2020

A Critical Appraisal of findings and solutions to overcome erroneous BIM model production and information delivery workflows

BIM TUDublin
bim@tudublin.ie

Ryan Forde
Technological University Dublin

A Critical Appraisal of findings and solutions to overcome erroneous BIM model production and information delivery workflows.

Ryan Forde

School of Multidisciplinary Technologies,
Technological University Dublin, Bolton Street, Dublin 1, Ireland

E-mail: [1] ryan.forde@mytudublin.ie [2] D17123886@mytudublin.ie

Abstract - There are many varying definitions of Building Information Modelling, all of which reflect its transformative capabilities and impact on the construction sector. BIM is an emerging technological and procedural shift within the AEC industry (Succar, 2009). BIM is not just a technological change, but also a procedural and workflow change (Charles Eastman, 2018). Despite the growth of BIM adoption and increasing levels of maturity regarding BIM standards, numerous issues still arise at a micro level during project execution. BIM invokes the need for workflows, frameworks and processes that imparts knowledge, heightens trust, increases efficiency and consistency while reducing fragmentation and coordination shortfalls.

The objective of this paper is to evaluate current industry workflows, and critique BIM model production processes, with a view to identifying a workflow framework to improve project information among stakeholders throughout the delivery stage of a project.

Keywords – BIM; Model Production; Workflows; Framework; Workshop; Standards.

I INTRODUCTION

Many groups and committees around the globe including Ireland's National BIM Council (NBC) are driving for BIM implementation by encouraging industry stakeholders to adopt the latest digital technologies, processes, and workflows. Notwithstanding that BIM implementation is progressing, key issues remain for example, some companies decide not to adopt the latest BIM tools and workflows. As stated by Merschbrock (2015), some companies decide to use workarounds to avoid BIM adoption, these workarounds reflect inadequate resources, and technical proficiency which leads to poor information exchanges between project teams. Other companies opt to develop their own processes and standards in complete isolation to other teams, known as silos. This approach is costly and time consuming and signifies a hesitance for adopting open workflows and processes. To improve BIM performance across the industry, stakeholders must acknowledge the importance of adopting common, trusted BIM workflows and processes as well as sharing past experiences and best practices.

Regarding team collaboration (Sinclair, 2013) asserts that effective workflows and process are essential for a BIM project to be successful. The ever-increasing use of digital technologies and applications for producing design and project information and the varied means of communicating requires a clear understanding on these subjects if project information delivery is to be successful.

In the RIBA published report Assembling a Collaborative Project Team, it is proposed that the best method of melding stakeholders into an effective project team is by ensuring all parties are fully aware of what their requirements are and the methods to successfully achieve these requirements in an efficient and collaborative manner. This can be reinforced at the beginning and at key work stages of the project by undertaking strategic workshops where the BIM requirements can be

demonstrated. Workshops can be facilitated to address BIM workflows focusing at a micro level on how models will be created, used, revised, shared and so on.

II RESEARCH OBJECTIVES & ASSOCIATED METHODOLOGIES

The recently superseded publicly available specifications known as PAS1192 are a series of national standards that define BIM Level 2 in the UK. Following their publication and recognising their benefit, many asset owners and clients in Ireland adopted these standards on their projects. The current ISO 19650 series of international standards is based upon the PAS1192 documents, altered to an international context. Both series of standards provide a common approach to the creation and management of information.

Building off the current industry BIM standards and best practices, the aim of this research is to investigate reoccurring issues that prevent successful execution of industry standards, and to propose a solution in the form of a micro-level BIM workflow framework in tandem with existing standards. The framework will be developed as a project delivery document which may be incorporated and aligned to project BIM Execution Plans.

The literature review of this research establishes that current industry standards define collaborative processes for creating and managing information when BIM is being used, at a macro or high level. This highlights the potential for new research to be contributed at a micro level. The research strategy utilises five key objectives, each providing context for the next objective. The figure below illustrates the top down approach applied.

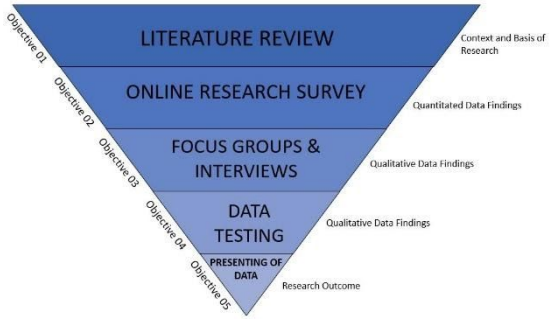

Fig. 1: Top down research approach

This research begins with a literature review study of peer-reviewed articles and published research, focusing on examples of project teams succeeding or failing to adhere to current BIM industry standards, both nationally and internationally. This review will form questions for an online survey which will be distributed to key industry professionals to critically investigate their own internal company BIM processes. Following this stage, the researcher will develop a BIM workflow framework. The information within this framework is to be implemented at key stages of the project and demonstrated to project teams in the form of strategic workshops. To critique and road-test this framework, the researcher will engage in an online focus group with BIM specialists in Ireland. The data collected will be triangulated and the workflow framework will be presented to a second group of industry professionals for further review and future implementation and study.

The following section of this paper will detail several peer-reviewed, academic data sources analysed to appraise current model production standards and frameworks in both a national and international context.

III LITERATURE REVIEW

The AEC UK BIM Protocol 2012 contended to achieve technical excellence and a successful outcome to a BIM project, it is critical that BIM data and modelling production is carefully planned. This requires clear attention to management, display, and quality of the design. Listed below are several key principles that will improve information delivery.

a) A Pre and Post Contract BIM Execution Plan BEP shall be put in place that classifies project tasks, outputs and model configuration, this document may form part of the Supply Chain Information Execution Plan.
b) BIM project reviews are to be agreed and must take place frequently to ensure model integrity and project workflow is maintained.
c) Develop clear unambiguous guidelines for internal and external collaborative working.
d) Identify clear ownership of modelled elements throughout the life cycle of the project.
e) Sub-divide models between different disciplines.
f) Understand and clearly document what is to be modelled and to what level of detail.
g) All changes to the model to be carried out as 3D revisions, rather than 2D revisions.

h) All outstanding warnings to be reviewed frequently and important issues resolved.

