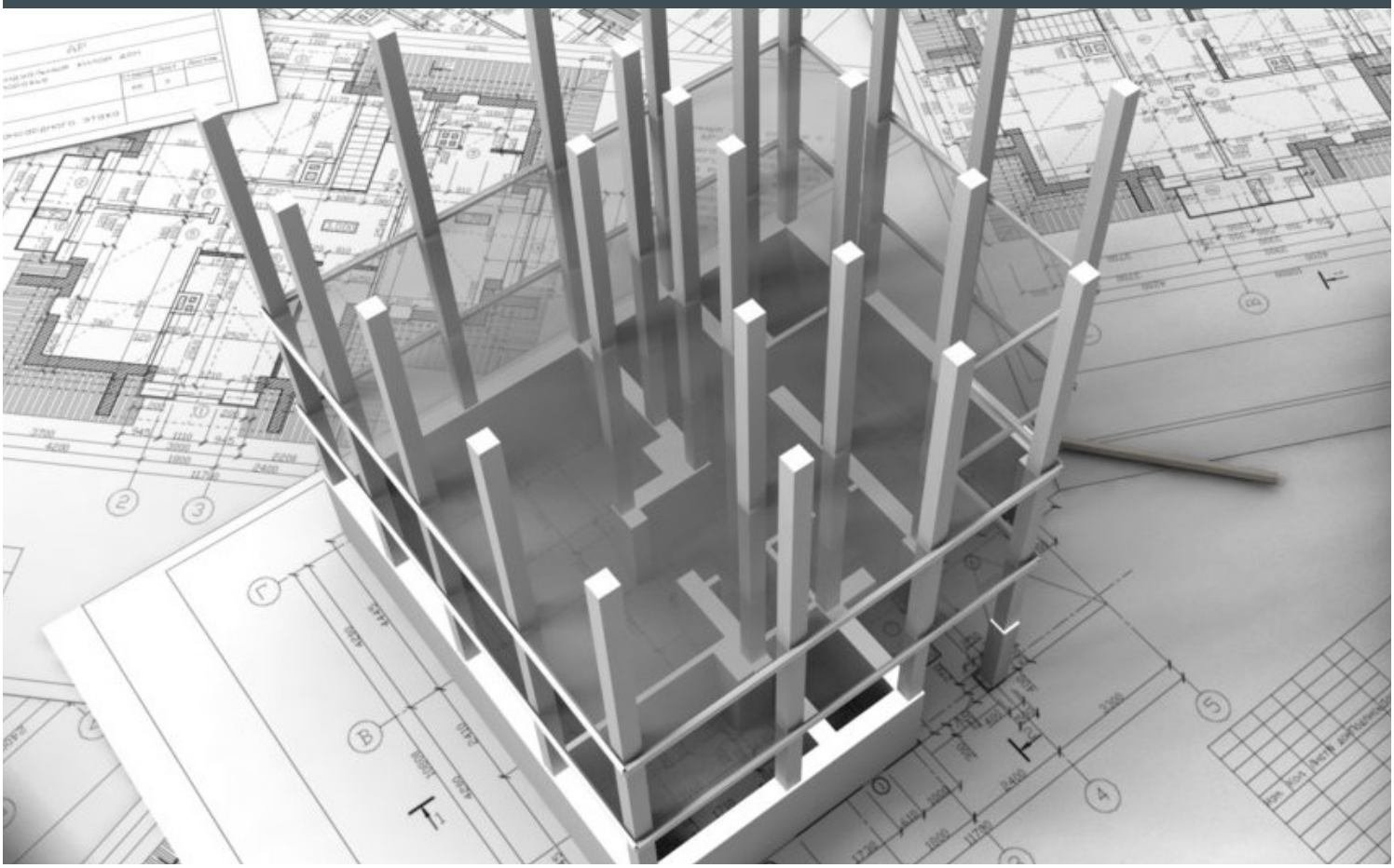
NSW GOVERNMENT

Health and safety management using building information modelling: Phase Two Report



Centre for WHS

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Executive summary

Background

The construction industry is infamous for having a high number of fatalities around the world. The use of Building Information Modelling (BIM) has been considered an influential way to improve Work Health and Safety (WHS) outcomes by improving communication, information flow and risk analysis in all phases of an asset's lifecycle. The research "Work Health and Safety Management using Building Information Modelling" is a four-phase study aiming to examine the opportunities to achieve WHS objectives through the application of BIM in major construction projects. This Technical Report presents the outcomes of Phase 2, including the results of an in-depth empirical study and the recommended contents of a Decision Framework. The proposed Decision Framework will support pathways for clients and project team leaders to collaboratively work together and develop high-quality information requirements that clarifies the data management environment expectations for all stakeholders. The tools underpinning the Decision Framework will support the development of high-quality criteria for tendering, evaluation and monitoring, and ultimately, the delivery performance of the primary contract throughout the supply chain.

Method

Data was gathered from five sources: 1) Australian and international BIM standards, frameworks and guidelines; 2) Existing tools and templates informing the adoption of BIM for WHS management, 3) Project documents from three real-life case study projects in New South Wales (NSW), Australia; 4) 12 interviews with participants involved in the case studies; and 5) Interviews with two Australian government clients and a UK-based BIM for WHS management expert. The five data sources were analysed in the following sequence:

- *Document analysis*. An in-depth analysis of standards, guidelines and frameworks provided a scaffold for organising project documents and for discerning threads of BIM for WHS management in the three case studies.

- *Level-1 and Level-2 interview analysis*. Two levels of analysis were conducted of the interview transcripts. Level-1 involved the identification of participant-driven thematic codes, while Level-2 identified researcher-driven axial codes.

- *Decision Framework development*. A knowledge translation process began mid-way through the Level-1 analysis and was iteratively refined throughout Phase 2. Level-2 themes informed the development of principles and tools for the Decision Framework.

Results

The document analysis identified preliminary areas of strength and areas of improvement in specifying for BIM for WHS management. While the documents provided an important foundation for developing interview strategies, the findings were considered preliminary because they did not provide a comprehensive analysis of the case studies nor a substantial foundation for tool building.

The Level-1 analysis was developed based on participant interviews from the three Case Studies. Themes from four sample interviews were additionally mapped to the six WHS Knowledge Domains for BIM-WHS integration (KDs) identified in Phase 1 (i.e., Scenario planning, Requirement briefing, Risk assessment, Education and training, Monitoring and surveillance, and Reporting and analysis). Data from sample interview 1 and 2 (Case Study 1) showed multiple examples of best practice in each of the six KDs. Data from sample interview 3 (Case Study 2) showed examples of best practice in all KDs, except Reporting and Analysis, while data from sample interview 4 (Case Study 3) included examples of best practice in all KDs, except Education and Training, and Monitoring and Surveillance.

The core result of the Level-2 analysis was the identification of themes and theme groups underpinning each of the four recommendation areas of investigation identified in Phase 1 (i.e., Client Leadership, Tendering Proficiency, Best Practice and Supply Chain Monitoring).

Client Leadership was linked to a total of 163 units of text, categorised into eight themes. The themes clustered into three theme groups that resonated with all six Knowledge Domains. The themes pointed to three specific directions for the emerging Decision Framework: 1) Emerging content for Client Leadership that would help to improve awareness and understanding of how critical clients and the project leadership group are to the integration of BIM WHS management adoption, 2) Emerging roadmap for Client Leadership in BIM for WHS management, and 3) initial considerations, mindsets, drivers and data management environment for Client Leadership in BIM for WHS management.

A total of 159 units of text were linked to Tendering Proficiency and also categorised into eight themes and three theme groups. The theme groups and themes resonated with all six KDs and will feed into the components of the Decision Framework that relates to 1) the development of information requirements and 2) guidance on procurement and tendering.

Supply Chain Monitoring was linked to 102 units of text, categorised into seven themes. The themes clustered into three theme groups that resonated with all Knowledge Domains except Scenario planning. The theme groups and themes indicate that contractual requirements could be designed to ensure the supply chain shifts to BIM-supported WHS management. These insights will inform guidance on supply chain monitoring within the Decision Framework.

A total of 178 units of text were linked to Best Practice, categorised into eight themes. The themes clustered into three theme groups that also resonated with all six Knowledge Domains. The Theme groups and themes under Best Practice will support the Decision Framework by providing examples, mini case studies and quotes of best-practice BIM-WHS integration.

Discussion

Phase 2 aimed to validate the Phase 1 recommended areas of investigation and use them as a platform for tool-building. A multi-stage analysis of qualitative data led to the development of the detail in the proposed Decision Framework.

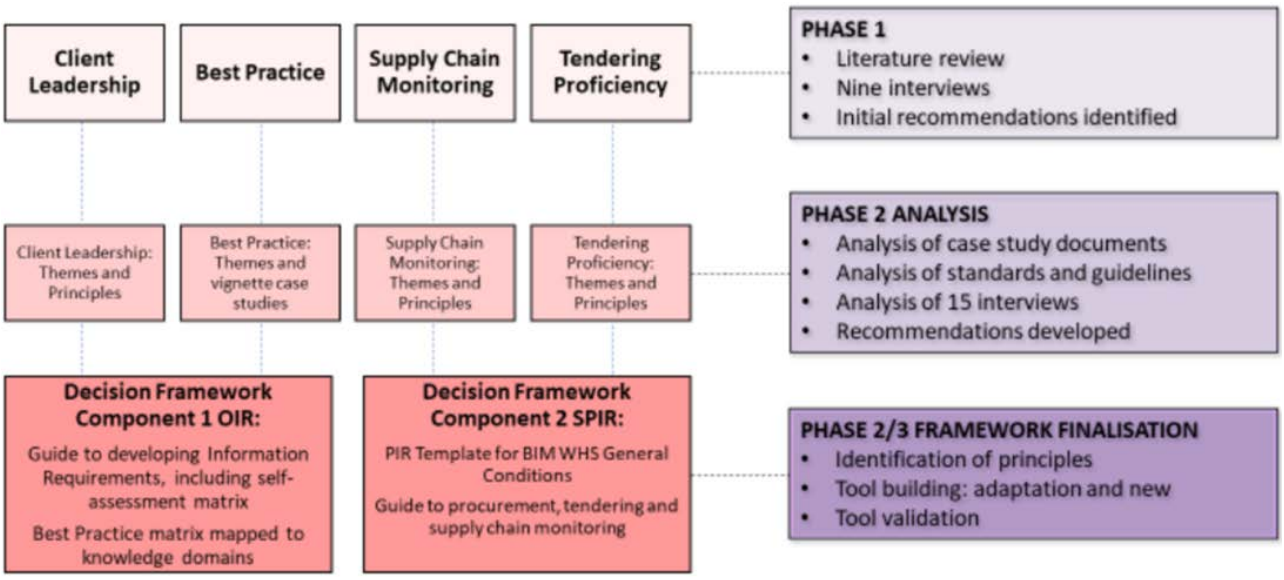
Level-1 analysis findings suggest that exemplars of BIM for WHS management can already be found in three of the six Knowledge Domain: namely Scenario planning, Risk assessment and Requirement briefing. However, BIM adoption for WHS management remains largely underexplored in the other three Knowledge Domains. BIM appears not to be used in a formal manner to educate and train supply chain actors about better WHS management. The use of BIM for directly monitoring WHS management also did not emerge in any of the case studies. There are exemplars that were identified in Phase 1 and which the Decision Framework shall draw upon.

The Level-2 analysis led to the identification of clear lessons as well as areas that remain open for further exploration and debate across the four areas of investigation. The themes within Client Leadership suggest that four elements are critical to mature adoption of BIM for WHS

management: 1) commitment to the centrality of integrated high-quality data to the organisations' asset management and capital works procurement strategies, 2) robust WHS management processes 3) explicit use of technology, and 4) the development of formal and informal strategies to achieve collaboration and compliance across the supply chain. The themes within Tendering Proficiency suggest that Tendering Proficiency emerges from Client Leadership, specifically in the client's ability to build a team and maintain it through broad and ongoing engagement as well as through sound communication strategies in pre-award/tender assessment and post-award. The Supply Chain Monitoring themes, combined with Level-1 results, suggest that BIM has not been used extensively for monitoring WHS, although possibilities and directions are emerging, particularly in Case Study 3. The critical enabling role of clients and the lack of clear direction supports our contention that clients need guidance on how to make decisions suitable to their own needs and circumstances in a complex and emerging environment. Finally, the Best Practice themes suggest that 'Best Practice' as an area of recommendation overlaps with the previous recommendation areas however is useful to highlight explicit examples to support principles in the Framework. An explicit map of Phase 1 Recommendations against the Phase 2 findings and the Decision Framework is provided in the Discussion section of the report.

Key recommendations for the Decision Framework

Further exploration of the four recommendation areas informed the design of the proposed Decision Framework, comprising two main components and four sub-components, as indicated in the following figure.

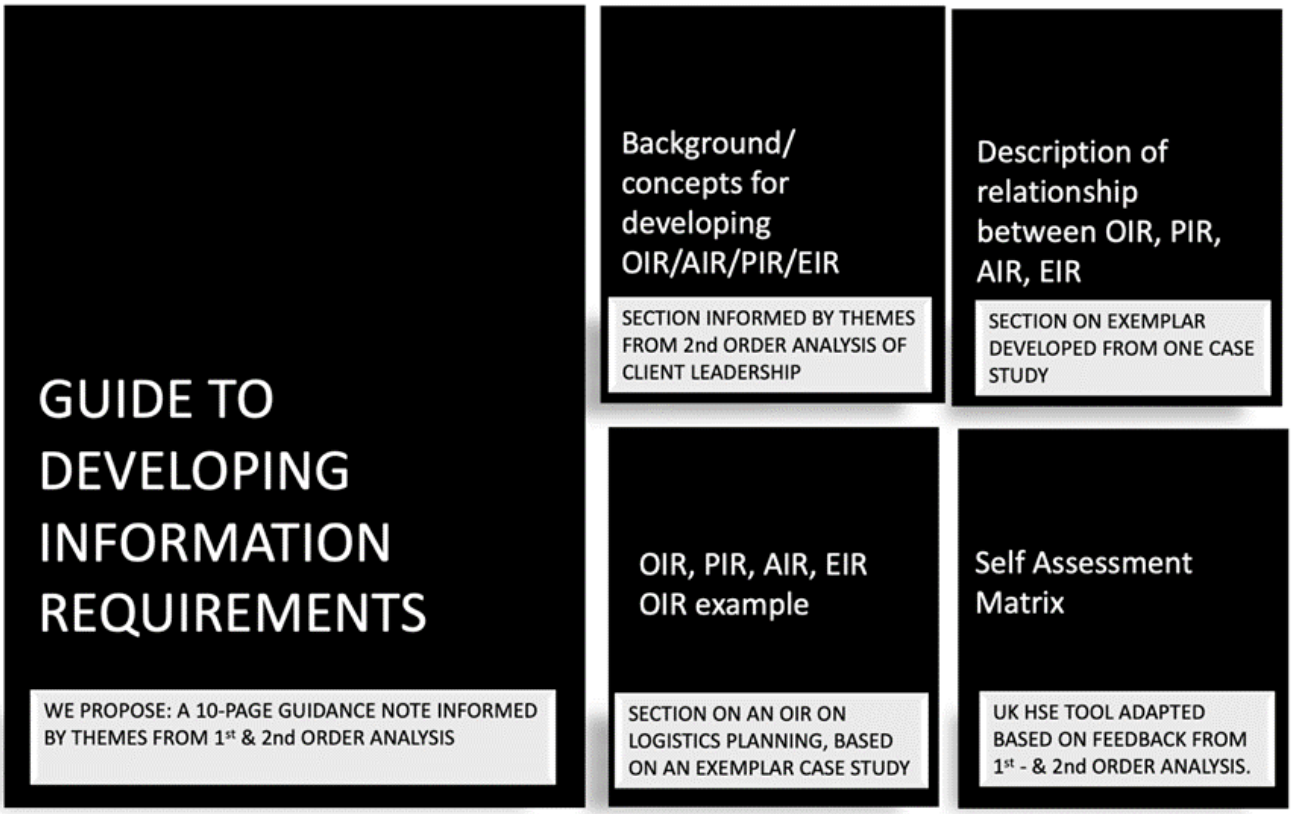


The first component (Guide to Developing Organisational Information Requirements) will be focussing on assisting clients in how to show leadership and develop Information Requirements, and the second component (Guide to Developing Strategic Project Information Requirements) will assist clients in developing Information Requirements at a project level. Although the study began in early 2020, it is important to note that the Decision Framework is aligned with the recently released NSW Infrastructure Data Management Framework, particularly in relation to

terminology, agency information requirements, and the types of models and their interrelationships.

The Guide to Developing Information Requirements will have two subcomponents, including 1a: a guide for clients (and project leaders) towards developing information requirements containing a client BIM for WHS management Self-Assessment Matrix (an adaptation of an existing Matrix from the UK), and 1b: a suite of best practice examples across the six Knowledge Domains. The second component supports the development of strategic project information requirements (SPIR). A SPIR is required to assure consideration is given to planning, design, construction and operation phases with respect to data being captured and structured consistently and securely in a reusable, accurate, integrated and standardised manner. The SPIR will have two subcomponents, including 2a: a guide note to support procurement, tendering, and supply chain monitoring, and 2b: an example of general conditions for inclusion at tender (an adaptation of an existing UK BIM for WHS management general conditions). The direction for Phase 3 is to draft and evaluate the two main components and four sub-components for the proposed Decision Framework.

GUIDANCE NOTE



PROPOSED ## GUIDANCE NOTE

Table of Contents

List of Tables

List of Figures

Background

The construction industry is infamous for having a high number of fatalities around the world (Garner-Purkis, 2018; International Labour Organisation 2020). Many national and international exemplars have espoused that the use of Building Information Modelling (BIM) could improve Work Health and Safety (WHS) outcomes in the construction industry by improving communication, information flow and analysis in all phases of the asset lifecycle. This Technical Report summarises the outcomes and recommendations from Phase 2 of the project "Work Health and Safety Management using Building Information Modelling". The aim of the project is to examine opportunities to achieve WHS objectives through the application of BIM in major construction projects.

The project has four phases:

Phase 1: Development of solutions for integration of WHS in BIM-enabled project planning, design and delivery - understand how and to what extent BIM is used and can be used for WHS management, including identifying the different options of implementation and associated barriers, enablers, limitations, and consequences for WHS risk reduction for the industry, the government and the regulator.

Phase 2: Evaluation of WHS aspects in BIM-enabled project proposals, as part of a procurement process - identify preferred procurement models and best practices to evaluate WHS management in BIM-enabled project proposals and recommend the best way for government agencies to evaluate the quality of WHS management in BIM-enabled project proposals.

Phase 3: Evaluation of the proposed approach for BIM adoption - understand the implications of the recommended solutions for integrating the WHS aspect in BIM-enabled project planning, design and delivery (objective 1) and for enabling the evaluation of WHS management in BIM-enabled project proposals at the procurement stage (objective 2).

Phase 4: Transfer of Knowledge and Dissemination of Information - disseminate findings to the industry, to NSW citizens, to the students and to the research community.

Phase 1 involved a detailed literature review of standards, guidelines and theoretical academic material, including international case studies (London et al. *in press*) and a qualitative empirical study involving semi-structured interviews with nine expert stakeholders. The interviews explored 1) General application and adoption of BIM in construction, 2) BIM adoption in relation to WHS management, and 3) Strategies for capacity building to support BIM for WHS. Interviewees were practitioners with expertise in BIM and/or WHS in Australia, Singapore and the United Kingdom.

Details on the findings and recommendations can be found in the Phase 1 Technical Report (London et al. 2020).

The key Phase 1 recommendation was to investigate the following four key drivers of BIM adoption, including various propositions; Client Leadership, Tendering Proficiency, Supply Chain Monitoring and Best Practice, and explore how they may inform the development of a Decision Framework.

Client Leadership

- Establishing WHS management requirements prior to tendering as a priority.
- Developing clear alignment to six knowledge domains of WHS management: scenario planning, requirement briefing, risk assessment, education and training, monitoring/surveillance and reporting and analysis.
- Ensuring client expectations on BIM for WHS management are clearly developed prior to tendering to enable client leadership.
- Developing Client Information Expectations/Requirements and Responsibility Matrices for BIM for WHS management.

Tendering proficiency

- Ensuring tender criteria and evaluation are transparent and authentic with respect to BIM for WHS management
- Framing BIM for WHS management outcomes and strategies across different procurement strategies
- Analysing and assuring supply chain capacity to deliver as well as appropriate supply chain monitoring during other project phases

Supply chain monitoring

- Identifying key areas of capacity building across all levels of stakeholders for implementing BIM for WHS management in Australia
- Monitoring the main contractor to ensure that the supply chain is delivering to the original expectations

Best practice

- Identifying exemplars in Australian major public and private sector client-led projects
- Identifying key decision areas in exemplars with respect to Project Information Integration Requirements

The aim of this Technical Report is thus to recommend specific content details of the Decision Framework, which will support tender evaluation and monitoring performance of the primary contract with respect to supply chain delivery on major construction projects.

Past research on BIM adoption frameworks indicates that contents can be very flexible and can encompass a broad suite of tools: roadmaps, checklists, assessment tools and flowcharts etc. (London et al., 2010). The specific content details of the Decision Framework proposed here thus builds directly on the findings of Phase 1, whereby both the literature review and empirical findings have laid a robust foundation for further empirical work in Phase 2, including analysis and critique of existing support tools, frameworks and guidelines related to the topic of WHS integration in BIM. There are Australian guidelines for BIM that were reviewed in Phase 1; however, they have little or no specific detail in relation to WHS management. The UK Publicly Available Specifications (PAS) and Employer's Information Requirements documents that relate to BIM for WHS management are useful as they present well-developed integration of WHS management in BIM. An analysis of their potential for adaptation for the NSW context was explored. Through Phase 2 interviews, we critiqued decision frameworks in use.

Methodology

This section provides an overview of the data collection methods and data analysis strategies, as well as a map of how the data analysis informed the contents of the Decision Framework.

Data collection method

Data for this study was gathered from five sources:

- Australian and international BIM standards, frameworks and guidelines
- Existing tools and templates informing the adoption of BIM for WHS management
- Project documents from three real-life case study projects
- Interviews with participants in these case studies
- Interviews with government clients and experts

Standards, frameworks and guidelines

The study was informed by a range of international and local standards, frameworks and guidelines. The UK is considered a leader in the adoption of BIM for WHS management; thus, most of these were UK-sourced. The research team analysed:

PAS 1192-6: a "Publicly Available Specification" that defines requirements for the collaborative sharing of structured WHS information throughout the project and asset life cycles. PAS 1192-6 is part of the PAS 1192 series. PAS 1192-1 to PAS 1192-5 have been converted to International Standard Organisation (ISO) standards, but PAS 1192-6 has lagged behind and remains under the custodianship of the British Standards Institute.

ISO 19650 series: a series of international standards (officially known as ISO 19650-1 to 5) for collaboratively managing information over the whole lifecycle of a built asset using BIM. ISO 19650 was based on the UK PAS 1192 series. ISO 19650-1 covers concepts and principles; ISO 19650-2 covers collaborative information sharing during the delivery phase of assets; ISO 19650-3 covers information sharing during the operational phase of assets. ISO 19650-4 is on the organisation and digitisation of information; translation from its PAS counterpart has taken longer because PAS 1192-4 was based on the Construction Operations Building Information Exchange (CoBIE) standard and is very specific to the UK setting. ISO 19650-5 covers information security.

UK BIM Alliance Guidance Note D: A guide based on ISO 19650 for Developing Information Requirements. The guidance note highlights a number of principles, including the need for consistent structuring of information and the need to use information to build a coherent story. The note discusses concepts such as "information risk" and "information waste". Information requirement resources such as OIRs, AIRs, PIRs and EIRs are also explained.

UK BIM Alliance Guidance Note E: A guide based on ISO 19650 for "Tendering and Procurement". The guidance note focuses on the purpose, format, contents as well as processes and checklists for developing the BIM Execution Plan (BEP).

The research team also analysed the following guidelines from Australian sources:

Infrastructure Data Management Framework (IDMF): a recently-released set of guidelines, procedures and standard approaches "to support consistent management of infrastructure data across the NSW Government sector". The IDMF was developed to support the vision of "a coordinated, shared, and standardised approach within NSW Government for the management of infrastructure data".

BIM Process Consistency Report by the Australian BIM Advisory Board (ABAB): An overview report that emphasises the importance of BIM process consistency, specifically, consistency in data formats, standards, protocols, systems and tools across asset lifecycles and across government.

Existing tools and instruments

The analysis of existing tools and instruments specifically focused on those designed to strengthen BIM adoption for WHS management purposes. Documents examined included a range of emerging templates on Organisation Information Requirements (OIR), Asset Information Requirements (AIR), Project Information requirements (PIR) and Exchange information requirements (EIR). Two of these documents are highlighted in this section. Both were developed by the UK BIM for Health and Safety (BIM4H&S) Working Group, a unit under the UK BIM Alliance that includes clients, project engineers, project managers, digital information specialists, academics and WHS professionals working together in a voluntary capacity. In 2020, shortly after ISO 19650 emerged as the international standard, the Working Group noted the increasing importance of PIRs and identified three key issues (BIM4WH&S, 2020):

- Clients lack knowledge in developing information requirements that would enable them to apply BIM to WHS management.
- Clients' ill-defined information requirements tend to get changed, diluted or confused as they are cascaded down the supply chain.
- Poorly coordinated risk discipline specialists in the design phases causing some safety-critical design functions to be rarely accounted for in information requirements.

The BIM4H&S Working Group Health & Safety PIR Template is a work in progress (see Appendix Figure B1). The BIM4H&S Working Group determined that robust, high-level information requirements defined in PIRs could significantly influence the quality of project management while also informing the development of other information requirements, like EIRs. The working group's recommendation is that PIRs should be developed by three parties working closely together: the client, the principal designer and the information manager, following a Preliminary Hazard Analysis and Safety Review. A work-in-progress version of this template was obtained in October 2020. In this version, the PIR template took the form of an air-table database comprising several sheets ("tabs"). Each tab relates to a specific area of risk, starting with "General Conditions"

(based on PAS 1192-6) and subsequent tabs for requirements in areas such as asbestos and fire safety. An example requirement for asbestos is "An Asbestos Survey Report to be prepared and accessible to those affected." Each condition is then mapped to columns specifying the "why, when, what, who and how" as evidence that the specific requirement has been met. It is envisioned that the template will be a flexible guideline, with users making selections that are relevant to their project.

Prior to ISO 19650, the BIM4H&S Working Group also developed a tool for clients to self-assess their capacity for adopting BIM for WHS management. The instrument was developed at a time when EIRs had not yet replaced Employer Information Requirements. The Plain Language Questions and BIM Maturity Matrix for Clients, Principal Designers and Project Leaders (refer to Appendix Figure B2) is a maturity matrix developed to assist clients in "consider[ing] what Health and Safety Information to specify in an EIR [Employer Information Requirements] Template."

The maturity matrix still remains relevant even though the Employer Information Requirements no longer apply under ISO 19650. As the matrix involves a client's assessment of its own maturity, it would form part of an OIR. The maturity matrix comprises ten plain-language questions, which a client is expected to respond to by selecting the level of maturity that best describes its current status: "first steps", "keeping up with the pack", or "taking the lead". Designers of the matrix intentionally employed qualitative descriptors rather than more "scientific-sounding" quantitative criteria. Part of the aim of developing the matrix was to encourage lagging clients to strengthen their capacities for using BIM for WHS management.

Case Studies

The standards, frameworks, guidelines and tools examined were all aspirational targets for the use of BIM for WHS management and are necessary for achieving the aim of Phase 2 of this study: exploring the content detail for a Decision Framework. However, a significant part of this study also involved analysing practices involving the use of BIM for WHS management in empirical settings so that Australian exemplars and context could be presented in the Decision Framework. These practices were captured through document analysis and interviews. The research team used qualitative case study methods to examine the use of BIM for WHS management in three real-life cases. All three case studies were located in NSW and projects that involved a Tier 1 construction, property and infrastructure company with operations in more than 40 countries. The multinational's role in the three projects varied (Table 1).

Case Study 1 involved a six-storey commercial building with a complex design, including a façade that was wrapped in 20 kilometres of sustainably sourced timber strips. The multinational was involved as a developer, design manager and construction manager, with each function executed by a separate division. An independent Architectural consulting firm was tasked to carry out the

concept design. A key stakeholder in this case study was the façade subcontractor because of the complexity of the timber strips wrapped around the structure.

Case Study 2 involved the design and construction of an underground metropolitan train station, pedestrian station access and two retail and residential towers. The project was awarded to a global financial group through an unsolicited proposal; the global firm then appointed the multinational as the design-and-construct partner for the project. There were significant interactions between the multinational and the government client responsible for transport infrastructure because of the station component. The Government Client (Transport) has, over the last decade, pushed very hard for digital engineering in its infrastructure projects.

Case Study 3 involved a hospital building to house acute services and was the first phase of a larger campus redevelopment project. The schematic design of the building was completed in May 2018. The new building project is expected to be completed in 2022 and will include adult emergency, expanded intensive care and new inpatient wards. The client for this project is referred to here as the Government Client (Health). Media reports have referred to the procurement model as traditional procurement because the Government Client (Health) had appointed the architectural consulting firm to create the design, and the multinational was brought on board to construct the building. However, as the project moved to implementation, the architectural consultant began reporting to the multinational, which could explain why the multinational now sees the arrangement as "Design and Construct".

The multinational company thus functioned as a private client, designer and contractor in Case Study 1, as designer and contractor in Case Study 2 and as the contractor in Case Study 3. The narratives will refer to the multinational as Private Client (Developer), except in cases where its other capacities are relevant, in which case it will be referred to as Private Client (Contractor/Designer).

Table 1: Summary of three case studies.

	Case Study 1: Commercial Office	Case Study 2: Rail and Office Building	Case Study 3: Hospital
Tender completed	*Yes*	*Yes*	*Yes*
Project completed	*Yes*	*No*	*No*
Client	*Private*	*Public + Private*	*Public*
Asset type	*Building*	*Building + Infrastructure*	*Building*
Building complexity	*High*	*High*	*High*
Contractor	*Tier 1*	*Tier 1*	*Tier 1*
Procurement model	*Design and construct*	*Design and construct*	*Traditional (Early contractor involvement)*

Project documents

The empirical study began with access to project documents. The research team made a broad request to the multinational for documents related to BIM, WHS management, or both. The multinational provided the research team with a total of 45 documents. The documents were wide-ranging. For example, for Case Study 1, the documents included detailed methodologies on balustrade and façade installations, an invitation to tender, a subcontractor guide to Environment Health and Safety (EHS), sample BIM execution plan, a pre-construction review, a list of BIM requirements for consultants and a BIM Execution Plan. Samples of the documents are shown in Table 2.

Table 2: Sample of documents provided by the multinational on three case study projects related to BIM, WHS management, or both.

	Sample BIM-related documents provided	Sample WHS-related documents provided	Other documents provided
Case study 1	*BIM execution plan* *BIM requirements for consultants* *Installation methodologies for balustrade* *Installation methodology for façade*	*Subcontractor guide to EHS (environment, health and safety)* *Guidebook on recurring alerts*	*Pre-construction review* *Tenderer management system assessment form*
Case study 2	*Digital engineering execution plan* *Digital delivery plan*	*Project EHS management plan*	*Invitation to tender* *Generic scope of works*
Case study 3	*---None provided---*	*Crane management plan* *Pandemic management plan* *Project EHS management plan*	*Construction management plan*

The documents from the multinational were provided through a shared folder as standalone documents; understandably, no accompanying background information about the case study or about individual documents was provided and sensitive information was redacted. To create a more organised, substantially complete picture of each case, the research team sought additional documents from online sources, and when opportunities arose, additional documents were requested during the interview stage. The documents were useful to provide context, develop targeted interview schedules, and to identify the most relevant interviewees.

Interviews

In addition to obtaining documents about the three case studies, the research team also conducted 15 semi-structured interviews. Of the 15, 12 interviews were with case study participants: five from Case Study 1, three from Case Study 2 and four from Case Study 3. Interviews were conducted between October 2020 and January 2021, typically lasted an hour, were conducted online and, in most cases, involved a single participant who responded to questions from three to five members of the research team. Interviews were recorded and transcribed. As noted previously, customised questions were developed based on information derived from the relevant case study documents. Details on the formulation of questions are discussed later in this section.

