from 2D traditional methods to 3D modelling. It has changed the delivery process of a project [3]. A new term, Civil Information Modelling (CIM), refers to the application of BIM for civil infrastructure projects and facilities. The main differences between CIM and BIM are the structure and components, the terminology and the modelling methodologies. Despite their differences, BIM and CIM use the same data management and exchange processes [3]. This paper sets out to examine the potential benefits and barriers to the adoption of BIM for the Irish water sector. A review will be carried out of available literature surrounding the use of BIM for infrastructure projects in general but also focusing on the use of BIM by the water sector. This review will be used to inform a stakeholder analysis process involving interviews with professionals in the Irish water sector. The stakeholder analysis aims to gain insight into the current adoption, understanding and opinions of BIM within the industry. Using the information gathered by this study, an assessment model template will be developed to provide a repeatable method to determine if BIM adoption is successful.

II BIM Adoption In Ireland

The first step of this study was to understand BIM adoption in Ireland. BIM was highlighted as an opportunity for the sector to enhance its competitiveness both at home and abroad [4]. The government, educators and the industry in Ireland have recognised this and it can be seen by the increased adoption of BIM [4]. The Third Irish National Survey which benchmarked the level of the BIM adoption in Ireland, marked an increase in confidence of organisations in their BIM knowledge and skills from 66% in 2015 to 75% in 2017. Some also noted an improvement in both their knowledge and skills related to BIM. The survey found that there is an increased demand for BIM within the Irish AEC sector. It was noted during the survey that the UK mandate influenced the uptake of BIM by Irish companies as private clients were adopting the Level 2 BIM requirements [5]. The National BIM Council released a roadmap for the adoption of BIM in 2017 aiming to achieve a 20% reduction in costs and programme and a 20% increase in construction exports by 2021 [6]. The roadmap proposed to achieve this by increasing BIM adoption in the construction industry. The document sets out the government's strategic goals and the key actions to achieve these goals. The goals aim to get government, industry, and academia working together to create an industry which possesses the skills, experience and knowledge to place Ireland as a competitor in this sector [6]. The Office of Government Procurement (OGP) [7] developed a position paper outlining their BIM adoption strategy for the public sector. This document describes the benefits, challenges and risks of adopting BIM. It also discusses the policy frameworks surrounding BIM in the EU. The position paper examines the Government's position on a BIM mandate. It looks at ensuring adequate investment by public bodies to provide the necessary resources for BIM adoption and to define uniform standards relating to BIM across the public sector. Public Private Partnerships already include BIM requirements. Within the document, projects are categorised into bands dependant on their complexity. These bands will determine the level requirements of BIM and the timeline in which the requirements are to be introduced.

It is clear that the AEC industry is adopting BIM in Ireland. However, specific sectors have different levels of adoption, which is true for the International AEC industry. The next step is to examine the BIM adoption for the infrastructure sector as a whole. It is important to acknowledge that BIM is being successfully adopted in other sectors, which raises the question of why BIM is less prevalent in the infrastructure sector.

III BIM For Infrastructure

The infrastructure industry is moving away from physical documentation and adopting digital technologies such as BIM. Infrastructure assets differ from other sectors as the asset is fundamental to the business rather than providing a space for the business to take place [1]. The use of BIM for an infrastructure project has a different desired outcome than other BIM applications. The primary driver on infrastructure projects is advanced asset management capabilities during the operational phase. Whereas construction benefits most from the detailed geometry data allowing for coordination and clash avoidance, infrastructure benefits more from the non-graphical data collected within the model [8]. For BIM to be a successful asset management tool, it is important that the information collected considers the object's function within the complete asset set and not just it's immediate attributes [1]. Infrastructure asset management systems currently comprise of documents, databases, GIS and multisource analogue data. The current asset management systems are built around work planning and maintenance instead of the asset itself [1]. Irish Water (IW) is a major investor in the infrastructure sector in Ireland. In order to be able to assess the suitability of BIM for the Irish water sector, it is important to understand IW's role in the industry.

IV Irish Water's Role in the Water Sector

IW is Ireland's national water utility, established in July 2013. The Irish Government tasked IW to take responsibility for the water and wastewater services previously provided by the 31 local authorities. This includes management of national water and wastewater assets, maintenance of national water and wastewater systems, investment and planning, managing capital projects and customer care and billing [9]. IW is responsible for the operation and maintenance of 88,000km of water mains and approximately 7000 water and wastewater assets [10]. IW inherited a largely fragmented network of assets from the local authorities [11]. The water sector also suffered from underfunding for decades which resulted in inadequate maintenance and upgrading of aging assets [11]. There is a lack of historical asset data which impedes the ability to reliably operate assets. It has resulted in inefficiencies in plant maintenance and impaired capital investment decision making [11]. IW plan to invest €5.5 billion between 2015 and 2021 and have set a goal of saving €1.1billion in Operational Expenditure (OPEX) and €500 million in Capital Expenditure (CAPEX) by 2021. Adopting BIM offers IW a potential methodology to help achieve their goals [10].

The literature examined below focuses on the use of BIM in the water sector. The literature was reviewed with the aim of investigating if IW was to adopt BIM as a standard operating practice, could BIM help them to achieve their goals of reducing inefficiencies. This study will investigate if the use of BIM will allow for better management of IW assets through improved asset information management.