(Lennart Andersson, 2016) suggests efficient BIM model workflows are crucial to the success of a BIM project. There are many sophisticated and powerful BIM authoring and review tools available on the market, but using these tools to their full capabilities requires experienced professionals to create, manage and update workflows and processes. When correctly configured and utilised, an efficient workflow provides model originators with a trusted method for model production. Workflows allow for knowledge to be transferred and standardised across various projects, enabling better coordination, collaboration, and communication between the delivery team.

The BIM Managers Handbook includes responses summarily from the world's leading BIM Managers noting problems attributed to poor or lack thereof BIM workflows.

a) Pseudo BIM is used to pretend BIM was applied whereas a CAD workflow was used instead. Pseudo BIM is used when teams use BIM tools to produce their 2D documentation. BIM software gets used to generate submission documents more efficiently. Coordination opportunities are lost when teams separate geometry from data.
b) Hybrid BIM, excessive CAD gets applied by teams who commit to using BIM but revert to 2D CAD part way through a project.
c) Problems emerge when modelling is done by different teams without sharing and overlaying these models for coordination.
d) An uncoordinated BIM effort results in duplication of information and re-work, Potential collaborative workflows are not being utilised and the BIM process becomes inefficient.
e) The absence of a BIM Execution Plan leads to conflicts among collaborators and a loss in productivity. BEP's increase the possibilities for teams to work concurrently on declared and common BIM goals. A lack of understanding occurs when BEPs are not created, or if they are not detailed enough to be useful.
f) Teams focusing on a high Level of Detail for graphical purposes at the expense of useful and embedded meta-data. This signifies too much geometric information which creates unnecessary effort, and makes models too heavy for daily use, thereby lowering the coordination for the team.

The BIM Manager's handbook concludes that the many problems relate to model workflow inefficiencies. Each team creates, updates, manages, and shares their models in non-collaborative ways. This causes confusion during weekly coordination and clash detection meetings, resulting in extra time being spent resolving issues that could have been eradicated by utilising a model workflow process at early stages of a project.

a) BIM Execution Plans

A BIM Execution Plan BEP is defined as a plan prepared by the suppliers to explain how the BIM aspects of a project will be carried out. The BEP is one of the key components of Level 2 BIM and must contain the following elements at a minimum.

a) A list of roles and responsibilities.
b) BIM deliverables related to project work stages
c) How will information be approved?
d) How collaborative information will be used.
e) How will the models be zoned for each discipline?
f) Modelling clash tolerances
g) Location and orientation of models
h) File and layer naming
i) Annotation standards
j) A list of information and documentation to be delivered in alignment with project work stages including formats
k) A model delivery strategy.

A BEP's primary function is to explain how the information management aspects of the project will be carried out by the delivery team. [1] asserted that BEP's are often poorly assembled and lack the micro and local level of information required for the document to be properly useful, this can expose risk and potential disputes and claims.

[2] summarised a simple scenario in their article, *'The Importance of a BEP'*. It is possible that a structural engineer needs to specify structural openings around ductwork. Are the ducts modelled to the approximate size or its designed dimensions? When will the mechanical engineer be providing that information? What if a contractor expects the ability to replace all doors with the manufactured, as constructed door types? What if the windows do not have attribute parameters to define them as

windows? A BEP must define how the author intends to construct their information and what other teams should be expecting from it. The difficulty is knowing what will be required.

This research aims to encourage people to provide additional detailed information aligned to a BEP to clarify some of these possible modelling ambiguities.

b) BIM Frameworks

BIM Frameworks are a metric tool used to identify and measure the level of BIM implementation and assessment. The assessment of BIM maturity is widely researched by Dr Bilal Succar author of many peer-reviewed BIM research papers. In Succar's paper, *'Building Information modelling framework: A research and delivery foundation for industry stakeholders'*, which is regarded as a scene-setting paper, identifies BIM deliverables and adoption in a new framework. This new framework provides BIM deliverables at a macro level. Future study is required to produce a new framework for BIM deliverables at a micro level, which is the purpose of this research study.

The BIM Innovation Capability Programme (BICP) research team delivered the BIM in Ireland 2017 report which presented results of Macro Maturity Component models that were utilised to quantify macro BIM adoption and utilisation. The study was based on the published research by Succar and Dr Mohammad Kassem. The results showed Ireland as mature in modelling processes, BIM roles and model workflows, but less mature regarding collaborative process and policies. Unfortunately, Ireland ranked poorly regarding regulatory frameworks.

c) Working in Silos

When producing information, each team should know what they are expected to produce as set out in the Responsibility Matrix. The matrix defines what model and information is produced by whom, and to what level of definition in relation to project stages. Typically, each team goes off and starts to work individually in fragmented silos to produce project information which causes collaborative problems from the beginning of the project.

The National BIM Report 2018 questioned, "What are the main barriers to using BIM?" a large percentage of survey respondents stated, when teams work in silos as a barrier. Silos are team units where there is a breakdown in communication, collaboration, and co-ordination with other teams.

To best alleviate silo working and to promote a fully collaborative process, a trusted multi-disciplinary workflow framework should be agreed and initiated at the earliest stage of model production. The workflow must be adapted for the fulfil the BIM model requirements for each team as set out by the client or appointing party. Teams must not deviate from the guidelines or best practices.

d) Clash Resolution & Avoidance

Team collaboration is vital if final design BIM models if they are to be clash free, and BIM as a process has the capability to reduce clashes through 3D Coordination. To achieve clash-free BIM models isolated working Silo's must be discouraged. Sufficient training, and level of experience for the effective use of BIM clash detection tools is crucial for clash resolution and clash avoidance.

A summary review of plausible drivers that influence 3D clashes in a BIM model is shown in the table below.

- Professional Errors by Designers
- Working in Silo's (Isolation)
- Time Constraints
- Use of Incorrect Level of Information
- Use of 2D Design rather than 3D Models
- 3D Models Objects Exceeding Allowable Clearance
- Inconsistency between Design and Actual Fabrication
- Designers Working in Different File Formats
- Use of Placeholders
- Complexity of Building Components

Fig. 2: Drivers of 3D Clashes

[3] produced the following table comparing the variables between clash detection and clash avoidance.