In addition to the case study participants interviews, an additional three interviews were conducted with government expert stakeholders. The first interview conducted at the very start of the empirical study was with a UK-based BIM for WHS management expert who provided perspectives on PAS 1192, ISO 19650 and the work of the BIM4H&S Working Group. It was this

interviewee who provided the PIR template discussed previously. Another two interviews were conducted during the latter part of the empirical study. These two interviews were with Australian-based government clients who were asked to provide feedback on the maturity matrix, the PIR template and on components of the emerging Decision Framework. A summary of interviewees is provided in Table 3.

Table 3: Summary of interview participants and details.

Interviewee	Position	Organisation	Area of expertise
Interviewee 1	*Project Manager*	*Façade Subcontractor*	*Case Study 1*
Interviewee 2	*Digital Engineering Manager*	*Private Client (Designer)*	*Case Study 2*
Interviewee 3	*Construction Manager*	*Private Client (Contractor)*	*Case Study 1*
Interviewee 4	*Senior Project Engineer*	*Private Client (Contractor)*	*Case Study 1*
Interviewee 5	*Environment, Health and Safety (EHS) Manager*	*Private Client (Contractor)*	*Case Study 2*
Interviewee 6	*Environment, Health and Safety (EHS) Manager*	*Private Client (Contractor)*	*Case Study 2*
Interviewee 7	*Environment, Health and Safety (EHS) Manager*	*Private Client (Contractor)*	*Case Study 1*
Interviewee 8	*Architecture and Urban Design Manager*	*Private Client (Designer)*	*Case Study 1*
Interviewee 9	*Health and Safety Inspector*	*UK Work Health and Safety Regulatory Agency*	*UK resource person on BIM for WHS management*
Interviewee 10	*Project Manager*	*Project Management consulting firm*	*Case Study 3*
Interviewee 11	*BIM Manager*	*Architectural consulting firm*	*Case Study 3*
Interviewee 12	*Senior BIM Software Specialist*	*Architectural consulting firm*	*Case Study 3*
Interviewee 13	*Senior Practice Director*	*Architectural consulting firm*	*Case Study 3*
Interviewee 14	*Director*	*Government Client (Treasury and Finance)*	*Client*
Interviewee 15	*Director*	*Government Client (Transport)*	*Client*

Data analysis strategy

The five data sources discussed in the previous section were analysed in a sequential manner. Analysis from each dataset informed subsequent stages; documents (guidelines, standards, frameworks, tools as well as the case study documents) informed the interview strategy; interview findings led to the identification of key themes; themes led to the identification of principles and principles led to the development of four tools comprising the Decision Framework. These stages are shown in Figure 1.

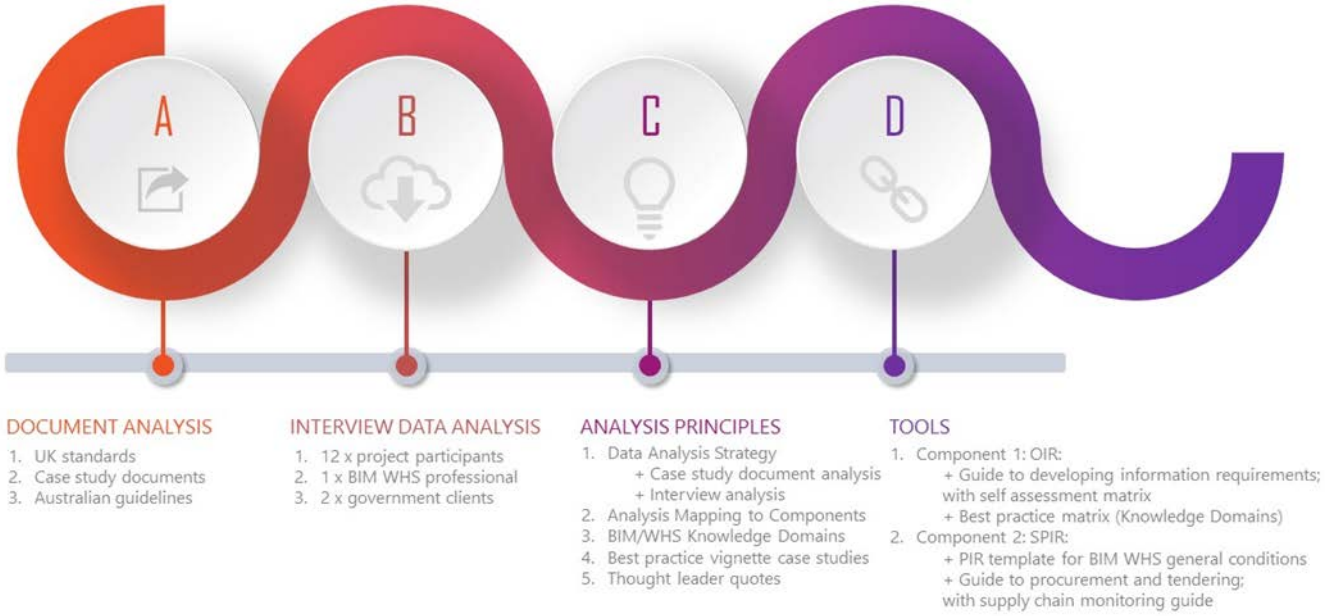


Figure 1: The analysis process for developing tools.

Document analysis

An in-depth analysis (refer to Appendix Figure B3) of standards, guidelines and frameworks provided a scaffold for organising project documents and for discerning threads of BIM for WHS management in the case studies. For example, a detailed reading of ISO 19650 informed the research team that there are eight key information management processes and that the first four are most relevant to this study as they shape procurement. These four stages are 1) assessment and need; 2) invitation to tender; 3) tender response; and 4) appointment. A detailed reading of ISO 19650 further indicated that the process "invitation to tender" involves three critical sets of documents: 1) EIRs (which define, among other things, project scope, procurement route and information milestones), 2) tendering criteria and 3) tendering requirements (including BIM Execution Plans as well as capacity and capability assessments). The processes identified in ISO 19650 and their corresponding information requirements provided the team with an analytical lens that could be held up against each set of case study documents. Importantly, the interview with the BIM4H&S member provided clarity of the emergence of the importance of the PIR versus the EIR.

The 13 documents of Case Study 1, for example, could then be organised as outlined in Figure 2:

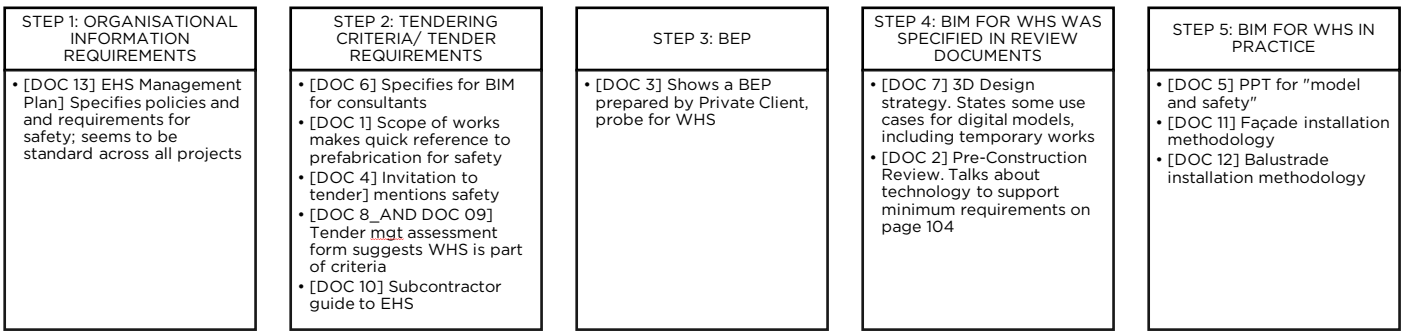


Figure 2: Use of ISO 19650 information management processes to organise project documents.

Organising the documents in this way was useful for two reasons. First, the research team had a way to trace the extent to which BIM was adopted (if at all) for WHS management during pre-tendering, tendering and post-tendering. This will be explained more fully in the Results section, but it is noted here as an example.

In Case Study 1, there was considerable use of BIM for WHS management in practice (Step 5 in Figure 2) but less so in earlier stages. A key question that was raised to Case Study 1 interviewees was, "what triggered the adoption of BIM for WHS management in practice, when in fact BIM and WHS management did not appear to be integrated into the tendering requirements?" Organising documents in this manner, therefore, proved useful as a platform for developing customised interview questions for each interviewee. For example, Interviewee 1, a Project Manager for the Façade Subcontractor on Case Study 1, was heavily involved in in the creation of the documents such as a presentation on the use of the model for safety, as well as documents on the façade and balustrade installation methodologies (Step 5 in Figure 2). The research team was thus able to formulate questions for Interviewee 1 specifically about these documents along with the related practices and processes. The research team was also able to probe more deeply about the conditions and requirements that preceded the creation of the documents. By asking interviewee 1, "What triggered the creation of the documents on façade and balustrade installation?" the research team was able to obtain greater clarity on other aspects of procurement such as tendering criteria, tendering requirements and the multinational's OIR.

Level-1 analysis

Once interviews had been conducted and transcribed, the research team carried out two levels of analysis. Level-1 analysis, also called first-order analysis, involved the identification of thematic codes, while Level-2 analysis, referred to as second-order analysis, involved the identification of axial codes. The two-level analysis approach is based on the rigorous method of Gioia, Corley and Hamilton (2013), where first-level themes ("thematic codes") are participant-driven, and second-

level themes ("axial codes") are researcher driven. This pairing of participant and researcher voices ensures that the full qualitative database is considered in identifying themes and, in this case, in the development of principles and tools for the Decision Framework.

To conduct the Level-1 analysis (refer to Appendix Figure B4), transcripts from the 15 interviews were distributed to four members of the research team. Each team member worked through each transcript in six steps following a standardised Level-1 Analysis Template. Specifically, each team member

1) Selected relevant quotes (units of text) from the transcript. To avoid closing down on the data too early, team members ensured that 80-90 per cent of the interview transcript was captured into the template, avoiding the dangers of biased selection.
2) Rated the level of significance of each quote to either the goals of the study or to the interviewee (based on, for example, the amount of time that the interviewee explained a point). Significance was ranked on a scale of one to three, with three being the highest.
3) Developed a thematic code to capture the main idea in each quote.
4) Grouped quotes with similar themes together within a single interview.
5) Identified common themes across interviews. Four sample interviews were analysed and mapped to the six Knowledge Domains identified in Phase 1:

- Scenario planning
- Requirement briefing
- Risk assessment
- Education and training
- Monitoring and surveillance
- Reporting and analysis

6) Identified possible links between first-order themes and second-order themes. Second-order themes are the four drivers of BIM adoption identified during Phase 1 of the study and are shown in Figure 3 as the columns CL (Client Leadership), TP (Tendering Proficiency), BP (Best Practice) and SC (Supply Chain Monitoring), to lay the groundwork for the Level-2 analysis. The four second-order themes were identified in Phase 1 of this study as important elements of the successful adoption of BIM for WHS management.

Once the Level-1 analysis was completed, the team members exchanged and reviewed the completed templates for quality assurance, thus strengthening the validity and reliability of the analyses.

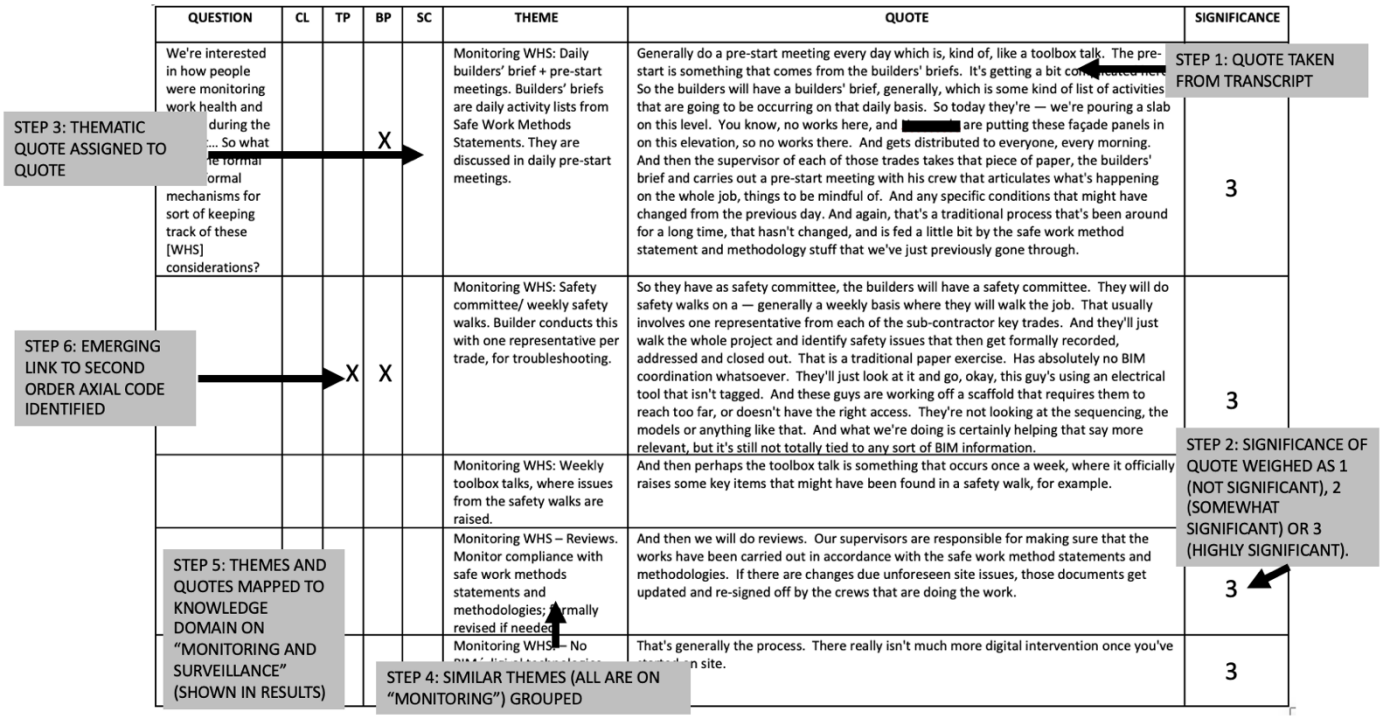


Figure 3: Sample template showing a partial Level-1 analysis.

Level 2 analysis

The template columns CL, TP, BP and SCM (Figure 3) were used as the basis for commencing Level-2 analysis (refer to Appendix Figure B5). Each team member was allocated one of the four themes: for example, Team Member 1 was assigned to Client Leadership gathered, from all 15 Level-1 templates, all of the quotes that had been identified as linked to Client Leadership. The team member then analysed these quotes as a corpus of data with the purpose of identifying the contours of Client Leadership in the context of BIM for WHS management using a standardised Level-2 Analysis Template (Figure 4).

While aggregating quotes, another round of quality assurance was performed where, for example, the team member in charge of Tendering Proficiency would review all quotes that had been marked" under the column TP. An item previously ticked as TP by another researcher during the Level-1 analysis could be vetoed, and an item left unticked could be included. Figure 4 shows part of the qualitative database for Client Leadership, with green rows being unticked items added and red rows as items vetoed. As a result of Level-2 analysis, new sets of themes and theme groups were identified for each of the four areas.

PROJECT	INTERVIEWEE	QUESTION	CLIENT LEADERSHIP TICKED BY (X MEANS ORIGINAL RESEARCHER)	THEME	RESEARCHER	QUOTE (BOLD HIGHLIGHTS MADE BY ZELINNA)	SIGNIFICANCE	EMERGING SECOND LEVEL THEME	QUOTE SHOWS + OR - EXAMPLE
[redacted]	[redacted]	We have talked a lot about the BIM for work, health and safety, and you mentioned that the digital information technology wasn't factored in the current health and safety management plans, in the future will you be considering to factor digital information technologies in (00:50:20) health and safety management systems?	x	There is an opportunity to factor digital information technologies in the EHS plan.	[redacted]	I don't know that because that would be Ross Trethewy, our Head of EHS, he's national, because I'm only regional, I don't have any control over the system unfortunately, as much as I would love to have control over it, I don't have control over that, that is a national system, so that is something that needs to cover across all our regions. **But I don't see why it wouldn't as long as we could – what we are very wary of, particularly in Australia, is making things over complicated, so the word gets thrown around a lot from our sites, simplification, so I don't think we've actually mastered that yet so that's the only, I wouldn't say hold point, but that would be our – we would have to make sure that we are not over complicating something if we're putting that as a requirement within our system.**	1	ABILITY TO IDENTIFY RISKS; IDENTIFY OPPORTUNITIES FOR BIM; DISTINGUISH BETWEEN MUST-HAVE AND NICE-TO-HAVE TOOLS; IDENTIFYING THE NEXT STEP IN THE BIM FOR WHS JOURNEY	(+)
[redacted]	[redacted]	If I'm the client, what do I ask when signing the contract, to the subcontractor, or to some others? So what would be the most important question that I would ask in the contracting, in the tendering stage?	x	Clients should identify areas of risk and incorporate those into a 4D program along with temporary works and safety precautions	[redacted]	**You can ask a client, maybe, to identify areas of risk doing that, which means that they're going to need to incorporate it into the program, the 4D.** They need to incorporate temporary works into it and safety devices and whatever it says – if it's a net or if it's scaffoldings and so on. You could ask for that. And you know what? Maybe it's going to drive it a bit better in the industry.	3	ABILITY TO IDENTIFY RISKS; IDENTIFY OPPORTUNITIES FOR BIM; DISTINGUISH BETWEEN MUST-HAVE AND NICE-TO-HAVE TOOLS; IDENTIFYING THE NEXT STEP IN THE BIM FOR WHS JOURNEY	(+)
[redacted]	[redacted]	So I'm interested – Lendlease is an international company, and we're talking about the Sydney project. But have you had experiences where you've had good clients – whether they're government clients or whatever – in other projects around the world? As in, a good client, and a client that has done procurement and done all of those things – understood the EIR, put the EIR out well.	ZP (+)	Defence in Australia are pretty good clients	[redacted]	Well, EIR is a new thing, really. But Defence are pretty good in understanding what it is that they want. | |They use BIM in some cases; not all of them, but they do. **We have clients here that wanted to go all bells and whistles on data, for example, which I don't think was the right approach. But again, at least they did something and asked for it because they wanted to look at using it for their own asset management and so on.**	1	ABILITY TO IDENTIFY RISKS; IDENTIFY OPPORTUNITIES FOR BIM; DISTINGUISH BETWEEN MUST-HAVE AND NICE-TO-HAVE TOOLS; IDENTIFYING THE NEXT STEP IN THE BIM FOR WHS JOURNEY	(+)
[redacted]	[redacted]	have you seen any examples of using any opportunities where the GMR requirements could be addressed through the use of digital models?	ZP (-)	Visualisation of EHS requirements	[redacted]	videos tell a thousand words | | if you play a video of what you are going to do, or if you show an animation of what the building is going to look like in the end, the workforce are captured by it, rather than reading a piece of paper | | the visualisation of [work procedures] alone, helps me and the team in risk management, coordination of trades, coordination of exclusion zones, which are a key control for the construction industry | | **If we have a visual model and the model tells us what it looks like, that is, I'm a huge fan of even just the displaying of that to the workforce, it gets them thinking more**	3	ABILITY TO IDENTIFY RISKS; IDENTIFY OPPORTUNITIES FOR BIM; DISTINGUISH BETWEEN MUST-HAVE AND NICE-TO-HAVE TOOLS; IDENTIFYING THE NEXT STEP IN THE BIM FOR WHS JOURNEY	(+)
[redacted]	[redacted]	have you seen any examples of using any opportunities where the GMR requirements could be addressed through the use of digital models?	x	BIM as a means of EHS communication	[redacted]	Our industry attracts a lot of people from a completely varied background | | we need these workers to carry large reinforcement bar on level forty and pour concrete, so their skillset is to that, and we need those people, so English and concentration levels are sometimes, it's difficult to get people in the right frame of mind to understand complex activities or key risk without actually showing them what could happen or what good looks like | | if we have a visual model and the model tells us what it looks like, that is, I'm a huge fan of even just the displaying of that to the workforce, it gets them thinking more | | **So obviously we use the BIM model here, we use it to communicate to our construction workers what they're actually building.**	3	ABILITY TO IDENTIFY RISKS; IDENTIFY OPPORTUNITIES FOR BIM; DISTINGUISH BETWEEN MUST-HAVE AND NICE-TO-HAVE TOOLS; IDENTIFYING THE NEXT STEP IN THE BIM FOR WHS JOURNEY	(+)

Figure 4: Sample template showing a partial Level-2 analysis for Client Leadership.

Decision Framework Development Principles

The final stage of analysis involved a knowledge translation process where Level 2 themes for each recommendation informed the development of tools. Phase 2 Client Leadership, Best Practice, Tendering Proficiency and Supply Chain Monitoring was concluded with Recommendations for the Decision Framework and Principles discussed in relation to tool building (Figure 5).

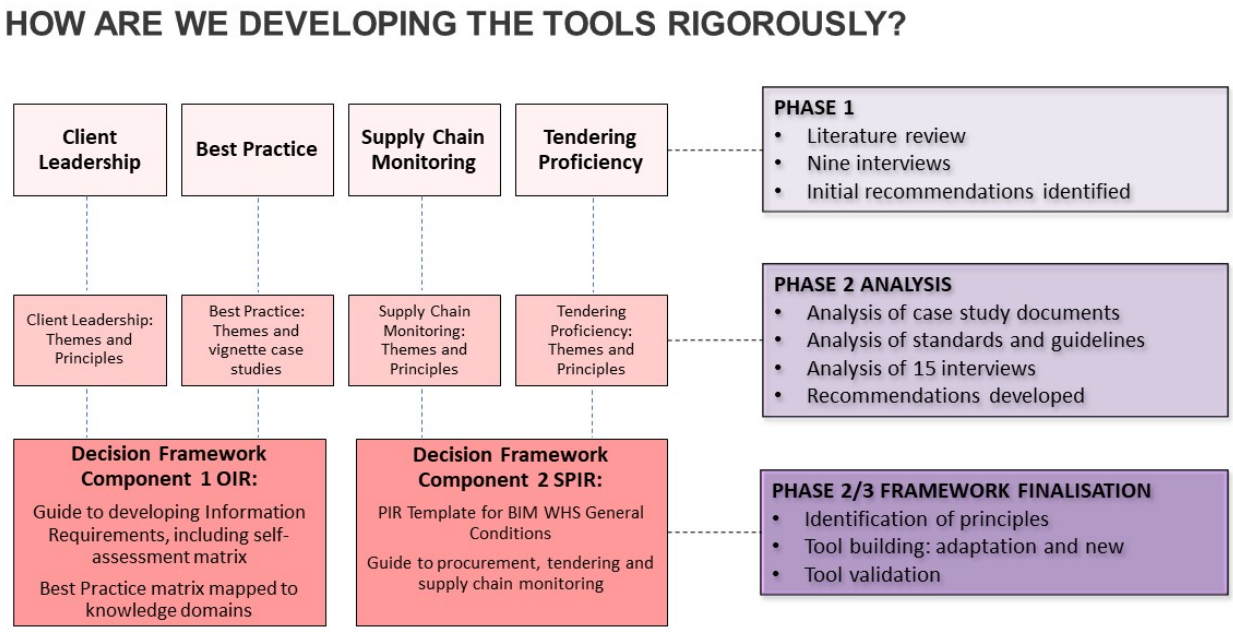


Figure 5: Preliminary Phase 1 recommendations, detailed Phase 2 recommendations and proposed tools.

Results

This section presents the results of the document, Level-1 and Level-2 analyses. The Level-1 results represent how data from four interviews specifically map to the six Knowledge Domains identified in Phase 1, a demonstration of common themes cutting across interviews. The Level-2 results represent themes and theme groups that underpin each of the four recommendations from Phase 1: Client Leadership, Tendering Proficiency, Supply Chain Monitoring and Best Practice. The detailed narratives for each recommendation are used as foundations for developing the tools that comprise the Decision Framework.

Document analysis

Document analysis involved iterative analysis between 1) standards, frameworks and guidelines and existing tools, and 2) real-life project documents representing actual implementation. Specifically, processes, sub-processes and information requirements specified in ISO 19650 were used as a scaffold for organising the project documents provided to the research team.

A key outcome of the approach was the identification of preliminary areas of strength and opportunities for improvement in specifying BIM for WHS management. Figure 2 shows documents received from Case Study 1 and how they mapped to the processes before, during and after procurement as defined in ISO 19650. Figure 6 expands on Figure 2 by showing additional comments in italics about BIM for WHS management made by the research team following document analysis.

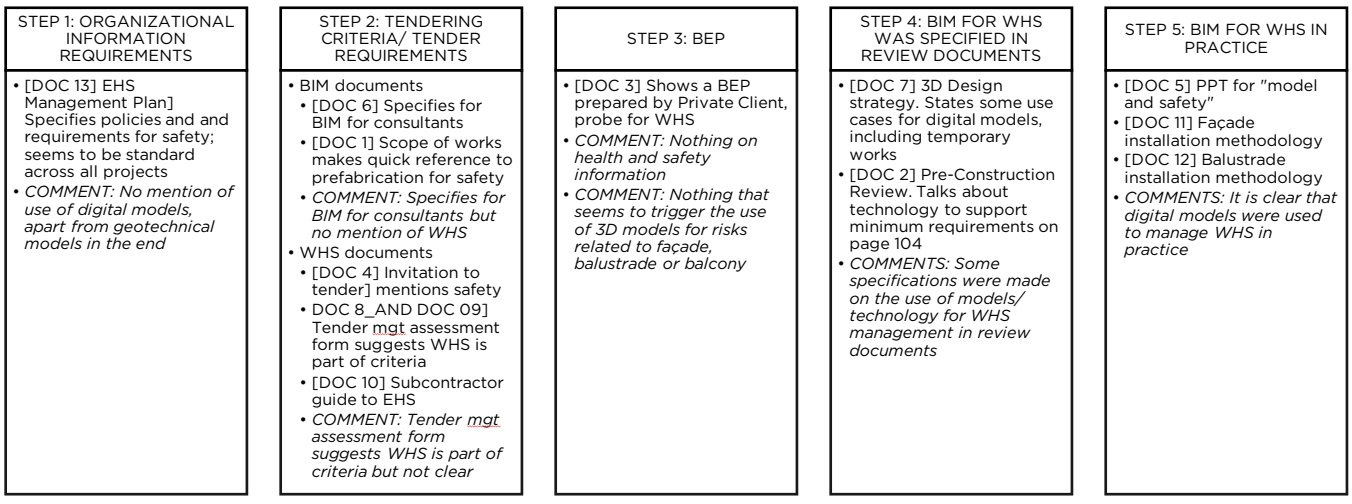


Figure 6: Updated figure 2, with commentary.

For example, a review of Documents 5, 11 and 12 showed detailed models and demonstrated how these informed, among other things, crane positions, exclusion zones and worker positions when installing building elements. These observations led to the comment being added under "Step 5:

BIM for WHS in practice" (Figure 6): 'It is clear that digital models were used to manage WHS in practice'". Step 5, then, suggests that "BIM for WHS management in practice" is an area of strength. It was less clear what triggered the creation of these three documents and, more importantly, what compelled the use of digital models for these activities. The question is important because earlier stages (Steps 1-3, Figure 6) appear to signal weaknesses in BIM for WHS management. Steps 1 and 2, for example, suggest what was later confirmed in interviews: that information requirements before and during procurement reflected a fundamental split between BIM and WHS management. Requirements on WHS management were defined in Document 13 (EHS Management plan), while BIM requirements were clarified through Document 6 (BIM requirements for consultants). Moreover, BIM documents made limited references to WHS management and WHS management documents made limited reference to the use of BIM or digital models. The early understanding of Case Study 1 was thus that a Façade Subcontractor was the initiating force behind the use of BIM for WHS management on-site, but it was unclear where this initiative originated. Client-initiated documents during pre-tendering and tendering processes did not successfully capture the integration of BIM and WHS management. This was thus an issue that was selected for further investigation during the interviews.

While the documents provided important foundations for developing interview strategies, the findings were taken by the research team to be preliminary, mainly because the documents did not provide an exhaustive picture of the case studies nor a substantial foundation for tool-building. Most of the findings informing the framework thus emerged from interview data.

First order analysis: thematic coding

In this section, the six Knowledge Domains were analysed and mapped across four interviews (five interview participants; Table 4). The following narratives explain each case study in more detail.

Table 4: Summary of best practice across the six Knowledge Domains of using BIM for WHS management.

Knowledge Domain	Case Study 1 Interviewee 1	Case Study 1 Interviewees 3 & 4	Case Study 2 Interviewee 2	Case Study 3 Interviewee 10
	Project Manager Façade Subcontractor	*Construction Manager Sen. Project Engineer*	*Digital Eng. Manager*	*Project Manager*
Scenario planning	*X*	*X*	*X (moderate)*	*X (potential)*
Requirement briefing	*X*	*X*	*X*	*X (potential)*
Risk assessment	*X*	*X*	*X (moderate)*	*X (moderate)*
Education/ training	*X*	*X*	*X*	
Monitoring/ surveillance	*X*	*X*	*X (moderate)*	
Reporting and analysis	*X*			*X (potential)*

Sample Interview 1

Interviewee 1
Position: Project Manager, Façade Subcontractor
Case: Case Study 1

The first sample interview involves Interviewee 1, a Project Manager for the Façade Subcontractor in Case Study 1. In the Methodology section, it was noted that Case Study 1 involved a commercial building with a highly complex design. The building was also constructed in a congested area. The Façade Subcontractor was brought onto the project by the Private Client (Developer) on the day that they received the final concept design from the architect. The proposed concept design entailed a timber building wrapped in timber strips slabs but had very limited technical detail. The Façade Subcontractor thus began the process of making extensive use of digital models to plan work sequencing and analyse methodologies for manufacture and assembly of the facade, including how prefabricated elements would be built and transported, and what constraints could be anticipated for painting, assembly and storage. Early contactor involvement in this case developed into a long-term relationship with the Private Client that spanned four years and provided the Façade Subcontractor with many opportunities to anticipate constructability issues with direct bearing on WHS management:

> *"So we worked through that with them, and because of our intimacy with the project, for that length of time, rather than being just brought in at the end once they thought it was resolved and then having to build what they've — where they've ended up, we had done mountains of work on methodologies and systems which allowed us to put together a very comprehensive set of documents about how it was going to be built. And piece by piece, day by programs, which we then feed into our safe work method statements and our methodologies that we then go back to [Private Client] with, and we present to the site team". – Interviewee 1, Project Manager, Facade Subcontractor*

Data from Interview 1 shows multiple examples of best practice in each of the six Knowledge Domains identified as priorities in this study: scenario planning, requirement briefing, risk assessment, education and training, monitoring and surveillance, and reporting and analysis. Examples are summarised in Table 5 and discussed in the narrative that follows. Note that the Knowledge Domains might be reordered in the narrative to achieve a more coherent discussion.

Table 5: Examples of best practice in different Knowledge Domains – Interviewee 1.