V BIM for the Water Sector

Jones and Laquinda-Carr [12] carried out a study assessing the value of BIM for water projects observed by engineers, contractors and owners who implemented BIM previously. It provides critical insights into the BIM process for the water sector. 74 engineers, contractors and owners within the water sector responded to the survey. It stated that the participants had high expectations of BIM use in design and construction to support operations and maintenance (O&M) as well as asset management [12]. It found that those who used BIM previously plan to use it more going forward. This suggests that the use of BIM in the water sector will become more common in the future. The majority of projects where BIM was used were water / wastewater treatment plant projects [12]. A vast majority reported that on some of their projects, BIM was used to enhance O&M activities. The most significant benefit to a business was found to be working collaboratively with other companies. The biggest benefit to a project was found to be the development of better design solutions [12].

BIM4Water is a group in the UK set up to support and promote BIM adoption in the water sector. The group is comprised of clients, designers, contractors, suppliers, sub-contractors and other bodies. BIM4Water developed a guidance document for the water industry. It examines the benefits of implementing BIM for the water sector, how BIM supports organisational objectives set out by UK regulators, benefits for the client, the customer, operational benefits and project delivery benefits [13]. The document defines six golden rules to ensure that BIM is successful. It highlights areas that may need attention when implementing BIM. The document provides guidance on how to utilise the PAS 1192 suite of documents for the water sector. The document finishes up by examining the potential for collaboration through BIM [13].

This document provides a well thought out and explanatory high level explanation of the BIM process. While this document is aimed towards the client and owners within the water sector, it can be used by other actors within the industry to determine what will be required from them when utilising BIM on water projects. One criticism of the document is it appears to be biased in favour of BIM without examining any potential limitations of its adoption for the water sector. The document focuses on the benefits and opportunities that come with implementing BIM. Despite the limitation of this document, there are still prevalent opportunities for Clients to apply the findings to assist with BIM implementation which will, in turn, encourage the supply chain to actively begin implementing BIM.

In an interview, Andrew Cowell the Chair of BIM4Water, maintains that it is essential for the water sector to ensure that it is involved in BIM to help mould the future of the process instead of complaining that BIM doesn't fit the water sector. According to Cowell, despite the fact the water sector in the UK bar Scottish Water has no obligation under the BIM mandate, the water sector in the UK is making progress implementing BIM. He indicated that the water sector is outside the requirements of the mandate and has in his opinion made the task of introducing BIM for water more difficult. He also stated that defining the benefits of implementing BIM for water has been arduous, hindering the adoption of BIM by water companies [14]. Cowell believes standardisation across the sector through development of a supply chain framework incorporating BIM may help in improving efficiency and reduce individual utilities developing standards. He believes the current perception is that BIM focuses on the 3D representation of a project despite the asset information gathered within BIM being more beneficial. He discusses how people tend to associate the standards such as the PAS 1192 suite of documents with BIM and they forget that the documents focus on information management [14].

Bentley Systems' Senior VP Santanu Das discussed the comparison of BIM processes and traditional modelling approaches used by the water sector. Das describes BIM as a process that collects data created by designers / contractors that can be coordinated with existing operational data held by the client. According to Das, one of the main advantages of BIM over traditional methods is the centralised repository that has both a 3D representation of the asset and the CAPEX and OPEX information used to run the asset [15]. Das conveys how BIM improves coordination through the use of a Common Data Environment (CDE) as a single source of the latest information, reducing the potential for project participants using outdated information. BIM also allows for better analysis of energy and operational costs. This supports better assessment and selection of design options. These benefits of BIM can lead to a reduction in total expenditure (TOTEX) [15]. Das states that few clients are utilising BIM and the sector has fallen behind other sectors. Das theorises that one reason for the lack of uptake may be that owners, designer and contractor believe that they can't justify upgrading their 2D process to a BIM process. He states "designers consider the complexity level to be lower for water sector facility designs" than the likes of offshore oil rigs [15]. He claims that industry leaders are realising that they must adopt BIM to remain competitive. He speculated that the relative cheapness of water compared to other sectors like oil and gas means that the industry is less driven by efficiencies [15].

Treatment plants are complex systems of structures which are required to manage multiple processes concerning fluid mechanics, microbiology and chemistry. The design of these systems involves input from different disciplines meaning collaboration is essential. Traditional design methodologies can no longer meet the demands of modern complex treatment works. BIM offers a solution to this complexity [16, 17].

A number of case studies on the use of BIM in water/wastewater assets were examined. Examples of the case studies are Shek Wu Hui Sewage treatment works, Liverpool Wastewater Treatment Works, Seafield Wastewater Treatment Works Thermal Hydrolysis Plant in Edinburgh, Scotland, the Skyway Wastewater Treatment Plant Expansion in Ontario, Canada and the upgrade of a secondary pumping station in Qingdao, China. From the review of these case studies, it is clear that BIM is beneficial for use on Water and Wastewater Treatment Plants. The benefits that were identified through these case studies are discussed below.

Better visualisation which leads to improving understanding of design, faster and more accurate design review with issues being identified during the design process instead of on site. 3D models can also demonstrate value engineering solutions to clients [18-20]. 4D simulations were also used to coordinate the works with operations staff to ensure that existing assets could be operational and maintenance works could continue during the works. 4D simulations were used to identify scheduling errors avoiding delays [16, 18, 19]. Leung [18] stated that adopting BIM on the project reduced working time and improved the clash detection process. The 3D model was used as a tool for communicating on site such as site inductions, toolbox talks and risk assessments [20]. Another benefit of BIM is its ability to create and handle complex, intelligent objects. These objects can have information about the object which can then be used in simulations and analysis to optimise the operation of assets [16]. Energy analysis utilises the embedded information within the objects in the model. Traditionally this information was stored in documentation and pump curves, which made it difficult and labour intensive to collate this data for analysis. This information can be directly exported from BIM into analysis software ensuring that the energy usage of assets is considered as a whole and not separated into the specific discipline silos [21].

