2020

To what extent does the knowledge gap between client's expectations and project construction team deliverables adversely impact commercial (Office Buildings) BIM projects?

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To what extent does the knowledge gap between client's expectations and project construction team deliverables adversely impact commercial (Office Buildings) BIM projects?

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Abstract – Building Information Modelling (BIM) is an evaluation methodology that has the potential to achieve an adequate communication of information between different construction project stakeholders and clients. Due to the amount of information involved in construction projects and the requirement in control of time, cost and waste, BIM can be perceived as a future-proofed design, construction and Facilities Management (FM) process. Having been involved in various projects working to Level 2 BIM standards over the past 3 years the author has seen a gap in terms of client's expectations of BIM deliverables and those which are actually produce by the project teams. This is most evident during the building to operations phase at project handover. A better way of communicating the BIM process to client should be implemented, exploiting its full potential, not only through the duration of design and construction phase of the building, but more importantly for the operation and maintenance of the building assets following handover to the client. Literature review was conducted investigating the gaps in communication and client and design and construction team stakeholder perspectives on the BIM process. A prototype solution, aiming to help and bridge the communication gap was derived. The objective of this research, which involved literature review, stakeholder interviews and proposed focus group discussions was to develop a prototype solution with the aim of helping to bridge the gap between client expectations and project team delivery.

Keywords – BIM, Client, Communication, Construction, Engagement, Knowledge Gaps

I INTRODUCTION

Building Information Modelling (BIM) allows for improvement and innovation in building visualisation, coordination, and communication for construction organisations (Wan Mohammad, Abdullah, Ismail & Takim, 2018). It enables project stakeholders to embrace the BIM model as a way of visualising, analysing, simulating, verifying and rehearsing complex procedures and manipulating the real operating construction conditions, that are important at the early project stages (Husain, Razali and Eni, 2018). Whole lifecycle asset management (AM) is embraced by BIM; therefore, it is promoting efficiency and productivity, speed of delivery, and increases profitability by reduction of errors, rework and overall waste in construction (Georgiadou, 2019). With proper definition of requirements and appointment of capable project delivery teams BIM has the potential to improve facility operations and maintenance (O&M) activities and provide new functionalities for Facility Managers (FMs), such as intuitional three-dimensional (3D) visualisation, comprehensive analysis, and real-time building information access (Gao & Pishdad-Bozorgi, 2019).

A range of BIM standards have been developed by British Standards Institution (BSI) supporting the statements about BIM process and are listed by BSI Group (2020) as follows:

- BS EN ISO 19650-1:2018 - Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling, Part 1: Concepts and principles
- BS EN ISO 19650-2:2018 – Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling, Part 2: Delivery phase of the assets,
- PAS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling,
- PAS 1192-4:2014 - Collaborative production of information, Part 4: Fulfilling employer's information exchange requirements using COBie – Code of practice,
- PAS 1192-5:2015 - Specification for security-minded building information modelling, digital

built environments and smart asset management,
- PAS 1192-6:2018 - Specification for collaborative sharing and use of structured Health and Safety information using BIM
- BS 8536-1:2015 - Briefing for design and construction – Part 1: Code of practice for facilities management (Buildings infrastructure),
- BS 8536-2:2016 Briefing for design and Construction Part 2: Code of practice for asset Management (Linear and Geographical infrastructure)

Dakhil, Underwood and Alshawi (2019) stated that the key stakeholders within the project delivery team need a system for the delivery and handover of the assets. The process should be communicated to clients, allowing them to fully understand and get the full benefit of BIM. Hu, Tian, Li and Zhong (2018) highlighted client concerns about adopting procedures that lack clarity, particularly where they are investing heavily in the BIM process. Ashworth, Tucker and Druhmann, (2016) outlines that here is a need for a guidance document, that briefs stakeholders in the creation of asset information, to ensure that the right information is handed across for the operational phase of the building. However, PAS 1192-3:2014: 'Specification for information management for the operational phase of assets using building information modelling.' by BSI Standards Publication (2014) already sets out the handover information requirements.

Li et al., (2014) stated that BIM helps to facilitate design and construction phases by involving various stakeholders involved in the construction process, such as contractors, civil engineers, structural engineers, mechanical and electrical engineers through the automated simulation of cost activity information. The visualization of construction activity analysis assists the costs planning operators in the identification of conflicts and in the communication of design alternatives that might be more cost-effective and timesaving (Li et al., 2014). The FM phase of the building is where BIM benefits clients the most, where it is used for the management of the building assets. Managing Interoperability of BIM and FM tools is one of the challenges faced by stakeholders and clients (Vass and Gustavsson, 2017). Munir, Kiviniemi and Jones (2019) highlight that most asset owners do not understand the systems or process to integrate BIM with AM to derive real business value.

This is an issue that should be addressed, streamlining the BIM process, providing clarity of the deliverables for all parties and to outline BIM expectations. The aim of this research is to identify the communication gaps at different stages of the BIM process and to propose a solution that allows for clear information transfer and transparency between delivery team stakeholders and the client, allowing the client to understand the process and utilise the information to its full potential.

II Research Objectives

Four objectives were outlined for the purpose of this research:

- **Objective 1:** To review delivery team and client experiences of Building Information Modelling Management (BIMM) in the context of commercial buildings.
- **Objective 2:** To appraise the communication between project delivery teams and their clients in relation to the benefits and outputs of Building Information Modelling Management (BIMM).
- **Objective 3:** To propose a structure/system built on existing standard documentation that allows clear communication between the client and project delivery team that allows the client to understand the BIMM outputs and requirements, allowing the BIMM process to be aligned with clients Asset Information Requirements (AIR) and Organisation Information Requirements (OIR).
- **Objective 4:** To critically evaluate the proposed structure / system through a series of tests involving project delivery teams and clients or client representatives, highlighting potential errors within the structure / system.

III Literature Review

The project delivery teams need a system in place for the delivery and handover of the assets and communication of the process to the client, allowing clients to get a full understanding of the BIM process. Stakeholders should demand the use of BIM on the project from the procurement stage of all construction projects. BIM impacts many aspects of the project design and procurement process, interfering with many programs of actions among the stakeholders within a construction project (Lindlab, 2019)

Some research around this topic and aligned/similar topics has been undertaken outside of Ireland. The purpose of this paper is to implement a system to be used in Ireland for BIMM and to ensure a smooth transfer of information between the delivery teams and the building owners. The following key topics were investigated through the literature review to identify the gaps in the BIM process that must be addressed when communicating it to clients:

a) BIM Process and Stages,
b) BIM for Clients,

c) BIM for Construction Teams,
d) Knowledge and Communication gaps between clients expectations and project construction teams deliverables,
e) Existing Frameworks.