Knowledge domain	Sample evidence in interview
Scenario planning	*Model was used to plan detailed position of cranes, for example, to confirm critical angles and distances, ensuring that cranes could be assembled and positioned correctly the first time and avoiding costly mistakes*
Requirement briefing	*Model used to plan for detailed work sequencing. Daily work activities were then shared with supervisors on-site, who used the information to brief trades during toolbox talks about potentially hazardous activities*
Risk assessment	*Because the model was used to identify where cranes would be positioned in a given week, the team was able to identify areas that were exclusion zones for safety purposes during a given week*
Education and training (including formal, informal, on-the-job training and induction into communities of practice)	*Model was used as a daily communication device. A television screen was made available at the project site to show how the project was progressing and explaining what was happening on a given day. Trades that were normally detached from the use of BIM were drawn into a community of practice making routine use of digital models for sequencing and safer work practices*
Monitoring and surveillance (including compliance)	*Model was used to demonstrate how activities were supposed to unfold over both the short-term and long term and mitigated the tendency for trades to rush through their work. Compliance with a work schedule that did not compromise safety was strengthened, and pressure to rush was alleviated*
Reporting and analysis	*Model was used to conduct analysis based on multiple variables such as site parameters, fencing, temporary lifts on-site and crane capacity. Digital coordinates of temporary lifts and cranes were inputted into the model to assess if a crane of the right capacity had been selected for a given task*

Scenario planning

The Façade Subcontractor made extensive use of the model to plan scenarios through detailed parameter checking, for example, with respect to the positioning of cranes:

> *"It's more parameter checking. So, we can identify the most ideal position to set our machines up in… And then digitally check the length to where we're going to try and lift up a façade module for example… So, we might determine that we can set up a crane here. We can then check, in the model, the distance to this façade model here… So rather than arriving on-site — and the guys will still do dry runs, they're called which is where you test the capacity of the crane to make sure that what you're about to do is within the limits of the crane's capabilities." – Interviewee 1, Project Manager, Façade Subcontractor*

The ability to conduct "dry runs" on crane operations was seen to be linked to significant safety benefits:

> *"But this is a big thing in the industry…people getting crane set ups wrong which causes loads to fall or cranes to become unstable. So, by being able to put all that information into the model and accurately check where we can fit the crane up, we*

can get it right in the first place." – Interviewee 1, Project Manager, Façade Subcontractor

Cost savings were also achieved because replacing mobile cranes or dismantling a tower crane due to failure to meet the prescribed parameters can be very expensive:

"It's very easy to make the mistake of thinking that you have a lot of space and you have room to set cranes up, and you have room to have access equipment, machines and storage space. And then you arrive on-site, and you have to throw all those plans out the window because site conditions are very different to what they look like on a drawing". – Interviewee 1, Project Manager, Façade Subcontractor

Analysis and reporting

Analysis of activities was also facilitated because of the rich digital data that had been captured in the model. Complex construction activities were parsed into minute details, which were then digitally manipulated to achieve well-informed decisions. For example, apart from planning a crane's position, for example, analysis was also undertaken to choose the right crane capacity:

"...we built in [to the model] the lift structures, the temporary lift structures, the crane, the site parameter, fencing. This helps you understand exactly what you're looking at on the ground in a one to one scale. So, this job, we went and got a survey done of the perimeter fencing, all around the work site. We got the digital coordinates of the temporary lifts and the crane. We put all that into our model, and that allowed us to very accurately analyse where we could set machines up, which means that you can analyse whether you've got the right machine to do that job." – Interviewee 1, Project Manager, Façade Subcontractor

"It's very easy to put a crane that has, let's say, a two-tonne capacity, in a position and then find out later that it doesn't have the capacity to get where you need it to get. That if you have all of these parameters in a model, you can analyse that before you get there...And not put the guys on-site, in a position where they will find out the hard way that it doesn't work". – Interviewee 1, Project Manager, Façade Subcontractor

Risk assessment/ Requirement briefing

Once decisions on crane capacity had been analysed and viable scenarios on a crane's positions planned and confirmed, the contractor had the ability to identify possible WHS risks. Information about these potential risks were then shared with the Private Client (Contractor) to communicate during toolbox talks and briefings:

"...we'll model out every single stage, take a snapshot of each daily activity, put it in a document, record the date that we expect it to happen. And then that helps the guys on site pass that information on to other trades as to where we're going to be, what we're going to be doing, what they need to be careful of... So yeah, we would run through something like this, and we would, say, okay, today we're going to analyse this blue band of timber here. And we're going to figure out where the crane set-up is for this week's worth of activities. And then we would say okay, we've identified that this area is the best place to do it. So, then you can notify the builder that we want that area off-limits to everyone else for that particular week whilst we do this area of work. And having that information just makes their life a

lot easier. Makes our life easy." – Interviewee 1, Project Manager, Facade Subcontractor

Education and training

There was no evidence from this interview that BIM was used for formal training aimed directly at improving WHS. However, two points can be noted. The first is that the contractor made use of BIM's visualisation capabilities in ways that were accessible to all trades. However, the use of BIM on construction sites can be polarising, dividing trades into groups that regularly engage with the model and those that are completely detached from it:

> *"So our guys are — they're living and breathing it, and they're along for the journey, whereas some of the simpler trades, like painting, for example, whilst it may be trade complex, it's repeated on a project to project basis. They arrive on-site, and they do what they're paid to do for a couple of months or a couple of weeks, and then they move to the next job." Interviewee 1, Project Manager, Facade Subcontractor*

In Case Study 1, activities for the day were shown to all trades through a large television at the front of the site, allowing to see how tasks would be unfolding on a given day:

> *"So, with [Case Study 1], what was great about how they ran it was they had big screen TV at the front. As everyone walked through the door, they saw the development of the project. They saw this and along with an explanation of what was happening that day. And perhaps there's an opportunity to further develop that side of it so that people that aren't involved in the design development can be brought up to speed quickly on what's happening on that job." – Interviewee 1, Project Manager, Façade Subcontractor*

This leads to a second point. While formal training for WHS management through BIM was not carried out, it can be argued that trades, specifically those who did not typically use BIM, were increasingly drawn into a community of practice that upheld the value of digital models for achieving WHS goals. This may be considered as informal, site-based training.

Monitoring/ surveillance/ compliance

There was also no evidence from this interview that BIM was used to support monitoring for WHS management. However, Interviewee 1 did point out that communicating with trades about the sequencing and timing of tasks did have a positive effect:

> *"...something in the construction industry to consider is that the pressure, program pressure to finish jobs, quickly, is immense. And that really does factor into the WHS side of things, like when the guys on the ground that are doing the work are being or felt to being pressured to work long hours or achieve milestones on a daily or weekly basis, it can lead to things being rushed or not done properly. And if you can model it out using these models and really develop a long-range program that explains how it's going to be done, can help alleviate a lot of that short-term program pressure. And the guys can stick to the plan and do it the right way." – Interviewee 1, Project Manager, Façade Subcontractor*

BIM's visualisation capabilities, then, were used to show trades how work was supposed to be paced over the short-term and long-term, and thus alleviated some of the pressure on them to

rush through jobs. BIM did not necessarily support WHS monitoring in this case, but it did strengthen compliance with a safer work schedule, mitigating some of the dangers that arise from completing tasks hurriedly within compressed time frames.

Sample interview 2

Interviewee 3
Position: Construction Manager
Case: Case Study 1

Interviewee 4
Position: Senior Project Engineer
Case: Case Study 1

The second sample interview involved Interviewee 3, a Construction Manager and Interviewee 4, a Senior Project Engineer in Case Study 1. Interviewees 3 and 4's interview shows multiple examples of best practice in each of the six Knowledge Domains. Examples are summarised in Table 6 and discussed in the narrative that follows.

Table 6: Examples of best practice in different Knowledge Domains – Interviewees 3 and 4.

Knowledge domain	Sample evidence in interview
Scenario planning	*Model was extensively used in the planning phase of the project. It helped to manage offsite manufacturing, temporary works, logistics, transportation, and works in tight spaces on site.*
Requirement briefing	*Model was used to brief the building project and progress to others.*
Risk assessment	*Model was used to proactively identify and assess the WHS risks on site.*
Education and training	*Model was used in daily WHS communications on site.*
Monitoring and surveillance	*Model was used to track the work progresses.*
Reporting and analysis	*The interviewee did not mention whether the model was used for reporting purposes nor whether any specific analyses were conducted based on the model.*

Sample interview 1 and 2 are both linked to Case Study 1. The majority of the findings from both interviews are consistent; both interviews showed evidence of using BIM for scenario planning, requirement briefing, risk assessment, education and training, monitoring and surveillance, and reporting and analysis.

Scenario planning

The data from Interviewees 3 and 4 showed that the BIM model was extensively used in the planning phase of the project to manage offsite manufacturing, temporary works, logistics, transportation, and works in tight spaces on-site.

"If we take this scenario here, it's a slightly different option because you would be working from the slab and from that slab above. So, we've got different instances as you work your way around the building and without pre-thinking about that and planning every elevation of every level of every different scenario, you can never really fully understand it." – Interviewee 4, Senior Project Engineer, Private Client (Contractor)

"The other thing that the model does is it actually starts helping us understand temporary works. So obviously scaffold being temporary works. How the temporary works worked in relation to the main works that need to be installed on-site, so what elements of temporary works do we strip down. Especially with a slab that moves in and out is the scaffolds, is it supported off-ground? Is the scaffold supported off the slab? Is the scaffold cancelled? Can we take that portion of scaffold down? So instead of just being out on the site and we finished the building, and then we start the conventional way to strip down, which is sort of top-down with scaffold. Were there areas that we couldn't do because of the way the slabs work? Yes, and that was what we discovered in the model. I was able to implement that on-site, so we actually decided to strip scaffolds in on vertical elevations as opposed to four-by-four elevations." – Interviewee 3, Construction Manager, Private Client (Contractor)

Requirement briefing

Interviewees 3 and 4 highlighted that the BIM model was useful in briefing subcontractors on the project scope and other requirements. For example, Interviewee 3 commented that:

"The next step was then how do we then portray that to a subcontractor who has been not really involved in any of this planning. We will do an induction at the end of our site, where we can then sit down with them and show them in 3D how they are going to potentially perform their works and bring them on the journey, and I think a lot of people embrace a 3D-concept more than they do just looking at a piece of paper and going, 'yep, I can put that bracket there' or 'I could put that piece of timber there'. That then sort of lead to the foundations where in our scopes, particularly with façade scopes, a little bit with our form work scope and our edge protection scope, where items such as getting them to model the elements in BIM, so, with our form worker, we had him model the scaffold and the edge protection in BIM, which allowed us to understand how the building was going to get built from a structure point of view." – Interviewee 3, Construction Manager, Private Client

Risk assessment

The BIM model was used to proactively identify and assess the WHS risks on-site. In addition to the evidence on risk assessment identified in the first sample interview, the second sample interview highlighted the value of BIM in planning on-site and off-site components to reduce WHS risks.

"The underlying idea of what we did in the early phase was to really develop our planning in a sense that we would de-risk every element. We know that when you don't plan something, that's when things tend to go wrong, so by us being able to do things off-site and create or reduce the amount of work that we need to do on-site, where we are eliminating risks, and we are thinking about different aspects of things without potentially having someone to become reactive and to do something that could potentially put them in a situation or a scenario where your ability to put yourself in a position where you might be harmed, or you might hurt

someone or someone else or drop something, or whatever it might be, is drastically reduced." – Interviewee 4, Senior Project Engineer, Private Client (Contractor)

Education and training

The second interview showed that the ability to visualise construction plans and scenarios helps with the training of subcontractors and workers on-site and with communication of WHS issues.

> *"It also made sense from the perspective that a lot of trades and subcontractors will use 2D-images for snapshots of plans or whatever, but we had the availability of this model at our disposal, and to what we were saying before, it's very difficult to grasp the nuances of the building without seeing it and this, as easy as taking a snapshot of this elevation for example. If we are installing something on this slab edge, you can physically see if something was to be happening above, then you're not going to be doing that, or if you are doing ceiling works above, you're not going to be doing anything on this level, which otherwise might be overseen or missed in a 2D-world." - Interviewee 4, Senior Project Engineer, Private Client (Contractor)*

Monitoring and surveillance

The BIM model was also used to track work progress. Interviewee 3 noted that:

> *"We used the model to show how we've tracked to date; sometimes we had images like this where it showed it live and then you could cut across from the actual live data into the modelled data and they could see, we could project out where we were going to be in the next three months' time as well." - Interviewee 3, Construction Manager, Private Client*

This second sample interview, however, agreed with the first interview that no evidence was found to support that BIM was used for monitoring or surveillance of WHS management.

Reporting and analysis

Interviewees 3 and 4 did not mention whether the model was used for reporting purposes nor whether any specific analyses were conducted based on the model. It should be noted, though, that Interviewee 1, a Project Manager from the Façade Subcontractor, was part of the same case study and did not include its use for analysis. The discrepancy is not problematic; Interviewees 3 and 4 were managers at the Private Client may not have been aware of how Interviewee 1's façade subcontractor team was using BIM for analysis of crane positions.

Sample interview 3

Interviewee 2
Position: Digital Engineering Manager, Private Client (Developer)
Case: Case Study 2

The third sample interview involved Interviewee 2, a Digital Engineering Manager for the Private Client (Designer) in Case Study 2. In the Methodology section, it was noted that Case Study 2 involved an underground metropolitan train station, pedestrian station access and two retail and residential towers. Interviewee 2 had been involved in developing the organisational standards for the Private Client (Designer) in relation to BIM and Digital Engineering over the past six years and authored the project-specific subcontractor requirements for Case Study 2 in relation to BIM and Digital Engineering. Interviewee 2 also ensured the Government Client (Transport) EIRs were addressed. Interviewee 2's involvement in on-site applications of the BIM model during construction was limited.

The data from Interviewee 2 shows examples of best practice in several of the Knowledge Domains. Examples are summarised in Table 7 and are discussed in the narrative that follows. Note that Interviewee 2 did not provide evidence of Scenario planning, Monitoring and surveillance, nor Reporting and analysis.

Table 7: Examples of best practice in different Knowledge Domains – Interviewee 2.

Knowledge domain	Sample evidence in interview
Scenario planning	*Model was used to visualise the delivery program in 4D, but Interviewee 2 did not mention comparisons of scenarios nor adjustment of the delivery program based on the review of the 4D model.*
Requirement briefing	*Model was displayed on screens on-site and used for site briefings to communicate how activities were supposed to unfold over both the short-term and long term, along with the requirements for the day.*
Risk assessment	*Model was used to support risk identification, assessment and mitigation at daily morning briefings as the 4D model was used to show workers how the day's activities were supposed to unfold. Interviewee 2 did, however, not mention any specific risk-identification analyses conducted based on the review of the model.*
Education and training (including communication/engagement)	*Model was used to facilitate communication around the delivery program and risk mitigation measures. The model also communicated high-level construction methodology to a range of stakeholders.*

Monitoring and surveillance	*Model was used to demonstrate how activities were supposed to unfold over both the short-term and long term, supporting compliance with the agreed approach and delivery program. Interviewee 2 did not mention using the model for monitoring or surveillance.*
Reporting and analysis	*Interviewee 2 did not mention further analysis or reporting activities based on or using the model.*

Scenario planning

Interviewee 2 spoke candidly about the benefits and limitations of 4D-BIM. Its use for clash detection and general visualisation was celebrated; however, detailed modelling must be justified. 4D modelling was considered useful when areas of concern or workflows need to be understood, such as constructing a lift shaft in a challenging part of the building. While critical of the universal application of 4D-BIM, Interviewee 2 acknowledged the importance of WHS and that WHS management could easily be incorporated into 4D-BIM.

> *"...you can bring health and safety into 4D, understanding how a crane moves, are they going to hit something, how the trucks and people moving on-site, and you can start simulating that." - Manager, Private Client (Designer)*

The interviewee developed an internal 4D model to assist visualisation of the delivery program. However, they did not elaborate on how the program was developed, level of detail, nor whether the program was adjusted based on 4D visualisation and scenario comparisons.

Requirement briefing

The primary benefit of the 4D model was as a communication tool. The model was anecdotally used at daily site briefings to help workers visualise the activities to be undertaken that day, along with potential risks and mitigation measures.

> *"It's a great communication tool; so, site briefing in the morning, you can have that on the screen, and you talk about what it is and areas that you're working on, what people need to look out for and so on. You may have things are being poured up here, and people still working down here. And so, for visualising that, that's a really good tool." - Interviewee 2, Digital Engineering Manager, Private Client (Designer)*

Risk assessment

While the model was used to visualise and communicate risk, Interviewee 2 did not mention model analyses being undertaken with the dedicated purpose of identifying and assessing WHS risk. However, insights from using a 4D model to manage WHS on a different construction project was shared.

> *"So, it was really useful to start putting the safety nets, for example, and having that 4D, where we realised that, 'oh wow, this is a really dangerous area in here because there's a lot of demolishing going up in here'. But we're building from underneath it. How do we protect the people who are working there? How do we*

protect people on the footpath? All that kind of stuff." - Interviewee 2, Digital Engineering Manager, Private Client (Designer)

Education and training

Along with using the 4D model as a communication device, as described in Case Study 1, the central placement of the model likely assisted in raising workers' awareness and capability in the use of digital models. It also likely assisted in building WHS management capability when using the model to visualise the delivery program and provide talking points about WHS risks. Interviewee 2 was firm in the belief that the future does not entail everyone inputting into the BIM model and where WHS is completely incorporated. Instead, BIM was considered a tool to enhance the culture for safety by bringing WHS management to the forefront for construction participants while planning daily activities.

> *"With health and safety, it's a lot more abstract, isn't it? Health and safety is culture; health and safety is people with experience walking on-site; health and safety is something you instil in everybody, regardless of what it is that they do. So, I think the better approach would be how we can enhance it, maybe, with BIM; where can we make it better? I don't necessarily think that you're going to say, 'We're going to move our health and safety and use BIM, and then everybody is going to use the model.' It's not necessarily the case. You're still going to go through a process of health and safety on whatever it is that you do every day." - Interviewee 2, Digital Engineering Manager, Private Client (Designer)*

Monitoring and surveillance, ensuring compliance

While the model was not used for formal monitoring or surveillance purposes, the model likely supported compliance among workers in following the agreed approach and program. The WHS manager at the Private Client (Designer) used the model to communicate how activities were to unfold over the short-term and longer-term, clarifying requirements and expectations, ensuring understanding, and providing discussion points for areas of uncertainty.

> *"Because for them [WHS Managers], if you said to me, I'm going to use it on-site briefing in the morning when I'm showing people where things are. Because this week, we are pouring this section over here; there's stuff happening in here. It's a lot easier to visualise when people look at the model than plans or just talk about it. We're going to the southeast corner. Where is the southeast corner again?" - Manager, Private Client (Designer)*

Reporting and analysis

The interviewee did not mention whether the model was used for reporting purposes nor whether any specific analyses were conducted based on the model.

Sample interview 4

Interviewee 10
Position: Project Manager, Project Management Consulting Firm
Case: Case Study 3

Interviewee 10 was involved in Case Study 3 as a Project Manager for the Government Client (Health). The interviewee is part of a large team within a professional services firm, the Project

Management Consulting Firm, which provides services to clients at planning and delivery stages of capital projects. The Project Management Consulting Firm's involvement began at the schematic design stage. Adoption of Early Contractor Involvement (ECI) in Case Study 3 presented the Project Manager with the opportunity to receive Private Client (Developer)'s input to the planning stage. The collaboration continued through the construction phase, where the Project Management Firm's team oversaw the actual delivery of the project and the construction on-site.

Interviewee 10's interview included several examples of best practice in four of the six Knowledge Domains identified as priorities in this study. Examples in Table 8 are followed by narratives to present the examples within the context of Case Study 3. To improve readability and logical flow, the narratives are not presented in the order they appear in Table 8.

Table 8: Examples of best practice in different Knowledge Domains – Interviewee 10.

Knowledge domain	Sample evidence in interview
Scenario planning	*Potential use of Construction BIM Management Plan for "staging", or for planning "how the building [will come] together", which allows construction teams to anticipate WHS management issues*
Requirement briefing	*Potential use of fly-through models to demonstrate sequencing and potential WHS management issues. However, models have limited value if the data input is incomplete or of poor quality*
Risk assessment	*Model was available identifying safety issues for construction. Limited evidence on the use of models for design safety reviews, despite increased opportunities and incentives for the Developer to do so*
Education and training	*No direct evidence*
Monitoring and surveillance	*No direct evidence*
Reporting and analysis	*Potential use of BIM to support detailed incident reporting; potential use of BIM for Developers to conduct analysis for safer site practices*

Scenario planning

Interviewee 10 noted that the Government Client (Health) made use of a Design BIM Management Plan (DBMP) as well as a Construction BIM Management Plan (CBMP). Of the two, the Construction BIM Management Plan was seen to have a more direct bearing on the management of WHS issues:

> *"I would expect in the construction BIM management plan that there would be a bit more in that plan on health and safety, to be honest, because I think that plan is more looking at the staging. It is taking into account the staging of how the building is coming together, in which case safety is a lot more of a factor and consideration, and there's more risk attached to health and safety issues due to getting the staging wrong and doing things in a suboptimal sequence." – Interviewee 10, Project Manager, Project Management Consulting Firm*

There are two points to note about this observation. First, BIM may be used to mitigate safety issues by ensuring that sequencing is done in an optimal manner. Importantly, though, Interviewee 10 expected but did not state that the CBMP was actually used to manage WHS. Second, the CBMP was seen to have a stronger focus on WHS management than the DBMP:

> *"I know [design BIM management plan] is more focused on managing clashes and detecting clashes in the design, which could impact the program if they are picked up too late and could result in commercial implications to the client." – Interviewee 10, Project Manager, Project Management Consulting Firm*

This point counters other empirical findings that suggest the use of BIM during design reviews can prevent significant WHS risks during construction.

Analysis and reporting

There was no direct evidence that the Government Client (Health) made use of BIM for analysis and reporting. However, considerable potential exists in this area. The Government Client (Health)

has stringent measures in place for WHS incident reporting. Furthermore, the provision of explanations and details of past incidents is part of the Government Client (Health)'s tender requirements:

> *"[T]here is [sic] obligations on everyone in the project team to take that notification and escalate that up through the ranks of [Government Client (Health)], all the way up to a chief executive level if there is any sort of injury, and then they are really quite firm in terms of everyone downstream investigating the incident and providing a comprehensive report up the line to explain what happened, why it happened and what the project team is going to do about it to ensure that type of incident never happens again." – Interviewee 10, Project Manager, Project Management Consulting Firm*

It is plausible that the rich data available through BIM could be mobilised to support detailed reporting practices such as these.

The wider application of BIM for analysis and reporting on WHS management can also be value-adding to the Private Client (Contractor), who in this case was seen to be responsible for WHS management on-site:

> *"[T]he reality is I have not been involved in any assessments where methodology has been deemed unsafe because generally [...] [the contractor] who is the expert out of everyone in that room [is trusted to be] putting forward something that is safe, or if it's not, if they cannot completely demonstrate that, you know they have an obligation moving forward when it actually comes to delivering, to make sure that they do it in a safe way." – Interviewee 10, Project Manager, Project Management Consulting Firm*

BIM adoption could thus enable the Government Client (Health) to conduct site activities "in a safe way" through the use of more sophisticated analyses within a BIM environment.

Risk assessment

Interviewee 10 noted that:

> *"The BIM model was there, it was developed, it was maintained, and it was available to be utilised to look at safety issues for construction." – Interviewee 10, Project Manager, Project Management Consulting Firm*

Potentially, then, BIM was available to support risk assessment. There were also increased incentives and opportunities for the model to be used in this manner. First, Case Study 3 involved ECI as well as direct negotiation between the Government Client (Health) and Private Client (Contractor) instead of a traditional competitive process. This procurement model put the onus on the Private Client (Contractor) to demonstrate value for money in order to secure the project in its entire scope. Second, the implementation of ECI in project procurement also gave Private Client (Contractor) opportunities to build on the designers' digital models. The increased pressure on the Private Client (Contractor) to demonstrate value, coupled with early access to digital models, could arguably lead to the expectation that models would be used for safety reviews of

construction methods. Still, there was no clear evidence that this was the case as the interviewee was not a participant when these reviews occurred.

> *"[A] BIM model was maintained throughout that ECI phase, there was safety and design reviews, which is an obligation of the contractor during part four, which I understand that the BIM model was available for use in those reviews. To the extent that it was utilised to complete those reviews, I am not sure, and I would be talking a little bit out of turn." – Interviewee 10, Project Manager, Project Management Consulting Firm*

Another point that emerged is that risk assessment carried out without the use of BIM appears to have led to a binary, "all or nothing", approach to assessing the WHS of construction methodologies:

> *"It is more of a binary assessment, I would say. If it looks like the construction methodology is simply not safe and cannot be accepted, then there would be a response back to the contractor to say, look, we do not think your proposal, your proposed methodology is safe, and so, therefore, you would probably say it is not conforming." – Interviewee 10, Project Manager, Project Management Consulting Firm*

Requirement briefing

Interviewee 10 noted the potential of BIM to be used as a communication tool for requirements briefing.

> *"You could also use [fly-through models] within the high-risk workshops which we hold, where we are working in and around, sort of, live services, again, just to create a model which can give you a bit of a time-lapse of the works being completed so that you can look at the risks in a virtual, sort of, setting." – Interviewee 10, Project Manager, Project Management Consulting Firm*

Such models, however, have limitations. Interviewee 10 recounted a near-miss excavation incident around unknown underground conduits near the medical gas facility. BIM would not have helped with mitigation of the incident on the basis that the location of the unknown gas lines was not mentioned in any available sources. The interviewee pointed out that the BIM model can only be a source of truth if valid project information is collected and maintained in a consistent way throughout the life of the facility.

> *"With the BIM model, to be honest, again it would not have helped [with the near-miss incident] because 'junk in and junk out', you know, you are feeding into that BIM model the survey information you have. If there is a hole in the survey information, then the BIM model is not going to help you." – Interviewee 10, Project Manager, Project Management Consulting Firm*

Apart from the near-miss excavation incident, the interviewee also mentioned two more incidents: an excavator running over an earthworks contractor's foot and the separation of a crane part that fell into the exclusion zone. The interviewee believed BIM would not have helped with the prevention of either of the incidents as they were attributable to operators departing from protocols.

Summary of first-order analysis thematic coding

Case Study 1 provided a useful suite of examples across all six knowledge domains and was a good example of the use of a BIM model integrated with WHS management systems and practices on the ground, even if it was not highly formalised. The integration was particularly beneficial in this case study, considering construction site management and the innovations initiated by the façade subcontractor.

Case Study 2 provided good examples for requirement briefing and education/training and presented a good example of Client Leadership in developing a strategic digital engineering common data environment and, in particular, the use of non-prescriptive expectations by the client.

Case Study 3 presented a unique format using the BIM model in design and design management but less so in terms of integration of WHS management systems in BIM. It appears that there is potential for this client to take leadership, with safety-in-design risk assessments in particular, in the future. There are also strong examples of WHS integration in BIM through scenario planning, risk assessment and requirement briefing. However, there is less strength in the case study of BIM being used for formal WHS education and training, WHS monitoring and Reporting and analysis.

Second-order analysis axial coding

This section presents the results of the analysis of the four recommendation areas identified in Phase 1 of the research: Client Leadership, Tendering Proficiency, Supply Chain Monitoring and Best Practice.

Client Leadership

Empirical findings from semi-structured interviews of project and client participants showed a total of 163 units of text that could be linked to Client Leadership. These units of text were categorised into eight themes, which in turn could be clustered into three theme groups. Client Leadership themes and theme groups are summarised in Table 9.

Table 9: Summary of themes and theme groups for Client Leadership.

Themes	Theme groups
Clear commitment to WHS management	*Clarity on WHS goals, processes and data*
Ability to translate WHS management processes into data requirements	
Ability to identify risks as potential opportunities to implement well-defined BIM solutions	*Clarity on BIM purposes, affordances and limitations*
Informed appreciation of the affordances and limitations of BIM for WHS management	
Understanding and optimising internal and external skillsets to support BIM for WHS management	*Strategies for compliance and collaboration towards adopting BIM for WHS management*

Intimate, meaningful and authentic involvement in BIM-supported design

Ability to drive supply chain participation across all project stages for holistic, BIM-supported WHS management

Use of formal and informal strategies to encourage BIM-supported WHS compliance

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Emerging themes from this section have been found to align with all six Knowledge Domains discussed in the section on Level-1 analysis.

Theme Group 1: Clarity on WHS goals, processes and data

The empirical data shows that Client Leadership is grounded in, and often begins with, a clear commitment to WHS management, coupled with the ability to translate WHS management processes into data requirements. Interviewee 5, an Environment Health and Safety Manager from the Private Client (Contractor), commented that, in general, government clients in NSW tend to be "really heavily involved" in WHS management. Initially, a client's commitment to WHS can be captured in a high level, broadly-framed vision. This vision can then cascade through the supply chain in the form of more detailed rules and standards. For example, the Government Client (Health) begins its projects by distributing an initial brief, which then is translated into more concrete standards and guidelines, especially as Local Health Districts get involved. Client leaders then articulate high-level visions and, more importantly, translate WHS management ideals into operational processes and procedures, which then coalesce into well-established systems and processes that cut across all projects.

For the Government Client (Transport), process definition is an important step carried out by working through detailed questions:

> *"How are you undertaking risk assessment? How are you assessing safety hazards? Which risk matrix are you using for that? Is it a five-by-five? Is it a six-by-six matrix?... Are you using any standardised processes for assessing safety and design? Or, how is a risk assessment done? What matrix do they use? What are the processes? Who are the parties? And then, so like, that's the starting point." – Interviewee 15, Director, Government Client (Transport)*

The Government Client (Transport) is another entity that has exceptionally high standards of safety. EHS managers from the Private Client who have worked on transport projects confirm this. One EHS manager noted that

> *"They have quite an extensive and elaborate requirement from a client perspective with regards to work, health and safety or EHS...in that standard, they're extremely specific in terms of what types of reporting, what types of requirements are needed to work on a project." – Interviewee 5, EHS Manager, Private Client (Contractor)*

An interesting observation is that that Government Client (Transport)'s current WHS management system is seen to be on par with, and in some ways even exceeding, the Private Client's own WHS management systems, which are already recognised as highly sophisticated and considered a leading standard in Australia.

For context: The Private Client (Developer) has a WHS management system that comprises several elements. A first key element is a standardised set of requirements for assessing and mitigating risk that is adhered to across its international operations. One group of minimum requirements, for example, involves the identification of 18 significant risks at the investment stage and which must be addressed before proceeding to the next design stage. The Private Client (Developer) also has an extensive library of supporting documents available on the company intranet that assists teams in addressing specific identified risks, for example, Workplace Delivery Codes or EHS Plans. Third, the Private Client (Developer) mandates the development of an EHS management plan for each project. Many aspects of the plan are similar across all projects, but a certain degree of customisation is usually needed because of variations in scope. The EHS management plan is supported by several sub-plans which depend on the project's risk profile. Case Study 1, for example, made use of a crane management sub-plan. Finally, the Private Client (Developer) also has other resources such as a handbook on alerts, developed by the Private Client to call attention to repetitive incidences and defects that could have WHS implications. Procedures are in place to ensure these "alerts" are not triggered, and as a control mechanism, deviations always require approval. Systematic, well-documented processes are in place for managing safety at the Private Client (Developer), yet its EHS managers still saw the Government Client (Transport) as comparable in terms of its WHS expectations.

As robust as WHS management systems such as these may be, they can still have limitations, and two are noted here. First, they do not guarantee that WHS is unproblematically sustained as a key priority during the project. WHS management goals are continuously negotiated and weighed relative to other goals, and can at times be compromised by other performance targets as a project progresses, most commonly cost and quality.

> *"Quality and safety do suffer depending on those expectations that are set to by the client. So, you always fight with the four [cost, time, quality and safety]. It's program dollars at first. Then it becomes safety when something does happen. I know it's not the right thing to say, but then safety becomes top of mind when something does happen and …then generally, come the end of the project, when some of the defects come through, quality starts to play a big role in it." - Interviewee 3, Construction Manager, Private Client (Contractor)*

The second point is that robust WHS management systems do not necessarily translate easily into digitised information systems and BIM. The Private Client (Developer) noted that as comprehensive as its WHS system is, much of it remains manual, onerous and heavily paper-based, even if opportunities for BIM have been increasingly capitalised upon over the last few years. An interviewee from the regulatory sector in the UK, who specialises in BIM for WHS

management, pointed out that a key challenge in moving from manual to BIM-driven systems is achieving a paradigm shift: from a mindset that foregrounds "WHS requirements" into a mindset that thinks in terms of "WHS information requirements":

> *"They might have some sort of general statement about structural safety, or steelwork, or the performance in a project, and you think, well, that's a really good requirement. But the problem with it is, it's not an information requirement… Where's the evidence, and in what place will I find the evidence, who do I have to go to, what state of the project will it come available? And most importantly, for the handover stage, who's going to create, who's the handover, who's going to make sure it's there. So, validation and verification of information at certain stages become very important. And this is an emerging area of definition." – Interviewee 9, Health and Safety Inspector, UK Work Health and Safety Regulatory Agency*

The need for this paradigm shift could explain, at least in part, why most of our interviewees reinforce that WHS and BIM have remained mostly separate areas. The Private Client (Developer), for example, is considered very mature in WHS management, but one subcontractor interviewee noted:

> *"I'm not really aware of any requirement or emphasis from the builders to use their modelling for WHS. They're totally aware and totally specific on what they want for both of those elements. But I've never seen a link between the two. …So very, very specific on both of those two elements, but they don't establish a link between them. As far as I'm aware, there's never been a necessity to use one or the other to benefit the other." – Interviewee 1, Project Manager, Façade Subcontractor*

A second theme under Client Leadership, therefore, is linked to the need to bridge this divide. This can only be done through a client's ability to translate WHS management processes into data requirements. Accurate, verified, and universally formatted data is central to achieving this. Furthermore, data creation and management functions are not to be treated as siloed, specialised technical areas. Instead, the view is that it is:

> *"…crucial for all employees to learn how to speak data. So, they need to have an appreciation of how to use data and how they can create data that others could reuse. And so, I see safety as one part of the overall value chain that reappears many times over through all the lifecycle stages." – Interviewee 15, Director, Government Client (Transport)*

This stance is evident by the Government Client (Transport), where teams are already building an "ecosystem" of data that supports scheduling, cost, value engineering and WHS management. Supporting WHS is seen to be a natural extension of this emerging data ecosystem.