One issue identified is that the planning and operation of these plants are not fully supported by Open BIM concepts using the current IFC schema [17]. “Open BIM” is defined as BIM using non-proprietary neutral file formats such as IFC. These projects would have to be carried out using “Closed BIM”. Closed BIM is defined as a BIM environment in which all participants are using the same software. Using the current standardised BIM data formats restricts the description of WTP/WWTP to necessary construction information such as geometry and materials, thus limiting its effectiveness. Development of a WTP/WWTP specific schema would allow for improved collaboration and data exchange [17]. It was noted that BIM was being used in the design and construction of water and wastewater management assets to a degree of success as covered above. However, it was also noted that there is a distinct lack of material comprising the use of BIM for distribution network projects. A review of the available literature regarding BIM for infrastructure was carried out by Cheng, Lu & Deng [3]. This review examined nine categories of infrastructure including utility infrastructure which was defined as electricity, natural gas, water and sewage delivery systems and pipelines. It found that only six of the one hundred and seventy one industry cases and three of the sixty two academic papers covered the category of utility infrastructure [3]. This lack of information surrounding the topic made it difficult to critically appraise the use of BIM for distribution network projects. The majority of the literature collected for this study highlighted the benefits of BIM for the water sector.

Hore [22] stated that it is no longer a question of why the construction industry should adopt BIM but more a matter of how to. Based on the literature reviewed, it is evident that there are benefits for the water sector in Ireland from adopting BIM for use on water and wastewater treatment plants. The benefits can be seen from the design stage to the operational stage. IW have set a number of goals about creating efficiencies within their project delivery practices. BIM offers the potential to help achieve this through various functionalities while also offering efficiencies during the whole lifecycle of an asset. However, there is a lack of information relating to the use of BIM for distribution network projects and utility infrastructure as a whole; it is difficult to determine whether there are benefits from the use of BIM on the linear infrastructure projects. This study will engage with professionals within the water industry in Ireland to evaluate if there are potential benefits from adopting BIM on water network distribution projects.

VI Methodology

This section examines the methodologies utilised to carry out this research and the rationale behind their selection. The central research question focuses on the suitability of the use of BIM on water infrastructure projects in Ireland to develop an assessment model that can be used by IW and other utilities. A multimethod approach was adopted comprising of three distinct phases. Phase 1 used a literature review to critically assess current literature to identify the benefits and barriers of using BIM on water infrastructure projects. Phase 2 consisted of a stakeholder analysis with fourth generation evaluation. The aim is to interview key staff from the client, consultants and contractors to establish the current workflow, the current level of BIM adoption on these projects and get validation of the findings from the literature review. Phase 3 is to develop an assessment model to be used by IW or any utility to track the BIM adoption and success for all BIM projects. The methodology proposed for this phase is Success Level Assessment Model (SLAM BIM). This methodology sets out a systematic process to evaluate the implementation of BIM.

VII Stakeholder analysis with Fourth Generation Evaluation

Stakeholder Analysis with Fourth Generation Evaluation examines the claims, concerns and issues of stakeholders in order to focus the evaluation [23]. This methodology attempts to help the participants reach a consensus about the topic or to identify discrepancies and to further educate the participants through others' perspectives on the topic. The process is built on negotiated stakeholders' ideas and opinions on the subject [24-26].

A stakeholder can be defined as a person or persons that can be influenced by or can influence the actions of an organisation / project [27]. The process begins by identifying the stakeholders who are then invited to be interviewed to examine their claims, issues and concerns about the construct. The participant is asked to nominate another participant with different views and opinions to be interviewed. Each participant will be provided with the ideas and opinions gathered from the other participants and asked to critique them as well as the findings, thoughts and opinions of the evaluator. A consensus among the stakeholders is sought to be achieved through discussion, negotiation and interchange [23, 25, 26].

This methodology was chosen due to the nature of the projects being investigated. A distribution network project has a number of stakeholders involved in a project, the client, the local authorities, the consultants and the contractors. Each stakeholder may have a different value for BIM. Therefore it is important to investigate each of their perspectives. It was decided that this methodology was the most relevant and would allow for the best engagement with the stakeholders. The fourth generation evaluation will also allow the stakeholders to provide insight and feedback on the findings and assessment model developed in this study. The timescale of the study also made this methodology more suitable than others as it could be carried out over a relatively short period.

Due to the time constraint of this report, a modified version of this methodology was utilised. It was proposed to omit the step where the participants nominate another potential participant. This step was omitted as it would lengthen the time required to complete the analysis considerably. All participants were selected in advance of carrying out the interviews. It was also proposed that the fourth generation evaluation step of this methodology will be limited to reviewing the assessment model (SLAM BIM) developed, based on the information gathered in the interviews, as this is the main outcome of this study.