a) BIM Process and Stages

BIM is transforming the construction industry – changing the way multidisciplinary project teams collaborate at every stage of the asset lifecycle to deliver significant efficiency and cost-saving benefits (BSI Group, 2019). Munir, Kiviniemi and Jones (2019) stated that BIM is a methodology that can assist asset managers to manage their portfolios and assets more efficiently and effectively. A BIM-enabled project offers quality assurance and on-time delivery, collaboration and communication improvement, visual representation and clash detection and whole lifecycle value, at a conceptual level (Georgiadou, 2019). Furthermore, BIM enables collaboration between engineers, owners, architects, and contractors in a three-dimensional virtual construction environment, and it shares information across these disciplines (BSI Group, 2020). Lewis & McPartland (2017) outlined eight key stages of Digital Plan of Work (DPoW), which are part of BIM process: Strategy (Stage 0), Brief (1), Concept (2), Definition (3), Design (4), Build and Commission (5), Handover and Closeout (6) and Operation and end of life (7).

b) BIM for Clients

Despite ISO 19650, PAS 1192 and BS 1192 standards outlined in the introduction part of this paper, Ashworth, Tucker & Druhmann, (2016) states that guidance is required to assist the development of BIM strategies around the clients' OIR and AIR to develop an Employers Information Requirements (EIR) document that specifies What, When and How the information should be delivered by the delivery team to the client. Hadzman, Takim & Nawawi (2015) outlines the project attributes to be; feasibility, definition, duration, location, objectives, size and type. Nevertheless, the three main client demands are time, cost and quality.

Clients would usually be concerned about unclear adoption procedures and the large investment required, preventing the widespread of BIM technology in the O&M Management (Hu, Tian, Li & Zhang, 2018). Furthermore, Almuntaser, Sanni-Anibire, and Hassanain (2018) outlined in their case study that clients neither demand nor are interested in what process has been employed to deliver their projects, thus, there is a lack of client awareness of the potential benefits of BIM delivery. Gao and Pishdad-Bozorgi (2019), also, highlighted that many facility managers and field technicians are lacking the knowledge and skills to use existing BIM-enabled facility management tools. As a result, they are hesitant to embrace new technologies finding them complicated to work with.

c) BIM for Construction Teams

A clear EIR from client is required to ensure that the delivery team to meet all the BIM deliverables (Ashworth, Tucker & Druhman, 2019).

Oraee et al. (2019) outlined the barriers to collaboration in BIM-based Construction Networks (BbCNs), which are summarised in Figure 1. The barriers outlined by Oraee et al. (2019) can be another cause for poor communication of BIM, when it comes to meeting a client's demands. Furthermore Oraee et al. (2019) stated that more simplified tools must be designed with secure platforms in which data ownership and interoperability concerns have been alleviated and the requirements for an efficient CDE have been satisfied. Bosch-Sijtsema, Gluch and Sezer (2019) highlighted from their survey/interview findings that establishing and maintaining a coordination model, making collision checks, maintaining BIM requirements, participating in consultancy procurement, compiling BIM experiences from the project and supporting cooperation through visualisation of the model are more important tasks for BIM professionals than non-BIM professionals, such as clients.

d) Knowledge and Communication gaps between Clients expectations and project Construction Teams deliverables

RIBA Enterprises (2017) highlighted in their annual survey of BIM professionals completed by the UK National Building Specification (NBS), that 72% of the surveyed professionals agreed with the statement that "clients do not understand the benefits of BIM" and 65% highlighted that "no client demand for BIM" is a barrier to BIM adoption. Despite these figures, 78% of BIM professionals believe that 'BIM is the future of project information'.

Hadzman, Takim & Nawawi (2015) outlined six findings for coefficient correlation of the impacts as follows:

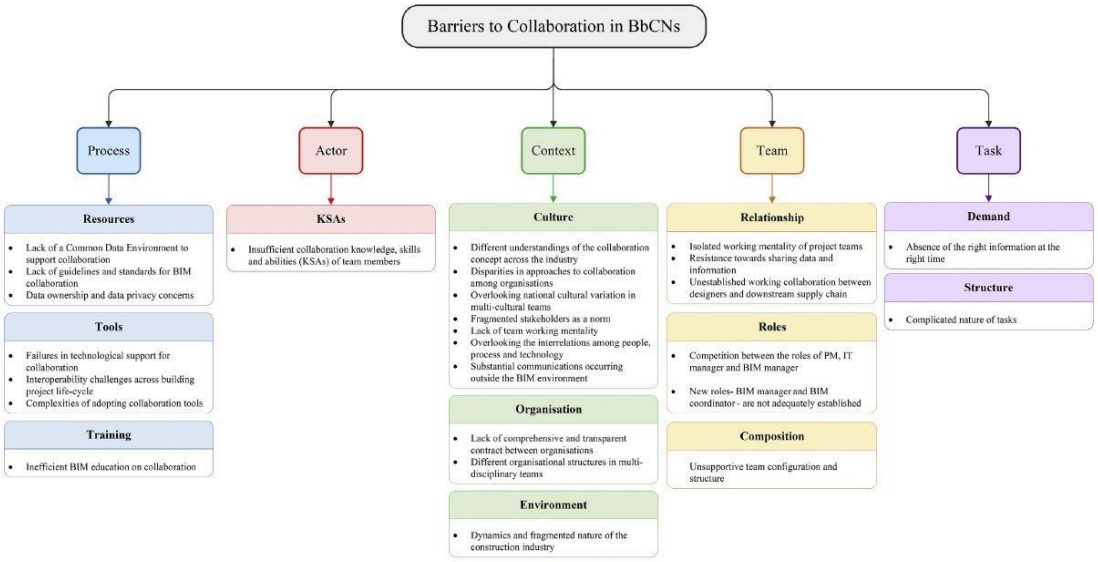

Figure 1: Barriers to Collaboration in BIM-based Construction Networks by Oraee et al. (2019)

● Project feasibility being correlated to time and cost,

● Project definition and formulation,

● Project duration, location and size are all collated to quality.

Ashworth, Tucker & Druhmann (2019) noted that one of the key challenges in the BIM process, is understanding the different acronyms referenced in the process, such as; OIR, AIR, EIR, PLQ, AIM, etc. Whereas Dakhil, Underwood and Shawi (2016) reinforced the need for a clear explanation of BIM benefits in conjunction with BIM's relationship to maturity levels and project phases, allowing clients to get a better understanding of the process. In addition to the client producing a well-defined EIR, the supply chain must be able to validate their deliverables against the clients' requirements (Dakhil, Underwood & Alshavi, 2019).

e) Existing Frameworks

A framework was proposed by Ahbabi and Alshawi (2015) allowing the client to continuously monitor the building following delivery of the BIM process on their building. This consists of the following steps:

a) Establish EIR,

b) Maturity Assessment,

c) Gap Identification,

d) Develop and update the process framework.

Whereas Supply Chain Capability, as highlighted by Mahamadu, Mahdjoubi, Booth, Manu P., and Manu E. (2019), should be categorised around the Supply chain contribution to the following BIM deployment attributes:

a) The quality of BIM,

b) Delivery of BIM on schedule,

c) Delivery of BIM within budget, and

d) Collaboration and Integration of Construction Supply Chain (CSC) through BIM.