> *"With safety, we would look at what are the activities which are used to manage safety right now. It might be safety in design, it might be risk assessment. So, risk assessment for planning, for design, for construction, for operations and maintenance. What is the safety risk for maintenance of whatever you're designing? What's the safety risk during construction of what you're designing?… Also defects management, any incidents that happen on site. At the moment, the way incidents are recorded, there's no structured data to do it. It's just one big run-sheet database. But if you can say there's a safety incident at this site on a map and you can see where there's clusters of these things happening, you can start*

grouping them together, you might have a trend that you can then assess." - Interviewee 15, Director, Government Client (Transport)

The Government Client (Transport)'s emphasis on data and the need for a "universal data schema" appears to be grounded in the assumption that a data-rich approach is ideal for making better decisions. Contractors who engage with the Government Client (Transport) have thus commented on the comprehensiveness, and the level of detail of the Government Client (Transport)'s tendering requirements. Having said that, the view that more data is better is not supported by all. A Digital Engineering Manager from the Private Client (Designer) commented that requesting large volumes of data could be an indication that the client does not know what it wants or what it will use the data for.

"So, what we see with governments now is that they ask for things, but they don't necessarily know why they're asking for them or how they're going to use that data." – Interviewee 2, Digital Engineering Manager, Private Client (Designer)

Theme Group 2: Clarity on the purpose, affordances and limitations of BIM

A move from "WHS requirements" to the more data-centred notion of "WHS information requirements" is a paradigm shift that sensitises supply chain participants to the value of using technological solutions such as BIM. An acknowledgement of the primacy of digital data thus paves the way for considering information technology solutions to manage this data. Starting from processes, then moving into "how could we make that better through automated data flows?" means that BIM now emerges as one potential solution to a problem. This is in contrast to a stance where BIM is brought in as an innovation without adequate consideration of process complexities and thus becomes what Interviewee 15 calls "a solution looking for a problem."

Client leaders who have done the work of understanding safety processes and risks must now exercise another competency: the ability to identify risks as potential opportunities to implement well-defined BIM solutions. Creative and novel examples of BIM for WHS management that were found across our three case studies will be described more extensively in other sections, notably in Best Practice. Specific examples noted here include the use of BIM to identify clash detection when multiple tower cranes are in use, managing overworks and underworks, or identifying exclusion zones. BIM has been used for communication, visualisation in 3D and for demonstrating work sequencing through simple resources like models in the form of "marked-up drawings with colour" or through more sophisticated techniques involving model fly-throughs. The capabilities of BIM are numerous, and one danger is to implement BIM solutions in hit-or-miss or suboptimal ways. A key element of Client Leadership is thus knowing where to start using BIM for WHS management. A project manager from a façade contractor, which made novel use of BIM to support not just complex designs but also site WHS, suggested that a viable starting point for BIM for WHS management should be work sequencing:

"I think the start of that process would be the methodological and sequencing side of it. If you get that right, you could feed all of that into a model where someone —

like you could take our sequencing and our modelling of the methodology and couple it with all the other trades, and identify where people are going to be working next to each other or over the top of each other, clashing with each other. That would — that's the obvious starting point because that's kind of currently where I think the limit is what people are using the technology for. That would probably be the first step. I'm sure that would open up the door for more benefits, other ways of doing things." – Interviewee 1, Project Manager, Façade Subcontractor

Interviewee 2, a Digital Engineering Manager from the Private Client (Designer), supports this view, suggesting that targeted 4D is a viable starting point for enabling WHS management. Client Leadership thus involves an informed approach to the benefits and limitations of BIM. Approaches are "informed" when they take into consideration how specific capabilities of BIM can be mobilised in the context of well-defined opportunities and problems, which in turn are understood from a rigorous assessment of risk and WHS processes. This considered approach of knowing where to use BIM on the next part of the journey allows client leaders to walk between the two extremes. One extreme being not mandating BIM at all and having people "use it to the bare minimum to get by and to make their life easier" (Interviewee 8). The second approach is going "all bells and whistles on data, for example, which I don't think was the right approach" (Interviewee 2).

The informed approach also considers other pragmatic factors, such as the skillsets of potential partners and specific tendering circumstances. The Government Client (Transport), for example, sets very clear standards and requirements on matters such as universal data schemas but does not mandate the same technologies across all projects. Thus, BIM models are not always required at tendering, sometimes for practical reasons:

"4D-modelling is not a requirement for non-complex or small projects because it can add to the cost of tendering…But we don't tend to ask for a BIM model or this type of stuff during tendering, because it costs tenderers a lot to do this, and there's no guarantee of work. But yeah, we're really conscious that we don't want to ask for too much." – Interviewee 15, Director, Government Client (Transport)

The question of where to use BIM in the next step of the journey presupposes that the more fundamental baseline decision to use BIM at all has been made. Sometimes this decision is made incrementally, with small experimental uses of BIM gradually gaining momentum over time. In other cases, a clear line in the sand is drawn at a point where a client decides to embrace new technology and implement it as a blanket requirement across all or many projects.

The experience of the Government Client (Health) provides some insight on the latter. The Government Client (Health) has not yet taken a hard line of mandating BIM across all projects, and BIM is not yet being mobilised to support WHS management. However, the Government Client (Health) does uphold a rather stringent requirement: the use of a certain database management tool, dRofus, across all projects valued over $100 million. Supply chain partners who do not have the capability to use dRofus would thus not be considered for project participation.

Making that decision was crucial to bringing the Government Client (Health) to where it is today, but there was considerable tension underlying this decision:

> *"But doing this in the beginning is difficult: It wasn't difficult from the point of view; the benefits are very obvious. I think the difficult part is living in today's world and imagining what it's going to be in 10 years' time and we struggle to do that, because 10 years is a long time in development in these areas. So, I think it was just convincing that if you invest now, the benefits are enormous. And it's the investment that is always the hardest. Getting people to see the value of it is so easy. We can demonstrate it to anybody. It's the investment side." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm*

Theme 3 Group: Strategies for compliance and collaboration towards adopting BIM for WHS management

A third theme group emerging from the empirical findings under Client Leadership is the need to ensure the views on BIM for WHS management are shared across the supply chain through a variety of collaboration and compliance strategies. To achieve meaningful collaboration and compliance, client leaders must consider their own skillsets and those of their partners, involve themselves meaningfully in design and ensure others' participation systematically.

To collaborate towards a more mature use of BIM for WHS management, client leaders must demonstrate the ability to understand and optimise internal and external skillsets to support BIM for WHS management. Clients must look at their own skillsets as well as those of their potential partners to understand the collective capabilities of the supply chain:

> *"That's the first thing you need to do. So, you need to come up with a list of understanding their level, because there's no point asking them for something if they're not capable of doing it, right? So, we do that do our subcontractors. We used to do that; we dropped the ball on a bit. And it's all assessing what it is. It's for anything from what software did they use to the skill level of their people on this particular software, have they done anything like before that in the past, an example of what they did, are they innovative, are they open to use technology, are they using technology other than just … modelling or whatever. So, you need to come up with questions. And I think if I was a government client, I would start building a database and understanding what it is that my contractors are – their capabilities." – Interviewee 2, Digital Engineering Manager, Private Client (Designer)*

Knowledge of the skillsets of potential partners can come from partners' reputations or from a history of working with trusted parties:

> *"…if we use a subcontractor, for example an electrical contractor, we know he's got the right processes and procedures in place because he's probably developed them throughout, with us, the last five or 10 jobs that we've gone through so we'll go with him because he's a known and he's got tried and true processes." – Interviewee 6, EHS Manager, Private Client (Contractor)*

In cases where partner skill quality might be subject to uncertainties, clear tendering requirements are defined to highlight what the client is looking for and to define a minimum level of competency:

"So, if we do get consultants that are not quite there, but at least we have a base that is a good base for us to go. What, typically, I would like to see is when the lead designer – particularly the architect, the lead coordinator coming on the job – I want them to develop a BIM management plan, which will be going to a lot more detail; think about it like that. In the (digital engineering execution plan), I'm asking them, that's what I want to do." – Manager, Private Client (Designer)

Skillsets that support BIM for WHS management are still difficult to find. If we build on previous arguments where Interviewees 1 and 2 claimed that sequencing and 4D-modelling are key starting points for BIM for WHS management, then it should be noted that a clear gap in skills still exists in this domain. Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), points out that 4D-modelling is a highly fragmented and specialised area:

"When I get a model from, say, a structural engineer, I'm going to get a model that shows me the floor plate – just one piece of slab that goes across the whole floor plate with crisscrossing of concrete beams and so on. It's not actually broken down to the pour joints. It's not broken down to the pour sequence. So, you need somebody that can come in, take that model, and start breaking it apart. And it's not going to be the structural engineer; it's going to be a specialist person. That person is able to manipulate the model and do the 4D." - Interviewee 2, Digital Engineering Manager, Private Client (Designer)

Interviewee 15, Director at the Government Client (Transport), also points out that the problem with skillsets is more systemic and requires large scale change across the sector:

"…there is an over-reliance on digital engineers. What I'd say is that so much of the focus and I think this is one of the reasons why BIM has failed in the past. It hasn't had that transformative effect, is because industry has been relying on sort of digital engineers or the people producing BIM models and stuff and what they call BIM managers, project-based." – Interviewee 15, Director, Government Client (Transport)

To address this, Interviewee 15 proposes the need for more widespread structural reform to support digital engineering through new layers of positions across the industry. These four layers are:

- Digital engineers, who coordinate and exchange digital project deliverables
- Digital engineer managers who are "project focussed and they're champions to manage and assure digital engineering deliverables."
- Digital engineering developers, who are business focussed, bring technical expertise and focus on framework development, change management, new data schemas and frameworks and business integration
- Digital engineering advisor, who focusses on strategic planning, executive engagement, development of the vision, policy, roadmap, business case and funding strategy to enable the other three roles

Client leaders acknowledge that not all competencies and skills have to be internalised within their own firms. Clients have been known, for example, to rely heavily on the main contractor's

knowledge and reputation in assessing the safety of construction methodologies. A Project Manager and a Senior Practice Director from an Architectural Consulting Firm, who were part of Case Study 3, noted that the client chose a Tier 1 contractor who could be "the expert [on construction methodology safety] out of everyone in that room."

Client leaders have also turned to specialised contractors for BIM expertise. In Case Study 1, the Private Client (Developer) approached the façade contractor very early in the project for its competencies in this area:

> *"[Private Client] came to us on the day that they received the documentation from the architect, which was about five or six years ago now. Once [Concept Architect] won the competition to design the building, or was chosen to, they received this building that was just concrete slabs with timber shown wrapped around it. But there was very little technical development on it. So, they came to us and requested our assistance with pricing the project for them, and also to develop the design for them. So, we worked with them for three or four years before we really got on to the job and started building. Just helping with the design development so that it could be priced. "– Interviewee 1, Project Manager, Façade Subcontractor*

The interviewee's noting "we worked with them for three or four years" points to yet another critical theme under Client Leadership: intimate, meaningful, and authentic involvement in BIM-supported design._The design stage, whether supported by BIM or not, presents considerable opportunities to anticipate and prevent WHS management issues. An interviewee from the state of Victoria, for example, stated that the use of digital tools for WHS management is nascent, but also that problems can be prevented or detected early when design is done properly:

> *And I would say the digital tools in projects are at a pretty early stage and there's huge room for improvement, especially with work, health, safety, but I would say that would be carried on the back of better design. – Interviewee 14, Director, Government Client (Treasury and Finance)*

In Case Study 1, the close relationship between the client and the façade contractor yielded a number of benefits. One was that the contractor, in the process of developing technical details based on concept design, was able to embed BIM-supported descriptions of their methodologies into their safe work method statements, which had very positive implications for WHS on the construction site:

> *"... we were all able to visualise what we were dealing with early, and challenge the thinking on it. So, there was some things – yes, there were some improved results by having the information in a way that I could challenge it, and we had better results, definitely. Like even, we used less boom lifts for some of the external works, and I even said, 'Where are we going to put the boom lifts; will they fit? Are they going to reach the façade with the ground plan?' They were able to zoom, and we were able to analyse that challenge." – Interviewee 7, Environment Health and Safety Manager, Private Client (Developer)*

Intimate involvement can be achieved through direct interaction between clients and designers, or it may be mediated through the mobilisation of strict standards by the client. There was no evidence from the interviews that representatives from the Government Client (Health) were

intimately involved in meetings with their designers as Private Client (Developer) was with their façade subcontractors. In fact, one interviewee pointed out that Local Health Districts were more involved than the Government Client (Health). However, the Government Client (Health) found a way to remain meaningfully involved in a different way: by influencing design through its mandated use of dRofus. The client has been using dRofus for many years and now has a growing library of Furniture, Fixture and Equipment (FFE) elements with clearly defined specifications that supply chain partners are provided with through templates and are expected to comply with. The tool could thus be seen as imposing WHS standards during design, acting "on behalf" of the client:

> *"So from a WH&S perspective people ask me for stuff that's dangerous and I refuse to make it, if you ask me for a cupboard that's 2100 high with a shelf on top, I say no, you're not having it. So, you can actually control the design through the item library because if it doesn't exist in the database then it doesn't exist." – Interviewee 12, Senior BIM Software Specialist, Architectural Consulting Firm*

For client leaders, the close interaction between clients and designers also extend to other relationships throughout the supply chain. Client leaders enable dense, richly connected networks of relationships, thus demonstrating the ability to drive supply chain participation across all project stages for holistic, BIM-supported WHS management. Clients push for systematic, intentional opportunities for multi-stakeholder engagement to take place across the supply chain throughout the project life cycle, a complex task because:

> *"…there's a whole heap of stakeholders we need to begin collaborating with, and I was one of them. I guess, there's a finance manager, a designer, a place maker, project manager, construction. There's all these stakeholders, the client, the council, et cetera." – Interviewee 7, Environment Health and Safety Manager, Private Client (Developer)*

Meetings, discussions, early stakeholder workshops and design reviews are just some opportunities for multi-stakeholder exchange of data. Early contractor involvement is seen to be a critical ingredient:

> *"And one key thing I'll point out is — and this is a good lesson to learn, and something I'm a big advocate and supporter of, is involving trade contractors, sub-contractors very early in the project. Because if you involve them early then they can help resolve issues with you as you go through. Because, ultimately, they're the one that will — they're the ones that will be building that part of the building." – Interviewee 8, Architecture and Urban Design Manager, Private Client (Designer)*

Empirical data suggests that there are still a number of challenges to multi-stakeholder participation towards improved BIM for WHS management. First, not all stakeholders will hold similar levels of commitment to using BIM for WHS management. In Case Study 1, for example, the concept architect remained engaged in participatory processes but did so mainly to ensure that their design was maintained. This leads to a second point: priorities in these forums can become diverse and potentially difficult to manage. Even the priorities of the client may not be clear cut because, at times, a complex project hierarchy obscures who the real client is:

"Sometimes, you wonder who your true client is and we have to draw back sometimes and look at the contract and say, 'No, it's actually [Builder]'. And different construction companies have different methodologies of engaging and managing that interaction. [The Private Client (Contractor)] are very professional and take their responsibility very seriously. So, they – theoretically, everything we do goes through [The Private Client (Contractor)]. So, the contractual relationship is always held with [The Government Client (Health)]. So just to go from the top, [Government Client (Health)] is the ultimate client. They employ a project manager and that project manager manages the … construction manager relationship. It gets quite complex and you can imagine there are hundreds of people involved when you start to expand with these companies. So, managing that stakeholder engagement and understanding contractually who you are taking direction from is always something that gets blurred and you have to come back and clarify." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm

While there is a large range of coordinative interactions that could be productive for WHS management in supply chains, one type of collaborative interaction has emerged as essential: early discussions involving the client, an information manager and a WHS professional:

"…the client can sit down, and then we think there's a triangle, there's the client himself and his advisors representing his interests, there's the information manager representing information interests through the project, and then there's the health and safety person who will be looking at risk through the project. And if you can get those three people together early, then you can start really fashioning these project information requirements, in a good way, and they're in place then, even before anybody's thought about tendering. So, before anybody's gone to the procurement department, they've got some high-level project information requirements which will steer." – Interviewee 9, Health and Safety Inspector, UK Work Health and Safety Regulatory Agency

Such systematic interactions do not emerge in a vacuum. A key finding of this research is that client leaders must encourage and facilitate these interactions in intentional ways.

Overall, an integrated supply chain achieves coordinated performance towards improved BIM-supported WHS management through a combination of formal and informal strategies. Formal requirements include tendering requirements (discussed in the section Tendering Proficiency), contractual requirements and legal requirements and guidelines. At times these layers of requirements are all mobilised simultaneously; in other cases, one type is selected. In interviews with participants on Case Study 3, for example, one commented that the Government Client (Health) did not specify its own set of contractual WHS requirements. However, supply chain partners were aware they were operating under legally mandated WHS requirements as well as national guidelines:

"From off the top of my head I don't remember seeing anything specifically about WHS in terms of design guidance notes or the [Government Client (Health)] knowledge library, but a lot of this is it's somewhat, I don't know, not a no brainer, but it's a bit of a given of designing safely. And from a design perspective, to design something that's unsafe and presents a hazard for someone is essentially a criminal offence in this country, you can't be private indemnified out of it, if someone slips over on the floor that I've designed not with enough slip resistance, and that person dies, I can go to jail for that, no PI is going to save me, not

anymore, maybe 20 years ago I'd be fine, but not anymore. So safety-in-design is as much in the forefront of architecture and design that often we don't necessarily we go looking for it or have to have it flagged or shoved in our face because we're very acutely aware of it." – Interviewee 12, Senior BIM Software Specialist, Architectural Consulting Firm

"Well, [Government Client (Health)] essentially, in a way, they default to the Australasian Health Facility Guideline for that kind of OH&S, is dealt with more within the Facility Guideline, the AHFG as it's known, which is a separate website. [Government Client (Health)] are very involved with the management of that site, but that AusHFG is a tool all throughout Australia and New Zealand and other parts of the world. So certainly, there's highlights within that around workplace health and safety." Interviewee 12, Senior BIM Software Specialist, Architectural Consulting Firm

As powerful as formal requirements can be, the empirical data suggests that coordinated performance for BIM for WHS management can also be achieved, or at least encouraged, through informal strategies. An interviewee from Case Study 1 noted that the client did not specify a "requirement of us to do BIM and safety" as part of tender requirements, yet the client found ways to make this "implied in the contract":

"In terms of the actual detailed scope [did we require BIM for WHS management at tendering?) … probably not, but what we did imply through the tender documents was that we wanted them to design in 3D, and we wanted them to present their methodology back to us in 3D. Now, because we required that from them at the tender time, part of the swings was for them to show us, you know, sort of make us satisfied that they have understood the building and the nature of the building and they've understood the task at hand for when they go to install it. The other thing too is obviously with safety statements and safety plans, if they can present to us a plan that we understand, then obviously their workers or their sub subcontractors can understand it straight away from the pictures they use." – Interviewee 3, Construction Manager, Private Client (Contractor)

Clients can also signal their preferences through their practices. For example, in the same situation involving Private Client (Developer) not requiring BIM for WHS management at tendering, the procurement team nevertheless conducted tender interviews in ways that foregrounded the centrality of BIM:

"…so, at the tender interviews with the contractors, even from the beginning the model was always the centre of our tender interview. So, all of our rooms was we had a desk, we had a lot of paperwork on the desk and we also had a big screen and we'd walk through the model. We'd show them roughly, 'look guys, our model was linked to our construction program as well'. We'd say 'guys, this is how we are going to build the model, this is how we're going to build the building' and they could look at it and go, 'oh, yeah, actually I didn't realise it was round'." - Interviewee 3, Construction Manager, Private Client (Contractor)

More broadly, the larger industry culture itself is changing and appears to be imposing new norms. One EHS manager from Private Client (Developer) noted that more and more contractors are becoming "savvy" and initiating the use of BIM on their own when they submit tenders, even when it is not required:

"...some of our leading subcontractors BIM model everything and use it as a presentation on how they're going to execute our work... so some of our savvy contractors by default will BIM model it and show us exactly how they're going to execute this job... I'll reiterate that a smart subcontractor will develop a model for a tender to articulate how he's going to install X, Y and Z." – Interviewee 7, Environment Health and Safety Manager, Private Client (Developer)

This trend could be fuelled in part by the nature of competition within the sector, but it could also be driven by technical developments. Trends in computer modelling raise opportunities for better integration of WHS management and BIM.

"BIM and ...computer modelling has developed over the last 10 or 15 years, there have been attempts at structuring the expectations... So, there's the LOD structure now, which you'll probably be familiar with, which is a Level Of Development of a model and documentation that comes from it... At least it's a recent uptake in the industry to help everyone understand what the level of required documentation is. So perhaps there's an opportunity to take that type of system and apply it to the integration of those two elements, being the BIM modelling and the WHS side of it." – Interviewee 1, Project Manager, Façade Subcontractor

The final point is that such widescale industry changes do not have to be driven in a top-down manner. They could be driven from bottom-up, by interactions and conversations between key people that begin to percolate as broad trends across the sector:

"I find it's conversations. I think – and also, we find that we come up against people who are involved over several projects. Within the building industry, you'll find people move. So, they might move from a contractor to Private Client (Developer) or they might even move from The Architectural Consulting firm to someone else who'd be working on it. It's the people that make the difference. It's their experiences that will convince others to do the same. So, we find it's experience and not just experience within one organisation, it's that bringing in new views from other projects. We've had representatives from other, for instance, from other health organisations. So other hospitals, come and have a talk. Let's talk about this to, let's just say [hospital location], let's bring them into an executive meeting, give them an hour or half an hour to talk about the things that they learnt most in the process that they've been through and you'd be surprised. Everybody's eyes are glued to the presenter, just realising what the implications and the benefits of other people's experience." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm

Discussion and Implications for the Decision Framework

The three theme groups and the eight themes under Client Leadership point to three specific directions for the emerging Decision Framework.

The theme groups suggest there are four important parts to achieving Client Leadership that enable a client to drive a mature and integrated supply chain that prioritises BIM for WHS management. These parts are 1) commitment to the centrality of integrated high-quality data to the organisations' asset management and capital works procurement strategies, 2) robust WHS management processes, 3) explicit use of technology, and 4) the development of formal and informal strategies to achieve collaboration and compliance across the supply chain. These four ingredients should thus inform the development of tools that will become part of the Decision

Framework. For example, if clients wish to assess how mature they are in terms of their capacity for BIM for WHS management, then any assessment tool, including the one proposed under Component 1a of the Decision Framework, must consider these four areas. If work is to be done, for example, to further develop or customise the BIM Maturity Matrix (Marshall 2018), then one possible direction is to ensure that two to three plain-language questions are framed for each of these parts.

The four parts taken together can point to a process in the form of a coherent roadmap to achieving Client Leadership, although care must be taken even at this stage to point out that there may be more than a single viable option. Interviewee 15, who played a key role in leading the Government Client (Transport) on its journey towards digital engineering, suggests that this pathway begins with the ingredient "robust WHS processes":

> *"So, we deeply understand the way project scheduling is done and what's the breakdown that they use for their work breakdown structure? Or how is a risk assessment done? What matrix do they use? What are the processes? Who are the parties? And then, so like, that's the starting point. We go okay, what you're doing is a good job, we want to try and make that better by going digital." – Interviewee 15, Director, Government Client (Transport)*

Understanding WHS processes precedes "going digital", which in this case means understanding data needs. Understanding data needs, in turn, precedes the selection of technology:

> *"...data must be central to everything. So with technology, before you go out and procure new technology or start applying technology to your business processes, you need to think about your data needs and you need to design your data structures first and then, only then, do you start looking at the technology to support your data workflows and stuff." - Interviewee 15, Director, Government Client (Transport)*

For Interviewee 15, then, the pathway progressively moves from WHS management processes to data, technology, and then presumably to collaboration and compliance, although the interview did not surface this fourth ingredient.

The pathway appears sensible; nonetheless, data from Phase 1 of this research suggests at least one alternative. A previous interviewee from Phase 1 commented that "we don't specify directly... for work health and safety as a requirement" but also that "we've got this information now, we are identifying work health and safety issues without specifying that that's how it was going to be used in the first place". This would indicate that a firm could also begin the BIM for WHS management journey by starting with rich, integrated data, which can then be managed through technology to create opportunities to improve WHS processes. This stance also reinforces findings from Interviewee 1, who described how WHS was not required by Private Client (Developer) in their project. The Façade Subcontractor used BIM to plan construction methodologies, but these methodologies still had WHS management implications: they found their way into their safe work method statements. This particular pathway, then, was different in

that it began with data, then moved to technology, followed by safety and finally, collaborative work. The two pathways were different, and while further empirical work is needed, both appear to be valid.

Having acknowledged that different starting points could be viable, this research nevertheless builds on Interviewee 15's stance that "data is central." Data, information, and information requirements appear to be powerful starting points and must be focal in the Decision Framework. One key reason is that recent developments in the infrastructure data management space compel this. The centrality of data will be discussed in later sections, in the context of the withdrawal of the PAS 1992 series, its replacement with the ISO 19650 series, and the recently-released IDMF in NSW are all strong signals that information requirements will become a key focus in the years to come. Subsequent sections will also highlight concepts such as OIR, AIR, PIR, EIR, Project Information Models (PIM) and Asset Information Models (AIM), which scaffold the new guidelines.

Tendering proficiency

A total of 159 units of text were linked to Tendering Proficiency and categorised into eight themes. The themes clustered into three theme groups: Pre-tendering, Tender evaluation, and Post-tendering. The themes and Theme groups are summarised in Table 10.

Table 10: Summary of themes and theme groups for Tendering Proficiency.

Themes	Theme groups
Defining the outcomes, priorities, and requirements.	*Pre-tendering*
Consulting early, broadly, and on an ongoing basis to identify risks and opportunities.	
Achieving a project-appropriate balance between general and specific requirements	
Using explicit and implicit means of communicating expectations and requirements	
Considering contractor capability across the supply chain	
Diversifying the evaluation panel and evaluation criteria	*Tender evaluation*
Utilising best-practice BIM to identify risks and issues at tender	
Ensuring compliance with requirements after tender	*Post-tendering*

The emerging eight themes from this section have been found to align with all six Knowledge Domains identified as priorities in this research.

Theme Group 1: Pre-tendering

The first step of Tendering Proficiency is for the client to clearly define the desired outcomes, priorities and requirements. As outlined earlier in Client Leadership, it is relatively simple to develop project and tender requirements if clients already have well-established systems and processes, a high-level and broadly-framed vision, and detailed supporting documents at hand.

As Interviewee 9, Health and Safety Inspector at a UK Work Health and Safety Regulatory Agency stated: "the OIR and the AIR flow into the PIR and then the EIR". Tenderers are then asked to respond to how they will comply with the PIR and EIR.

A leading client is also aware of its priorities and clear about the weighting of WHS management goals compared to other considerations, such as cost and quality. A similar decision exists between the benefits of BIM and the resources required for its development. A client can also easily draft broad WHS project requirements. However, as Interviewee 9 stated, WHS *information* requirements are commonly neglected, possibly because WHS and BIM remain separated areas. The client must therefore make an intentional baseline decision whether to embrace BIM and BIM for WHS management, specifically. A proficient client interested in requiring BIM for WHS management is one that can translate general requirements into WHS information requirements.

Interviewee 9 considered the biggest mistakes a client could make to be "leaping into the tendering process before they have properly thought through the project requirements" and delegating the task to contractors when clients do not "have the head room, the advisors, or the capability to work out in advance what the requirements should be". While delegation is a justified approach, it requires strong Client Leadership to ensure control remains with the client. Interviewee 9 shared a story where the lack of client control led to a bargaining process and the client ultimately not getting what they wanted:

> *"...when you analysed it back, it was probably quite clear that, although he [the client] thought he'd required something at the head of the project, by the time it had been through the bargaining process, which is the EIR and BEP, because that's what happens, is the contractor takes the – traditionally - the contractor takes the EIR, looks at it and says 'well, I'm good at this, this and this, and I can add a bit of that, and the client will love that, but actually, these bits I don't know what he's talking about, so I'm going to stay quiet on those' and so it becomes a bargaining process, and whether the client actually gets what the client thinks he's getting is a little bit hit and miss." -Interviewee 9, Health and Safety Inspector, UK Health and Safety Regulatory Agency*

Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), shared similar experiences where clients had been unsure of what they wanted to do or, for other reasons, lacked information requirements. The Private Client (Designer) then filled the gap by using its own information requirement templates. In other instances, Interviewee 2 shared that clients had required large volumes of data or demanded compliance with specific standards but without justifying the purpose or understanding the implications of those requirements. Moreover, different BIM maturity levels will be appropriate for different stages of the project, with different tools serving different purposes and mitigating different risks. For example, in some cases, for example, a database may be more informative than a 3D model. It is therefore not productive to apply a one-size-fits-all approach. As highlighted in Client Leadership, a client must be clear about its WHS management goals, processes and data requirements, understand the nature of the

project at hand, and develop a nuanced appreciation of the purposes, affordances and limitations of BIM.

An impactful way to support client control and supply chain understanding of expectations is by consulting early, broadly, and on an ongoing basis to identify risks and opportunities. A proficient client brings together a multidisciplinary team of advisors to support the drafting of requirements. Depending on the nature of the project, the level of risk and the complexity, the team may include expertise in information management, construction, operations, and WHS management, among others. However, broad and early engagement can be resource-intensive and challenging. Interviewee 9, Health and Safety Inspector at a UK Work Health and Safety Regulatory Agency, complained that despite advisor consultation, WHS requirements have historically not been well-served in the procurement and tendering process.

> *"...the one who shouts the loudest gets heard, and often that's the cost consultant and people who have decisions to make about money. It's rarely the Health and Safety Consultant who actually gets his voice heard at the top table." – Interviewee 9, Health and Safety Inspector, UK Work Health and Safety Regulatory Agency*

As mentioned in Client Leadership, intimate, meaningful and authentic engagement between clients, their advisors and the supply chain may yield a number of benefits that lend themselves not only to the crafting of the project and tendering requirements but also to the broader project goals and objectives.

A key decision that influences the ability to engage and maintain supply chain relationships is the procurement model. Interviewee 13, Senior Practice Director at the Architectural Consulting Firm, highlighted that the phased approach, where design and construction phases are separated and contractors retendered, makes it difficult for design contractors to discern the holistic plan for the project. Continuity is important and allows experts to be brought on board early to share their expertise and lessons learnt with the design team. Interviewee 1, Project Manager at the Façade Subcontractor, spoke positively about the confidence they felt from having been involved from the start in Case Study 1 and not just "brought in at the end" and "having to build what they've [the design team] ended up with". Using a "Design-and-Construct" procurement model provided an opportunity to address WHS issues at the design stage. Interviewee 5, EHS Manager at the Private Client (Contractor), stressed that their employer required additional risk assessments and mitigation strategies if tendering for a "Construct-Only" project. Consequently, Interviewee 5's organisation mainly tenders for design-and-construct projects.

A third procurement model mentioned by the interviewees of Case Study 3 was ECI. Interviewee 13, Senior Practice Director at the Architectural Consulting Firm, shared that the Government Client (Health) used this procurement model along with a Guaranteed Maximum Price to leverage the expertise and history they shared with Private Client (Developer) to develop the early stages of their project. Interviewee 10, Project Manager at the Project Management Consulting Firm in

Case Study 3, elaborated on how they used a "value for money test" to appoint Private Client (Developer) on behalf of the client, along with a scenario to run a traditional competitive process for the main works contract had the value test failed.

Relationships among stakeholders can also be managed using project requirements, for example, binding design consultants to supporting construction contractors with the development and use of 3D models or through systematic scheduling of events, such as review meetings for parties to get together and discuss the project. An example provided by Interviewee 14, the Government Client (Treasury and Finance), was to require supply chain partners to provide relevant BIM files along with their analyses on how the asset would be used, accessed and installed. The requirement necessitates ongoing interaction between the supply chain partner and the quality control officer. Early and ongoing involvement allow stakeholders the opportunity to be heard and may thus assist the project to evolve as priorities and objectives shift, and risks and opportunities are identified and considered pre-tender.