The interviews carried out were semi-structured to allow the interviewer to follow avenues that may arise during the process, therefore providing greater insight on the research topic. The researcher contacted a selection of people with knowledge of the industry to identify the most suitable participants.

a) Stakeholder Analysis Findings

During the Stakeholder Analysis process, a number of professionals were interviewed regarding the use of BIM for distribution network projects. The professionals were made up of Contractors, Consultants, Local Authority staff, Clients and software suppliers. The interviews were semi-structured with a set of key question relating to current workflows and their opinions on BIM. The interviews were where possible carried out in person, however some were carried out over the phone. The interviews were recorded and analysed at a later date. The interviews were reviewed a number of times to identify themes within in the answers. These themes will be discussed below.

b) Distribution Network Project Types

It was observed that there are currently two vastly different project types used for distribution network projects in Ireland that need to be considered. The first type is Water Network Projects (WNP). The second type of project is the traditional distribution network project using Design Build contracts. The WNP is used to replace aging and poorly performing assets through rehabilitation and replacement of existing watermains. This typically involves like for like replacement or upsizing of the existing main. Whereas the traditional project type is typically used for the construction of new infrastructure addressing supply or operational needs. These projects are more complex than the WNP and may include structures and other assets such as pumping stations. The WNP relies heavily on GIS while the traditional project uses various different software to carry out the more complex design. It would appear there is limited scope for BIM adoption for WNP as the design is uncomplicated and typically involves a single design team. Due to the added complexity and design requirements of traditional projects, implementing BIM would be beneficial. Some of the main benefits identified for traditional projects were as follows:

- the use of a CDE to act a single source of project information,
- the automation of manual or repetitive tasks,

- the production of sections for structures and chambers,
- quantity take-off from the model,
- access to asset information,
- better visualisation of the design,
- clash avoidance and rule checking capabilities,
- allows for a lot of issues to be resolved during design.

The main barriers to adopting BIM for traditional projects were identified as the cost and time investment as well as the changes required to cultural mind-set and contracts. The WNP has a number of barriers for the adoption of BIM

- software that carry out similar functions to that of BIM software: Enterprise Content Management (ECM) which acts similarly to CDE and Leakage Management System which fills a similar role to an Asset Information Model managing the asset information and performance. The Client has invested heavily in these systems and replacing them with BIM is not logical at this time as it would require additional investment into software and training of staff.
- heavy reliance on GIS, interoperability issues between GIS and BIM.
- works are typically carried out in urban areas with a large number of other buried services. The records for these services are for guidance only and are not reliable.

Some participants that are involved in the WNP said that aspects of BIM may be beneficial but that the investment required would not justify adopting BIM for these projects.

c) BIM Knowledge and Experience

A number of participants stated that they had limited knowledge of the BIM process. Approximately half of the participants in this study indicated that they had a limited knowledge or understanding of BIM. Despite stating that they had limited knowledge of the BIM process, the participants were both aware of and had some understanding of the process. Participants were asked what their understanding of BIM was; there was a number of different responses. Some focused on the production of a 3D model; others focused on the management of information. It is apparent that BIM means different things to different people. Raising awareness of what BIM is and its capabilities could help to increase its adoption. The use of various levels of education relating to BIM may help to raise awareness and provide clarity on the concepts and philosophies of BIM.

d) BIM Involvement and Drivers

The majority of participants stated that their organisation was involved in some sort of BIM project or are currently investigating BIM. It is noted that all BIM projects that were mentioned are Water and Waste Water projects. However, some participants advised that their organisation is currently investigating the use of BIM on distribution network projects. Whilst the majority stated that their organisation is involved in BIM projects or planning to implement BIM on projects, it appears that the current main driver for BIM implementation is the Contractor. Based on the information gathered during this study, the Client is currently developing a BIM strategy. At the time of this study, it is still under review by the Client's technical forum. However until that strategy is approved, the industry is relying on Contractors to propose the use of BIM on projects.

All participants stated that interoperability issues between BIM with other current software could be a potential barrier to adopting BIM. This was also noted in the literature review. The Client has invested in their GIS system and have a number of systems linked to the GIS that perform various functions helping the management of their assets. It was also noted that any hydraulic models used are built separately to design or as-built drawings / models. There is a growing number of software that allow for the integration of hydraulic modelling data in BIM software. This offers a significant efficiency to the Client and designers as they can use the design or as-built models to create or update hydraulic models. This, in turn, means better tools for planning and assessing the operation of the Client's network.

Each participant was asked if they thought that a government mandate similar to the UK could drive BIM adoption or impose BIM on an unreceptive industry. There were mixed reactions to this question. Some believe that a mandate may force BIM where it was not suitable. Others think that it has been successfully implemented in other countries and should be adopted here. Some of those opposed to the mandate were involved with the WNP. BIM may not be suitable for the WNP, therefore a mandate would not be beneficial for those involved. The reasons given by those opposing the mandate are that it would require a significant change to existing systems and processes. It would potentially be onerous on stakeholders and it may not be suitable for all projects. Those that support the use of a mandate were typically more familiar with BIM and had a better understanding of the process than those that opposed it. Based on information collected during the stakeholder analysis, work on a mandate is underway by a public body working group as part of the OGP BIM strategy. It was eluded to that there will potentially be a complexity threshold for projects that fall under this mandate. If this is the case, it may address some participants concerns regarding a BIM mandate in Ireland.

e) Current Practices and BIM Practices

It was noted that a number of elements of BIM have been adopted by the various stakeholders. It was pointed out that variations of cloud storage solutions had been adopted for both internal and project use, as similar to the role of a CDE. One participant stated that they were using a naming convention and status codes that to the researcher were identical to the naming convention set out in the PAS1192 suite of documents. Another participant compared the Client's asset register documentation to COBie spreadsheets and found them to be similar. Another participant advised that they were using Autodesk's Infraworks to create models for a drainage scheme. Infraworks is a BIM-enabled software. It appears that the industry is currently utilising elements of BIM without being aware of it.

f) Efficiencies

Throughout the study, a number of efficiencies gained through the adoption of BIM on distribution network projects were identified.