Yang and Chou (2019) proposed a subjective BIM benefit evaluation model for immature BIM-enabled stakeholders that do not fully understand the different stages of the BIM process – pre-project, in-progress and post-project. Authors outline the measures adopted through their study:

(a) improved overall quality,

(b) enhanced cost control/predictability,

(c) faster client approval cycles,

(d) reduced conflicts during construction,

(e) an improved collective understanding of design intentions,

(f) reduced changes during construction,

(g) a reduced number of RFI's, and

(h) Other items that can be objectively proposed by the evaluator.

A benefit evaluation structure for BIM implementation was proposed:

(a) Common benefit-related evaluation methods,

(b) Contextual benefit,

(c) Country-based benefit,

(d) Industry-based benefit,

(e) Organisation-based benefit,

(f) Project-Based benefit,

(g) BIM use-based benefit.

The points outlined by the Yang & Chou (2019) will be cross checked within the stakeholder interviews forming part of this study paper.

Hu, Tian, Li & Zhang (2018) presented a logic structure in their research paper, indicating type logic structures for elements types within several typical MEP Systems, allowing the client or FM to easily follow the building asset information.

The literature reviewed in the paragraphs above, outlining BIM process and stages, BIM for clients, BIM for construction teams, knowledge and communication gaps between clients expectations and construction teams deliverables, and existing frameworks, shows an existing communication and knowledge gap between clients and construction teams that needs to be addressed in order to streamline the BIM process through the various project stages. The literature review has influenced to produce an overlooking Excel document as part of this research covering various aspects of the BIM process in one place to aim and bridge the communication gap between the clients and BIM professionals.

IV METHODOLOGY

A number of research methodology routes were selected to achieve the desired outcome from the research. These were aligned with the four research objectives. Figure 2 represents a step by step research methodology outlined in a graph format with the steps required to achieve the research objectives. The methodology routes are described in more detail below. See Figure 2 and the following sections for more detail:

Research Methodology 1: Action research methodology, critically evaluating the literature relating to the delivery of BIM projects to clients, evaluating the findings within the literature reviewed and listing outstanding gaps in the BIM process between the client and project delivery team. The literature review was used to research, analyse and outline the issues and communication gaps that clients and design and construction teams encounter when implementing BIM on a project. The literature review was used to establish the interview questionnaire to assist objective two of the research ascertaining the current understanding of BIM within the industry by clients. The literature review also assisted the production of a prototype solution for objective three of this study.

Research Methodology 2: A qualitative interview methodology was used to critically evaluate expert industry opinion on how the BIM process is communicated to the client together with understanding the clients opinion on the BIM process. These interviews were set against the context of commercial office developments. In order to provide a breadth of opinion a number of key BIM professionals representing a wide cross section of the construction industry were interviewed. These included Architects, Engineers, Construction Managers and BIM Consultants. The stakeholder interviewees were selected due to their experience in the sector and their interest in engaging with, and commending BIM to the highest standards. The qualitative interview methodology helped to identify common problems that BIM delivery professionals and clients have when trying to communicate through the BIM process. Responses and data gathered from the interview process was collated and used to further develop the prototype solution. Table 1 provides a list of stakeholder professionals interviewed for the purpose of this study:

Table 1: Stakeholder Professionals Interviewed

No.	Discipline	Job Title
1.	Main Contractor 1, Interviewee 1	Design Manager
2.	Main Contractor 1, Interviewee 2	Design Coordinator
3.	Main Contractor 1, Interviewee 3	Viewpoint and FieldView Coordinator
4.	Main Contractor 1, Interviewee 4	Pre-Construction Director
5.	Main Contractor 1, Interviewee 5	BIM Coordinator
6.	Main Contractor 1, Interviewee 6	BIM Manager
7.	Main Contractor 2	Digital Construction Manager
8.	Architect 1	Architectural Technologist
9.	BIM Consultant 1	Managing Director
10.	Client 1	Information Manager using BIM

Research Methodology 3: An Action research methodology was used in conjunction with existing BIM process and standards to develop a prototype document. The aim of the document being a reduction

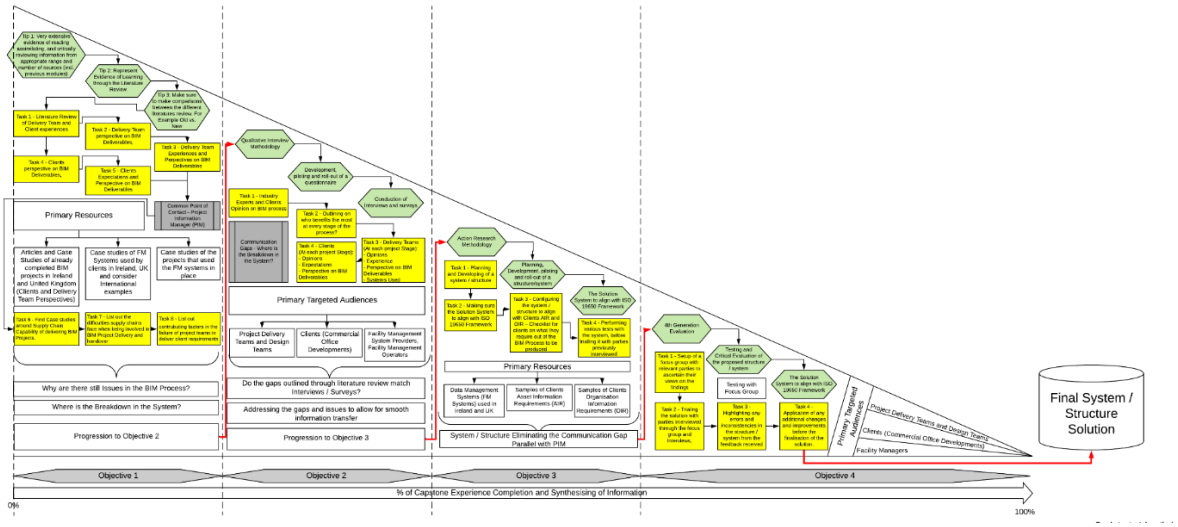

Figure 2: Capstone Experience Methodology and Tasks Plan Diagram

in communication shortfalls between all stakeholders through each stage of project maturity.

Research Methodology 4: 4th Generation evaluation methodology on trialling the solution with clients, facility managers and project delivery teams previously interviewed, in order to receive feedback on any additional changes and improvements before finalising the solution. Consideration has been given to the holding of an online focus group, however, securing the attendance of a focus group has been challenging. Alternative testing routes have been considered to provide feedback on the solution prototype, to finalise the proposal solution.

The methodology routes outlined and described enabled to achieve the desired outcomes of this research objectives, helping to bridge the existing communication and knowledge gap between design and construction teams and clients.