Clash Detection	Clash Avoidance
Key Differences	
It is a **reactive** process (after-the-fact) and checks for collisions and coordination only after design decisions have been taken	It is a **proactive** process and ensures that design decisions and outcomes are agreed to collaboratively through joint design
Mainly a pre-construction activity	Runs throughout all phases of the project
Focus is on the clash detective tool and improving the clash-rule sets	Focus extends beyond the tools. Emphasis is paid on the nature of collaboration between the MEP discipline and others
Requires basic level coordination skills	Requires more rigorous management and coordination skills
Does not require shared situational awareness	Requires shared situational awareness and how each player's design affects the others
Encourages silo-based working and hoarding of design information	Promotes information sharing and co-creation
May or may not be done by an experienced designer. A thorough understanding of the clash detective software by a newbie is deemed sufficient	Requires more experienced designers with a broader view of the design process
Longer design iteration time. Designers may keep going back and forth to get things right because of over-the-wall collaboration	Reduces design iteration time since decisions are taken jointly and information is shared freely as needed
Key Similarities	
The major objective is to issue clash-free models	The objective is similar
It identifies and fixes issues at the design phase which can lead to time and cost overruns at the construction phase	In many respects, similar
Aims to improve design quality	Similar

Fig. 2: Clash Detection vs Clash Avoidance [3]

The requirement in ISO 19650-2 is for clash avoidance to be used as a proactive measure in place of the traditional reactive clash detection methods. Yet currently, clash detection is so important for delivering a clash free 3D model that dedicated clash detection meetings are held where clashes are identified and resolved. The importance of these meetings signifies that clash avoidance is not practiced or perhaps not even considered, in direct contradiction to the current standards.

e) Current Industry Standards.

The "Roadmap to the Digital Transition of Ireland's Construction Industry 2018-2021" is steadily ongoing, aswell as the Irish Government's 2019 BIM Mandate for public procurement for complex projects and will continue to roll out for medium and simple projects over the next two years. BIM Level 2 requires all designers, contractors, specialists, and manufacturers that produce project information are required to so from a BIM process, by adhering to the ISO-19650 standard series which recently supersedes the PAS-1192 standard series. [4] highlights key points from the standard.

a) An Exchange Information Requirement (EIR) must be provided.
b) Each team is required to sign up to a BIM Protocol, which includes a responsibility matrix or Model Production Delivery Table (MPDT).
c) The lead designer, and main contractor, are required to take on the role of Project Information Manager (PIM) for design and construction stage.
d) At tender stage, a pre-contract BEP is required by suppliers, in response to the EIR, including a Project Implementation Plan (PIP), and BIM Capability Assessments.
e) Once appointed, a post-contract BEP is to be produced, in response to the EIR, including the Master Information Delivery Plan (MIDP).
f) A Common Data Environment (CDE) is required, following BS1192 file naming convention, and approval workflows.
g) A Digital Plan of Work (DPoW) is required, clearly defining the Level of Information Need, and assigning responsibilities.
h) A common classification system (Uniclass) must be used by all for organising models, documents, and project information.

The previous section mentions BIM requirements adapted from current industry standards. These requirements set the scene at a very micro-level of the conditions of Level 2 BIM. Unfortunately, most project teams use contrasting and independent working methods to fulfil these requirements, which creates silo's and therefore a disconnected collaborative approach.

[5] declares that true collaborative working requires mutual understanding, and a standardised process. Information must be produced and made available in a consistent timely manner. The standard states at present, considerable resources are spent making corrections to unstructured information, on solving problems arising from uncoordinated efforts between project teams. The standard expresses that delays can be reduced if the concepts and principles in the ISO 19650 standards are adopted.

To adopt the standards successfully the following features must be applied.

- Clear definitions for the information needed by the client, and for the methods, processes and protocols for production and checking.
- The quality of information produced to satisfy the level of information needed.
- Efficient transfers of information between parties.

The macro level process is illustrated in the following diagram.

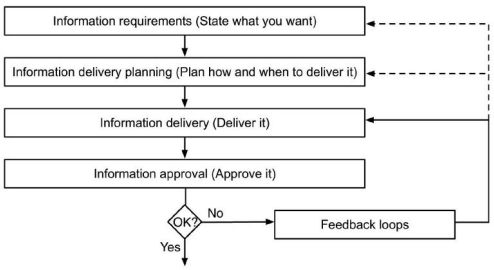

Fig. 2: High-level information delivery flow-chart [5]

This simple diagram shows that true collaborative working amongst teams can be achieved when a BIM process is followed according to the guidance of the ISO 19650 series. However, unfortunately true collaborative working remains as a constant challenge for the industry.

This research presents an opportunity to alleviate this challenge by developing a workflow framework that can be aligned to current BIM documents. This proposed framework should provide structured micro level workflows for key project stages. Each party must adhere to this framework document as they would with current BIM documents and standards.

The introduction of new terms within the ISO 19650 series may cause confusion, for instance replacing the employer to a more neutral term such as appointing party, hence the EIR now becomes the project information requirements (PIR). New acronyms are also introduced such as the PIPMP, PMP, PIS, PIDM. BIM language has caused confusion over the years, [6] suggests that the UK BIM Task Group of 2011 created a new special language for users, making the process arcane, and vague to industry outsiders including clients. [7] asserts "We are doing a lot of exciting things with our industry, but how do we expect to share these new developments if no one understands a word we're saying?".

[8] state the application of standards is dependent on many often poorly understood or articulated factors. Standards are generally supported but not applied rigorously. They are nominally supported; no one is against them, but few apply them comprehensively. [9] assert that construction projects are costing too much and taking too long as a consequence of unnecessary omissions, errors and re-work in project documentation and sub-optimal coordination processes of design information between consultant disciplines, these issues can be addressed by process standards and collaborative workflows to improve the creation and management of project documentation.

The UK BIM Alliance in association with Building SMART and CDBB, published several framework guidance documents in April 2019. [10] state the purpose of these documents are to help individuals and organisations that are struggling to understand the principles of BIM according to ISO 19650 Parts 1 and 2. However although these documents were published to provide guidance, the author of the document asserts that the guidance is deliberately brief and high-level, with broad general topics cross referenced with the ISO series. This researcher questions the purpose of a guidance document that is purposefully broad and high-level with the intention of simplifying the ISO 19650 series that at its core fundamentally describes principles and functions at a high-level. This research accepts that the ISO 19650 series does exactly what it was intended to do and provides an international framework for information management using BIM as the foundation, however there is another level of detail that the industry requires to be developed to avoid misunderstandings, debates and even dispute.

f) Procedures & Measures from an International Context

It is important to understand how other countries and cultures are implementing, managing, and supporting BIM compared to our own industry. This section briefly focuses on successful BIM attributes internationally.