An efficiency identified by a number of the participants was the improved information exchange using a CDE. Information exchanges currently use a number of different methods depending on those involved resulting in project information being stored in various locations. The WNP has adopted a solution very similar to a CDE. However, it was noted that the Local Authorities do not utilise this. They receive sketches for design review directly from the contractor. This potentially means that records of design changes or comments are not fully recorded and may be missed by others.

Another efficiency identified was better visualisation as a result of 3D modelling opening up opportunities to better communicate the design. It enables better and faster design review. It also helps plan works while considering operational requirements of existing assets. By identifying issues during the design stage, it reduces costs and delays on site benefitting all project stakeholders. BIM also offers the functionality of creating viewpoints of issues to clearly and visually identify the problem. The issue can be assigned to the person responsible for its resolution and shared through the live model. The 3D model can be used for planning application and consultation with the public allowing people without an engineering background to understand the implications of the project.

The automation of tasks was also noted during the study as significant efficiency gained with BIM. BIM offers functionality that can automate a number of manual tasks. Examples of this are the production of long section and section drawings, energy analysis, clash detection and avoidance and quantity take-off. This functionality encourages more accurate designs as it reduces the potential for human error.

VIII Interoperability Concerns

During the literature review a number of potential interoperability concerns were identified that the author believes may hinder the adoption of BIM on water network projects or if addressed would significantly improve workflows and promote BIM adoption. The two interoperability concerns identified were firstly between BIM and GIS software and secondly between BIM and hydraulic modelling software. It was decided that these issues required further examination.

a) BIM & GIS

BIM and GIS software are fundamentally different. The concept of Level of Detail (LoD) differs between the two software [28, 29]. GIS displays the information topographically whereas BIM displays the data graphically as a 3D geometric representation [30]. This lack of interoperability was identified as a challenge for implementing BIM [31]. Building projects will typically use LoD standards like IFC, from level 100 to level 500. IFC is a international object-oriented open standard which supports geometric representations and rich semantic information. These standards do not provide LoD references for civil infrastructure [3]. GIS will typically use CityGML. CityGML is an open geospatial standard which supports component-based modelling. CityGML has five discrete LoDs, LoD0 to LoD4 [3]. Figure 1 below illustrates the differences between the two schemas [32].

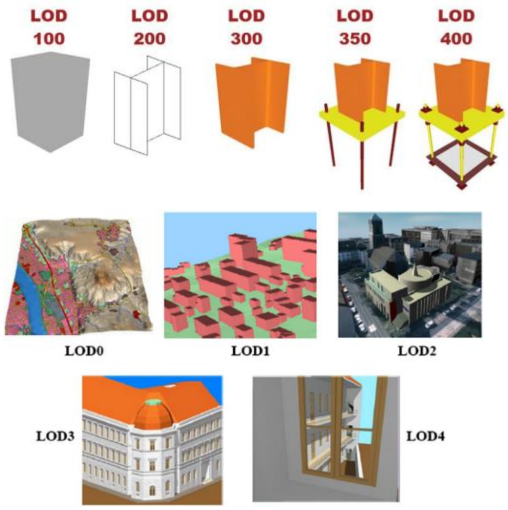

Figure 1 - Comparison of LoD in CityGML and IFC [29]

The current workflow between BIM and GIS is limited to connectivity between the GIS and Infraworks software. This opposes the "data at the centre" philosophy being adopted in the AEC sector [33]. A number of organisations have begun to form partnerships in order to address these issues. Examples of these partnerships are Autodesk ESRI partnership and buildingSMART Open Geospatial Consortium (OGC) partnership. The aim of these partnerships is in creating a direct, faster and more transparent information exchange between BIM and GIS software. These partnerships will hopefully eliminate the slow and inefficient data exchange between BIM and GIS [34-36]. They aim to provide an open vendor-neutral standards platform for exchanging spatial and semantic data [37]. These partnerships are working towards addressing the interoperability issues between BIM and GIS software and appear to be making good progress. This will benefit utility operators by allowing for better information exchange and improved workflows. IW uses GIS as their asset management software. Typically, contractors and designers use software like Autodesk's AutoCAD, Civil3D and Revit. The information exchange between them and GIS software, as pointed out previously, is limited. If these partnerships are successful at meeting their goals, it will mean the information exchange between Clients and Contractors / Consultants will be vastly improved in both directions, benefiting all involved. Figure 2 below shows the desired workflow between BIM and GIS whereby the asset data stored in GIS is fed into BIM to inform design and construction and the project data stored in BIM gathered during the project is fed back in the asset data.