Once identified, requirements must be crafted into formal tender and project requirements, which can range from highly prescriptive instructions to high-level or principles-based objectives. An example of a general vs. specific tender requirement to use BIM for WHS management was provided by Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), comparing "show me how you utilise the model for health and safety" with "I want you to use the model for site briefing".

General requirements give contractors space to innovate and problem solve, whereas detailed requirements highlight the need to work in certain ways. As mentioned earlier in Client Leadership, leading clients with well-established systems and processes, clear vision, and detailed supporting documentation might be tempted to require contractors to comply with their established processes and standards and to use their templates. For example, the Government Client (Health) holds the safety of the final building to a very high standard. The standard is not only for the WHS of the working occupants but also for the patients in their care. As mentioned earlier, Government Client (Health) has thus developed a very detailed digital database library and standards that are inherited by their contractors. The library includes pre-approved room structures and fittings and enables realistic costing even during early schematic design. In Case Study 3, detailed information such as partitions, windows and furniture were therefore expected to be part of the model submitted at tender. At times this is welcomed by the contractors, such as by Interviewee 10, Project Manager at Project Management Consulting Firm, who spoke positively about the sophisticated system:

> *[The Government Client (Health)] is probably one of the most sophisticated government clients I've ever worked for in terms of having developed processes and having really clear limits of authority and providing guidance notes to all the different consultants that work for them. – Interviewee 10, Project Manager, Project Management Consulting Firm*

In contrast, Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), questioned the value of providing detailed costings to a client on a commercial project, comparing it to the norms of buying a car. You do not ask for an itemised cost - the wheels, brakes or upholstery; instead, you negotiate on the overall price.

Requiring compliance with the client's systems and processes can also cause a lot of extra work, particularly if requirements do not match the systems and processes of the contractor. The Government Client (Transport) has been described by Interviewee 6, an EHS Manager at the Private Client (Contractor), as having "a 110-page document and in that document it identified the key risks or activities, and it prescribes what we need to do". Interviewee 5, another EHS Manager at the Private Client (Contractor), elaborated and described how they had to embark on a mapping exercise to identify how their EHS system matched that of the client.

> *"What we ended up having to do is to ensure that we complied with the requirements of the [client's standard], we pretty much had to do a bit of a mapping exercise at the back of our [WHS plan] … So, there was a very big mapping exercise to show that we're not just, not doing it, we are doing it, but we're doing it very differently and this is how it's mapped out." – Interviewee 5, EHS Manager, Private Client (Contractor)*

Confident contractors may take a different approach and refuse the client's templates if they deem them unsuitable for the project. Reasons may include requirements where elements appear to have minimal impact or will be difficult to achieve or where the elements do not make sense because the client does not appear to know what they are asking for. An alternative approach is thus to draft their own brief to justify what and how they will do things differently:

> *"…we actually go through what they [the client] ask us with a fine-tooth comb and then rewrite a reverse one [brief] that says, 'oh, that thing you asked for, we're not doing that', or 'this thing you've asked for, we're achieving that like this instead of the way you stipulated', so it's like a return brief where we're departing from what they've asked for". - Interviewee 12, Senior BIM Software Specialist, Architectural Consulting Firm*

Interviewee 12, Senior BIM Software Specialist at the Architectural Consulting Firm, shared the experience of working with a client at the other end of the spectrum. It was the first time Interviewee 12 worked with the Government Client (Health), and the client had not yet developed a management plan for dRofus. Interviewee 12's employer, therefore, had to draft one themselves.

> *"'whoa, this is so big, you're not telling us how to do it, so we're going to tell you how we'll do it'. And from that they I think realised, 'oh, we actually' – they knew they needed their own dRofus management plan". – Interviewee 12, Senior BIM Software Specialist, Architectural Consulting Firm*

The example demonstrates that lack of requirements can foster contractor innovation to the benefit of the client, and Interviewee 12 explained that the resulting dRofus management plan was later adopted by the client as an organisational requirement across projects.

While beneficial, as mentioned earlier in this section, giving contractors freedom through general requirements can also increase the risk of decisions being made not for the benefit of the client but for the contractor. For example, Interviewee 8, an Architecture and Urban Design Manager at the Private Client (Designer) reflected on the actual use of BIM if not mandated.

> *"I guess the — if it's not mandated and if it's not said 'you shall do this model to this level of detail and blah, blah, blah', then they'll just use it to the bare minimum to get by and to make their life easier." - Interviewee 8, Architecture and Urban Design Manager, Private Client (Designer).*

Other interviewees, such as Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), also argued that "We cannot expose them [the government client] to anything but the contract program. That's what we sign up for", underscoring the importance of noting requirements explicitly at tender and in the contract if they are essential to the project.

General requirements also make it more difficult to compare tenders. For example, some may include the cost of BIM in their price, while others may not. Interviewee 1, a Project Manager at the Façade Subcontractor, emphasised that detailed planning and modelling provides enhanced certainty for their firm. However, with increased certainty comes increased costs, and they may lose projects when other firms provide cheaper tenders by "just winging their way through it". Interviewee 1 said, "it's difficult for us sometimes, where the cost of doing this could be factored in for one company and not another". Providing structured guidance on required effort was seen as a way to help level the playing field.

The solution to requirement specificity thus likely lies in achieving a project-appropriate balance between general and specific requirements. The interviewees provided evidence of this among the three case study clients. For example, as mentioned in Client Leadership, the Government Client (Transport) set very clear standards on universal data schemas and but does not mandate specific technologies across all projects. According to Interviewee 5, EHS Manager at the Private Client (Contractor), the same client also has quite extensive and elaborate requirements with regards to WHS and that "they're extremely specific in terms of what types of reporting, what types of requirements are needed to work on a project". Interviewee 5 then contrasted the Government Client (Transport) with the Government Client (Health), with the latter:

> *"just really want[ing] to know what types of systems we had and then monitoring how we are implementing our own… it's more about them monitoring and vetting that we are doing our processes". - Interviewee 5, EHS Manager, Private Client (Contractor)*

Related to requirement specificity is whether or not the requirements need to be mandated. While most requirements are and should be spelled out in tendering criteria and contract terms or as part of supporting documents, expectations can also be made implicitly. Where objectives are aspirational rather than essential, implicit requirements can encourage uptake without eliminating those potentially unable to meet the requirements. Tendering Proficiency is also about striking a

balance between explicit and implicit means of communicating expectations and requirements. For example, Interviewee 1, a Project Manager at the Façade Subcontractor, warned that if the use of BIM or other digital systems is mandated, the decision will exclude supply chain partners lacking the relevant capabilities. Moreover, BIM model development can be time-consuming and a significant investment from the perspective of a contractor who may not win the contract. Interviewee 10, a Project Manager at the Project Management Consulting Firm working on behalf of the Government Client (Health), reasoned that BIM is rarely required at tender due to the government's commitment to keeping tendering costs low.

> *"I would say not because one of the, sort of, obligations of New South Wales Government is obviously to keep tender costs down. So, we typically would not ask for a contractor to submit a, sort of, building model with their proposal, and in fact it's very rare that they will even do any design work with their submission." - Interviewee 10, Project Manager at Project Management Consulting Firm*

Interviewee 15, a Director at the Government Client (Transport), confirmed the commitment and said that they "don't tend to ask for BIM models during tendering, because we're not paying them to do the work" and that they are conscious of not placing a financial burden on industry. "If they can't tender because we're making it too expensive, then there's a problem". Consequently, there have been times when tenderers have been paid to put in a submission if the government had a complex project that required modelling. In many instances, the tender requirements are high-level with details to be worked out among stakeholders at a later stage, and thus the details required to build a model at tender may not yet be available. Interviewee 4, a Senior Project Engineer at the Private Client (Contractor), provided a different perspective and proposed the requirement of BIM to be based on project value. This is the approach of countries like the UK, and Interviewee 12, Senior BIM Software Specialist at the Architectural Consulting Firm, shared that the Government Client (Health) uses this approach by requiring the use of dRofus as a matter of policy on projects valued over $100 million. Budget and time constraints are therefore important considerations if digital modelling is a priority to the client.

In Case Study 1, the use of BIM was not formally required at tender. However, as discussed in Client Leadership, its use was implied through the tender documents and foregrounded by the centrality of BIM throughout the tender process. Interviewee 3 described how they used a TV screen to display a 4D-BIM of the construction program and used it as a communication tool during tender interviews.

Also, as mentioned earlier in Client Leadership, the industry is evolving, and there is a culture shift occurring where BIM is increasingly becoming the new norm. While not explicitly required, "savvy" contractors who use BIM on a daily basis often initiate the use of BIM on their own, using it "as a sales pitch and to demonstrate how professional they are and how they are going to execute the job" (Interviewee 6). Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), was of the same mind, highlighting that one of the purposes of 4D-modelling is "Hollywood". That

is, sequencing the work and adding animations to generate an impressive demonstration of the high-level methodology to stakeholders and clients. At other times, the use of BIM may be due to necessity. Interviewees 3, a Construction Manager at the Private Client (Developer), reflected that the use of BIM mainly arose as a technological solution to the need to understand the complexity of the building.

> *"…this originated based on how we are going to put it together and it's us wanting an understanding to make sure that everyone who comes to our site understood the same thing from both program methodology and a safety point of view, how are you going to install it." – Interviewee 3, Construction Manager, Private Client (Contractor)*

In addition to understanding the nature of the project, Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), also stressed the importance of clients understanding contractor capability across the supply chain pre-tender, emphasising that "there's no point asking them for something if they're not capable of doing it". This was also mentioned by Interviewee 8.

For some contractors, using digital models is a daily exercise, whereas, for others, it is only done if it is in their interest to do so or if they need to do so, e.g. due to project complexity. The decision on whether or not to mandate BIM at tender and for the project must be an informed one. As described in Client Leadership, an informed approach considers the benefits and costs of BIM, contractor capabilities, and how BIM can best improve specific processes of the project. Interviewee 15, Director at the Government Client (Transport), emphasised that 4D-modelling is not required for non-complex projects, but where tender requirements include the project schedule, it may give some tenderers an edge.

Theme Group 2: Tender evaluation

Tender evaluation involves assembling an evaluation panel and assessing the merits of the proposal, tenderer competency, along with weaknesses and risks in line with the client's priorities and requirements. The evaluation is often guided by an evaluation spreadsheet that quantifies the contractor's understanding of what the client wants to do, their ability to bring it to fruition, and ability to comply with requirements, including standards, regulations and codes. Examples of non-price-related tendering questions mentioned by the interviewees generally covered the following topics:

- Design methodologies (if a Design-and-Construct contract)
- Use of technology
- Level of innovation
- Change management processes
- Management supervision processes
- Quality assurance processes

- Worker capabilities
- WHS capabilities

Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), suggested asking:

> *"...anything from what software did they use to the skill level of their people on this particular software. Have they done anything like before that in the past, an example of what they did. Are they innovative? Are they open to use technology? Are they using technology other than just BIM modelling?" - Interviewee 2, Digital Engineering Manager, Private Client (Designer)*

Interviewee 13, a Senior Practice Director at the Architectural Consulting Firm, highlighted the importance of selecting the right team with the right attitude, the right culture, and one that will "play a strong part in the tender process", while Interviewee 6, EHS Manager at the Private Client (Contractor), highlighted the weight of past performance and experience.

> *"...obviously the dollar [cost], their performance and past experiences, again, is probably what's relied on a lot. If we use a subcontractor, for example an electrical contractor, we know he's got the right processes and procedures in place because he's probably developed them throughout, with us, the last five or 10 jobs that we've gone through so we'll go with him because he's known and he's got tried and true processes... we're not scoring them from an EHS perspective, it's more about capabilities, previous experience with that contractor and discussions about their capabilities, what they've done previously, their supervision ratios, and experience with their teams." - Interviewee 6, EHS Manager, Private Client (Contractor)*

Another EHS Manager at the Private Client (Contractor), Interviewee 5, commented that "We really don't get involved in that tender stage, that is completely managed by our package managers, which are our engineers".

When the Private Client (Developer) tenders for its own projects or for subcontractors as a Developer, several interviewees described the use of a tender interview process. In terms of assessing WHS management, a checklist is used to step the evaluation panel through the most common high-risk activities so that tenderers can demonstrate how relevant risks will be controlled and if the tenderer has other quality initiatives. The interviews verify that the tenderers have WHS management systems, policies and procedures in place and that these can be translated into the WHS systems of the Private Client (Developer). Interviewee 5, EHS Manager at the Private Client (Contractor), however, commented that the checklist is often used as a tick-box exercise: "to be honest, I feel that it just gets filled out for the sake of getting filled out". The lack of WHS experts at the tender evaluation was also seen as unfortunate, as WHS risk assessment is a skill.

> *"I think a lot of people out there, particularly PMs[Project Managers] or people who don't do it on a daily basis, it's almost like they cover their eyes and pick, 'is it going to be a low, medium or high-risk?' type of thing." - Interviewee 5, EHS Manager, Private Client (Contractor)*

The tender award decision is therefore seen as primarily a commercial and financial one with little weight given to WHS management. Interviewee 10, a Project Manager at the Project Management Consulting Firm, described WHS management as a binary assessment; it is either acceptable or not.

Interviewee 7, an EHS Manager at the Private Client (Contractor), stated that if a large number of complex issues are identified at the tender interview, one must challenge how the design and planning will comply with organisational requirements, how it will be peer-reviewed, and so on. Moreover, if these questions are asked to one tenderer, the same area of questioning must also be explored with other tenderers.

Interviewee 10, a Project Manager at the Project Management Consulting Firm, also commented on safe or unsafe methodologies: "I haven't been involved in any assessments where the methodology has been deemed unsafe" and reasoned that the decision to go ahead was likely based on trust. After all, the tenderer is the expert out of everyone in the room.

> *"...if they are putting the methodology forward and they are a reputable tier one contractor, then they will be putting forward something that is safe, or if it's not, if they can't completely demonstrate that, you know, they have an obligation moving forward when it actually comes to delivering, to make sure that they do it in a safe way." - Interviewee 10, Project Manager, Project Management Consulting Firm*

The interviewees also shared experiences working with less sophisticated clients where WHS management assessments at tender had been limited. For example, Interviewee 5, EHS Manager at the Private Client (Contractor), commented: "There are two questions, do they have an EHS management system and a plan? That's it". Interviewee 10, a Project Manager at the Project Management Consulting Firm, confirmed this approach and shared that often WHS assessment at tender is limited to previous WHS compliance and the need to provide detail or explanation for any incidents that have occurred nationally across their organisation in the past 3 or 5 years. Interviewee 10 also reasoned that the division of responsibility for WHS management under the WHS laws might be influencing the differing motivations to assess WHS management at tender.

> *"[WHS] probably doesn't get weighted as highly as what it does with the contractors, because, I guess, we, kind of, have a secondary role on the health and safety side of things, because the contractor is the principal contractor, under law, they do hold a lot of the risk and responsibility for maintaining a safe site." - Interviewee 10, Project Manager, Project Management Consulting Firm*

This was also apparent in other interviews where architects and clients were motivated to ensure WHS of end-users, the public and the occupants of the final structure, while interviewees from the Private Client (Developer) and subcontractors were more concerned with WHS management during construction.

Interviewee 13, a Senior Practice Director at the Architectural Consulting Firm, described how the architect was involved in the selection of major consultants on Case Study 3 "because the

architect generally becomes the coordinating consultant". Interviewee 10, a Project Manager at the Project Management Consulting Firm, elaborated on the Government Client (Health)'s tendering approach, commenting that the evaluation panel would consist of the government client, often someone with a strong commercial lens, and some senior members of the end-user, which are not construction people. The evaluation of Case Study 3 was split 50% price and 50% non-price, of which WHS management was weighted at 20% (i.e. 10% overall), highlighting that "they do look very closely at work health and safety record" but also that 10% would have little impact on the overall evaluation score. Interviewee 13, Senior Practice Director at the Architectural Consulting Firm, confirmed that "Work Health and Safety is definitely in there" and has a similar ranking to quality assurance.

As mentioned earlier in Client Leadership, it is clear that some clients rely on the contractor's experience and reputation in managing the project and specifically in managing WHS specifically. To reduce this dependency, clients could aim to diversify the evaluation panel and evaluation criteria to include more relevant areas of expertise and priority.

As for BIM, a BIM model and particularly a 4D-BIM model has been proposed as a viable starting point for managing WHS using BIM. This is relevant where there are high-risk tasks or risky areas of concern to the client. An example was provided by Interviewee 15, Director at the Government Client (Transport), where the contractor modelled certain works in detail to demonstrate how they would minimise impacts on nearby train services.

> *"…they literally plan it, it's like to the nearest five or 15 minutes or something and then, it's just showing geographically how the overall site looks. So, it's – it was just an exercise in educating, saying, look, we've thought about the optimal way that this work will be done." - Interviewee 15, Director, Government Client (Transport)*

As mentioned in Theme group 1: Pre-tendering, BIM is rarely required at tender but may be implied or otherwise voluntarily provided by tenderers as a competitive advantage to showcase their expertise, ability to innovate and as a communication tool. Layers can be turned on in the model when certain parts of the program come through and, as Interviewee 15 explained, the contractors are signalling, "look, we've really thought about the construction, look how smart we are". And while a BIM model is not required nor scored, clients aim to be very clear about what they are looking for when evaluating tenders, and BIM models can provide a more comprehensive understanding of what the contractor is planning on doing. As described in the section Best Practice, several examples of benefits from using BIM at tender emerged across the interviews; therefore, utilising best-practice BIM to identify risks and issues at tender should be encouraged. While it is not typically seen as a WHS management tool, BIM supports communication of the design and provides a model that can be handed over to the operational staff for facility management once construction is complete. Interviewee 10, Project Manager at the Project Management Consulting Firm, shared that BIM is a useful tool "to detect and manage clashes in the design that could affect the program and result in commercial implications for the client".

Interviewees from Case Study 1 specifically commented on how the 4D-model supported the evaluation of their subcontractor tenders as the model helped demonstrate whether the tenderer understood the nature of the build and the task at hand. Similarly, the use of dRofus in Case Study 3 allowed realistic early costing of the project.

The use of BIM is, however primarily seen as a means to solve problems and to analyse risky parts of the build rather than a solution for business-as-usual risks. It is therefore not systematically required nor used for assessment in the selection processes. Interviewee 1, a Project Manager at the Façade Subcontractor on Case Study 1, cautioned that unclear BIM tender requirements might impact the ability to compare tenders based on price, as some tenderers will include the cost of BIM and others will not. Since cost is often one of the highest weighted tender evaluation criteria, it is an important consideration to compare tenderers like-for-like.

When reflecting on tender evaluation, the interviewees all recognised the tensions of the competing priorities that exist in a project. Broadly, these can be categorised as cost, program (time), quality and safety, and the stance on which to prioritise will vary among stakeholders. It was mentioned earlier that Interviewee 3, Construction Manager at the Private Client (Developer), commented that out of the four, program and cost are always at the top of the list and that quality and safety suffer depending on the expectations set by the client. At tender, "dollars and program win you the job, not necessarily safety and quality". As a proficient tendering client, it is important to discuss how the four priorities will be managed, knowing that the focus will change over time. Interviewee 3 saw it as the client's responsibility to put "more weight and onus on it" if the focus is to change - clients must provide allowances for best practice BIM to be implemented.

> *"If the client said no, we haven't got the budget for that, this is where we've got to be. You've got to go scaffold; you've got to go stick build, then probably a lot of this would not have happened." - Interviewee 3, Construction Manager, Private Client (Contractor).*

Interviewee 8, an Architecture and Urban Design Manager at the Private Client (Designer), confirmed the importance of cost and that depending on the client's overarching priorities and philosophies, if a project can be delivered without 3D-models and it is "10% cheaper on the whole project, they'd probably take it". Interviewee 8 concluded that it is great that clients are "willing to acknowledge, accept and want BIM and safety and use BIM for safety purposes. But they need to be willing to pay for it". The reason Case Study 1 used BIM as successfully as it did was, according to Interviewee 8, because "we had a good budget. I had a good team, and it meant that we could invest and spend a bit more time here and there to make our lives easier in the long run". They also had buy-in from all stakeholders, which Interviewee 8 saw as vital for success. Interviewee 8 specifically noted that "everyone has to be on board and wanting to use it [BIM]".

Theme Group 3: Post-Tendering

The previous section, Theme group 2: Tender evaluation, covered both client and subcontractor tendering. Subcontracting is, therefore, only briefly covered in this section, with the focus being on ensuring that tendering and contract requirements are appropriate and efficient in ensuring compliance with requirements after tender. Similarly, supply chain monitoring will be covered in greater detail in the subsequent section.

Post-tendering, project requirements are passed down the supply chain through subcontracting. A key difference between client and principal contractor tender evaluation is, therefore, the need to ask whether the subcontractor understands and are able to comply with not only the Principal Contractor's requirements but also the Government Client's standards, processes and unique project requirements. As mentioned earlier, Interviewee 3, a Construction Manager at the Private Client (Developer), highlighted the importance of simplicity when tendering in the supply chain: "if they can present to us a plan that we understand, then obviously their workers or their subcontractors can understand it straight away from the pictures they use". Interviewee 6, an EHS Manager at the Private Client (Contractor), commented further that inputting into the BIM model is a requirement for most, but not all, subcontractor contracts. Some subcontractors are simply working off what the architects have provided them. The focus of BIM contract requirements is thus mainly on service trades, such that an as-built model can be provided to the client upon completion. More detail on tendering can be found in the previous sections (Theme group 1 and 2).

In tendering processes where general requirements have been used, contractors are typically required to provide more detailed plans post-tender before the project commences. For example, Interviewee 2, Digital Engineering Manager at the Private Client (Designer), explained that they usually provide a template with 3D and BIM requirements pre-tender but that it is an "umbrella document". The detailed execution plan is typically not written until the job actually starts. Similarly, Interviewee 5, an EHS Manager at the Private Client (Contractor), shared that generic WHS management information is often submitted upfront, particularly for government tenders. They "require some of this [WHS] information upfront, so we do develop them upfront, but it may be based on very early information and not really that specific". Consequently, where generic information has been provided during tender, the detailed EHS Plan, sub plans, and any other plans as required by the client must be developed, reviewed and approved before project commencement:

> *"...so it's actually a requirement of our pre-construction review, which happens right before a project commences and it's not just an EHS review, it's all commercial, programming, all that type of stuff, but at that pre-con review, you must have all your EHS Plans, sub plans developed and approved." - Interviewee 5, EHS Manager, Private Client (Contractor)*

In addition to general project requirements and more specific management plans, requirements to monitor supply chain compliance is often included. Supply chain monitoring can take many

shapes, and the details are described in further detail in the next section: Supply Chain Monitoring. A tendering approach to ensure monitoring is undertaken require regular reporting or audits. For example, the Government Client (Transport) require both weekly, and six-monthly WHS audits throughout the lifecycle of the project. As Interviewee 6, EHS Manager at the Private Client (Contractor), explained, these obligations then cascade down the subcontractor workforce such that the Private Client (Contractor) can demonstrate that "what needs to be done, has been done". Similarly, the Private Client (Developer) uses requirements outlined in BIM management plans for design and construction to detail the actions and outputs that require reporting.

The interviewees also mentioned the requirement for regular updating of plans and the scheduling of systematic events to meet and review various aspects of the project with stakeholders. Interviewee 14, Director at the Government Client (Treasury and Finance), specifically mentioned the need to embed hazard analyses workshops along with progressive reviews throughout the project. The inclusion of diverse and experienced workshop participants, accountable for different elements of the project, was seen as vital to making the workshops successful: "it can't just be a government employee that they just shove in a room and say, 'right, you're now accountable for construction', and they're, like, 'I don't know, I've never done construction'".

The use of reviews was a common theme among interviewees, including design reviews, quality reviews, construction reviews, and safety reviews. The reviews were seen by interviewees as opportunities for engagement, clarification of expectations, and evaluation of the project against the client's requirements. Interviewee 13, Senor Practice Director at the Architectural Consulting Firm, emphasised that BIM and other digital information systems can be of great assistance for backtracking and demonstrating compliance with requirements, for example, by providing schedules at key points to validate progress. As detailed requirements and expectations often evolve during the project, another use of digital tools is to document diversions and changes along with the reasoning and those accountable for the changes. As mentioned earlier, it is important for clients to lead these discussions to minimise diversions from the original intent and purpose. A lack of client leadership and use of requirements that are not mandatory or unconvincing may allow contractors to pick and choose based on their needs, preferences and capabilities instead of focusing on the client's needs. Large projects also tend to involve a large number of stakeholders, all with diverse priorities and requirements. It can therefore become difficult for contractors to know who the real client is and their place in the hierarchy in the setting of priorities. In large projects, it is therefore particularly important to require progressive reviews to ensure effective delivery.

Finally, lessons learnt need to be captured to inform future projects and support continuous improvement. An example provided in previous sections was where the Government Client (Health) adopted a dRofus management plan that was developed by a contractor as an organisational requirement across projects. Another experience was shared by Interviewee 13,

Senior Practice Director at the Architectural Consulting Firm, who shared that representatives from other health projects would join early executive meetings to talk for an hour “about the things that they learnt most in the process that they’ve been through”. Interviewee 13 described it as a rewarding activity as "everybody’s eyes are glued to the presenter, just realising what the implications, and the benefits of other people’s experience”.

Discussion and Implications for the Decision Framework

The themes identified as part of Tendering Proficiency will form part of the two components of the Decision Framework and will inform tool development.

Component 1 of the Decision Framework consists of tools that guide the development of information requirements. The drafting of information requirements is the core of Theme group 1: Pre-tendering. Clients must define the outcomes, priorities and requirements to develop quality PIRs. Clients would benefit from consulting early, widely and continuously to identify and capture project risks and opportunities. The PIRs must also achieve a project balance between general and specific requirements and consider the implications for tendering and project delivery. Related to PIR specificity is the classification of requirements as essential or aspirational, considering the use of both explicit and implicit means of communicating expectations and requirements. The PIRs drafting must also consider contractor capability across the supply chain to determine what is in scope for the project and what can feasibly be accomplished.

Component 2 of the Decision framework consists of guidance to clients on procurement and tendering and forms the core to this section on Tendering Proficiency. Theme group 1: Pre-tendering relates to the processes that may inform the drafting of requirements and how to avoid common mistakes. Theme group 2: Tender evaluation speaks to the need for diversifying the evaluation team and the evaluation criteria to enable informed and valid assessments of the aspects that are of particular interest to the client. Theme group 2 also covers the use of best-practice BIM to identify risks and issues at tender, which is becoming increasingly common. Theme group 3: Post-tendering expands on the concepts introduced in the other theme groups and sections but focuses on ensuring compliance with requirements after tender, which should also be a key consideration during the tender to ensure successful project delivery.

Supply chain monitoring

A total of 102 units of interview text were linked to Supply Chain Monitoring. Second-order axial coding led to seven themes categorised into three overarching theme groups (refer to Table 11). The themes explain the required capacity within the construction supply chain to enable BIM-supported chain monitoring to strengthen WHS management.

Table 11: Summary of themes and theme groups for Supply Chain Monitoring.

Themes	Theme groups
The need for a strategy to adjust the level of WHS analysis in a BIM environment based on feedback from the supply chain	*Adaptation to the culture, practice and process shaped by BIM-enabled WHS management*
Supporting a new normal of digital-build culture that values accuracy and certainty	
Commitment to WHS discussions with the supply chain using digital models	
An accessible online platform for sharing, updating and expanding BIM-WHS information throughout the supply chain is essential	*Technical capacity building to effectively use BIM technology, data and platforms for WHS management*
Acknowledgment of the resources required for accommodating BIM-WHS information, including data collection, model alteration and on-site access	
Establishing a strategy to take responsibility for the currency and accuracy of frequently updated WHS information and decisions within the BIM platform	
Acknowledgment of the increased accountability expected from the supply chain as BIM is used for WHS management	*Increased WHS accountability following the implementation of BIM for safety reinforcement*

The themes identified in this section resonate with five of WHS Knowledge Domains; the one Knowledge Domain that is not reflected is Scenario Planning.

Theme Group 1: Adaptation to the culture, practice and process shaped by BIM-enabled WHS management

BIM increases the volume of information captured on the different aspects of a project as well as the ability to access such information. Whether more WHS information is actually better is a point of ongoing debate. Contrasting views persist as to whether a data-rich philosophy is better than a more purposive approach. Large volumes of data will not necessarily benefit the company if it is not integrated or updated or if supply chain participants do not embrace a culture that embraces its use in the normal course of decision-making.

The level of detail is another key issue. Different supply chain participants need information at different levels of granularity. Interviewee 2, a Digital Engineering Manager at the Private Client (Designer), compared WHS data with cost data, noting breaking down costs in meaningful, customised ways can be beneficial. Domains of project management like scheduling and WHS might, for example, need high levels of detail, but current practice does not support the breaking down of WHS information in meaningful ways. There is a need for a strategy to optimise the level of detail supporting WHS analysis in a BIM environment based on feedback from the supply chain.

Interviewee 2 also noted that there is "no particular way to move forward" in this area to guide the optimisation of information volume against expected outcomes.

Hurdles to achieving optimal levels of detail in WHS management include the unilateral control of the principal contractor over the level of required detail, which may result in adding unnecessary layers of analysis. Given the limited resources of smaller players and the industry trend to separate specialisations, the overemphasis on unnecessary micro-detail in BIM can be counterproductive to achieving better WHS performance.

Failure to involve a broad base of participants in defining data requirements is another hurdle. Input from trades is particularly important; they are close to WHS issues on-site as they are involved in everyday activities like safety walks. Input from a range of other stakeholders is also important, and management of WHS issues using BIM must be based on input from each relevant stakeholder. "Virtual walk throughs" using BIM are convenient but still require input from a broad range of experts to achieve a rich understanding of WHS-related constraints, risks and opportunities.

Broad-based participation in defining optimal levels of data is rooted in something deeper. The willingness of the supply chain to participate in the proactive rectification of issues using BIM is a critical cultural factor. Subcontractors are expected to "work as a team" in using BIM to enable the principal contractor to devise safety solutions:

> *"We found as the biggest key factor of this 3D-planning was the ability to see something and build it in the computer world before we physically build it on-site. We know that we are going to have a thousand different problems every day that we have got to solve, but if we can even eliminate 100 of those or 200 of those that we have picked up in some degree with either ourselves or with a review with other contractors, it makes everything more efficient, safer, and I guess in a sense, easier for everyone. The real benefit with us as well is we surrounded ourselves with a group of really, really good and competent contractors that also wanted to have the same grasp in the model." – Interviewee 4, Senior Project Engineer, the Private Client (Contractor)*

Another way to explore optimal levels of WHS management data is by categorising risks. Based on the feedback from subcontractors, the complexity of BIM solutions must differentiate "business as usual risk" from "key subcontractor risk". The level of detail in information for a digital build to support WHS decision-making must be commensurate to the level of risk perceived for a task. The interviewees used the word "intuitive" to refer to lower-risk construction activities that are not normally modelled for safety assessments. Ultimately, a core function of BIM models in assuring safe work is to stimulate improved thinking among the workforce to see "the visualised work procedure". Overall, the discussion around the need for an optimal level of information was captured succinctly by Interviewee 13, a Senior Practice Director at the Architectural Consulting Firm: "We basically filter the model to be as intelligent as required for the purpose."

The need for optimal levels of WHS management information could in part be driving the trend where more subcontractors are using BIM models than before to secure contracts. As mentioned earlier, Interviewee 6, an EHS Manager for the Private Client (Contractor), referred to those subcontractors as "smart" and "savvy". A subcontractor's use of BIM at tender can also be used to strengthen its credibility, especially when the subcontractor does not have an extensive record of past experience.

Our data suggests that the industry is beginning to appreciate digital visualisation as a suitable response to the dynamics of site activities that, at the moment, rely heavily on human factors. BIM's capabilities support problem prevention, i.e. problems are not left to the workers on-site, and BIM, therefore, adds a level of certainty to WHS management procedures. BIM technology also streamlines the site decision-making, including WHS issues, and by doing so is setting a new norm:

> *"It is more about the ease of [change of design] happening, and it happening consistently, and done by qualified people. Technology makes the plan work with more assurance and certainty." – Interviewee 7, EHS Manager, Private Client (Contractor)*

Interviewee 12, a Senior BIM Software Specialist at the Architectural Consulting Firm, also noted that project managers should employ BIM-based WHS management from "the very outset of the project". The reassurance offered in "the BIM world", it is claimed, has made it normal to "make sure everything is right before you actually start building".