V SOLUTION PROTOTYPE DERIVED FROM THE LITERATURE REVIEWED AND CURRENT STANDARD DOCUMENTS IN PLACE

Further to completion of the literature review and building on his existing professional experience the researcher produced a first draft of the Master Excel Document (MED). This document was broken down into tabs covering a number of information delivery requirements across varying stages of the project. The objective of the document was to enable a detailed and structured specification of all project information delivery requirements. The document which includes links to relevant existing industry standards is intended to support a Project Information Manager with specification and delivery of the clients requirements.

Solution Prototype 1

A Master Excel Document (MED) covering all aspects of BIM, including links to documentation, outlining the standard to be followed is proposed as part of this study. The aim is to make the process easy for clients to follow, allowing them to get the most from BIM, through the design, tender, construction and facilities management phases of the building; eliminating the communication gap, but running in parallel with Project Information Manager (PIM). The solution will be developed in line with ISO 19650 – 1 & 2, PAS 1192-3, PAS 1192-4 and other relevant BIM standard documentation and will allow the system to be configured to align with clients AIR and OIR. Please see Figure 3 representing a cascade of included Excel tabs in the MED. The proposed MED currently consists of thirty-six (36) tab sections, which are described in more detail in ePortfolio and the following sections:

Tab one of the MED is to include a Project Information Sheet, giving an overview of the project and covering all the relevant information.

The proposed structure will have a guidance document in Tab two assisting with the interpretation of the Excel document.

Tab three will include a master document register of all drawings, documents, registers, etc. with easy to filter options.

A naming convention guide is to be included to assist stakeholders and clients when naming files and assets. There are two documents to be considered for the naming convention: 1) File Naming Convention as per standard Master Information Delivery Plan

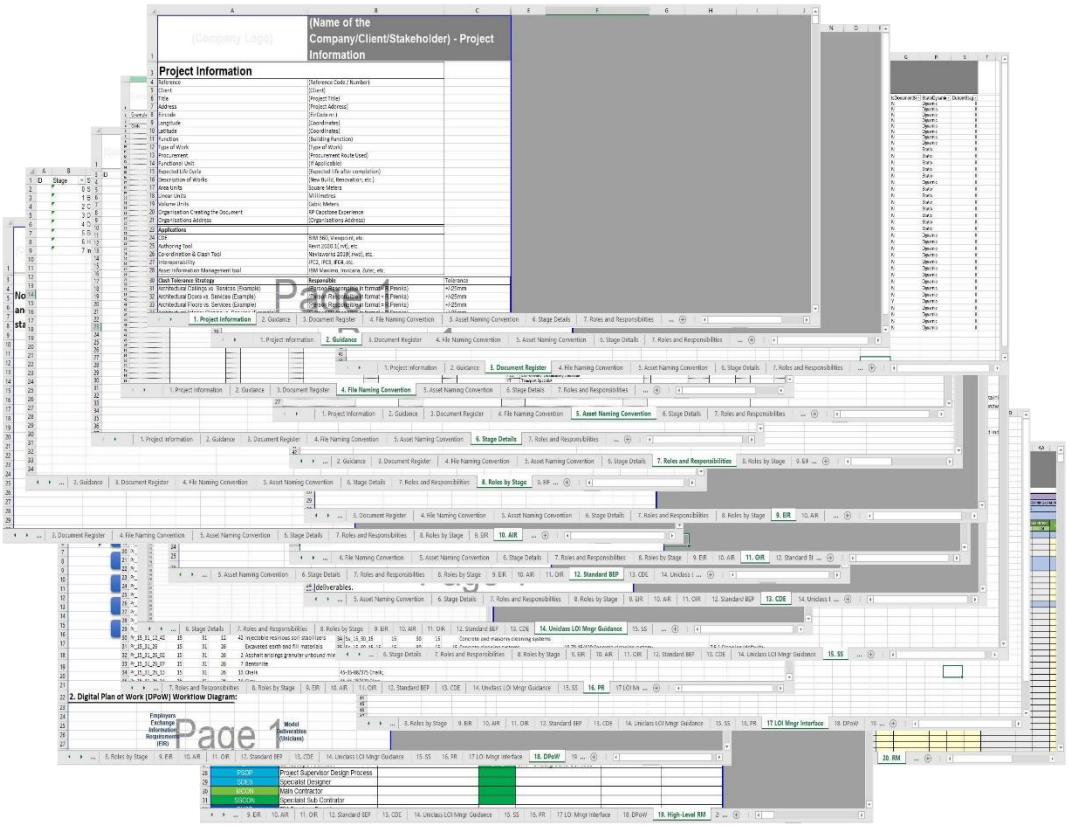

Figure 3: Cascade of Prototype 1 MED tabs

(MIDP) and 2) Asset Naming Convention as per IBM Maximo naming convention requirements. Maximo asset management system has been selected for the purpose of this research. Asset naming convention will always depend on the clients preferred AIM solution, which would define the format of asset data to be delivered to client.

Project Roles and Roles by Stage overview tabs included covering the different roles and disciplines of the projects and to what stage of the process different disciplines and roles apply to, making it easy to review for client.

A standard Exchange Information Requirements (EIR) document, Asset Information Requirements (AIR) document and BIM Execution Plan (BEP) structure created in line with BIM standards documentation and IBM Maximo information requirements included in a separate tabs.

The proposed MED will include an asset checklist for the selection of client requirements for each stage of the building delivery. The structure will outline what is required of the client in relation to BIM delivery. For example, what data must be covered in the Common Data Environment (CDE) process, as part of the overall BIM process.

Descriptions for Geometrical / Non-geometrical data and documents related to this data will be included for client and project stakeholder consideration during the BIM delivery process. The proposal provides an outline definition of Digital Twin for physical assets, in line with the client requirements checklist, providing details for the level of information and client requirements from the BIM process at every stage of the process. (Note: the CDE tab has been developed in conjunction with BIM standard documentation and documentation shared by BIM Consultant interviewee).

Uniclass Level of Information (LOI) Manager guidance tab added with the reference to Uniclass System (Ss) and Product (Pr) information Uniclass table tabs, and Uniclass interface tab added. The MED includes reference to product data templates. NBS Uniclass information is the default information commonly required on projects. (Note: the Uniclass interface has to be run with the LOI Manager Document open as a separate Excel document. The LOI Manager document was acquired with BIM consultant interviewees permission).

The Digital Plan of Works (DPoW) acquired with BIM consultant interviewees permission, is included in the document together with High Level and a

detailed Responsibility Matrix (RM), providing an outline of tasks related to different elements of the process and responsibilities for the tasks, including links to relevant documentation associated with the tasks. The document will include a Model Production Delivery Table (MPDT) with live links to the project information.

A Master specification document in line with Uniclass will be incorporated into the document with reference to the asset database in the MED. The master document will highlight the importance of delivering a digital asset before the physical asset. BIM coordination tasks should be completed at least six weeks before the physical task takes place, reducing delays. The standard Responsibility Matrix (RM) will be used to specify the requirements for the BIM project delivery programme.