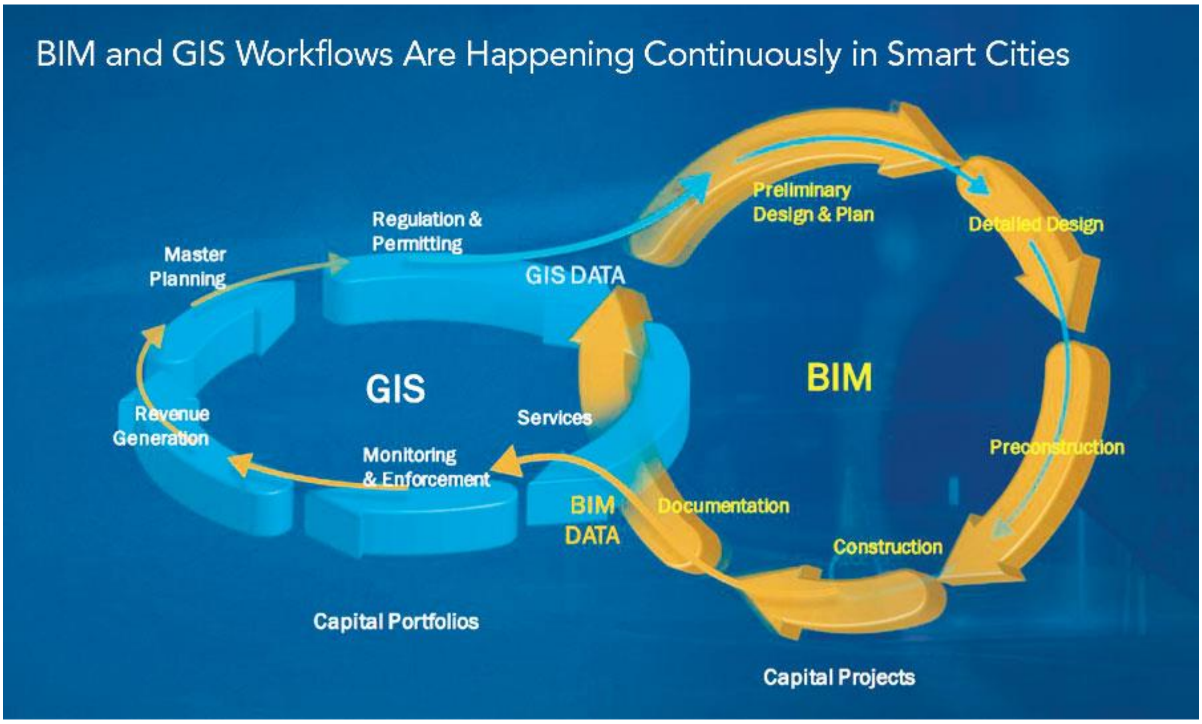

Figure 2 - Proposed improved data flows as a result of BIM and GIS integration [34]

A member of ESRI Ireland advised that they have not yet drawn on the resources available through the Autodesk partnership. They stated that some clients are investigating the use of BIM however they are not aware of any who have implemented it in a real world scenario [38]. IW use a Geometric Network model for asset information management. These models are a set of connected lines and junctions which include connectivity rules that are used to represent and model a network infrastructure that reflects existing or proposed assets [39]. This type of model does not include for the concept of an internal world and any asset recorded in this type of model is represented by a line or point. IW GIS information is in 2D [38].

b) BIM & Hydraulic Modelling Software

The second interoperability concern relates to BIM and hydraulic modelling software. There are a number of different hydraulic modelling software with varying degrees of interoperability with BIM. There is some software which offer BIM compatability such as Bentley Systems WaterGEMS and SewerGEMS which can integrate with Bentley's CDE Software, Projectwise[40-43] . EPANET is an open source modelling software [44, 45]. A number of software providers have used the EPANET engine to develop other tools and add-ins. One example of this is the Studio ARS software. Studio ARS offer a number of AutoCAD applications for water network design that allow analysis to be carried out within AutoCAD reducing the requirement to utilise a secondary hydraulic modelling software [46, 47]. Hydra and Canalis software are BIM ready according to Studio ARS [48]. IW currenly use Synergi Water. Synergi Water is a simulation software package that can be used to analyse the performance of a distribution network, equipment and fittings [49]. This software can currently integrate with GIS systems and some Autodesk products using .shp files. They are currently working on developing the ability to create a digital twin for clients. They are working to develop an Application Programming Interface (API) with the aim of allowing end users to develop tools to integrate with BIM [50].

The interoperability concerns discussed above if addressed could improve the workflow for distribution network projects. With the development of software like Hydra and Canalis, and the partnerships between organisations like Autodesk and ESRI, it is clear that these issues have been identified by the sector and efforts are being made to resolve these problems. The work being carried out by these organisations can only help to convince the industry that BIM is the future.

The stakeholder analysis revealed a number of opportunities and barriers to the adoption of BIM by the water sector. If BIM is to be adopted by the sector these will have to be taken into consideration and addressed. The complexity of the project should be considered when deciding if BIM is suitable. Smaller network rehabilitation projects do not appear to warrant the adoption of BIM to a standard such as Level 2 BIM. However there are aspects of BIM that could be beneficial for these projects such as the use of a CDE. Larger, more complex projects will benefit from the use of BIM. The majority of stakeholders involved in the water sector are currently investigating or trialing the use of BIM. However the current drivers of BIM are the contractors. It is also important for IW to consider the existing systems in place and their interoperability with BIM software, there has been significant investment in systems to improve capital and operational works. It is important that BIM can integrate with these systems if it is to be beneficial.

IX Success Level Assessment Model for Building Information Modelling

Success Level Assessment Model for Building Information Modelling (SLAM BIM) is a methodology for assessing the success of the BIM process at an organisational or project level. Previous methodologies of evaluating BIM either examined the maturity of the BIM or measured the benefits of using BIM. The methodologies that evaluate BIM maturity do not evaluate BIM project success directly. The methodologies that evaluate the benefits of BIM provide a comparison of BIM versus non-BIM works but do not employ appropriate metrics to measure the success of BIM implementation. SLAM BIM aims to set evaluation criteria that can be repeated to assess the success of BIM implementation [51].