Evidence from this research, therefore, suggests a second theme: that trends in the construction industry support a new normal of digital-build culture that values accuracy and certainty. In an industry where clients tend to pass on risk to contractors, increased accuracy, certainty, predictability, and control can translate into bigger profit margins. The use of BIM thus benefits participants across the supply chain. There is emerging evidence that the use of digital models helps contractors save costs, for example, when they support the comparison of expensive alternative construction options and thus allow avoidance of costly mistakes. BIM's economic benefits are fuelling this new normal.

The new normal is demonstrated in various ways. Day-to-day tasks, for example, assuring the safety of scaffolding installed on the edge of floor slabs with unusual perimeter shapes, are now increasingly supported by BIM:

> *"The model [...] started helping us understand temporary works. So obviously scaffold being temporary works. Especially with a slab that moves in and out is the scaffolds, is it supported off-ground? Is the scaffold supported off the slab? Is the scaffold cancelled? Can we take that portion of scaffold down? Were there areas that we could not do because of the way the slabs work? Yes, and that was what we discovered in the model." – Interviewee 3, Construction Manager, Private Client (Contractor)*

The new normal is also evident in changing roles and job descriptions. For example, Interviewee 2 had the title of "Digital Engineering Manager" at the Private Client (Designer), a role that signifies the increasing prevalence of digital tools, such as simulations, to support projects. Interviewee 2 pointed out that digital capabilities are already an assessment criterion for the award of contracts within their organisation. To do otherwise would preclude contractors, as they would not be able to cope with the expanding BIM requirements. Such criteria again suggest a shift to the new normal. "Using technology other than just modelling", for example, for WHS applications, was also mentioned as an advantage in the assessment of digital capabilities.

Another interesting point noted by Interviewee 2 was that the Government Client (Transport) provided specifications for BIM requirements, including requirements related to WHS, but that these requirements were "loose". Loose requirements suggest that the so-called BIM agenda, and the new normal, might be a trajectory that is being shaped by Tier 1 contractors rather than by clients, at least for now. A similar observation was made in the UK by Interviewee 9, a Health and Safety Inspector at a UK Work Health and Safety Regulatory Agency, highlighting the need for studies seeking to strengthen clients' capacities to drive BIM for WHS management on their own terms.

BIM's inherent legacy of higher accuracy and certainty makes it a robust WHS management tool. The new normal thus also involves the increasingly widespread assumption that construction in the digital world should precede physical construction. In this sense, productivity, cost, safety or quality are likely to be a "certainty" in the virtual build before site construction could proceed:

> *"Using [BIM] correctly will give you advantages from a safety and quality [perspective]. Quality is a big one, accuracy. Certainty. Certainty is probably also a massive one. […] So, the BIM model is, really, a 3D representation of what you are going to build in its simplest form. If it works in the model, yeah, it is going to work in real life." – Interviewee 8, Architecture and Urban Design Manager, Private Client (Designer)*

For the purpose of risk assessment and control, a major advantage of using 3D- models over 2D drawings is the consistency of volumetric representations of a construction process with human cognitive processes. Animated work sequences subconsciously trigger 'storytelling,' which help to explain WHS concerns to people who have not been part of the design:

> *"The next step was then how do we then portray that to a subcontractor who has been not really involved in any of this planning. We will do an induction at the end of our site, where we can then sit down with them and show them in 3D how they are going to potentially perform their works and bring them on the journey, and I think a lot of people embrace a 3D-concept more than they do just looking at a piece of paper". – Interviewee 3, Construction Manager, Private Client (Contractor)*

Mature clients who use digital modelling for WHS management can:

> *"…model out every single stage, take a snapshot of each daily activity, put it in a document, record the date that we expect it to happen. And then that helps the*

guys on site pass that information on to other trades as to where we are going to be, what we are going to be doing, what they need to be careful of." – Interviewee 1, Project Manager, Façade Subcontractor

3D- models are thus generally more easily understood; in contrast, professionals or trades often struggle with interpreting 2D drawings. This lack of understanding of actual work processes poses a risk to WHS. Animations showing the construction process are of great WHS benefit, especially in toolbox meetings, site inductions and risk workshops. The positive feedback on the use of video simulations was repeatedly mentioned in the interviews.

A third theme, therefore, is a commitment to WHS discussions with the supply chain using digital models, as a fundamental expectation to assure digital modelling yields WHS benefits:

"Because for [Health and Safety Officers], if you said to me, I am going to use [digital model] on-site briefing in the morning when I am showing people where things are. Because this week, we are pouring this section over here; there is stuff happening in here. It is a lot easier to visualise when people look at the model than plans or just talk about it. We are going to the southeast corner. Where is the southeast corner again?" – Interviewee 2, Digital Engineering Manager, Private Client (Designer)

Findings from our case studies suggest the level of digitisation during the construction phase is far less than during frontend phases, like planning and design. The execution of frontend processes in digital platforms, however, creates more digital encounters on the site. The more interactive the digital models that arrive at site are, the more committed the site personnel are to using them in WHS discussions. Contractual requirements to conduct WHS discussions using digital models can also catalyse higher levels of commitment to using BIM for WHS discussions with the supply chain. Interviewee 5, an EHS Manager from the Private Client (Contractor), envisioned a "futuristic" level of interactivity with BIM models during construction, involving the overlay of the model with current works of different trades in each area. However, the resourceful use of existing technologies is also emerging, including the use of iPads on-site, observations with phones and automatic weather alerts to lock down the site. The commitment is expected to revolutionise the traditional ways of safety communications on-site. An electrician, for example, could be contractually required to input the details of site works into the model. As Interviewee 7, an EHS Manager at Private Client (Contractor), noted, the goal is "to get people to have a conversation about high-risk tasks they want to successfully do today." Contractual obligations regarding risk assessment, safe work method statements and other WHS data would strengthen practices in line with this theme.

The use of BIM as the source of truth in projects helps address persistent problems of stratification in communication that are common in the construction sector. Information, including WHS information, is filtered through many layers before reaching users. BIM is a way to achieve the much-needed integration of communication:

"That kind of integration of the communication of [design and construction] processes, I think can help ensure that everyone is following the same track and communicating to everyone correctly." – Interviewee 1, Project Manager, Façade Subcontractor

Theme Group 2: Technical capacity building to effectively use BIM technology, data and platforms for WHS management

BIM's impact on WHS management depends significantly on the acceptance of the technology by the supply chain. Factors shaping acceptance were discussed in Theme Group 1. Impact, however, is also subject to technical considerations.

An accessible online platform for sharing, updating and expanding BIM-WHS information throughout the supply chain is the backbone of any practical attempt to overcome WHS challenges. A key steppingstone to developing this platform is a common data environment:

"I mean the same is absolutely true in the UK [i.e. not many public sector clients in Australia would have an effective Common Data Environment that they would use across a number of projects], and the business of having one place where you can see models across, or look at several projects, or lessons learned from several projects, is really at an infancy over here." - Interviewee 9, Health and Safety Inspector, UK Work Health and Safety Regulatory Agency

An online platform would provide all ranks of the supply chain a certain level of access to the centrally administered WHS information database, depending on their WHS authorities and duties. The platform would have to be equipped with features to maximise the quality of WHS information in terms of 1) modelling WHS aspects in the best possible way, 2) optimising the amount of information available for a task and 3) ensuring the stored information matches works on-site. A major difference of a BIM platform for WHS management to document control systems currently in use is the connectedness of WHS information to other project data in the model. In other words, the routine of updating WHS plans need to be conducted in a more integrated way, together with other project plans on cost, schedule and rework:

"So just to give you a picture [of the use of 3D-models to interface with all of our other consultants]. So, we are modelling the fabric of the building. The engineers are obviously modelling structure and services and basically, all of those models come together in a large model, which is our base model, which is a huge, huge thing to deal with. But literally, you can see everything that is going into the building. So that interface is really, really important." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm

The benefits of an integrated platform have already been experienced by the WHS management teams at the Private Client (Contractor) in a recent shift from paper-based reporting to an electronic project reporting tool used for a holistic review of project performance. A benefit of the automated approach was increased accuracy and reliability:

"If somebody was manually generating the report in the old paper version, some statistics could get skewed depending on how they are recording it, how they are looking at the data. When it gets automatically generated [the name of the electronic platform] it is what it is, that is what it is, they cannot fudge any

numbers, there is no missing decimal points, that is the live data in there and I believe it is current 24 hours." – Interviewee 5, EHS Manager, Private Client (Contractor)

An accessible online platform is key to enabling site management and subcontractors to map construction activities to the construction model. For example, project-wide access to the model helps prevent interruptions to productivity and work progress:

"[The availability of the model] helps us program how we manage the over/underworks and the exclusion zones, exclusion zones have a huge impact on program because an exclusion zone is an exclusion zone, no-one can work in that area. So, if we do not get that right subcontractors will struggle." – Interviewee 6, EHS Manager, Private Client (Contractor)

An accessible online platform would also support access by all stakeholders to digital models. Case Study 1, described by Interviewee 7, an EHS Manager at the Private Client (Contractor), as "absolutely the most well planned, well defined, designed, coordinated project" they had ever been on, involved the use of BIM models by all stakeholders well before construction commenced:

"[A] year before a shovel hit the ground, we started, all the stakeholders got together and visualised together, using 3D models." – Interviewee 7, EHS Manager, Private Client (Contractor)

The model remained the centrepiece of effective communication between teams, including those involved in WHS management, for decision-making during construction:

"So, it was like there was this [3D] model in the background where everyone could just keep – manage the change as well." – Interviewee 7, EHS Manager, Private Client (Contractor)

Apart from a central repository of information, a range of competencies and technologies is also required to sync site and office information flow. Another theme is thus the acknowledgment of the resources required for accommodating BIM-WHS information, including data collection, model alteration and on-site access:

"When there was a design change, I remember the team will pop out, they would have their iPad, they would take a photo, they made some notes. Sent it back to the designer. I think they input it into [3D] model. I was happy from an EHS point of view because they were not people unqualified making decisions on the spot." - Interviewee 7, EHS Manager, Private Client (Contractor)

The quote explicitly points to the presence of an appropriate device (the iPad) and simultaneously implies the presence of appropriate competencies ("not people unqualified").

In terms of skills, competencies in model development, model manipulation and scenario testing have been shown to be useful. In Case Study 3, the Government Client (Health) added to the scope of the project at a stage when design was almost complete. This significant addition was in the range of 10% of the project budget and included elements involving complex construction. Both the Architectural Consulting Firm and the Private Client (Developer) adapted well to the

change because they possessed in-house skillsets to effectively respond to the extension of the project scope:

> *"The interfaces with roads and other buildings [proposed in the added scope] was quite complex. So, phasing [in terms of an orderly expansion of digital models as the scope expands] is important and often, it is difficult, because managing the data so you are only showing it in phases without duplication is quite difficult. We get involved with that. But more and more, the actual construction manager have people on board who can do that, do these tests from a construction point of view. There was a video produced on the building – the excavation went down and the building grew, so that they could show the client how everything was going to evolve over time. […] We [as project Architect] found [the Contractor] were pretty smart with this. We often get involved with other clients who are not maybe as large or working with these complicated projects." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm*

Any prospective specifications for using BIM for WHS management within construction projects should consider the existing pool of skills within the sector. The Interviewees' reflections on potential WHS applications of BIM consistently presuppose the availability of certain skillsets:

> *"I built [the] construction simulation internally, for internal use, and that is going on delivery program, so it is a bit more realistic for us. It is a great communication tool; so, site briefing in the morning, you can have that on the screen, and you talk about what it is and areas that you are working on, what people need to look out for and so on." – Interviewee 2, Digital Engineering Manager, Private Client (Designer)*

It is also important to note that WHS procedures are heavily reliant on on-site data, and this reliance can be expected to increase with the use of BIM:

> *"Piece by piece, day by programs, which we then feed into our safe work method statements and our methodologies that we then go back to [the Client] with, and we present to the site team. So, we will sit with their site managers, the other critical trades that might be in the areas." – Interviewee 1, Project Manager, Façade Subcontractor*

Adequate arrangements must therefore be made to support sustainable feed of site activities data to the model, particularly in relation to overseeing WHS.

While the use of BIM may not radically redefine the role of trades, the expectation that they will use the model does add a layer of technological complexity to their role that may trigger resistance or require upskilling:

> *"Guys onsite have spent their lifetime perfecting their trade, not operating 3D models." – Interviewee 1, Project Manager, Façade Subcontractor*

Digitising WHS management is resource-intensive. Developing, updating and maintaining digital models require time, effort and money. That said, these investments must be weighed relative to improved WHS performance, which in some cases could be lifesaving.

The interviews show clear examples of moving beyond 3D-BIM use to 4D and 5D-BIM use by the supply chain as a response to contractual requirements. This shift occurs even if, at times,

contractors and consultants are not fully convinced this expanded use of BIM is beneficial. When more widespread use of BIM is contractually mandated, care must be taken so that BIM is not reduced to a reporting platform. BIM should be used to support effective WHS decision-making at all levels, and where this is the case, the data underpinning WHS decisions must be accurate, updated and verified. Flawed WHS decisions could be catastrophic. A poor WHS decision based on inaccurate BIM data is a material risk far more dangerous than a poor scheduling or budgeting decision. Clients and supply chain partners must come to an agreement about maintaining the quality of WHS-related input to the model, and this requires technical capacity across the supply chain. This leads to a sixth theme: a strategy must be established to ensure that different actors in the supply chain take responsibility for the currency and accuracy of WHS information and decisions within the BIM platform. Currency and accuracy of WHS information are not novel ideas as identified by the Private Client (Developer), where contributors and reviewers had shared ownership for creating and maintaining more manual EHS plans. The point is that shared ownership, responsibility and maintenance of high-quality data are still expected and perhaps significantly heightened when BIM is used, particularly when models are relied upon by the supply chain as the single source of truth. Furthermore, it is clients, not contractors, that must push for high-quality models in support of WHS decisions, a practice that UK WHS regulators are trying to encourage:

> *"So, we [the WHS Regulator] are very much trying to focus on this idea that if a client can say at the head of the project, 'I want a 4D model, I am particularly interested in this sequence of the build because it is high risk and it is a problem and I want to be able to maintain it. I want you, Mr contractor, to create a 4D model of this process'. It makes it much clearer. And that kind of level of definition has not been typically in procurement documentation up until now, unless it has been hidden right down in the detail and you have got a very-very directive client." – Interviewee 9, Health and Safety Inspector, UK Work Health and Safety Regulatory Agency*

Users of BIM-based WHS systems must be competent and take responsibility for their contributions to the model. The strategy must address the need for updating BIM with WHS data based on work progress on-site by assigning responsibilities and defining the expected level of accuracy. For example, would there be a procedure to sign off the changes to safe work methods due to unforeseen site issues by the crew that are doing the work in the BIM model, as it is currently part of the common safety practice?

The strategy must also ensure that BIM removes communication siloes by assuring an accurate update reaches people who need them at the right time. One example of a silo is the excessive centralisation of WHS decision-making with a single person:

> *"I think there is a bit of a stratification problem with the [WHS] communication … There is [sic] hundreds of people involved on these projects, thousands on bigger ones. And the builders have their design managers and their project managers. And then all of these people work on the jobs for years. And then it all just gets dumped onto a construction manager's desk. And then the construction manager*

starts up again, trying to figure it out. And that is a bit of a problem." – Interviewee 1, Project Manager, Façade Subcontractor

The reason for the "dump" of project plans and information on construction or project managers is the hierarchical structure of site management and the convenience of holding the person on the top responsible for site activities and WHS.

BIM addresses the issue of communication siloes by supporting transparency. In Case Study 3, a data management tool supporting BIM had the facility to track minute decisions and actions that could have implications for WHS:

"dRofus is very interesting though because it is in the data and actually every single thing you do is logged in that database. So if I was to delete a mechanical item from a room, it leaves a track of when I did it, what the old value in the database was, what the new value in the database was, and it also allows me to log a change list to say, 'well, this is the broadscale reason that I did it', and it also allows me to leave a detailed note. So, I might have a specific instruction by a consultant user where they've agreed to the change that we wanted and then I'd be able to log that note in the database change." – Interviewee 12, Senior BIM Software Specialist, Architectural Consulting Firm

Finally, the strategy must ensure clear lines of responsibility in relation to input to the BIM-WHS system. This can be achieved through a permissions matrix:

" [The] Permissions matrix outlines a particular user group and which part of the database they can have access to and whether they can have read access, whether they can have write and read access or whether they have no access. And that is typically aligned across disciplines and also across the different stages of the project so there's a different permissions matrix that we establish for each stage of the project." - Interviewee 12, Senior BIM Software Specialist, Architectural Consulting Firm

Such matrices may be designed in a top-down manner; alternatively, mechanisms can be put in place so that responsibilities can be fluid and negotiated, but still clear:

"dRofus allows you to change permissions of different users, so the permissions that Public Client (Health) would allow various users within the database we disagree with and we provide entirely different permissions matrix." – Interviewee 12, Senior BIM Software Specialist, Architectural Consulting Firm

In the absence of a strategy determining users' obligations towards the model, it is unlikely for users to agree on the boundaries of their responsibilities, especially for sensitive WHS-related information.

Theme group 3: Increased WHS accountability following the implementation of BIM for safety reinforcement

The enhanced ability to collect, analyse, store and recycle WHS information in BIM models, such as the location of underground utilities, indicates that the scope of WHS responsibilities are expanding to become forward-looking. For example, the near-miss excavation incident around

the unsurveyed gas lines explained by Interviewee 10, a Project Manager at a Project Management Consulting Firm, involved updating the BIM model with accurate as-built data. This updating process did not have an immediate WHS use but was critical for safety during future maintenance, rework or new work around the buried pipes:

> *"[Y]ou are feeding into that BIM model the survey information you have. If there is a hole in the survey information, then the BIM model is not going to help you." – Interviewee 10, Project Manager, Project Management Consulting Firm*

WHS management, traditionally focused on preventing accidents at the time of construction, is now increasingly emphasised across the entire asset lifecycle. Understandably, client leaders who hold heightened expectations about WHS seek to cascade it as a priority down the supply chain. Tier 1 contractors, in turn, could seek to lift their game and accordingly expect their subcontractors to do the same. This pattern of heightened WHS expectations, supported through BIM, leads to a seventh theme: the need to acknowledge the increased accountability expected from the supply chain as BIM is used for WSH management. Because BIM makes it possible to analyse hazardous works through digital models and to test different construction materials and methods, BIM adoption for WHS management creates the expectation from the supply chain to de-risk every element of work. When digital modelling is used, for example, for planning and simulation, a reactive approach is unlikely to be defensible:

> *"...thinking about different aspects of things without potentially having someone to become reactive and to do something that could potentially put them in a situation or a scenario where your ability to put yourself in a position where you might be harmed or you might hurt someone or someone else or drop something, or whatever it might be, is drastically reduced." – Interviewee 4, Senior Project Engineer, the Private Client (Developer)*

BIM offers opportunities to analyse more complex buildings more effectively and to deliver them in safer ways. Paradoxically, however, BIM adoption can also bring about an increased WHS management burden in projects:

> *"So, the revolution of high-level 3D-modelling has made projects easier, but at the same time, because the modelling has become better and has opened up different avenues for conceptualising buildings, everything's become more difficult." – Interviewee 1, Project Manager, Façade Subcontractor*

Through the use of BIM, complicated designs that were not possible 20 years ago can now be made a reality. These complex designs generally impose far higher construction risks than those associated with typical designs of multistorey buildings, described as "a series of concrete slabs with some glass wrapped around it." The complexity of today's designs necessitates a higher level of coordination for WHS management. Just as BIM supports designing in 3D and building in 4D and 5D models, BIM could support WHS management as well.

The use of BIM for WHS management does not change the subcontractor-oriented nature of Australia's construction industry. It is hypothesised that principal contractors could rely even

more on subcontractors to use BIM to mitigate risk, both commercial and WHS. In the era of BIM, sub-contractors are burdened with the accountability for the development of effective risk control solutions more than ever:

> *"From that EHS interview, tender interview process, we can identify some key risks that are associated with the job, subcontractors are aware, for example chain of responsibility … It is become more and more prevalent in our industry that we were probably not as up-to-speed with chain of responsibility and it has potentially a massive impact on large projects like this one here, in our pre-tender interview checklist if the right people are contacted we've actually asked for the pre tender interview template to capture some key risks there that align with our business now. And in that pre-tender interview the subcontractor has to identify how he's going to control those key risks and then those risks migrate to delivery and then each subcontractor has to develop their own EHS plan and it filters from there through. - EHS Manager, Private Client (Contractor)*

Discussion and Implications for the Decision Framework

Contractual requirements could be designed to ensure the supply chain shifts to BIM-supported WHS management. First, dedicated references to WHS in documents such as the PIR and EIR should be integral in provisions of contracts that envisage the use of BIM for WHS purposes. The information requirements should trigger a deeper assessment of risks associated with construction processes by supply chain participants and thus support enhanced WHS performance.

Second, contractual requirements could mandate the supply chain to consider WHS beyond the construction phase. A forward-looking vision is to support attitude change through the development of BIM-related contract documents. For example, contracts could be worded such that they instil a sense of responsibility in supply chain participants to collect and save information on relevant matters, such as the location of buried utilities for future uses.

Third, contractual requirements should either explicitly define, or provide guidelines for, the optimal amount of information to be presented to the supply chain for effective WHS decision making, with the optimum level being determined in consultation with the supply chain. The implication is that a critical document, like an EIR, should not be developed in isolation from the supply chain.

Fourth, contractual requirements should specify a common data environment or a universal data schema. These are prerequisites to the supply chain's capacity to collaboratively address WHS management issues. Common data should then be 1) updated through supply chain participants feeding accurate WHS information to BIM in a timely manner and 2) shared, for example, through requirements briefings and regular reporting.

Matters in supply chain monitoring that would have an impact on the decision framework include:

- The level of flexibility afforded to the supply chain in determining the amount of information they must regard in their WHS decision-making
- Identifying boundaries of the supply chain's discretion to decide WHS issues that must be resolved in the BIM environment
- Making an informed decision about the risk-bearing capacity of the supply chain to rely on for resolution of WHS concerns using BIM
- Attributes of players who can be trusted to successfully execute WHS management through BIM
- Defining the criteria to distinguish a quality digital build from models that are not suitable for supporting WHS management
- An integrated approach towards WHS management, where every stakeholder is supported in BIM to remain on track with WHS decisions
- Supply chain's needs and constraints in access to and working with digital models for WHS applications
- Technological preparedness and skillset expected from the supply chain to succeed in BIM-enable WHS management
- The contractual arrangements required for holding the supply chain responsible for providing the WHS data necessary for effective modelling of hazardous construction processes
- Elements of design that point to mandating the use of BIM for management of WHS issues pertaining to the construction of the designed component

Best Practice

Empirical findings from semi-structured interviews of 15 project participants showed a total of 178 units of text that could be linked to Best Practice. These units of text were categorised into eight themes, which were clustered into three theme groups. Themes and theme groups are summarised in Table 12.

Table 12: Summary of themes and theme groups relevant to Best Practice.

Themes	Theme groups
Government and industry collaboration on Design for Safety	*Client best practice*
Client leadership	
Organisation, Asset and Project BIM and WHS alignment	
Supply chain tendering	*Supply chain best practice*
Common data environment	
Collaboration between government and industry to progressively adopt BIM for WHS management	
Site safety communication	*Best practice on site*
Site safety BIM integration planning	

Emerging themes from this section have been found to align with all six Knowledge Domains.

Theme Group 1 – Client best practice

All the clients in the three case studies demonstrated Client Leadership in ways that could be described as best practice. Many of these have been discussed in previous sections. Findings emphasise that Client Leadership begins with setting up and communicating client expectations to influence the adoption of BIM for WHS management. BIM and 3D modelling can have profound benefits, but these are not always understood by people who have a superficial grasp of their capabilities. Loose client requirements make it seem as though they do not know what they will use it for.

> *"I think the first step for them is to understand what it is that they want to do with it; that's the first step. If you don't understand, what are you asking for? I'm happy to give you a contract program 4D, but what is the benefit of it? This is something that they need to answer; we can't answer that." – Interviewee 2, Digital Engineering Manager, Private Client (Designer)*

Clear client requirements can lead to 4D modelling of critical processes that can enhance WHS management. As mentioned in Client Leadership, sequencing, construction methodologies, and 4D modelling are potentially powerful starting points for adopting BIM for WHS management. Strong client leadership and clear WHS management requirements can push reluctant contractors to realise they can actually use BIM in this area. In contrast, lack of client leadership and clarity in PIRs can make contractors question how to meet the requirement and why. The earlier quote from Interviewee 9 about "Requiring Mr Contractor to create a 4D model of this process" reflects this.

One of the first things clients must do is work to translate high-level requirements to specific safety requirements. This was discussed in Client Leadership, where the Government Client (Health) was described as beginning a project with a BIM brief. To cite another example, design review outcomes must be translated into specific requirements, such as fire safety requirements linked to codes:

> *"Now that technically would be part of, in the PAS there is a requirement for a high-level design strategy, or a design plan. So logically, is obviously that that fire strategy statement sits in the initial design plan. So, you see, in that way, you try and knit things together. So, you're trying to say, there's a general requirement for a design plan, and a specific element of that is a fire strategy statement. So, in that way you can knit things together." – Interviewee 9, Health and Safety Inspector, UK Work Health and Safety Regulatory Agency*

It was recognised that not all clients are experienced in setting clear requirements about BIM for WHS management. Learning what to ask for and communicating how the data will be used seems imperative:

> *"So, what we see with governments now is that they ask for things, but they don't necessarily know why they're asking for them or how they're going to use that data. But it's a first step, right? They're learning. So EIR on [different project], for example, is version 5. It's a lot more refined document. They dropped the 4D and the 5D from it because they didn't find a use for it. So, it's an evolution; that's all it is." - Interviewee 2, Digital Engineering Manager, Private Client (Designer)*

Noting the reality of clients having different levels of experience, Interviewee 9 also highlighted the use of a client maturity matrix as a self-assessment tool to identify good practices and areas that need improvement. However, in reality, clients' self-assessments might be overly optimistic, as they tend to focus on their last good project when estimating their maturity and level of practice and not their average performance, thus limiting accuracy.

> *"The other interesting thing is of course, is any big public sector client will have their landmark projects that they'll be raving about. But for every landmark project there's 10 also-ran projects. And if you look at those 10, the same client has got his name on some pretty questionable practice in another part of the country or whatever. So that's always a thing with public sector client, which is more difficult. And so, any public sector client who says they're brilliant is actually generally reflecting their last good project." – Interviewee 9, Health and Safety Inspector, UK Work Health and Safety Regulatory Agency*

Among the three Case Study clients, the Government Client (Health) appears to be the strongest in communicating expectations. The Government Client (Health) sets clear requirements and expectations about BIM and WHS management in the form of a brief. Specifically, the client has adopted the software dRofus and uses a tailored dRofus management plan with detailed standards and specifications as an organisational requirement across projects. IT should be noted a system like dRofus has clear benefits for complex projects, such as those undertaken by the Government Client (Health), but the benefits may be less clear for simpler commercial projects

But even strong client leaders might find it difficult to unilaterally mandate the use of BIM for WHS management. One approach used by the Government Client (Health) was to establish collaboration between government and industry to progressively adopt BIM for WHS management. In Case Study 3, the design consultant partnered with the Government Client (Health) towards mandating dRofus as the data management program for all projects above $30 million:

> *"We were lucky enough to be one of the early projects. We adopted Revit as our 3D platform. We think it was a pretty smart choice internationally. We did a lot of research. So, Revit definitely was our 3D platform. We actually pair it with dRofus, which is our data management program. We believe we influenced [the Government Client (Health)]'s decision to make that mandated for all of their projects. And that means that all of the consultants have to work within the BIM – so Revit, BIM field. And that took a long time, because you deal with lots and lots of different consultants. The larger ones engage and the smaller ones either fall by the wayside or have to work within the system somehow." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm*

The capabilities of dRofus as a data management tool allow all consultants to use it for design, construction, and monitoring of what is happening with the build in a detailed way. It has a bi-directional interface with the model, which allows users to access as well as make changes. The database is a library of components used for all of the Government Client (Health)'s projects and is continuously updated. dRofus supports quality control and service coordination, and more benefits are realised as more clients engage. dRofus supports BIM models, which in turn support WHS decisions:

> *"From a health and safety point of view, we model every element that goes into the building, so we have the beds modelled, we have the doorways modelled. We have all the bathrooms modelled from an accessibility point of view. We can export all of that data. We can check that it's all working and where there are clashes and they're not working, we can export them out and address them. So yeah, it's a pretty powerful tool. Even the project managers are now engaging with assessing the project on the way through the database." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm*

dRofus also supports the transfer of lessons learnt across projects.

> *"Before you have a schedule of accommodation you can be building all this data, you can be harvesting what you've learnt from other projects and carrying it on to these projects from a very early stage, before the model exists." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm*

Interviewee 13 also believed that preventing WHS issues is preferably done through a database such as dRofus rather than in a 3D model because a model can hide certain things.

> *"I see the contractors using the database like that very early on, they're seeing this stuff much sooner than if it was just lurking in a model, because in a model you can just draw something and put a silly code on it and hide it, but in the database, it has to be properly described in a way that it's identifying it and so they're armed with a lot more knowledge about what is in their project early on." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm*

A key investment payoff for the Government Client (Health) is that it now has a database and documents that define its standards, which then become inherited by consultants and contractors as new projects begin. An important point to note about this experience, though, is that learning was collaborative and two-way. The Government Client (Health) educated different supply chains about the use of digital models and database tools by transferring lessons learned across projects, and in the process, they have also learned from their counterparts on how to better use the system. As mentioned earlier, the Architectural Consulting Firm has influenced the client to adopt more productive practices on dRofus use, including extending architectural permissions to service items, making decision-making decentralised and more agile.

A third theme is a need for organisation, asset and project BIM and WHS alignment. That is, plans and actions for BIM and WHS should be aligned at organisational, asset and project levels to maximise information quality, ensuring the information matches all elements in the project and maximising the information available to users.

A key part of this theme is using BIM for monitoring WHS management issues across the supply chain. Findings suggest that the Government Client (Health) did not make use of dRofus' reporting capabilities for monitoring, but there is evidence of benchmarking, review activities and checks and balances being conducted at critical stages, for example, at the end of design development:

> *"They [Government Client (Health)] mandate that we have to benchmark against the original brief at certain periods during the project. So, they will have a quality tick-off process at the end of design development. Have we done our checks and balances? One of the most critical ones is that a room has not been deleted for some reason. Because you can imagine that if we go into a user group process, there are many opinions. You know, we don't need this room, we'd rather have an X rather than a Y or two Xs instead of a Y. And that design can be made at sort of grassroots level. But from a [Government Client (Health)] point of view, that might not be the way that they actually want their infrastructure to be developed. So, there's this checks and balances along the way, where they can put up their hand and say, 'I can see you've deleted a bedroom off one of the floors. That's not the brief and who told you to do that?' So, there's a – because the client has many heads, it's really, really important." – Interviewee 13, Senior Practice Director, Architectural Consulting Firm*

A hierarchy of WHS management procedures, documented in different plans, has the potential for digital management of information flow and seems to work well. Combined with BIM Execution Plans, it could set out a digital framework for how everyone could work and collaborate on a model that incorporates WHS management.

> *"It's very clear in the business that there needs to be a — at the time we used to call it a BIM execution plan or a BIM manual, which is what was done for [Case Study 1]. In recent time, we've brought in that scope or that document and we call it a digital strategy, because BIM is only one aspect of digital. And so yeah, that was executed – we had a BIM execution plan, virtually, from day one on [Case Study 1]. And that, basically, set out the framework to how everyone in the — from a design*

perspective, would work and collaborate." – Interviewee 8, Architecture and Urban Design Manager, Private Client (Designer)

This interviewee also believed that the use of BIM at the design stage, or at a risk-assessment stage, needs to be embedded into the WHS system.