Building Control (Amendment) Regulations (BC(a)R), safety file and technical submittals should be considered and included in the MED structure, as part of the BIM process.

The creation of a smart object library consisting of Objects, Product Data Sheets and relevant information associated with the objects will be considered. The MED specifies the parameters to be populated in the BIM model and at what stage of the process they apply. The proposed MED will highlight the importance of "Codifying" assets and elements within the building asset, making it easy to follow the structure and highlighting the importance of retaining a consistent structure.

The MED will include a checking structure for models, allowing the stakeholders to validate that the models and it's elements are correctly classified from an early stage.

Proposed document to include "Date Required" and "Date Issued" for different documents, drawings, models, schedules, issues, etc. A standard Master Information Delivery Plan (MIDP) will be considered to track different documentation within the proposed structure, making it easier for clients follow the process with delivery team stakeholders:

A Facility Management handover structure will be included in the document, populating automatically throughout the BIM project delivery cycle. The tab containing the asset information gathered through the delivery and handover of the process, should be configurable, allowing alignment with Computer Aided Facilities Management (CAFM) Systems used by clients to import information where relevant.

COBie will be included as a separate linked document, containing the asset information, as per PAS 1192 Part 4.

Dynamo script guidance and structure will be created to allow for pushing and pulling of the associated project and asset information between the spreadsheet and Revit model.

Government Soft Landings (GSL) tab added, with reference to MCP project, where the template was acquired from:

VI Qualitative Analysis & Synthesis of Qualitative Interview Findings

Further to the information collected in the literature review, in order to ascertain a better understanding of the client perspective of BIM within the industry, several semi-structured one-to-one interviews were completed. As highlighted in objective 2 of the methodology, interview candidates were specifically chosen because of their experience with BIM within the Irish Construction Sector. To add balance to the research a number of non-BIM professionals were also canvassed, identifying various professional perspectives of the BIM process outside the BIM department, for a greater insight of the perceived communication gaps that exist within the BIM process, between the different disciplines and clients. Stakeholder professionals as per Table 1 under Methodology section in this paper were interviewed for the purpose of the study.

Some of the different organisation stakeholders interviewed had previously been professionally involved with other stakeholders and were chosen to provide alternative perspectives towards the BIM process and the implementation misalignments that exist on building projects. An interview questionnaire derived from a literature review was used to further explore communication gaps within the BIM process. A proposal prototype solution was communicated to each interviewee at the end of the interview allowing for early feedback. The collective responses enabled the adjustment of the system/structure before roll-out of the final solution. Questions aligned with research objectives were presented to each interviewee. The responses provided different perspectives across the professional disciplines of the BIM process. The interview questions were organised in four main sections, in a logical order to gain the following information; a) Understanding and Communication of BIM, b) Value of BIM, c) Training and d) Solution Proposal. All interviewees are anonymous and confidential.

a) Understanding and Communication of Building Information Modelling (BIM)

The qualitative survey confirmed the findings from the literature study, revealing that the lack of communication, lack of common goal and issues

related to work culture are the most prevalent issues (Piroozfar et al., 2019). Software interoperability, lack of training and resistance to change by professionals, according to Piroozfar et al., are only few of the reasons preventing the projects and stakeholders implementing BIM (Piroozfar et al., 2019). Findings within the research have pointed to a clear need to further educate clients in relation to BIM standards and guidelines. Existing templates, such as EIR templates are not focussed on clients or FM needs (Ashworth, Tucker & Druhman, 2016).

Interview data revealed that most professional stakeholders believe clients are unsure of potential outcomes and benefits from the BIM process through design and construction efficiency or post completion during FM operation when implemented on their buildings.

In all cases interview participants were of the opinion that information requirements have been poorly communicated from clients through their design teams. This points to a lack of understanding or failure to appoint suitably qualified project information managers. In some cases, through sheer project to project experience these requirements can become more streamlined. Contractor Stakeholders outlined that it is project to project dependent typically and in few case scenarios there is an appointing party of the project that knows what they want to achieve from the process being delivered to them, which would make the requirements clearly established. However, every project has project information requirements (PIR) and it may not be established as EIR in all cases. The PIR must be evaluated to understand exactly what client requires from the process.

Ashworth, Tucker and Druhmann (2019) highlights that 'There is a gap in research specifically addressing the important issue of the role of facility managers and clients in ensuring their organisations have the fundamental elements in place at the start of the BIM process, namely, the OIR, AIR, and EIR'. All of the stakeholders interviewed believe there is a disparity between project outcomes and client expectations. Architects have found this to alter and hinge on the stage in which the construction team is integrated into a job. The contractors interviewed all agree that clients would typically have higher expectations, than the requirements set out in the contract agreed in the first place. Contractors highlights if the requirements are not fully defined with roles and responsibilities then design teams will generally try to limit the delivery of information and coordination. Clients interviewed acknowledged their lack of understanding which results in their inability to direct the delivery teams to meet their expected requirements. This issue again points to the importance of the role of the information manager in supporting the client to develop clearly defined information briefs.

Heaton, Parlikad and Schooling (2019) outlined that there is a clear knowledge gap on how the BIM model should be structured, allowing its efficient use in O&M phase. Six out of seven contractor stakeholders interviewed do not believe the FM integration requirements are clearly defined. BIM consultant agrees there are standards that set out the O&M requirements to which stakeholders must be working to when delivering BIM to clients. However, the client should be able to understand how he will use the information and the level of information (LOI) required, allowing them to set out the requirements for O&M effectively. Furthermore, educated clients believe the models cannot be used in the O&M phase and structured information would be what clients would typically require from the process. However, model at a handover becomes a record of the as built elements. The models handed over can be used as a basis for future phases of a development assisting with design coordination.

IBM Corporation (2016) states that different stakeholders, such as architects, contractors, owners, operators, and maintainers or facility managers of the assets may all have different commercial objectives, cultures, systems and processes. Stakeholders interviewed all believe the commercial drivers at varying stages for delivery teams influence the effectiveness of communication between parties. BIM requirements must be defined from the outset of the project to avoid issues in the following stages of the process, such as sharing of the information between different disciplines. Typically, commercial drivers would not see something as an investment, however, they would see it as an extra cost, which can also create trust issues between parties.

Papadonikolaki, Oel and Kagioglou (2019) highlight that BIM artefacts act as boundary objects and influence BIM-based collaboration from a structuration perspective, including both a structural-based view of collaboration and agential aspects of knowledge sharing and innovation. All the stakeholders interviewed believe that the BIM information is not used to its full potential through design, construction and facilities management phases. Stakeholders all agree that there is still a lack of full understanding of the full BIM potential with many parties, meaning the information is not used to its fullest.