The assessment methodology is divided into five steps:

Determine BIM goals

The first step of the process is to determine the desired outcomes of adopting BIM. By clearly defining goals for the implementation of BIM, it will determine if the use of BIM was successful or not if said goals are achieved. These goals should be shared among all stakeholders to ensure that they are all working to the same desired outcomes. They can be organisational goals or project specific goals. The goals should be achievable to insure that a realistic objective is set. The goals can be quantitative such as achieving a desired cost saving for projects. They can also be qualitative such as improving staff's understanding of the BIM process [51]. This assessment model should evolve with the organisation or project implementing it. As the organisation or project completes its goals, new goals should be set and existing goals should come further into focus.

Determine BIM uses

Uses can be defined as services or functions, which are unique tasks or procedures where BIM is utilised by an organisation/project. The BIM uses are determined based on the BIM goals of the organisation/project. Some BIM uses will be required on all projects while others will be optional and dependant of the specific objectives of the project. One or more BIM uses may be necessary to achieve a BIM goal [51].

Identify BIM KPIs

KPIs are used to measure the performance of project/organisation and how close it is to meet its objectives. Two steps are required to identify the performance indicators (PI) most appropriate to the organisation/project. The KPIs vary and are dependent of the BIM goals and BIM uses for the organisation/project. The KPIs selected should be standard for both the BIM goals and the BIM uses. The KPIs chosen should be measurable using quantitative criteria, data should be collectible with minimal additional data input and comparable to benchmark cases on non-BIM projects [51].

Develop the unit measurement

In order to track the performance of the organisation/project using KPIs, it must be possible to specify a unit of measurement. Example of this might be the number of change orders issued or actual cost vs. planned cost [51].

Develop collection form

Methods of collecting the data to inform the KPIs is the final step to establish this methodology. The data collection must be non-invasive and integrated into existing work processes. It should also be aligned with predefined data collection processes, allowing for benchmarking with previous time periods or projects [51].

The author applying the steps involved in this methodology has developed an assessment model for use by Irish Water to examine their level of BIM adoption and success of implementing it. Due to the time constraints of this study, it is likely that this assessment model will only be created as a guide for IW to adopt. A flow diagram of how the model will be developed has been included below in *Figure 3*. As part of the fourth generation evaluation, this assessment model will be validated by issuing the draft assessment model to the participants of the stakeholder analysis for review. They will be asked to review the model and revert with any comments they may have. These comments will be reviewed and then incorporated into the final model.

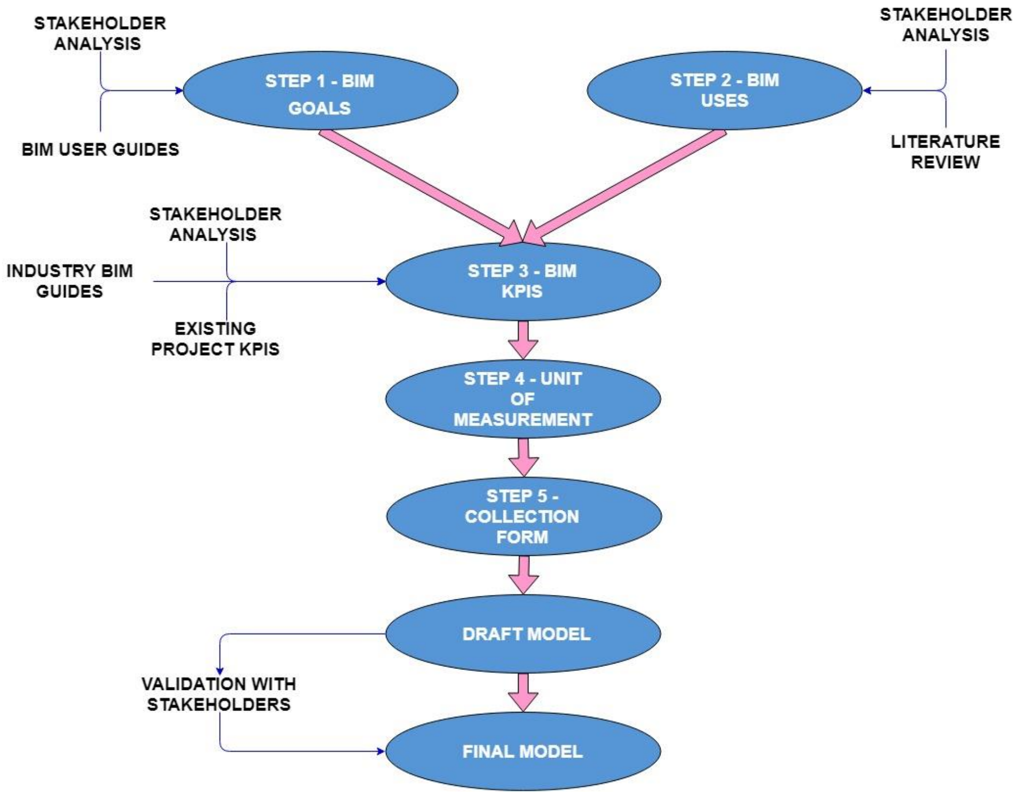

Figure 3 - Flow Diagram for SLAM BIM Methodology

X SLAM BIM ASSESSMENT MODEL

The aim of this section was to develop an assessment model to be used by a Client in the Water sector. This assessment model could also be adopted by other utility operators and modified to suit their goals and needs. This assessment model can be used to track BIM adoption and determine if it is beneficial.