In 2013, the second version of the Singapore BIM guide was published by the Singapore Building and Construction Authority. The document defines how to create and share BIM deliverables at different stages of a project. It includes BIM modelling guidelines and collaboration procedures demonstrated at a project local level. Similarly, the Australia BIM-MEPAUS provided the Australian construction industry with best-practice BIM information, standards, workflows, and templates. Specifications are developed with the support of industry including many of Australia's leading BIM practitioners. The documents ensure models are precise and accurate, practices are applied routinely and consistently, and the creation and sharing of information follows a trusted workflow.

In 2014, the Construction Industry Council of Hong Kong published a report named Roadmap for the Strategic Implementation of BIM. The document established a local BIM standard as

a common platform and language for Hong Kong's BIM practitioners. These standards are implemented in stages, with phase one to focus directly on, how to prepare a discipline specific BIM model right through the project lifecycle. The document focuses on model production methodologies and good practices. The document has been highly successful and is widely accepted within the industry.

Like Singapore, New Zealand published its first edition of the New Zealand BIM handbook in 2019 which includes the recent ISO 19650 standards, the publicly available report includes information on BIM for construction, facilities management, and linear infrastructure. A wide range of appendices from the report, provide templates and examples of BIM planning documents and more detail on specific aspects of the BIM workflow, including model coordination and varying workflow processes.

At the time of writing Ireland and the UK have not published an industry BIM Handbook like the countries mentioned. The evidence suggests that Ireland and the UK's construction industry would benefit from such a document which could be aligned to current industry standards and guidance. Notwithstanding, Ireland has made considerable progress in recent years with the publication of Ireland's Roadmap to Digital Transition, and the release of the RIAI BIM pack, with a large increase in third-level BIM based education. These are all recent steps forward in Ireland's own BIM journey

g) Literature Review Summary

From critically assimilating and reviewing industry leading and accredited academic resources, this initial stage of the research has explored previous and current industry BIM standards, frameworks, and exemplar measures taken from an international context. From the data collected the research establishes that there is a disconnect between expectation versus reality, such as BIM pro industry standards and documents contrary to what is typically happening on the ground regarding BIM model production and information delivery.

As previously mentioned, many of the current industry standards and supporting guidance documents are broadly explained at a macro high level, without providing the required level of detail to understand these concepts and principals required for teams adapting their workflows to a BIM process. This research recognises plausible BIM and information delivery issues often emerge at a far more micro low level, caused by confusion, lack of understanding, breakdown of communication and non-collaborative workflows, among others. With this opinion in mind and with the participation and assistance from a large group of industry professionals, the following stages of this research investigates previous and current trends, statistics, problems, and proposes solutions to improve model production and information delivery workflows, proceeding with an online research survey.

IV QUANTITATIVE & QUALITATIVE ANALYSIS

To provide current real-world scenarios an online academic survey was issued to 55 industry professionals. To provide cohesive, rounded, and unbiased results the selected respondents were from varying disciplines and professional backgrounds. This followed with an online focus group discussion and interviews with several industry professionals to discuss the findings and data collected.

When the data was gathered from the literature review and quantitative online survey, the researcher focused on a number of topics including problems and plausible solutions, which were discussed in depth and critically evaluated during the online focus group and interview stages of the research.

It is important to consider the ethical issues that may arise, in any research work. This research is accountable to external bodies to demonstrate that all work followed best practice. As such, this research required that each focus group member and interviewee participant completed an informed consent form and a research participation form prior to any involvement.

a) Survey Strategy

The online survey was issued to 55 industry professionals from varying professional backgrounds known to be knowledgeable in this research. A total of 50 completed surveys were received within a two-week period providing a very high response rate. The survey consisted of a balance of open-ended, closed, rating and Likert style questions. The closed questions allowed statistical analysis while the open questions allowed respondents an opportunity for free expression.

b) Survey Findings

The objective at the beginning of the survey was to determine the type of discipline, BIM experience

and the organisational type the participants are involved in. This was to determine the variance of industry professionals across multiple disciplines and backgrounds.

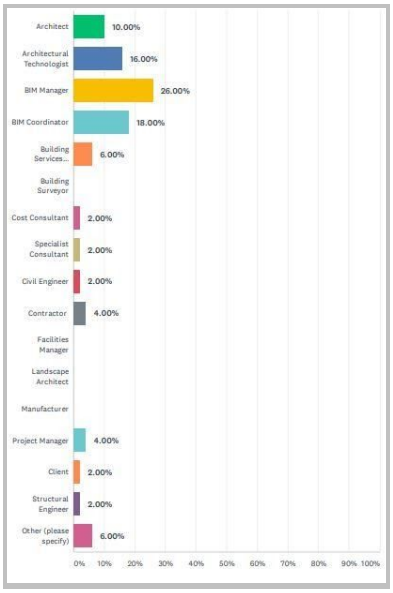

Fig. 3: Survey Response, Discipline Type

The survey questions predominantly focused on industry standards, company procedures protocols and workflows.

Only 15/50 respondents believed that BIM used on projects were aligned to the current ISO 19650 standards. One respondent noted, “design teams are not experienced enough with Level 2 BIM projects and therefore do not always comply completely with the requirements per the EIR/BEP”. Another respondent declared, “People are mostly using BIM software to produce traditional paper-based deliverables, and not strictly following the information management principles in the standards. The BIM deliverables at the end are very seldom a true reflection of the building constructed. Models are often incomplete and missing important data”.

The survey revealed that 38/50 respondents claimed their company had a BIM process and measures focused on model production and information delivery. However, less than half of noted they had very good or good adherence to their companies BIM procedures and measures.