> *"But to go back to [Private Client-Developer's risk assessment requirement] I think there is an opportunity. I don't believe [the current requirements] references BIM, as such, in there, but I think there is absolutely, as BIM involves. And I mentioned that BIM used to be a big keyword couple of years ago and now it's more about digital. Because BIM is only one aspect of the digital strategy. But I think there is a big place to weave in health and safety in design in the, yeah, in the project's digital strategy. It's about design and planning and ensuring that the appropriate risk mitigation processes around, like reviews, safety in design reviews, is a big part of it within the design and planning process undertaken and captured. So, you can do a review, but you need evidence and you need to back it up and you need to follow it up, that it follows a certain framework." – Interviewee 8, Architecture and Urban Design Manager, Private Client (Designer)*

Theme Group 2 – Supply chain best practice

Theme group 2 focuses on best practices that cut across the entire supply chain, including supply chain tendering. Tendering proficiency has been discussed extensively, and the interview data highlights the necessity of integrating BIM for WHS management in the tendering process, in particular, the use of BIM to evaluate WHS risks associated with the tender proposals.

A complex and recurring issue during tendering is the cost that is seen by some to be associated with BIM. Almost all interviewees considered cost as the main barrier for integrating BIM for WHS management in tendering.

> *"It does raise an interesting dilemma for us, I guess on the tendering part of this, where we have a particular cost structure in the company. We run expensive machines that can handle the software. We have expensive humans that can do the work. And it's a — definitely a factor of our overhead costs. And at the end of the day, that is the only reason anyone's doing any of this. Is, yeah, how we have reports to issue to our bosses of project profitability, and the builders have budgets to hit. And when we factor in the cost of running these projects and doing what we consider to be doing it the right way, by doing this level of analysis and going through it so it happens correctly, it happens efficiently and it happens safely." – Interviewee 1, Project Manager, Façade Subcontractor*

For clients, one best practice could involve requesting all tenderers that BIM for WHS integration be incorporated in the pricing at tender. This sends a clear signal to tenderers that BIM for WHS management is a priority for the client while also levelling the playing field:

> *"I think it would be an extension of where I was just going. Integrating the two of them, one for tendering purposes so that everyone's on the same page of what the expectation is. That way we don't get caught in a position where we might be pricing something higher than our competitors because we're expecting to do a level of analysis and modelling that others aren't. So that was certainly evening the playing field from a competitive point of view." - Interviewee 1, Project Manager, Façade Subcontractor*

Another set of best practices involves collaborative practice for BIM-WHS integration. Early involvement of contractors, suppliers and other stakeholders in the project planning and decision-making stages is considered an important strategy to improve WHS integration in BIM. In Case Study 1, the Façade Subcontractor was involved very early and for an extended period of time in developing the design and had input to constructability, manufacturing and transport, finishing, assembly in architectural design to ensure WHS outcomes. In Case Study 3, the Private Client (Contractor) was also brought in under an ECI arrangement. Design for safety was discussed at the start of the project and involved clinical architects, the Private Client (Contractor), other contractors and medical staff. Design for safety is supported when architects join discussions about safety on site. There are opportunities to improve WHS by sharing models for safety with the structural consultants (Interviewee 11, a BIM Manager at the Architectural Consulting Firm). Interviewee 9, a Health and Safety Inspector at the UK Work Health and Safety Regulatory Agency, likewise pointed out that clients should listen to their operational staff to benefit them, not just the contractors. Finally, Interviewee 1, a Project Manager at the Façade Subcontractor, recommended that the use of BIM for WHS management be extended to other stakeholders, like less informed builders:

> *"And, like you guys are obviously talking to the tier 1 builders in most cases, who, of course do this the best, [the Private Client (Developer)], the [other tier 1 builder], they're implementing their WHS requirements, by far the best out of everyone, but if you go down a couple of tiers or get into the residential game, it's very, very different kettle of fish. Both in use of BIM and WHS compliance. So maybe that's an opportunity, as well, is to try and extend the usage of these systems down the line as well. Because [the Private Client (Developer)] is the absolute top of the game, doing it better than everyone. There's a definitely an opportunity to hit a broader market and help more by helping some of the lower end builders." – Interviewee 1, Project Manager, Façade Subcontractor*

Collaboration is supported not just by early involvement but also by data-sharing. Another theme underpinning Best Practice is the use of a common data environment. At the Government Client (Transport), a universal data schema is used, and a project schema is created for each project. The project schema involves project data building blocks that act as standardised labels and are applied to all project deliverables:

> *"So how you code the title blocks in your drawings or the line types in your drawings. How you code your BIM objects. How you code the scheduling activities and everything else, that is using this universal language that we call the project data building blocks. At the beginning of a project, before we go out to tender, when we're setting up our procurement documents, we set up what we call project data schemas. And so, this is how we're going to code everything and here's how the coding is going to be applied to all deliverables." - Interviewee 15, Director, Government Client (Transport)*

Although integration of BIM for WHS management in tendering is considered necessary by many interviewees as a way to improve WHS performance, the interviews revealed a gap in practice in the tendering process. The best practice examples, such as factoring the cost of WHS integration

in BIM in tendering, using a common data environment, and supply chain collaboration, may catalyse the WHS integration in BIM.

Theme Group 3 – Best practice on site

Previous theme groups have focused on matters related to the areas of Client Leadership, Tendering Proficiency and Supply Chain Monitoring. The third theme group focuses on exemplars of BIM for WHS management on-site, or best practices with respect to BIM for site safety.

One such practice is BIM facilitated site safety communications. In Case Study 1, BIM was used for day-to-day communications on WHS issues, work sequencing, scenario planning, crane safety planning, and parameter checking.

Interviewee 2, a Digital Engineering Manager at Private Client (Designer), also highlighted that BIM can be a tool that excites WHS experts as it can enhance work coordination and risk management communications on site:

> *"Videos tell a thousand words. If you play a video of what you are going to do, or if you show an animation of what the building is going to look like in the end, the workforce are captured by it, rather than reading a piece of paper. The visualisation of work procedures alone, helps me and the team in risk management, coordination of trades, coordination of exclusion zones, which are a key control for the construction industry. If we have a visual model and the model tells us what it looks like, that is, I'm a huge fan of even just the displaying of that to the workforce, it gets them thinking more." – Interviewee 6, EHS Manager, Private Client (Contractor)*

> *"So obviously we use the BIM model here, we use it to communicate to our construction workers what they're actually building. We get more positive feedback from the video display than any other thing." – Interviewee 7, EHS Manager, Private Client (Contractor)*

Visualisation of a nonstandard design and build is a key risk management tool, and a 3D demonstration may help stakeholders understand the construction process, including key WHS issues.

> *"It's not something replicated like high-rise apartments, there's a level of duplication there, there's always design challenges. We had our warning that there was exposure to fallen materials, exposure to fallen persons, interface with the public. What can we do to eliminate the downside risk by eliminating that risk in the design and the planning of the project? The technology enabled us to visualise, basically where every nut and bolt and bracket was going to fit in." – Interviewee 7, EHS Manager, Private Client (Contractor)*

Interviewees also recognised that trends in computer modelling raise opportunities for better integration of WHS management in BIM. For example, Immersive Reality has considerable potential to improve WHS understanding on-site.

> *"There's currently, [the Private Client (Developer)] have in their head office a visual experience room, where they put a headset on and you can walk around the job in digital space. Whether it's a headset or holographic type technology that will allow*

people to be on the job, working on the job and see, for example if we're back looking at this slide that I have here, you be standing at the base of a building, about to install a staircase and be able to see where that staircase is going to go. And if there's something in the way that's going to clash. Maybe there's a scaffold around it. To be able to take the model and to put into reality rather than having to go to a separate area that has nothing to do with, you know, it's really just giving you a means of stepping into the model and a bit more of a tangible sense, the current technology. I can see a big advantage to that." – Interviewee 1, Project Manager, Façade Subcontractor

Case Study 1 also used BIM for site safety planning, as discussed in the Level 1 analysis of Interviewee 1; BIM was extensively used for scenario planning, risk assessment, crane safety, temporary works, site layout, parameter checking, monitoring and compliance, prefabrication, training and education.

"But this is a big thing in the industry, is people getting crane set-ups wrong, which causes loads to fall or cranes to become unstable. So, by being able to put all that information into the model and accurately check where we can fit the crane up, we can get it right in the first place which alleviates dismantling. Arriving on site, finding out it doesn't work, having to pack everything up, send it away. Leads to program pressure, waste of money; all of these things have tangible impacts on WHS." – Interviewee 1, Project Manager, Façade Subcontractor

"Having this kind of modelling facilitates you to run different scenarios and consider how you're going to do each element, break it down into different areas. Analyse one thought, decide whether it's the right way or not or go back and go another way." - Interviewee 1, Project Manager, Façade Subcontractor

"It's probably not simulation in that we analyse what could happen. It's more parameter checking. So, we can identify the most ideal position to set our machines up in. And then digitally check the length to where we're going to try and lift up a façade module for example. So, we can look at — I'll go back to this model. So, we might determine that we can set up a crane here. We can then check, in the model, the distance to this façade model here. And we can determine exactly whether or not the crane, at that length, at that angle, has the capacity to do that work." - Interviewee 1, Project Manager, Façade Subcontractor

Discussion and Implications for the Decision Framework

The three theme groups and the eight themes under best practice have implications for Component 1b of the emerging Decision Framework. Component 1b aims to provide a matrix of examples of WHS integration in BIM, categorised according to the six knowledge domains, i.e., Scenario planning, Requirement briefing, Risk assessment, Education and training, Monitoring and surveillance, and Reporting and analysis. Examples of Best Practice highlight the role of the client in shaping the integration of BIM and WHS management. Through government and industry collaboration on best practice for safety in design, client leadership and organisation, assessment, and project BIM and WHS alignment, clients' requirements and expectations on BIM and WHS integration can be reflected, mapped, and embedded. Supply chain best practice emphasises the role of information sharing and collaboration between various stakeholders along the supply chain to support WHS integration in BIM. Innovations in the supply chain tendering model, information sharing and supply chain collaboration will help WHS risks to be identified and managed from the

source. Best practice on-site provides further solid examples of how BIM can be used to improve WHS management on-site, including examples across the six knowledge domains.

Framework Development

The Recommendation areas and the propositions have informed the development of the Decision Framework, which comprises two key components. (Figure 7). Each of the components will have two subcomponents, specifying the tools that make up the Decision Framework. The tools, informed by the findings of Phases 1 and 2 of this study, are described in greater detail below and can be visualised in Figures 9-16.

Figure 7: Relationship between Themes, Decision Framework and Outcomes.

The components and subcomponents are the results of an iterative process, particularly informed by the document analysis and the interviews of Phase 2. Importantly, the Decision Framework aligns with the recently released NSW Infrastructure Data Management Framework (NSW Government, 2020), particularly in relation to terminology, agency information requirements, and the types of models and their interrelationships (Figure 8). The IDMF further aligns with the ISO 19650, making the content of the Decision Framework not only relevant to the NSW context but also relevant internationally.

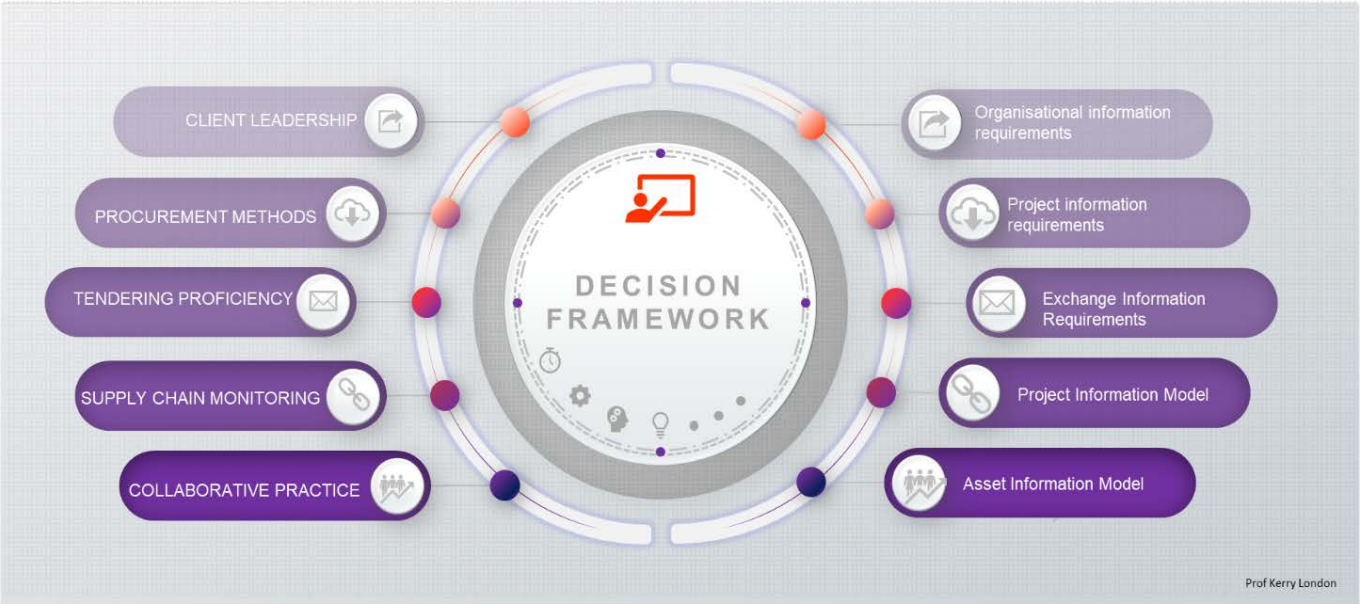

Figure 8: Relationship between recommendation areas and information requirements.

The first component focusses on assisting clients to show leadership and how to develop the various information requirements. The second component is more focused and will assist clients in developing a strategic PIR (SPIR) to inform future project-specific PIR, EIR and AIR, which subsequently drive the development of the PIM and AIM (Figure 9).

Component 1: Guide for Developing Information Requirements

Component 1a: Guide to Developing Information Requirements with Client Self-Assessment Matrix

Client Leadership findings highlight the need to strengthen client capabilities in terms of WHS commitment, processes, technology, collaboration, compliance and, most importantly for this research, the creation of a collaborative culture that is built on accurate, timely and integrated WHS information. Client Leadership findings will inform the development of the Guide to Developing Information Requirements, which will include principles supporting leaders working collaboratively to create quality information, including robust information resources (i.e., OIR, AIR, PIR and EIR).

As indicated in the book chapter in the appendix, there has been a plethora of studies highlighting pathways to BIM adoption and the added complexity in the adoption of the integration of BIM and WHS management perhaps further exacerbates the challenge. Alternatively, the opportunity afforded through this study to improve adoption through a focus on one of the most critical ultimate objectives of a project, a safe work environment, offers a more specific and concrete approach to adoption. However, as a priority, the first step towards adoption is client commitment to creating the enabling environment. The sole purpose of the Decision Framework is to inform and guide after the decision is made and is not primarily to persuade clients to adopt a BIM WHS management system; however, the research has indicated that with careful and judicial design, the Decision Framework may be an instrument of persuasion within various other measures.

The Guide to Developing Information Requirements will have two subcomponents. The first component 1a: a guide for clients and other leaders associated with construction projects towards developing information requirements (refer to Figure 9). The Guide shall have three key elements, including background and concepts for developing organisation, asset, project and exchange information requirements. The Guide to Developing Information Requirements will be underpinned by specific principles that emerged from the research, which will sensitise clients to ongoing debates, for example, whether to pursue a vision where data is rich or purposeful and inform clients' choices among these alternatives. Discussions on these high-level principles will be supported by concrete explanations and examples clarifying how these link to one another. The commitment to developing the suite of information requirements is underpinned by an understanding of the interrelationship between the four elements. To illustrate this, a particular focus on a WHS exemplar from one of the case studies will be utilised, coupled with an example of an organisational information requirement, in particular the façade planning, design and construction.

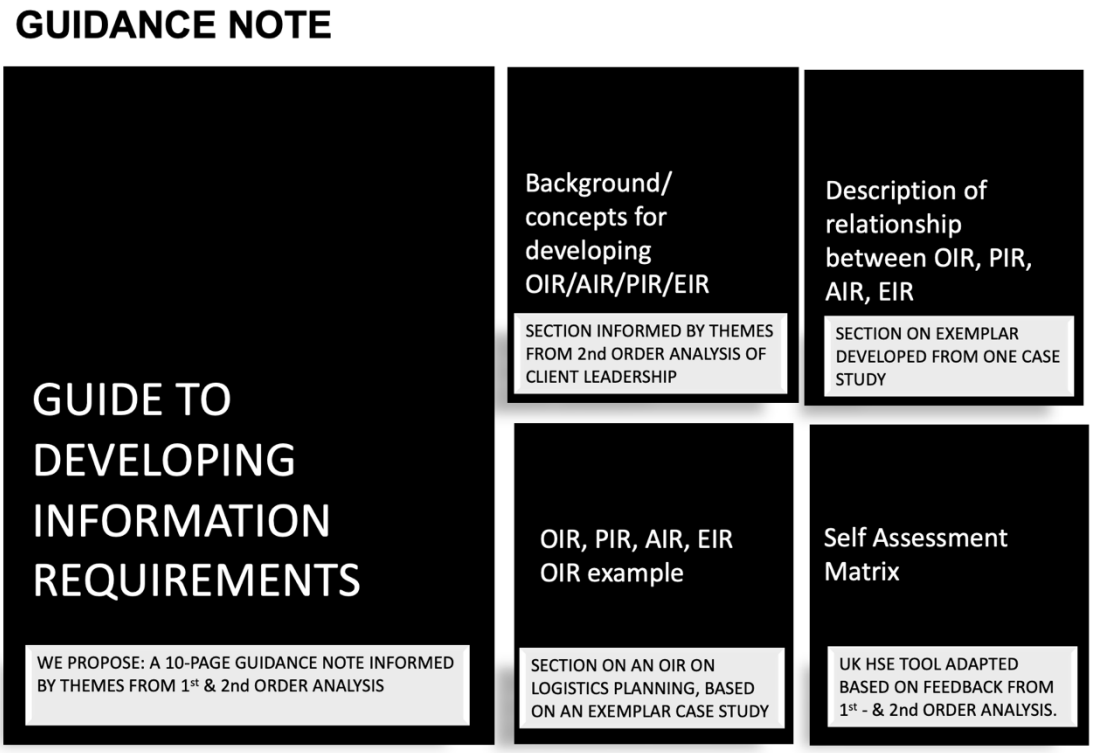

Figure 9: Component 1a: Guide to Developing Information Requirements including the Self-Assessment Matrix.

The empirical study has further reinforced our knowledge about clients; there is a body of knowledge that can be drawn upon in relation to clients; however, it is not extensive. Clients are diverse in capability level and are not a homogeneous organisation; that is, within client organisations, the people who work on projects are not all the same. We had three case studies that had very experienced clients, and yet each had different approaches, expertise and mindset

and attitudes and thus commitment to BIM and WHS separately and integrated. To help clients identify the level at which they are operating, the guide will include a BIM-WHS Client Self-Assessment Matrix. The Self-Assessment Matrix will be an adaptation of an existing example developed by the BIM4H&S Working Group (refer to Figures 10-12). Presentation of information is an important and necessary aspect of a Decision Framework; therefore, both visual and written communication approaches will be undertaken.

While the original version assesses client maturity through ten plain language questions developed from PAS 1192-6, the proposed version will have questions based on empirical findings. The interviews with clients clearly indicated that redrafting is required, and a focus on simplification is needed. The Self-Assessment Matrix will also have questions framed around domains that have been identified as important based on analysis. For example, one suggestion that emerged in feedback sessions on the matrix was to include a question on the willingness of clients to have contractors interrogate designs for constructability. Taken collectively, the questions will cover all four areas identified as critical elements for BIM for WHS management under Client Leadership: WHS processes, data, technology and collaboration and compliance. Questions will also be developed and framed according to three phases, comprising 1) Vision of the Value and Use of Data; 2) Requirements WHS Management and 3) Digital Requirements for WHS Management for Planning, Design, Construction and Operation. The general three-fold approach will be to organise thinking along a journey for organisations to self-assess and understand their own data environment more broadly; how important WHS data management is for their organisation, and lastly, how a BIM model would contribute to the data management for their projects. Three levels of maturity will be redefined based on research findings. Instead of "First Steps", "Keeping up with the pack", and "Taking the Lead", the proposed maturity matrix will be built on a hierarchy with three tiers:

- LEVEL 1: Base standard, regulatory compliance, moderate adopters
- LEVEL 2: Best practice, innovation early adopters, exploratory, base standard well accomplished
- LEVEL 3: Market leaders, innovation initiators, experimental, exceptional adopters

As much as possible, based upon the analysis and findings, the matrix will include examples from practice to highlight various aspects. Phase 3 will involve drafting the tools in more detail.

SELF ASSESSMENT MATRIX: EXAMPLE FROM UK HSE

CURRENT TOOL HAS TEN PLAIN LANGUAGE QUESTIONS; TO BE ADAPTED

CURRENT TOOL HAS THREE LEVELS OF MATURITY; TO BE DEVELOPED BASED ON EMPIRICAL FINDINGS

SAMPLE PRACTICES UNDER EACH LEVEL; TO BE DEVELOPED BASED ON EMPIRICAL FINDINGS

Microsoft PowerPoint

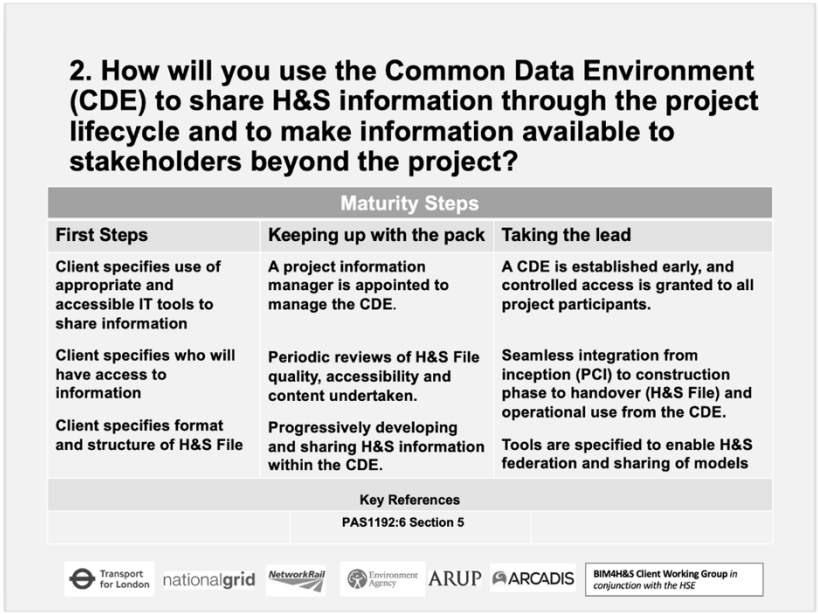

Figure 10: Self-Assessment Matrix Principles for Adaptation of exemplar from the BIM4H&S Working Group. (Source: Marshall 2018)

PROPOSED ADAPTED MATURITY MATRIX

WE PROPOSE: REVISED QUESTIONS AND LANGUAGE BASED ON FIRST LEVEL ANALYSIS.

QUESTIONS WILL BE IN FOUR CATEGORIES:

WHS process
Data
Technology
Collaboration and compliance strategies

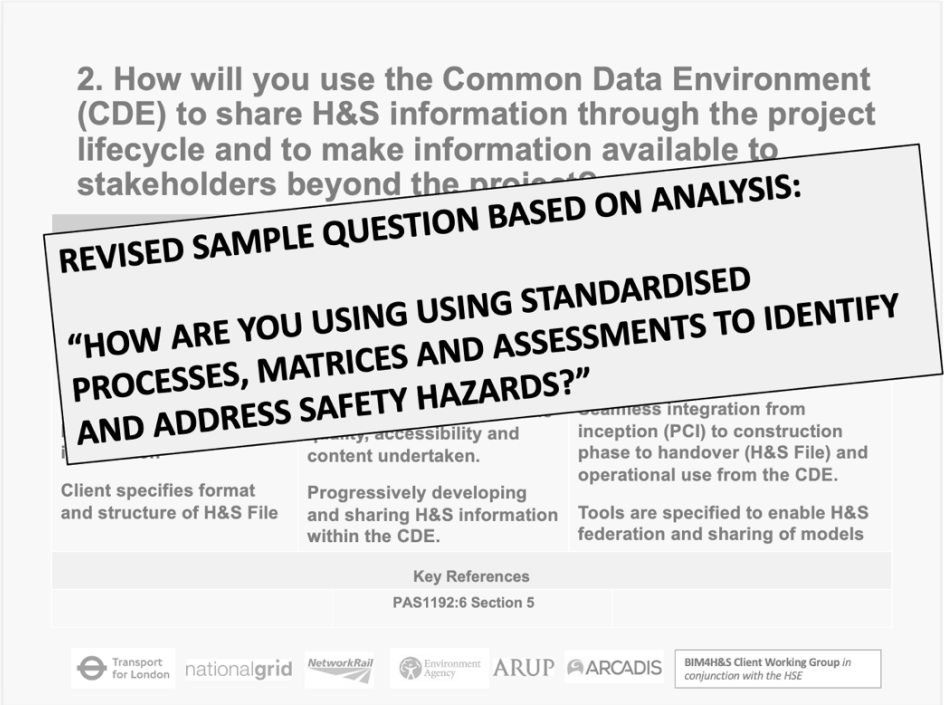

Figure 11: Self-Assessment Matrix Ten Plain Language Statements Categorisation and Revision.

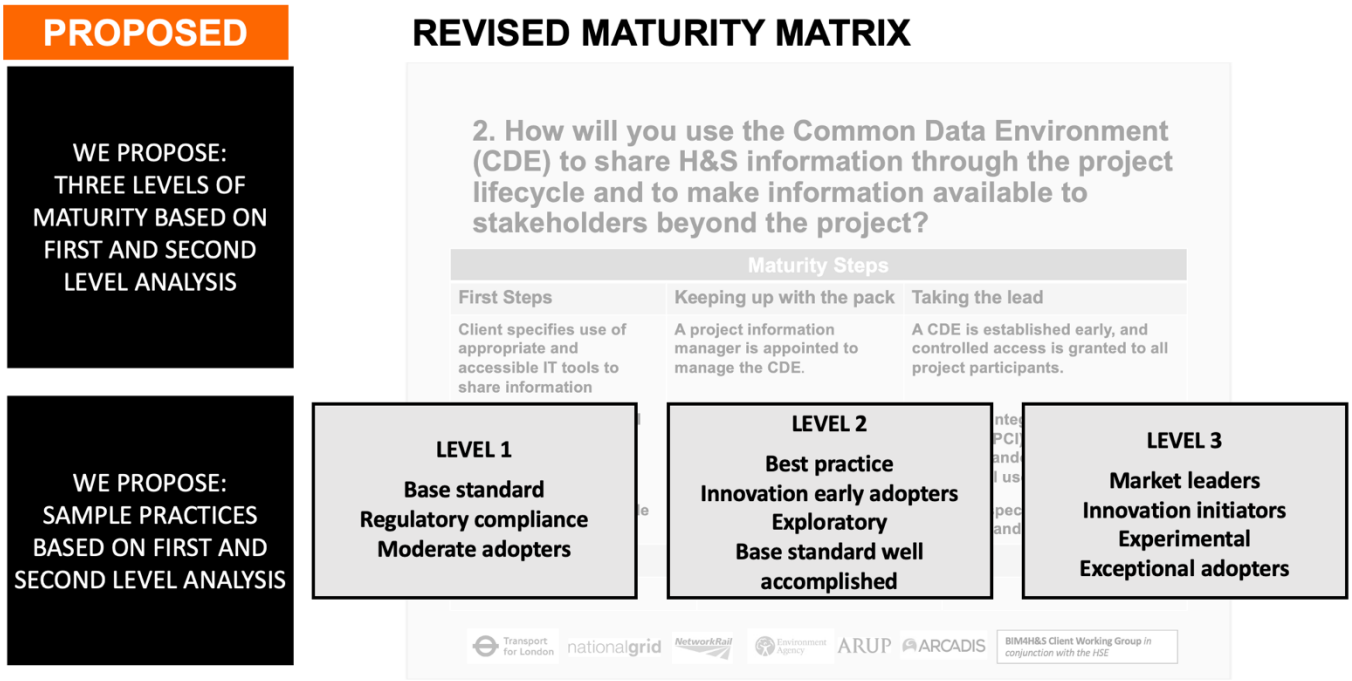

Figure 12: Self-Assessment Matrix Revised Level Descriptors.

Component 1b of the Decision Framework: Best Practice Matrix Mapped to WHS Knowledge Domains

Best Practice Level-2 findings, as well as Level-1 findings, show a combination of actual, emerging and potential examples of BIM adoption for WHS management across the six WHS Knowledge Domains. Actual compelling examples of BIM and WHS integration have been found for scenario planning, risk assessment and requirements briefing. Examples of potential use are also emerging in the other areas: education and training, monitoring and surveillance, and reporting and analysis. These findings will be incorporated into a comprehensive matrix through mini case studies and quotes from thought leaders, using the six Knowledge Domains as a scaffold (Figure 13). While the matrix will provide specificity and examples of BIM and WHS management integration, findings suggest that examples dealing with the use of 4D-BIM and BIM work sequencing and visualisation capabilities for high-risk activities and high-risk trades are of particular importance.

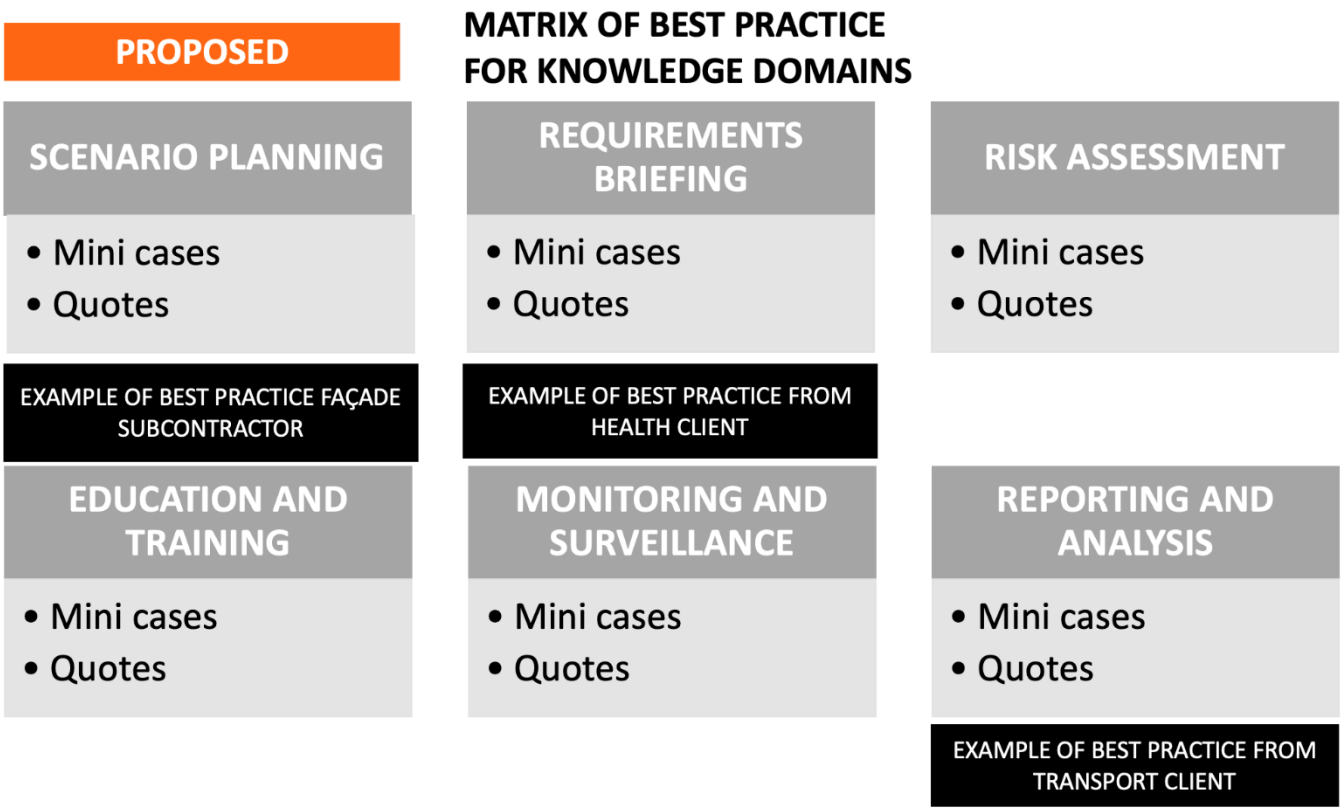

Figure 13: Best Practise Matrix with examples mapped to the six Knowledge Domains of BIM use for WHS management.