In order to develop BIM goals for the assessment model, a number of sources were used. During the Stakeholder Analysis interviews, each participant was asked what they would like to get from adopting BIM. This information was used to determine BIM goals that were incorporated into the assessment model. A number of BIM user guides were also consulted to inform the selection of BIM Goals. The goals identified were categorised into Short Term, Medium Term and Long Term. They were also categorised into organisational and project goals.

The BIM Uses were identified by asking participants in the stakeholder analysis what they would like to see BIM used for and the benefits they perceive to be gained by adopting BIM. During the literature review, a list of BIM uses was collated from a number of sources. This list was then reviewed and based on the stakeholder analysis, the BIM goals identified and the literature review, the most suitable BIM uses were selected.

To identify the BIM KPIs, firstly a list of KPIs suitable for BIM was established from existing literature. This list was then reviewed referring to the stakeholder analysis, the BIM user guides and existing KPIs. Appropriate KPIs were then selected from this list and linked to specific BIM goals and uses. Some KPIs may be used to assess a number of purposes or uses. Based on the KPIs selected, units of measurement were chosen as were methods to collect the data.

Any units of measurement attached to the KPIs were included in the assessment model. Where not available, standard units of measurements used for other KPIs were proposed.

Finally, the data collection method was identified. The units of measurement for the KPIs were reviewed, and the data source was identified based on the information required to inform the KPIs.

Based on the information gathered for the assessment model, an initial draft was developed. As part of the fourth generation evaluation methodology adopted, this draft model was then issued to the participants of the stakeholder analysis for validation and comments. Any comments that were received were reviewed and incorporated into the final assessment model. An example of the model is shown above in Figure 4.

When the draft assessment model was issued to the participants of the stakeholder analysis, the feedback was positive and the model was well received. The feedback was reviewed and the suggestions were encorperated into the model. The feedback mainly focused on making inclusions for insuring stakeholder adoption and the integration of BIM into management systems and workflows. These comments fit under some of the BIM goals identified and therefore were incorporated into the BIM uses and KPIs. Adoption of this assessment model would require buy in from various departments within the Client's organisation. It requires that information be gathered from various stakeholders during projects. This assessment model was developed to be used by a client involved in the utility sector. The methodology can be adopted by other stakeholders and the process can be replicated working through the steps to tailor it to their specific purpose.

Time Scale	Function	BIM Goal	BIM Use	BIM KPIs	Unit of Measurement	Data Collection Method
Short Term	Organisational	Increased BIM adoption / Maturity		Employee Skills & Knowledge	CPD Hours completed in BIM space	CPD records & Performance Management Plans
				Percentage of Projects with BIM requirements included in tender package	Percentage of Projects	Tender Package Requirements
				Return on Investment	Payback period (Years)	Software costs, Hardware costs, Training costs, Savings on BIM projects
				BIM Maturity	BIM Maturity Assessment Score	Internal Assessment by BIM Team
Short Term	Organisational	Develop Organisational, Asset and Employer's Information Requirements	Asset Information Management	Percentage of BIM Document Templates created that are required in BIM Standards	Percentage	Document Register
Short Term	Project	Better Visualisation of Assets & Design	Site Analysis Engineering Analysis Design Authoring	Number of Requests for Information (RFI)	Sum	Contractor Progress Reports
			Design Review Clash Detection / Avoidance	Number of Errors/ Omissions on Site	Sum	Project Claims Register, Contractor Progress Reports
			3D Coordination Site Utilisation Planning	Number of Change Orders	Sum	Contractor Progress Report

Figure 4 - SLAM BIM assessment model example

XI Conclusions

This study investigated the use of BIM on distribution network projects within the water industry. Based on the findings of this study it is clear that there is definite scope for the adoption of BIM by the water sector in Ireland. However, it is important to note that while there is scope for using BIM, not all projects are suitable or require BIM. The simpler watermains replacement projects do not justify the use of BIM due to their simplicity. It is clear that a large percentage of organisations within the industry are currently working towards adopting BIM to varying degrees. It was established that the use of BIM on WTP/WWTP assets is currently more common than for distribution network projects. There are a number of WTP/WWTP underway utilising BIM however there is no BIM distribution network project underway. The client is planning to begin introducing BIM requirements on distribution network projects of a certain complexity in the near future. From engaging with professionals working in the industry, it was clear that there was a lack of definition surrounding BIM, with varying levels of knowledge and understanding of what BIM is or can do. It would be beneficial for industry leaders or industry BIM champions to raise awareness surrounding the functionality of BIM and its potential uses. As the water sector in Ireland is publicly funded, there is a limit to the amount of investment capital available. There is also a significant importance to be efficient and to get value for money. BIM offers a number of benefits that can lead to efficiencies in both project delivery and asset management. BIM offers a potential solution to the problems inherited from the previous management system. It will not be an instant solution but over time it could be built into far superior asset management system for the water sector in Ireland. Finally, it is important to identify the best way to promote the adoption of BIM by the industry. The suggestion of a BIM mandate similar to that of the one used in the UK received mixed reactions. The use of an assessment tool like the one developed during this study can be used to demonstrate the success of BIM within the industry. The first step is education surrounding the topic. By establishing a uniform concept of BIM for the water sector and using an assessment model like SLAM to demonstrate the benefits of BIM, it would demonstrate why BIM should be adopted. The next step for this study would be testing and field validation of the assessment model.

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