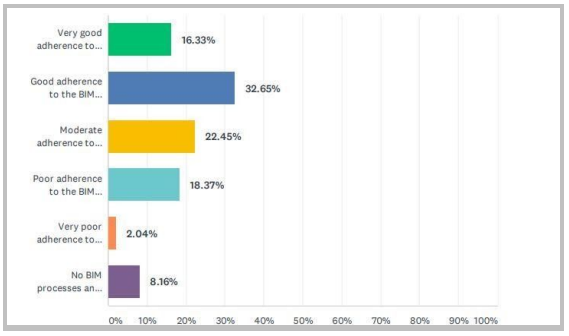

Fig. 4: Survey Response, Adherence to Company BIM Procedures

The researcher pursued an attitudinal response when the survey respondents were asked to determine at which work-stage does BIM model production and delivery problems arise. The respondents believed the Design and Build and Commission as being the most fragmented stages.

It is evident that Autodesk Revit has undoubtedly surpassed AutoCAD as the respondents picked the modelling tool as the primary design authoring tool in today’s industry. Autodesk Navisworks was utilised by 40/50 of the respondents for model checking purposes.

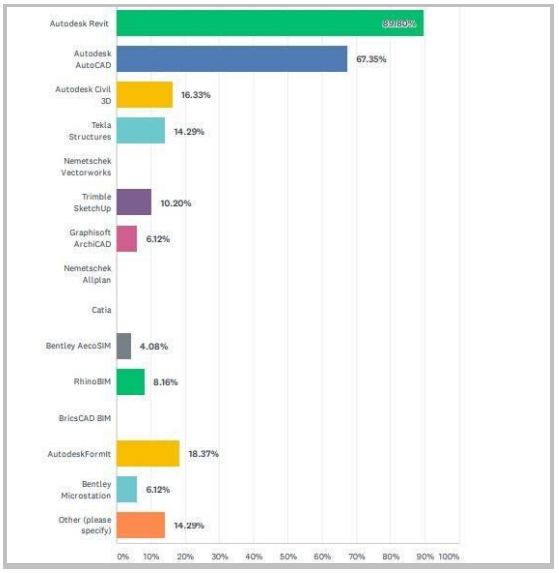

Fig. 7: Survey Responses BIM Design Authoring Tool

Relating to understanding of current BIM standards, 35/50 respondents acknowledged that within their own organisation there is a lack of understanding of the standards, while almost all respondents agreed that failing to understand and adhere to the standards impedes BIM model production and information delivery.

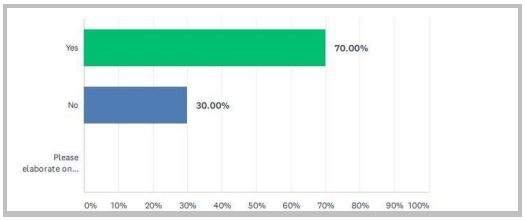

Fig. 8: Survey Response, Misunderstanding BIM Standards

c) Summary of Survey Results

These results would imply there is a lack of understanding or reluctance to comply with the current BIM standards, especially towards BIM model production. Almost all respondents were aware and acknowledged that by not following these standards the BIM process would be hindered where problems arise during the Design and Build & Commission stage. BIM problems arise, whenever one party, must exchange information with another party, where the expectations are not clear, and the exchange is not checked/validated. There was a significantly high response rate of those utilising Autodesk Revit, and Navisworks as the primary BIM software tools.

V QUALITATIVE ANALYSIS & SYNTHESIS OF FOCUS GROUP & INTERVIEW FINDINGS

a) Focus Group & Interview Strategy

Once the proposed workflow framework was drafted, the next stage of the research was to develop an open discussion focusing on the validity and robustness of the proposed solution. To ascertain industry feedback, several semi-structured interviews were completed. The focus group and interviews included, leading BIM experts, members of the NBC, architects, MEP engineers, information managers, Plannerly members, BIM trainers, BIM coordinators, all specifically chosen to provide different perspectives for each topic. The topics chosen were derived from the data collected during the literature review and online survey. The semi-structured interview technique allowed for open discussions on the following topics.

- Training Requirements
- Level of Information Need
- Common Data Environment Processes
- Coordination & Clash Avoidance
- Information to be Included/Excluded
- Exchange Formats
- Standards Methods and Procedures
- Delivery Strategies
- Authorization Processes

b) Proposing the Solution

This research has identified several areas of BIM fragmentation and plausible issues for concern. From the data collected, and aforementioned in the literature review, this research accepts that the ISO 19650 series does exactly what it was intended to do and provides an international framework for information management using BIM as the foundation, however there is another level of detail that the industry requires to be developed to avoid misunderstandings, debates and even dispute.

Although many of these issues are outlined in the industry standards and included in different sections of a BEP, delivery teams struggle to find a unified, collaborative approach to overcome these recurring themes. Possibly because they are defined at a macro level in these documents, potentially leading to interpretation and uncertainty.

The purpose of this workflow framework is to tackle these topics which are important sections of a BEP. A plausible set of solutions will be created with the aim of producing a workflow framework to be aligned in conjunction with the traditional BEP. The core elements to the workflow framework is the macro level BEP, the proposed workflow framework, the Project information Manager PIM and the supply chain BIM workshops.

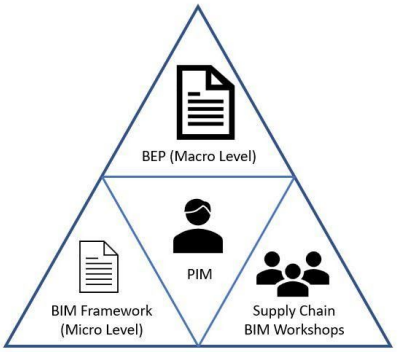

Fig. 9: Workflow Framework Core Elements

Within this proposed workflow framework, the PIM is responsible for leading the supply chain BIM workshops. The workshops will consist of the relevant delivery team members. These workshops may be facilitated online or onsite and may be recorded as a project resource.

The goal of each workshop is to agree on specific workflows, procedures, best practices applicable to the project.

c) Devising the Workflow Framework

Simply put, a BEP is a document split into sections all of which forms the basis for several BIM deliverables and requirements as per industry standards on a project, this sets the scene for collaborative BIM at a macro level on a project.