Ashworth, Matthew Tucker, Carsten K. Druhmann (2016) stated that FM's need to engage early in BIM process, helping to ensure the clients information requirements are defined clearly. All stakeholders interviewed believe that facilities managers and clients should be involved from the

very start of the design process, setting out the end requirements for the Facilities Management phase, allowing for a proper BIM strategy to be developed from day one. Therefore, this would allow every stakeholder to work to the plan, with a clear view of delivering the client's requirements. Furthermore, clients should have a consultant who has Facilities Management experience if they do not have someone in-house, to consider the Facilities Management phase in addition to the capital delivery. However, clients only want what they need, and design team and manufacturers should specify what clients need to operate the assets within the building.

b) Value of BIM

Vass and Gustavsson (2017) outlines that Information Technology (IT) business value model allows to understand the public clients' implementation of BIM as an IT-Supported change process and for understanding the associated intra- and inter-organisational challenges. Contractors agree that they derive most value of BIM process at the pre-construction and construction phase. Contractors also outlines that their organisations would also benefit in tendering stage as BIM can be good to define the work requirements in terms of visualisation and can assist in the pricing of the works. Most value would be derived where design meets procurement and procurement meets construction. The construction to operation stage is where Contractor and Client organisations would derive a lot of value. Royal Institute of British Architects (RIBA) stages three and four drive significant value to a project from the Architectural point of view. BIM consultants would derive value at all stages, as specialises in this process and they would be more efficient in all stages of the process. However, Clients highlights that they want the process to be repetitive, making it easy to follow the process in a structured way to a high quality.

Ahbabi and Alshawi (2015) highlight the role of the client leading the BIM process implementation, enabling a continuous improvement approach to allow clients to continuously improve their performance and processes in order to maximise the BIM benefits. All stakeholders interviewed do believe clients should take a leading role when it comes to BIM implementation on their building. However, this should be a consultant appointed by the client with a strong knowledge of BIM who would advise the client on the BIM process. Client must be very clear on what the requirements are with the assistance of BIM consultant. However, Clients interviewed believe clients should not take a leading role, but that design and construction teams should be more efficient using BIM and not seeing it as an extra cost.

IBM Corporation (2016) stated that valuable information is often miscommunicated or lost in translation when assets are handed over from one stakeholder to another. All of the interviewed stakeholders agree with this statement. Contractors agree that the information is not necessarily lost in translation or miscommunicated. However, communication could be improved or access to the information improved through improved direction from client and thought on the handover at the beginning of the project. The information management plans, such as EIR and BEP must be communicated between the different stakeholders from the outset of the process.

Dakhil, Underwood, and Al Shawi (2016) outlined that clients are still challenged with the problem of making decisions about whether or not to implement BIM, based on uncertain benefits. All of the stakeholders interviewed believe this statement is true, as client would typically need to see the BIM process and outputs of this process in action to realise the benefits of BIM. Contractors believe that so far many clients believe BIM adds cost and do not assess the output benefits fully. However, one of the contractor stakeholders interviewed believes that BIM on a project should not be an extra cost to the client. The extra cost should only be considered if there are very demanding asset data requirements from the client. BIM process makes the building delivery easier and should not be seen as an additional cost to the client. Clients interviewed believe that a structured information is all they would require from the BIM process.

c) Training

All of the stakeholders interviewed agree that the BIM requirements should include upskilling of clients with the use of the FM system in place for their building. However, interview findings show that most of the clients would rely on external FM companies when it comes to FM systems, which typically is the correct process. Contractors would deliver the structured information clients FM system would require using industry standards such as ISO 19650 and COBie, ensuring the data is structured in an industry format. Furthermore, Architects outlined that typically a client who asks for FM information delivery as a requirement would be already knowledgeable and have a team in place which is capable of delivering such a system. However, Clients highlighted that it is design and M&E teams responsibility to design around the clients' requirements and put an operational plan in place.

Interview data revealed the resources involved in the upskill of clients to use facility management tools would typically be client dependent. This mainly depends if the client already has an FM system in place for their organisation or if they require the design team and construction teams to establish an FM system for them. If clients have no FM system and team in place, then a significant upskill is required from clients side.

All stakeholders believe that it can be challenging to ensure the attendance of parties involved in testing and asset classification only if the requirements are not properly set out from the start. If the requirements are established and agreed from the outset of the project and if stakeholders are engaged to participate, there should be no issue to ensure attendance.

All of the stakeholders interviewed agree that the biggest challenge they would face when adopting new systems is the resistance of change and the lack of seeing the benefits of adopting to new systems by different stakeholders.

d) Solution Proposal

The interview data gathered allowed for further improvement of the proposal solution which would aid to help and bridge the communication and knowledge gap between clients and project design and construction teams in the BIM process.

VII Focus Group Testing

The prototype solution was initially planned to be tested with stakeholders that interviews were conducted with through an online focus group, allowing to receive further feedback on the prototype solution before its finalisation. Focus group would help to identify further gaps in the proposed solution before the finalisation of the prototype. However, to ensure complete testing of the prototype, the proposed solution would have to be implemented on a real-life project throughout all stages. The final prototype will be something that should be the subject of research-based testing for future research. The timeframe for full testing of the final prototype needs to be for the full duration of a sample live project, from design through to handover. If the testing of solution would be possible, it would far exceed the duration of CE research. Please see 'IX Limitations of the Research' section highlighting the reasoning why the focus group could not be held as part of this research. However, improvements and restructuring was done to the prototype solution one described under section V of this paper. Therefore, this allowed for production of the final solution prototype described under following section VIII.

VIII final solution Prototype

The proposed MED was finalised, aimed to bridge the communication and knowledge gap between clients and design and construction teams, resulting in streamlining of the BIM process. The final solution prototype is a culmination of research undertaken and has been significantly further developed from what has been described under section V. The final proposed MED consists of total of thirty-six tabs. Please see Figure 4 representing a cascade of included Excel tabs in the final MED prototype. A test model has also been created from Revit default project representing the linking of information from the MED to the model using the created Dynamo scripts, which is represented in the ePortfolio of this research. The tabs have been reorganised and updated in MED from what has been outlined in section V of this paper, which are listed in Table 2 as follows (Note: Tabs are only listed in this section and are as per description under section V of this paper):

Table 2: Final Solution Tabs

Tab No.	Tab Description
1	A Project Information Sheet, giving an overview and covering all the relevant information.
2	A guidance tab assisting with the interpretation of the MED.
3	A document register of all project drawings, documents, registers, etc. with easy to filter options
4	File Naming Convention as per standard MIDP.
5	Asset Naming Convention as per IBM Maximo naming convention requirements. If different FM system is used by client, different information structure may need to be developed.
6	Stage Details tab outlining High-level details of each stage of the BIM process.
7	Project Roles and Responsibilities covering
8	Roles by Stage covering to what stage of the process different roles apply to.
9	Standard EIR document.
10	Standard AIR Document.
11	OIR – Note: This is a new tab added that was not included in the previous prototype, as it was something recommended by some of the stakeholders interviewed.
12	Standard BEP Document.
13	CDE Overview, CDE Typical Workflow, CDE Compatibility Requirements, Platform Option List and Communication Protocol.