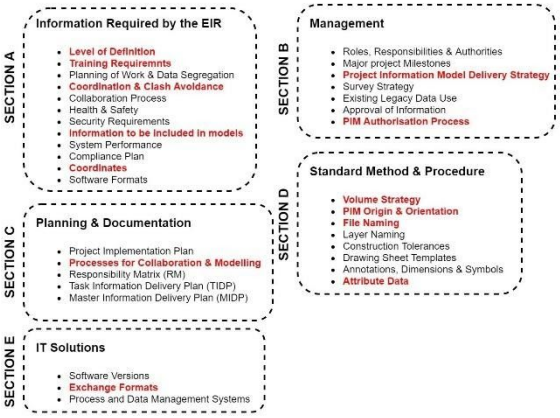

Fig. 10: Primary sections of a BIM Execution Plan

This diagram above denotes the main sections within the RIAI BEP post contract template. The highlighted items are important sections of a BEP. These highlighted items are key problematic areas of concern and will be discussed in depth during the focus groups and interviews stages with the intention of providing plausible solutions to each section and finally embedding these solutions into the proposed workflow framework that will be aligned to the main BEP.

The workflow framework will be divided into sections. These sections will be aligned to the following plan of work stages.

- Stage 1: Brief
- Stage 2: Concept
- Stage 3: Definition
- Stage 4: Design
- Stage 5: Construction
- Stage 6: Handover
- Stage 7: Operations & Maintenance

d) Training Requirements

Training is discussed in the mobilization plan section of ISO19650. It is essential that each team involved in a BIM project meet the required level of capability. One participant of the research interview's stated, "a big challenge from the beginning is that teams don't always tell the truth about their capability, and this becomes apparent very quickly". It is critical to know the levels of expertise and each team's capability for delivering information directly from a BIM model.

A second participant mentioned during the focus group that most projects involve the use of Revit and Navisworks, which concurs with the survey responses. The participant asserted, "most teams can deliver Revit and Navisworks models, however it's the additional model requirements that teams struggle to deliver such as Uni-class Classification and COBie deliverables". Participants discussed the potential for the PIM or a member of the design or construction team to provide support resources that is bespoke to the project requirements. The participants agreed that additional guidance could also be demonstrated during a strategic BIM workshop with all relevant team's present. The workshop can be recorded with the intention of sharing with new teams as they come onto the project.

e) Level of Information Need

As mentioned in the literature review, project teams spend countless hours creating a high Level of Detail LOD for graphical purposes, often at the expense of useful meta-data. Too much geometric information creates unnecessary effort, and increases the model size, this lowers the usability of the model for both internal and external teams and therefore negatively impacting collaborative efforts. One participant noted, "when objects are too large, quite often they are downloaded online coming directly from the manufacturer". A participant mentioned a tool called the LOI Manager, that he uses on most projects, he followed by stating, "the NBS have defined every product and system as a set of parameters, If the NBS states that for a product or system you need certain parameters, the LOI Manager tool can tailor what parameters you actually need, then you can produce a product data template for each product or system". "Now you have an agreement for each type of system and product, and once you have an agreement, you can check against it to make sure it's complete".

All participants agreed that the responsibility matrix must list out everything before any models are produced. A participant noted that "each team must go through the RM and find the items that they are going to be modelling, and put them into a project library, then the PIM must check and approve the objects, then they can be used in the models".

To improve model information delivery, the participants agreed that a BIM workshop should be facilitated to agree the elements within the RM. Guidance and support must be prepared outlining the appropriate steps to fulfil the level of information needed for each object that teams are to deliver based off the RM.

f) CDE Processes

The PIM is responsible for the CDE processes and procedures to enable reliable information exchanges between all parties, and to also validate compliance and non-compliance. One participant stated that although the current and previous BIM standards explained the process in micro level detail, teams with little BIM experience make errors when uploading files to the CDE, therefore these files get rejected until the files go through the correct procedures. However, the participant mentioned that typically, when teams are shown the CDE requirements and processes, errors do not happen again.

One participant added that on most projects, the CDE is not used correctly, it is used in conjunction with another online cloud-based storage where teams upload their information. He followed, "the CDE process is not explained in any BEP to a level of detail that new teams adopting BIM can understand the process, unfortunately they upload information incorrectly, which gets refused and causes time-delays". The group discussed the possibility of a designated online recorded BIM workshop with relevant team members and the PIM as the host. The meeting would demonstrate how each delivery team should be made aware of the processes and protocols and steps involved with the project CDE.

g) Coordination & Clash Avoidance

Most interview participants agreed that BIM clash detection meetings are used as a method for identifying and resolving issues in the models as a reactive technique. In the article, *Clash Detection or Clash Avoidance? An Investigation into Coordination Problems in 3D BIM,* [3] insists teams do not possess the necessary clash avoidance training to produce a clash free model, and the main reason for clashes in BIM models is down to isolated silos.

One participant asserted, "to run a clash avoidance workshop is quite simple, before you start modelling anything, you must zone out your spaces, and provide volumes to where people will be working in". Another participant stated, "teams know they can model whatever they want within that volume, and they won't clash, it's simply about agreeing where you're going to work, before you work on it". The participants agreed this can be a simple plan and some section drawings, and teams agree what area they need on the section drawings.

The participants also agreed that a micro low-level how-to manual should be created and shared with relevant teams. The methods involved should be demonstrated and recorded in a facilitated BIM workshop at the beginning of the project when all teams are present.

h) Information to be Included & Excluded

One participant stated that "teams must never talk about excluding information from the model, we are only interested in the level of information needed, Uni-class classification is fundamental and we then add the extra information to the objects as required". Another participant asserted that "a schedule of specific assets should be communicated to the client and to the rest of the delivery teams during design and again at construction stage, this details the information to be included or excluded from the BIM models".

One speaker noted, "traditionally, all teams put information into their models in dissimilar ways, which causes inconsistency in how the information is created and embedded into the models". The group contested that the PIM may prevent some of these issues from ever arising by creating bespoke shared parameters relevant to the project requirements and issuing to the relevant teams. One member reinstated, "make a list of objects that are going to be modelled, create an object library, classify and add the required parameters to a single object, and get the PIM to verify the object for suitability". This is a better approach than creating large models that have incorrect object information, and spending countless hours trying to fix the models. This approach must be documented and issued to all teams prior to any modelling.

i) Exchange Formats

This section within a BEP provides a defined list of file formats at specific project data drops. For each data drop, information is typically required in the following format.

a) Native – 3D model files product specific for all design and analysis models.
b) IFC 2x3 – 3D models to be used to extract clash detection.
c) PDF files.