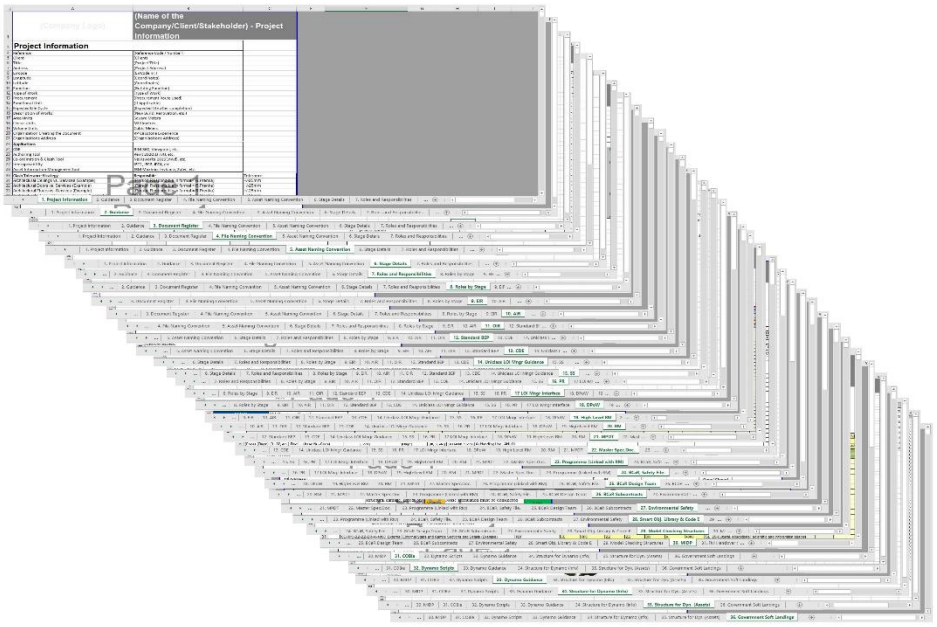

Figure 4: Cascade of Final Prototype MED tabs

Tab No.	Tab Description
14	Uniclass LOI Manager guidance – Note: The Uniclass interface has to be run with the LOI Manager Document open as a separate Excel document. The LOI Manager document was acquired with BIM consultant interviewees permission
15	Uniclass System (Ss) table,
16	Uniclass Product (Pr) table,
17	LOI Manager Interface,
18	DPoW,
19	High-Level RM,
20	Detailed RM,
21	MPDT,
22	Master Specification Document,
23	Programme structure,
24	BC(a)R, Safety File Overview,
25	BC(a)R Design Team Technical Submittals,
26	BC(a)R Subcontractor Technical Submittals,
27	Environmental Safety – Included and must be considered as part of the BIM process. However, this is not essential in alignment with current BIM standards. This section can be further developed for future research,
28	Smart Object Library and Codifying Elements,
29	Model Checking Structures,
30	MIDP,
31	COBie,
32	Dynamo Scripts,
33	Dynamo Guidance,
34	Information Structure for Dynamo Scripting,
35	Asset Information Structure for Dynamo Scripting,
36	GSL

IX Limitations of the Research

As outlined under section VII, it was initially planned to test the final prototype through an online focus group through Fourth Generation Evaluation methodology. The focus group could not be held due to availability of key participants, current COVID-19 situation in the country of Ireland and the time constraint of the research. Furthermore, to establish if the proposed prototype would assist with bridging the communication and knowledge gap between stakeholders and clients, the prototype should be implemented on a live BIM project. The proposed document should be used by PIM throughout the design and delivery, and the outcomes of the prototype must be observed for the project duration.

X Conclusion & Recommendations

This paper presents an investigation of the experiences of numerous professional stakeholders across a wide spectrum of the construction industry with regard to their understanding of BIM. A number of trends have been identified relating to shortfalls in terms of clients expectations and project teams

delivery in terms of BIM outcomes. This shortfall is evident across all stages of the asset life cycle despite the existence of well-established international standards to support the process. The research has pointed to a clear requirement for better mechanisms to allow the clients information requirements to be accurately defined. As a result of the findings of both the literature review and qualitative interview process the author has developed a prototype information management tool, building on existing frameworks, which should provide improved mechanisms for managing the capture, specification and delivery of clients information requirements. This research aimed to identify communication and knowledge gaps in the BIM process at different stages of the project, where BIM has been implemented. It is evident from the literature reviewed and the interviews conducted that information out of the BIM process is where clients benefit the most. 3D aspect of the BIM process is where design and construction teams would benefit from the process assisting with design coordination before the physical delivery. BIM models tend to confuse clients when brought in the picture of a project. Furthermore, most recent ISO 19650 standards have moved away from modelling in BIM and highlights the importance of information data management through the BIM process.

The action research and qualitative interview methodology routes investigated and selected in alignment with research objectives allowed for detailed examination of the barriers of BIM when communicating between project team stakeholders and clients. Action research methodology assisted with the production of solution prototype one, which was then further developed after interview findings.

Final Prototype has been developed to assist in reducing the communication and knowledge gap between design and construction team professionals and clients involved in the BIM process. Relevant BIM standard documentation included in the final prototype solution were gathered from various sources and some of which were produced by the author in alignment with the current standards in place. The solution derived from the research and interview findings aimed to bring all BIM standard documentation in one place and in a logical order. Therefore, making it easy to follow and understand for all parties involved, especially when it comes to meeting the clients requirements and expectations.

In terms of future research, the proposed final prototype should be implemented on a live BIM project, supporting PIM. This could not be achieved as part of this research, due to time constraint of the CE. The time for full testing of the solution would be full duration of a BIM project, from design through to handover. This would then establish further refinements required for the solution, making it more efficient and further addressing the knowledge and communication gap between design and construction teams and most importantly clients in the involved in the BIM process.

REFERENCES

Al Ahbabi, M., & Alshawi, M. (2015). BIM for client organisations: a continuous improvement approach. *Construction* Innovation, 15(4), 402-408. https://doi.org/10.1108/ci-04-2015-0023

Almuntaser, T., Sanni-Anibire, M., & Hassanain, M. (2018). Adoption and implementation of BIM – case study of a Saudi Arabian AEC firm. *International Journal of Managing Projects in Business,* 11(3), 608-624. https://doi.org/10.1108/ijmpb-05-2017-0046

Ashworth S., Tucker M. & Druhmann C. (2016). Integration of FM expertise and end-user needs in the BIM process using the Employer`s Information Requirements (EIR). Retrieved from: https://www.researchgate.net/publication/301776775

Ashworth S., Tucker M., Druhmann C. (2016). The Role of FM in Preparing a BIM Strategy and Employer's Information Requirements (EIR) to Align with Client Asset Management Strategy. *15th Euro FM Research Symposium, Euro FM Research Papers 2016.* Retrieved from: https://www.researchgate.net/publication/301776904