The following table illustrates a typical example of an exchange format that is included in most BEP's. This vague and broad diagram of typical file formats is used to explain important data exchanges. Unfortunately, this diagram outlines just the deliverable requirement, but it is the micro level steps taken to get this deliverable that is required and useful. Typically, most BEP's that are derived from the industry standards will not specify the detail required to achieve the required deliverables as each team has different ways of producing information.

Data Type	Exchange File Format	Comment
3D Design BIM Model	RVT, DWFx, IFC	2019 version
3D Coordination Model	NWF, NWC, NWD	2019 version
2D Drawing	DWFx, DWG, PDF	
Report	DOCx, PDF	
Schedule	XLSx	
4D BIM Model	NWF, NWC, NWD	2019 version
Master Information Delivery Plan	XLSx, DPoW	
Structural Analysis		
Energy Analysis		
Cobie	N/A	
Others		

Fig. 11: Table of Model Exchange Formats

One participant noted that it is useful to trial each exchange format early in the project, "if you're designing a 300 room hotel, model one room and test the exchange between the mechanical, electrical and the interior design team to make sure the exchanges work".

All participants agreed that there are multiple factors to consider when exchanging information derived from a BIM model, all of which should be explored and agreed at the outset of the project. The PIM should prepare a designated support workshop which again must be recorded for oncoming delivery teams covering all aspects of the exchange formats. The participants agreed that delivery teams must be fully aware and capable of delivering these exchanges in the correct format.

j) Standard Methods and Procedures

The primary elements within this section focus on

a) Volume strategy.
b) Model Orientation and Origin.
c) File naming convention.
d) Model Attribute data.

Successful Collaboration and Project Coordination relies on standard methods and procedures SMP's which are agreed and committed to by all project teams. SMP's are included in most BEP's which unfortunately provide a vague explanation for the BIM modelling criteria. Traditionally, the responsibility lies with each team to add the required attribute parameters and values and positioning the model to the coordinates specified in the BEP. Typically, project teams tackle these tasks independently which hinders the collaborative environment, this causes a duplication in effort spent working to achieve the same goal.

A participant recalled during the initial stages of a project where the lead designer defined the project coordinates and building orientation in a sample model. This was shared with the rest of the project teams with the instruction that the teams were to acquire the coordinates into their own models. This resulted in all teams sharing the same coordinate and orientation system and reduced possible future conflicts.

The participants discussed a solution regarding the attribute data required for each team model. The solution proposed creating a shared parameter for the project which includes the attribute and asset data required for the project and specified in the BEP. The shared parameter file acting as a template is issued to relevant teams to add the parameter template file to their own models, for each team to add the relevant data into the shared parameters. This method increases model accuracy and efficiency, therefore preventing abortive work.

Most participants agreed, that although file naming conventions are explicitly detailed in the current standards, most teams still provide information with incorrect file naming. One participant stated, "it's not that teams are struggling with the naming, teams don't bother or care, their requirement is to submit a drawing and they will match their own internal naming and issue the data to the CDE". Another participant asserted that PIM's must be strict with delivery teams and must reject non-compliant files to pass through the CDE approval process. [11] stated that unless information is complete, coordinated, structured,

and named correctly, it will not be effective and no matter how good the design, it will not be issued to site.

k) Project Information Model Delivery Strategy

In a BIM Ireland article [12] stated that everyone involved in the delivery of building information should have complete clarity on what information they are responsible for and in what delivery format. When project information deliverables and responsibilities are absent this leads to delays, variations, cost overruns and unreliable building asset information.

By creating lists of the information required in the form of the MIDP and MPDT, this enables project teams delivering BIM models to collaborate to the same BIM delivery strategy. If these two documents are not created and shared with the project teams responsible for delivering BIM models, then there is no clarity or certainty on who is responsible for delivering what information at each project stage.

Recent research results from [13] showed that interview respondents from the study noted, the MPDT and MIDP is an evolving document that should be developed at each stage, also noting that the documents should start at the brief stage of the project. One participant commented that the MIDP and MPDT aligned correctly to the project work stages are possibly the most important documents after the BEP. He mentioned, the PIM in conjunction with the project teams must combine efforts to create and agree with the content of the MIDP and MPDT at a very early stage of the project. This should be facilitated in a dedicated BIM workshop and guidance documentation to be circulated to the delivery teams.

l) PIM Authorisation Process

To ensure that project information is adequately checked prior to publishing, an agreed authorisation process needs to be in place to enable the employer to approve the information. There was a consensus among the participants that the design and construction approval process must be specified at a much more detailed level that is currently shown on any of the current BIM standards. They agreed that the approvals process currently is not acceptable which often leads to costly delays and even disputes. One participant noted that the process must be read, understood, demonstrated, and agreed as early as possible in the project.

Validation of the BIM model provides a basis for certifying the model is fit for purpose. The table below illustrates checks to be performed as a minimum to assure quality.

PIM Authorisation Checks				
Checks	**Definition**	**Responsible Party**	**Software**	**Frequency**
Visual Check	Ensure no unintended model components and the design intent has been followed.	**ALL MODEL AUTHORS**	**REVIT / NAVISWORKS**	**ON ISSUE**
Interference Check	Detect problems in the model where two or more building components are clashing including hard and soft clashes.	**ALL MODEL AUTHORS**	**NAVISWORKS**	**COORDINATION REVIEW**
Standards Check	Ensure that all BIM standards have been followed.	**ALL MODEL AUTHORS**	**REVIT / NAVISWORKS**	**ON ISSUE**
Model Integrity Checks	QC validation process used to ensure that the project facility dataset has no undefined, incorrectly defined or duplicated elements and the reporting process on non-compliant elements and corrective actions are being undertaken.	**ALL MODEL AUTHORS**	**NAVISWORKS**	**ON ISSUE**

Fig 12: Table of Authorisation Checks

One participant stated that these checks are not being carried out as specified in the standards and in the BEP's. He noted that these checks are the responsibility of the task information manager of each team involved in producing a BIM model. "they are not being checked if at all prior to sharing, teams hope that somebody along the line will eventually raise and resolve the issue". Another participant asserted, "the clients are not 100% sure that the companies that are producing the information or doing rigorous checks, they also feel reluctant to put their name on signing it off in terms of an acceptance". The participants proposed a solution to improve this scenario, that with every major issue of information there is a form or something that a manager must sign to confirm their responsibility to the information held in the model is accurate and fit for the purpose of the current work stage. The approvals process can be facilitated in a designated BIM Workshop with all relevant stakeholders starting at the early stage of the project.