Ashworth, S., Tucker, M. & Druhmann, C. (2019). Critical success factors for facility management employer's information requirements (EIR) for BIM. *Facilities,* 37(1/2), 103-118. https://doi.org/10.1108/f-02-2018-0027

Bosch-Sijtsema, P., Gluch, P., & Sezer, A. (2019). Professional development of the BIM actor role. *Automation in Construction,* 97, 44-51. https://doi.org/10.1016/j.autcon.2018.10.024

BSI Standards Publication (2018). BS EN ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 1: Concepts and principles. *BSI Standards Publication.* Retrieved from https://shop.bsigroup.com/ProductDetail/?pid=000000000030389655

BSI Standards Publication (2018). BS EN ISO 19650-2:2018 Organization of information about construction works — Information management using building information modelling — Part 2: Delivery phase of assets. *BSI Standards Publication.* Retrieved from

https://shop.bsigroup.com/ProductDetail/?pid=000000000030389655

BSI Standards Publication (2014). PAS 1192-3:2014 Specification for information management for the operational phase of assets using building information modelling. *BSI Standards Publication.* Retrieved from: https://shop.bsigroup.com/ProductDetail?pid=00000000030311237

BSI Group. (2019). A Passport to Global Opportunities and Transformative Collaboration. Retrieved 14 April 2020, from https://www.bsigroup.com/globalassets/localfiles/en-gb/bsol-construction/bsi-building-information-modelling-report.pdf

BSI Group. (2020). BIM - Building Information Modelling Certification. Retrieved 6 April 2020, from https://www.bsigroup.com/en-IE/Building-Information-Modelling-BIM/

Dakhil, A., Underwood, J. and Alshavi, M. (2016), BIM benefits-maturity relationship awareness among UK construction clients. In: First International Conference of BIM Academic Forum. [online] *Glasgow: First International Conference of BIM Academic Forum.* Retrieved from https://www.researchgate.net/publication/308375997

Dakhil, AJ, Underwood, J and Alshavi, M. (2019), Critical success competencies for the BIM implementation process: UK construction clients, *Journal of Information Technology in Construction (ITcon)*, 24 , pp. 80-94, Retrieved from https://www.itcon.org/2019/5

Gao, X., & Pishdad-Bozorgi, P. (2019). BIM-enabled facilities operation and maintenance: A review. *Advanced Engineering Informatics*, 39, 227-247. https://doi.org/10.1016/j.aei.2019.01.005

Georgiadou, M. (2019). An overview of benefits and challenges of building information modelling (BIM) adoption in UK residential projects. *Construction Innovation*, 19(3), 298-320. https://doi.org/10.1108/ci-04-2017-0030

Hadzaman, N., Takim, R., & Nawawi, A. (2015). Building Information Modelling (BIM): the impact of project attributes towards clients' demand in BIM-based project. *Building Information Modelling (BIM) In Design, Construction and Operations*, 149, 59-69. https://doi.org/10.2495/bim150061

Heaton, J., Parlikad, A., & Schooling, J. (2019). Design and development of BIM models to support operations and maintenance. *Computers in Industry*, 111, 172-186. https://doi.org/10.1016/j.compind.2019.08.001

Hu, Z., Tian, P., Li, S., & Zhang, J. (2018). BIM-based integrated delivery technologies for intelligent MEP management in the operation and maintenance phase. *Advances in Engineering Software*, 115(1), 1-16. https://doi.org/10.1016/j.advengsoft.2017.08.007

Husain, A., Razali, M., & Eni, S. (2018). Stakeholders' expectations on building information modelling (BIM) concept in Malaysia. *Property Management*, 36(4), 400-422. https://doi.org/10.1108/pm-02-2017-0013

IBM Corporation. (2016). Investigating the case for lifecycle asset information integration for infrastructure and buildings. IBM. Retrieved from https://www.ibm.com/case-studies/u787559y73586r76

Lewis, R., & McPartland, J. (2017). Nondefault loss allocation at central counterparties. *The Journal of Financial Market Infrastructures*, 6(1), 29-44. http://doi.org/10.0.83.66/jfmi.2017.082

Li, J., Hou, L., Wang, X., Wang, J., Guo, J., Zhang, S., & Jiao, Y. (2014). A Project-Based Quantification of BIM Benefits. *International Journal of Advanced Robotic Systems*, 11(8), 123. https://doi.org/10.0.22.140/58448

Lindblad, H. (2018). Black boxing BIM: the public client's strategy in BIM implementation. *Construction Management and Economics*, 37(1), 1-12. https://doi.org/10.1080/01446193.2018.1472385

Mahamadu, A., Mahdjoubi, L., Booth, C., Manu, P., & Manu, E. (2019). Building information modelling (BIM) capability and delivery success on construction projects. *Construction Innovation*, 19(2), 170-192. https://doi.org/10.1108/ci-03-2018-0016

Munir, M., Kiviniemi, A., & Jones, S. (2019). Business value of integrated BIM-based asset management. *Engineering, Construction and Architectural Management*, 26(6), 1171-1191. https://doi.org/10.1108/ecam-03-2018-0105

Oraee, M., Hosseini, M., Edwards, D., Li, H., Papadonikolaki, E., & Cao, D. (2019). Collaboration barriers in BIM-based construction networks: A conceptual model. *International Journal of Project Management*, 37(6), 839-854. https://doi.org/10.1016/j.ijproman.2019.05.004

Papadonikolaki, E., van Oel, C., & Kagioglou, M. (2019). Organising and Managing boundaries: A structurational view of collaboration with Building Information Modelling (BIM). *International Journal of Project Management*, 37(3), 378-394. https://doi.org/10.1016/j.ijproman.2019.01.010

Piroozfar, P., Farr, E., Zadeh, A., Timoteo Inacio, S., Kilgallon, S., & Jin, R. (2019). Facilitating Building Information Modelling (BIM) using Integrated Project Delivery (IPD): A UK perspective. *Journal of Building Engineering*, 26, 100907. https://doi.org/10.1016/j.jobe.2019.100907

RIBA Enterprises (2017). RIBA Enterprises. National BIM Report, pp. 1–28. Retrieved from: https://www.thenbs.com/knowledge/nbs-national-bim-report-2017

Vass, S., & Gustavsson, T. (2017). Challenges when implementing BIM for industry change. *Construction Management and Economics*, 35(10), 597-610. https://doi.org/10.1080/01446193.2017.1314519

Wan Mohammad, W., Abdullah, M., Ismail, S., & Takim, R. (2018). Overview of Building Information Modelling (BIM) adoption factors for construction organisations. IOP Conference Series: *Earth and Environmental Science*, 140, 012107. https://doi.org/10.1088/1755-1315/140/1/012107

Yang, J., & Chou, H. (2019). Subjective benefit evaluation model for immature BIM-enabled stakeholders. *Automation in Construction*, 106, 102908. https://doi.org/10.1016/j.autcon.2019.102908