VI CONCLUSIONS & RECOMMENDATIONS

This paper sought to appraise findings and provide solutions to overcome erroneous BIM model production and information delivery by proposing a micro level workflow framework aligned to project BEP's. There is an apparent detachment between expectation and reality regarding BIM. Industry standards, and guidance documents do not capture

what is typically happening “on the ground”. With many new teams adopting Level 2 BIM and the introduction of the relatively new ISO 19650 standard provides opportunity for existing and new BIM practitioners to embrace a unified approach that enables delivery teams to collaborate around an internationally agreed set of standards with BIM as the foundation. However, the current standard series are depicted as a high-level process driven document which do not delve into the micro level detailed information that teams require to understand and adopt the principles within the standards. This inevitably results in a delivery team’s misinterpretation, lack of understanding or ignorance towards the standards, which at its core drives the success and all the advantages to be gained from a BIM process.

The major efficiency and accuracy that BIM can deliver will only be realised when the entire project team adopts a truly collaborative and standardized environment. Unfortunately, with many misleading interpretations of ‘best practice’ and teams working to internal standards in non-collaborative silo’s, it is evident that issues manifest ‘on the ground’ at a micro level.

This research proposed a micro level solution to alleviate a macro level problem. The data collected from 50 surveyed industry professionals alongside focus group interviews, provided the context for a unified model production and information delivery workflow framework that is aligned to the requirements of each project work stage. Critical aspects of a typical post-contract BEP were examined as key problematic areas that cause fragmentation and confusion among delivery teams. Opinions and advice from leading industry experts agreed with the concept of a project specific micro-level workflow framework, derived from the principles and concepts of ISO 19650 standards, and aligned to the project BEP. With the introduction of detailed support documents including a series of strategic BIM workshops under the guidance of the PIM provides the opportunity to avoid erroneous model production workflows and improving information delivery.

Future research would involve implementing and testing the proposed workflow framework including facilitating designated BIM workshops throughout the duration of a live BIM project from design to handover. This would provide an opportunity to refine the new framework, and possibly add more sections within the workflow framework aligned to the project BEP and project standards. Unfortunately, this could not be achieved during this research due to time constraints.

VII LIMITATIONS OF THE RESEARCH

This research paper was constricted to a 8000 word count, which limited the study to propose (based off the data collected) the micro level workflow framework without defining the detailed steps and processes that would be included for each of the sections within the workflow. This allows for further research to be conducted based on the original findings collected in this study.

VII REFERENCES

[1] T. Luke, "6 BIM Failures," 12 07 2020. [Online]. Available: https://irp-cdn.multiscreensite.com/b3bb6344/files/uploaded/6-BIM-FAILURES-a-Basepin-ebook.pdf.

[2] Evolve Consultancy, "The Importance of a BIM Execution Plan," 25 January 2016. [Online]. Available: https://evolve-consultancy.com/importance-bim-execution-plan/.

[3] A. O. Akponeware, "Clash Detection or Clash Avoidance? An Investigation into Coordination Problems in 3D BIM," School of Civil and Building Engineering, Loughborough University, Loughborough, 2017.

[4] R. Montague, "To BIM, or not to BIM? That is the Question!," 7 Jan 2019. [Online]. Available: http://www.bimireland.ie/2019/01/07/to-bim-or-not-to-bim-that-is-the-question/.

[5] ISO, "BS EN ISO 19650-2 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling," BSI Standards, 2018.

[6] R. Saxon, "Going Digital - A guide for construction clients building owners and their advisors.," Oct 2018. [Online]. Available: https://www.ukbimalliance.org/wp-content/uploads/2018/11/UKBIMA_Going-Digital_Reportl.pdf.

[7] D. Rossiter, "Constructing Language Pledge," 2019. [Online]. Available:

https://www.ukbimalliance.org/project/constructing-language-pledge/.

[8] B. McAuley, R. Moore and A. Hore, "The application of industry standards as an alternative to in-house proprietary standards within the AEC industry," in *CitA BIM Gathering 2015*, Dublin, 2015.

[9] M. Hooper and A. Ekholm, "A Pilot Study: Towards BIM Integration - An Analysis of Design Information Exchange," in *CIB W78 2010: 27th International Conference*, Cairo, Egypt, 2010.

[10] UK BIM Alliance, "Information Management according to BS EN ISO 19650 Guidance Part 1: Concepts," BSI, 2019.

[11] M. Richards, Building Information Management A Standard Framework and Guide to BS1192, London: BSI, 2010.

[12] P. Slattery, "Clarifying the BIM Project Deliverables with Information Delivery Lists and BIM," 7 July 2017. [Online]. Available: http://www.bimireland.ie/2017/07/07/clarifying-the-bim-project-deliverables-with-information-delivery-lists-and-bim/.

[13] M. Mathews and J. Peters, "What is a BIM Design Model?," in *CITA BIM Gathering 2019*, Galway, Ireland, 2017.

[14] Construction Industry Council, "BIM Adoption Survey 2019," CIC, Hong Kong, 2019.

[15] Construction Industry Council, "CIC Building Information Modelling Standards (Phase One)," CIC, Hong Kong, 2015.

[16] The New Zealand BIM Handbook Third Edition, New Zealand: BRANZ Building Research Levy, Ministry of Business, Innovation and Employment, 2019.

[17] Building and Construction Authority, "Singapore BIM Guide Version 2," Building and Construction Authority Singapore, Singapore, 2013.

[18] M. Winfield and S. Rock, "The Winfield Rock Report - Overcoming The Legal and Contractual Barriers of BIM," UK BIM Alliance, 2018.

[19] D. Shepherd, BIM Management Handbook, Newcastle: RIBA Publishing, 2015.

[20] AEC UK, "AEC (UK) BIM Protocol 2012: Implementing UK BIM Standards for the Architectural, Engineering and Construction Industry.," 13 07 2020. [Online]. Available: https://aecuk.files.wordpress.com/2012/09/aecukbimprotocol-v2-0.pdf.