Component 2: Strategic Project Information Requirements (SPIR)

The second component aims to support clients and leaders in developing PIRs. A strategic PIR, or SPIR, is required to assure consideration is given to planning, design, construction and operation phases with respect to WHS data being captured and structured in a consistent, secure, reusable and accurate way that is integrated and standardised. The data is an asset that, if interoperable and accessible, can be used to analyse and develop better business decisions for government physical infrastructure to support investment decisions. NSW government agencies are required to confirm that state facilities and infrastructure are designed and constructed safely and to ensure a safe working environment for occupants. Secondly, clients are required to ensure that WHS management systems comply with legal and compliance requirements.

The SPIR will include two subcomponents: 2a: a guide note on best practice tendering, procurement and supply chain monitoring (Figure 14) and 2b: an example of general WHS requirements for tendering (Figure 15), and This will be an adaptation of an existing BIM WHS General Conditions template developed by the BIM4H&S Working Group.

Component 2a of the Decision Framework: Guide to Procurement Models and Tendering

Tendering proficiency findings, combined with supply chain monitoring findings, will provide guidance on robust tendering processes and thus provide the foundations for Component 2a: Guide to Procurement Models and Tendering.

The Tendering Proficiency findings highlight the need for clients to identify, specify, justify and communicate information requirements in ways that capture their WHS management priorities well before projects begin. Establishing WHS management objectives and explicitly prioritising these objectives will help clients establish the enabling environment for a BIM WHS agenda set by their priorities and avoid the persistent challenge of having the main contractors set the BIM agenda, often in ways that obscure WHS. In developing the Guide for Procurement and Tendering, an exemplar case study will inform the guideline, along with a discussion on how BIM Execution Plans can be requested and evaluated in response to non-prescriptive tender requirements. The guideline will also include an overview of prescriptive approaches available to clients with respect to tendering requirements (i.e., explicit vs. implicit, specific vs. broad). Component 2b will provide a level of detail that would guide project scope and thus provide more prescription in developing tendering criteria. While these alternatives are meant to provide choice, the guide will also indicate that findings generally point to the advantages of clear, simple and consistent tendering requirements. A discussion on the debates related to different procurement models will be included, along with examples of one model. The final element of the Guide for Procurement and Tendering is a guideline for supply chain monitoring. Supply chain monitoring has been noted as a challenging area for smaller subcontractors. As such, vignettes showing best practices for small or medium enterprises will be provided as well.

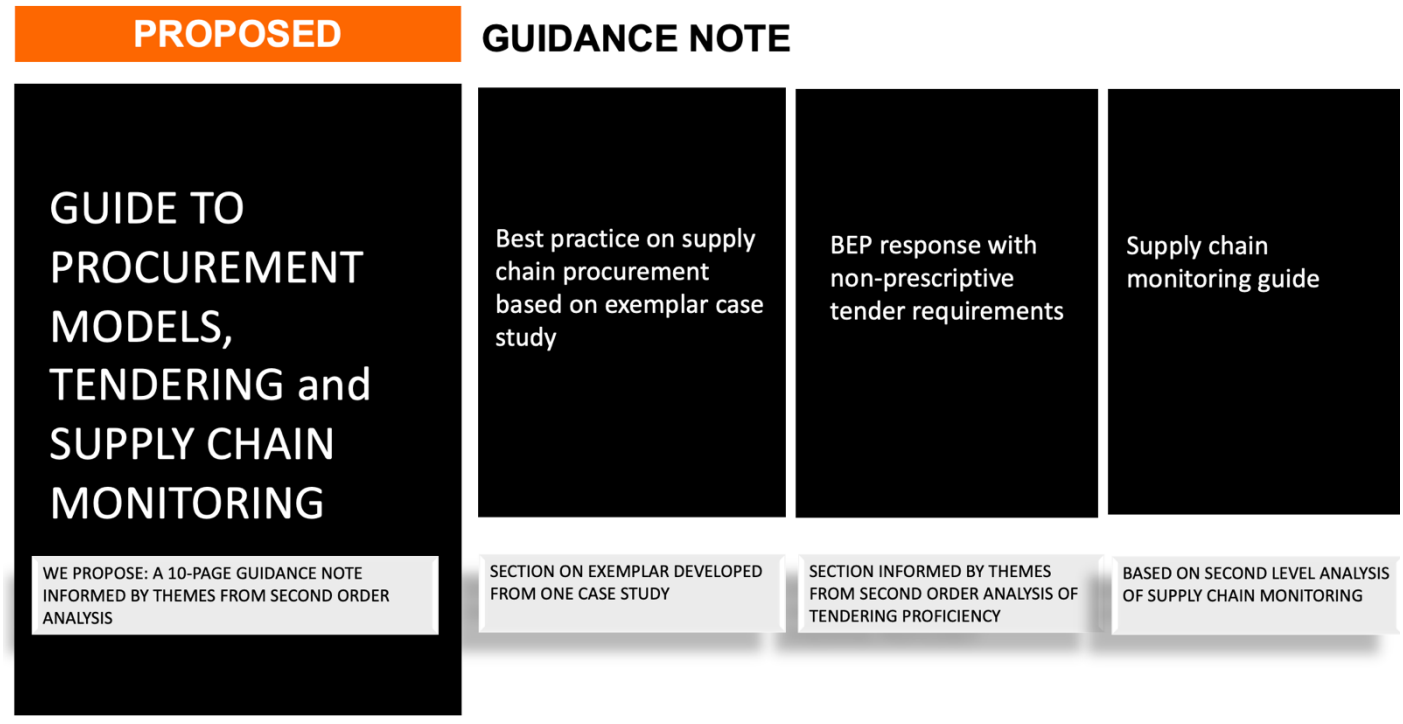

Figure 14: Component 2a: Guide Note Procurement Models, Tendering and Supply chain monitoring

Component 2b of the Decision Framework: PIR Template for BIM for WHS General Conditions

Findings suggest that an important information resource that captures clients' BIM for WHS management goals is the PIR. The PIR has moved into a key position since the publication of the

ISO 19650 series. The BIM4H&S Working Group argues that "PIR's should form a key part of the Clients Brief, setting out the Information Requirements for a project to ensure that risks are correctly treated through planning, managing, monitoring and co-ordination." Component 2(b) of the Decision Framework is thus a PIR template, based on a version that is currently under development by the BIM4H&S Working Group but adopted based on empirical findings. While the BIM4H&S version lists a total of 19 general conditions, Component 2b of the proposed Decision Framework will present a revised and categorised list of general conditions. The 19 general conditions will be adapted, refined and grouped according to the following categories: client information, roles and responsibilities, risk identification, data digitisation, information protocols and validation. Further refinement may be required with these areas with the SafeWork NSW/SafeWork Australia's priority high risk harms to ensure contextualisation for the NSW construction industry.

Again, findings suggest that the value of 4D-BIM, as well as 5D and possibly 6D, must be highlighted, particularly in relation to high-risk areas.

The current version of the general conditions template also lists specific conditions for selected risk areas (e.g., asbestos, steel design, fire safety) relevant to the UK context. The next phase of the research will thus explore the possibility of developing a set of specific conditions for priority risk areas, such as logistics planning and façade prefabrication, given the extensive empirical data gathered on these topics. A potential scenario will be defined (e.g., installation of façade components in a high-rise), and a list of specific conditions will be identified. Other specific conditions in related areas like cranage, working at heights, and temporary structures could also be developed as part of the façade installation scenario. Table 13 provides an explanation of how the four Phase 1 Recommendation areas and the propositions put forward have been mapped to a summary of the Phase 2 analysis.

Table 13: Explanation of Phase 1 Recommendations and Propositions Mapped to Analysis Summary.

Topic area	Proposition	Discussion
Client Leadership	*Establishing WHS management requirements prior to tendering as a priority*	*The findings of the empirical analysis clearly indicated that clients need to be much clearer in defining information requirements.*
	Developing clear alignment to six knowledge domains of WHS management: scenario planning, requirement briefing, risk assessment, education and training, monitoring/surveillance and reporting and analysis.	*The six Knowledge Domains were validated with some minor refinements. Very good examples were identified in three Knowledge domains, including scenario planning, risk assessment and requirement briefing. The Australian exemplars can be used in the Decision-making Framework. The international exemplars identified in the desktop review and interviews with international industry participants in Phase 1 will be sourced to complement these exemplars for the other three Knowledge Domains.*
	Ensuring client expectations on BIM for WHS management are clearly developed prior to tendering to enable client leadership	*Similar to establishing client information requirements, the expectation of clients on how they envisage the BIM model to be used in relation to WHS management systems is critical. There are two approaches to developing information requirements that are on a continuum between data-rich vs data purposeful information requirement development. The key purpose of how the information is to be used is critical not only for the client but to maintain authenticity and credibility as clients leading the process. The Self-Assessment Matrix once adapted for the Australian context with a particular focus on language and terminology, will be a useful tool in raising this awareness within client organisations.*
	Developing Client Information Expectations/Requirements and Responsibility Matrices for BIM for WHS management	*Past approaches to guidelines for BIM adoption has typically focussed on generic advice. This study has taken a very different approach and is a novel approach. There is still some resistance to this approach of specificity. It is still maintained that this innovative approach shall lead the industry and, in particular, clients in BIM WHS integration and adoption. Once the decision is made to develop a model, then a more detailed approach is needed, and this study and the tools provide that specificity. The industry does not need any more generic guidelines.*
Best practice	*Identifying exemplars in Australian major public and private sector client-led projects*	*Exemplars were identified in the empirical study. The three case studies provide detail for the guide notes, including vignette case studies as well as quotations from industry participants and thought leaders. The results indicate that there were three Knowledge Domains with exemplars and Knowledge Domains with moderate examples or unrealised potential. For the Guide note, we will need to supplement the Knowledge Domains with information obtained from Phase 1 international exemplars.*
	Identifying key decision areas in exemplars with respect to Project Information Integration Requirements	*The analysis of the exemplars and the UK example provide PIR examples which will be used as a template for adaptation of the logistics exemplar (the façade subcontractor case study).*

Tendering proficiency	*Ensuring tender criteria and evaluation are transparent and authentic with respect to BIM for WHS management*	*The findings in relation to pre-tendering included a clear definition of outcomes/priorities and requirements, consulting early to identify risks and opportunities for the project, identification of contractor capability and explicit communication of expectations and how the information shall be utilised during all project phases. Such that these can be captured in the PIRs. The PIRs must also achieve a project-appropriate balance between general and specific requirements and consider the implications for tendering and project delivery.*
	Framing BIM for WHS management outcomes and strategies across different procurement strategies	*There is a strongly divided opinion on which procurement method is most conducive to BIM WHS management integration adoption. The PIR shall reflect the ongoing debate. However, what is clear is that clients need to be clear in their expectations and have the capability to follow through pre-tendering, tender evaluation and post tending compliance for enhanced credibility and authenticity.*
	Analysing and assuring supply chain capacity to deliver as well as appropriate supply chain monitoring during other project phases	*Different supply chains have different levels of capacity to provide information into models for WHS. The façade subcontractors have an exemplary capacity and are excellent integrators. This will provide an exemplar on logistics planning, site construction methodology, risk analysis and scenario planning and shall be utilised in the decision-making framework. Other subcontractors have emerging BIM capabilities and certainly do understand the benefit of early (sub) contractor involvement in relation to WHS management (e.g. cranes)*
Supply chain monitoring	*Identifying key areas of capacity building across all levels of stakeholders for implementing BIM for WHS management in Australia*	*Capacity building is required in both cultural, technical and accountability areas. There is a need to provide insights to the client of the benefit of utilising BIM technology, data and an online collaborative platform for sharing, updating and expanding of data and data analysis to support WHS, and we shall have to source an international exemplar to provide depth to the guide note. The examples in the Knowledge Domain section of Component 1b should be supplemented by this section.*
	Monitoring the main contractor to ensure that the supply chain is delivering to the original expectations	*There was an example of supply chain tendering and monitoring of the model from the contractor down through the subcontractor supply chain. There was no example from the case studies where the contractor was monitored for WHS management nor BIM WHS management monitoring. An acknowledgement of the resources that may be required for accommodating BIM WHS when setting such expectations at the client to contractor level so that if data is inputted into the model, there is a methodology for risk analysis, scenario planning, monitoring and model updating as new data is created during construction. This does not have to be an exhaustive and complicated process as tagging is already done during design and construction reviews; it simply requires the concerted, systematic approach of involving both regular connections between BIM and WHS experts during phases.*

The following tables (Table 14 and 15) map how each section of the results shall be incorporated into the tools that underpin the Decision Framework.

Table 14: Component 1 mapped to Data Analysis and Results.

Element	Analysis
Defined organisation's vision of the value and use of Infrastructure Data	*1st order analysis experiences client interviews* *2nd order analysis client leadership* *Links to Data standards/frameworks (from lit review)* *UK guideline analysis and reframing* *Outcome: guided note with quotes from interviews/standards and documents*
Development of organisations' requirements with respect to six knowledge domains of WHS management: scenario planning, requirement briefing, risk assessment, education and training, monitoring/surveillance and reporting and analysis	*1st order analysis experiences all interviews; code according to the six knowledge domains* *1st order analysis WHS interview* *2nd order analysis best practice* *Exemplars from desktop review* *Links to WHS standards* *Outcome: matrix across six domains at three levels 1) base standard/regulatory compliance, 2) Exploratory innovation/best practice, and 3) Leaders innovation*
Identification of organisations' expectations on BIM for WHS management, synthesising element 1 and 2	*HSE Client self-assessment matrix analysis and restructuring/refining* *1st order analysis challenges in integrating BIM and WHS management and Client interviews on self-assessment matrix* *2nd order analysis client leadership* *PAS/ISO guideline analysis and TfNSW – DE Plan template* *Outcome: Self-Assessment Matrix across three levels with the addition of quotes from interviews*

Table 15: Component 2 mapped to Data Analysis and Results.

Element	Analysis
Exemplar template for General Conditions integrating BIM and WHS Management	*1st order analysis HSE interview, Client interviews and 1st order analysis IAG*
BIM for WHS management outcomes and strategies across different procurement strategies	*1st order analysis of all interviews experiences and outcomes and 2nd order analysis of Best practice exemplar analysis mapped to different procurement strategies of case study projects* *Outcome: discussion on mapping procurement and tendering to purpose*
Description of tender criteria and evaluation with respect to BIM for WHS management	*1st order analysis thematic analysis confirming tender criteria and evaluation; Document analysis and 2nd order analysis tender proficiency*
Supply chain capacity analysis including expectations and monitoring during design, construction and in use	*1st order analysis of all interviews: Contractor and subcontractors experiences and BIM Execution Plans on exemplar projects; Project document analysis (flowcharts) and 2nd order analysis supply chain monitoring on all interviews* *Analysis of project documents and 1st order analysis, e.g. BIM Execution Plans from 3 case studies, indicates capability with BIM to apply to WHS management and capability of where BIM is currently being applied to WHS management; Private Client (Developer) down the supply chain requirements. Outcome: Responsibility Accountability consultation information (RACI) template with guide notes*

Discussion and Recommendations

The Recommendation of Phase 1 was that the Decision Framework would explore four drivers with respect to the adoption of BIM for WHS management: Client Leadership, Tendering Proficiency, Supply Chain Monitoring and Best Practice.

The aim of Phase 2 was to validate these recommended areas and use them as a platform for tool-building. The process underpinning Phase 2 was a multi-stage analysis of qualitative data that led to the development of the proposed Decision Framework, comprising two main components and four sub-components. This report concludes with a summary of the findings from key stages of the analysis, provides recommendations for the Decision Framework, and outlines the implications of this study's findings for Australian practice, international practice and theory-building.

Key findings from Level-1 analysis

Findings from the Level-1 analysis were summarised in Table 4, which presents the six Knowledge Domains and how selected interview findings map to these domains. Exemplars of BIM for WHS management were identified in three of the six Knowledge Domains, namely scenario planning, risk assessment and requirement briefing. BIM adoption for WHS management appear to remain largely underexplored in the other three Knowledge Domains; education and training, monitoring and surveillance, and reporting and analysis. Specifically, BIM is not used, at least not in a formal way, to educate and train supply chain actors about better WHS management. A promising trend is that BIM is being increasingly used as a communication device and that novel practices are used to engage trade subcontractors that are normally detached from the model. An example is the use of television screens on-site during weekly WHS toolbox meetings to show model-based work sequences. This approach has proven quite valuable for trade subcontractors such as painters, who normally have "nothing to do" with the model. Initiatives of this kind can certainly be understood as informal, site-based training that gradually sensitises workers to the value of BIM for WHS management. However, none of the case studies used BIM for more formal educational initiatives to strengthen WHS management skills and competencies. As such, this is a promising area for further exploration.

The use of BIM for monitoring and surveillance of WHS management also did not emerge, although one case study did show how a model could strengthen compliance. In Case Study 1, BIM-supported visualisations showing ideal work sequencing and scheduling appeared to strengthen compliance with safe work methods (e.g., alleviating the pressure to rush through work), but there were no clear examples of BIM-supported monitoring. Case Study 2 and 3 did not provide any examples either, although in Case Study 3, the potential to use dRofus for monitoring was mentioned, specifically through design reviews. The client "mandate[d] that we have to benchmark against the original brief at certain periods during the project," and the

Architectural Consulting Firm demonstrated compliance (or variations) with the brief using the database tool. For example, a quality tick-off process was carried out at the end of design development, and dRofus was used to produce schedules showing where design complied or departed from the original brief. This monitoring was, however, not extended to WHS. The lack of formal monitoring using BIM could also explain why no examples emerged of using BIM for formal Reporting across the three case studies.

The level-1 findings indicate the current state of BIM for WHS management in three real-live projects, all involving the Private Client (Developer), a multinational with a reputation for exemplary WHS management. An important point to note is that the Level 1 summary (Table 4) focuses on a select sample of interviews, so the descriptions presented, while informative, is necessarily partial. The Level-1 findings also provide grounding for Level-2 analysis, focusing on the four recommendation areas that, taken collectively, help define an aspirational state of BIM for WHS management.

Key findings from Level 2 analysis

The Level-2 findings led to the identification of clear lessons as well as areas that remain open for further exploration and debate across the four areas identified in Phase 1 as drivers of BIM adoption. For such open issues, the reader is sensitised to the debate and, when possible, provided with alternatives and guidelines for choosing among them.

Client Leadership

The theme groups discussed under Client Leadership suggest that four elements are critical to mature adoption of BIM for WHS management: 1) robust WHS processes, 2) acknowledgement of the centrality of data, 3) considered use of technology and 4) the mobilisation of formal and informal strategies to achieve collaboration and compliance across the supply chain. Using this analytical framework would suggest that each of the three clients examined in the case studies has a unique position of strength. The Private Client (Developer) had robust WHS processes (much of which was yet to be digitised); the Government Client (Transport) had a culture where "speaking data" was the norm, and the Government Client (Health) made use of a specialised data management technology, which imposed strict standards of compliance across the supply chain. Empirical data suggested that the ideal pathway involved moving from sound WHS management processes to defining data requirements and then identifying technologies for data management, an approach that seems suitable for the Private Client (Developer). However, conflicting findings indicate that there may be more than one valid pathway to maturity. A key area of exploration then would be how different clients might pursue different trajectories towards increased maturity BIM for WHS management. The Private Client (Developer) is strong in terms of WHS management processes; Government Client (Transport) is strong in data, and Government Client (Health) is strong in technology that promotes collaboration and compliance.

While the possibility of varied pathways is acknowledged, there are compelling reasons to explore data and information as a starting point for strengthening Client Leadership. New local standards, such as the IDMF and recent international standards, such as the ISO 19650, are reshaping the information landscape and foregrounding information requirements. The jargon is changing, with terms such as OIR, AIR, PIR and EIR becoming increasingly pervasive. Case Studies 2 and 3 illustrate the important point of focussing on data usage, data analysis and reporting, and data integration. In Case Study 3, the supply chain achieved significant levels of data integration through the Government Client (Health)'s mandating the use of dRofus. The initial decision to use the technology has now yielded an extensive resource of rich data, which are now ongoingly captured in specifications and templates mandated across the supply chain. While the data has not been explicitly linked to support WHS management goals, there is considerable potential. The empirical data suggests that unsafe designs are now automatically avoided because non-specified elements are simply not accepted by the system. Of course, one can argue that Case Study 3 had the technology (dRofus), not data, as a starting point, and it is acknowledged that the technology played a key role in making data standardised. Mandating a single technology across government clients may be unnecessarily restrictive. Furthermore, Case Study 2 suggests that universal data schemas can be developed without committing to a single technology. In this research, universal data is seen to be foundational for BIM for WHS management. Thus the Decision Framework will include tools that support this.

Tendering Proficiency

The Level-2 analysis showed that Tendering Proficiency emerges from Client Leadership, specifically in the client's ability to build a team and maintain it through broad and ongoing engagement as well as through sound communication strategies. The case studies show a number of clear lessons about what it means to be proficient in tendering. The ability of the client to identify, specify, justify and communicate clear requirements is essential. Such clarity helps clients avoid situations where contractors hijack client goals, direct client focus away from priority areas or provide contractors with too much leeway to pick their own requirements. A client that has committed to specifying WHS requirements during tendering will be prepared to manage tensions between WHS and other goals (i.e., cost, time, and quality) and to manage the complex negotiations that take place between individuals and organisations with different priorities. WHS-committed clients will be aware that while the current legislative landscape shifts the majority of the burden of WHS away from clients to the primary contractor, the client still has duties and will work to ensure that they and their contractors retain the initiative for pushing BIM for WHS management. A key strategy for articulating and maintaining this commitment during tender is by bringing WHS professionals "to the table" early, for example, by conducting three-way talks (involving the client, an information manager and a WHS manager) such that a preliminary hazard analysis can be conducted in preparation for a project, and by ensuring a WHS professional becomes part of the tender evaluation panel.

While some lessons learned from the case studies were clear and unequivocal, a number of areas remain open to exploration; any attempt to impose strict guidelines on these issues would be premature. An open issue that stands out is that of requirement specificity. It is counterproductive to define exactly how prescriptive or open-ended tendering requirements should be. Tendering requirements can rest on a range of continua: essential vs. desirable, explicated in the contract vs. implied; outcome-based vs. process-specific; client-controlled vs. supply chain innovation-driven. One guideline that can be offered is that when a requirement is seen to be essential, it is more productive to make this (a) explicit in the contract rather than implied and (b) more process-specific rather than outcome-based, in an environment that is (c) more client-controlled rather than open and exploratory. Such a guideline is consistent with earlier findings in Phase 1, where UK and Singapore national mandates on the use of BIM for public sector projects were implemented in very different ways because of cultural considerations. UK implementation was more outcome-based and more open to industry innovation, while Singapore's implementation was the opposite (London et al., 2020). In addition, the ability of the client to create client-controlled environments, explicate requirements and specify detailed processes will depend on the client's level of maturity. A self-assessment maturity matrix would be useful to determine this.

A second open-ended issue relates to models of procurement and whether higher levels of tendering proficiency with respect to BIM adoption means favouring specific procurement models over others. There is research that suggests that BIM is most productively mobilised under procurement models that are seen as more collaborative. Holzer (2018), for example, proposes that procurement models like "Design Only" and "Construct Only" are less productive because they lead to "lonely" (fragmented) use of BIM. Procurement models like "Public-Private Partnerships" are linked to mid-level collaboration, while alliances are seen to be high-level collaborations and are thus more "social" in terms of the use of BIM. If this analysis is correct, then by extension, BIM-supported WHS management, which should involve the collaboration of all supply chain participants, can best be achieved through alliances and models like "Construct Only" should be avoided.

Findings from this research, however, have deepened this debate. Case Study 3, for example, can be understood as a "Construct Only" arrangement, at least from the Private Client (Contractor)'s point of view, yet its potential for BIM for WHS management is significant. One reason is the robust underpinning of data integration across all stages of the project afforded by the use of dRofus, which was used by the Architectural Consulting Firm from the very beginning. The example confirms a finding in Phase 1 of the research, which indicated that there are strategies that can make traditional procurement highly productive for the use of BIM for WHS management. Early contractor involvement and integrated data developed from early stages appear to be two of these factors. Thus empirical data can support the view that the type of procurement model is not a decisive factor when it comes to the success of BIM for WHS management; what matters is that contracts are sufficiently developed to bring all participants on board to support WHS

management goals. The importance of contractual requirements is further discussed in the next section.

Supply Chain Monitoring

The Level 1 findings showed that BIM was not used extensively for monitoring WHS management, although its possibilities were emerging, particularly in Case Study 3, where dRofus was already being used to monitor the achievement of design milestones. The Level-2 findings provide more details as to how to maximise this potential. Again, findings show a mix of clear lessons and open-ended issues, the latter being matters for clients to consider and decide upon depending on their circumstances.

The themes on Supply Chain Monitoring emphasise the need to establish a culture for BIM-enabled WHS management, a digital culture where "the new normal" is to make WHS decisions with BIM as part of business as usual. The establishment and maintenance of such a culture presupposes the availability of supporting technical resources: an accessible (online) platform and assets (hardware, software, and devices) that enable the supply chain to engage with BIM. Ideally, the combined cultural and technological capabilities create an environment where all members of the supply chain develop and maintain accurate, up-to-date, verified and integrated data that can support an ecology of goals, including WHS objectives.

Creating and maintaining quality data require responsibility and accountability on the part of individual supply chain participants. A key lesson that emerged from the case study data is that such high levels of responsibility and accountability, for example, in terms of frequently and faithfully updating the common data environment, cannot be left to chance and are best achieved through contractual requirements. The contract, then, is seen to be the client's primary vehicle for specifying its expectations about supply chain participants' skills and competencies, about information requirements, ranging from the common data environment that must be maintained to the supply chain's commitment to WHS management beyond the construction stage. Drawing on the Phase 1 Technical Report, (London et al., 2020) the contract can specify requirements in the following areas (Table 16):

Table 16: Possible contractual requirements for Supply Chain Monitoring (adapted Table 9 from London et al. 2020. Previously framed as prospective questions, now rephrased as guidelines for supply chain monitoring).

Supply chain assessment	*Criteria to be for supply chain assessment (Assessment of hardware, software, capacity)* *Tools to be used for assessment (WHS management assessment checklists)*
Common data environment	*How and to what extent a common data environment will be established* *At what point were subcontractors will be brought in to discuss WHS*
Early contractor involvement	*Mechanisms put in place to identify design safety issues as pre-construction?* *How BIM WHS requirements are to be communicated*

Subcontractor monitoring	*How the client or main contactor monitor will the performance of high-risk tasks (Regular meetings; if so, how frequent will these meetings be)* *Mechanisms in place to ensure that quality data is submitted at the right time* *How, if at all, data audits are to be conducted for WHS information requirements* *To what extent BIM specialists will be used to ensure that teams are meeting WHS requirements*
Education and training	*Training and education to be made available to subcontractors, especially in relation to data and technology use* *Arrangements (e.g. "workshopping") to be used to discuss BIM WHS requirements*
Supply chain empowerment	*How subcontractors are to be made accountable for WHS outcomes* *Mechanisms used to support connectivity and remote connectivity of sub-contractors*
Communication and collaboration	*Governance mechanisms were to put in place for design coordination and issue management* *How sharing of issues and concerns will be encouraged* *How models will be handed over across different project phases*

As with previous sections, a number of areas remain open for exploration. First, an ongoing debate remains on how much information is the optimal volume to share across a supply chain seeking to use BIM for WHS management. The advantages of data-rich and data-purposeful environments were both raised by interviewees. Clients much articulate their stance and develop their information management visions, policies and common data environment accordingly. It is worth noting that the UK BIM Alliance Guidance Notes appear to favour data-purposeful environments, but some of our interviewees have provided anecdotal information that data-rich environments can provide a versatility that enriches WHS management.

A second issue is deciding on individual levels of authority, responsibility and accountability when it comes to the use of BIM for WHS management. The empirical data showed different levels of authority or permissions, such as making changes in BIM models. Regardless of the level of (de)centralisation, audit trails must be rendered transparent so that individuals can be made accountable for any changes made.

Best Practice

"Best Practice" as an area of recommendation can be nebulous, as it significantly overlaps with the previous recommendation areas. To minimise repetition, selected highlights are presented below, as these have already been previously discussed:

- Best Practice (Client Leadership) – potentially evidenced by the Government Client (Health), which made use of a specific technology to build an extensive and growing library of elements that translate into detailed information requirements that supply chain participants

are compelled to fulfil. Compliance with the specifications embedded in this library ensures that unsafe designs are avoided

- Best Practice (Common Data Environment) – evidenced by the Government Client (Transport), which has developed a culture that "speaks data", builds projects on universal data schemas and supports this through an overarching vision for digital engineering
- Best Practice (Supply Chain Tendering) – evidenced in the Private Client (Developer), which made use of a complex ecology of explicit as well as implied requirements to create an environment where subcontractors could push for high-level integration of BIM and WHS management in a highly complex project, successfully executed through sophisticated planning
- Best Practice (Supply Chain Monitoring) – potentially evidenced by the Government Client (Health), where the use of dRofus created a form of OIR, AIR and PIR, all tightly aligned and creating a form of surveillance that ensured the supply chain participants were using approved model elements only
- Best Practice (Site Safety) – potentially evidenced by the Façade Subcontractor in Case Study 1, who made extensive use of BIM models to plan and communicate construction methodologies in ways that improved safety on-site, even when WHS management specifications did not require the use of BIM. Case Study 1 thus also highlights that "Best Practice" does not always have to emerge due to Client Leadership.

Concluding remarks

This research has contributed to both the knowledge base that underpins this topic area and has implications for industry practice. Taking an innovative approach, this research will establish leadership in this area both nationally and internationally.

The detailed empirical study has indicated a clear separation between BIM and WHS management, demonstrating that the potential of BIM for WHS management is underexplored. Given the unacceptable dangers of the construction industry, the importance of quality data management is clear, and integration is emerging, albeit in an ad hoc manner. There is, therefore, still considerable scope for innovation, such as creative ways of integrating formal and informal ways to achieve compliance and use experimentation across different procurement models.

The findings from Phase 1 of this research highlighted that specifying for BIM at tender is a decisive way to counteract the weak regulatory landscape in relation to BIM adoption. Both the literature and interviewees of Phase 1 noted that the only standard that has made a strong link between BIM and WHS was the UK PAS 1192-6. One interviewee from Australia commented that the industry would not voluntarily take it up if the standards were not "legally enforceable". The only way to compel industry, according to this interviewee, was to make sure the standards were referenced in the National Construction Code or explicitly required in a contract. The proposed

Decision Framework thus aims to support clients and other construction leaders with the latter. Phase 2 outcomes now begin to address this gap.

The multi-stage analysis of qualitative data in Phase 2 identified clear lessons as well as areas that remain open for further exploration and debate across the four areas identified in Phase 1 as key drivers of BIM adoption; Client Leadership, Tendering Proficiency, Supply Chain Monitoring and Best Practice. These findings informed the development of the Decision Framework through an interactive process, resulting in two key components, each with two subcomponents. In Phase 3, the components and tools that comprise the Decision Framework will be developed and evaluated through two methods 1) engagement with key stakeholders and 2) a separate desktop evaluative process across two case study projects. The process of drafting, piloting, testing, evaluation and redrafting will contribute to ensuring that the Decision Framework is fit for purpose and aligns with existing standards, guidance material and work processes.

Consistent with the recently released NSW IDMF, the proposed Decision Framework is timely and presents a practical method, guidance, and a pathway to couple with specifying WHS information requirements. Alignment with international standards on the use of BIM also highlights that the proposed Decision Framework has the potential to make important contributions to international knowledge and practice, particularly in providing guidance for countries that do not have the necessary regulatory landscape.

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Appendices

Appendix A

Book Chapter "Construction Work Health and Safety Management using Building Information Modelling"

Construction Work Health and Safety Management using Building Information Modelling

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Abstract

The high rates of fatalities and injuries in the construction industry highlight the importance and the challenges of work health and safety (WHS). Building Information Modelling (BIM) can play a significant role in improving WHS in construction, but its use has been varied and inconsistent. The chapter explores the application of BIM for WHS management and specifically, the clients' role in catalysing a BIM-enabled WHS management ecosystem by incorporating it in procurement strategies and tendering requirements. An international comparative analysis of exemplars and frameworks that have successfully initiated WHS management using a BIM-enabled environment

is presented as well as a critique on BIM drivers and barriers; which are clustered into seven areas of market, perceptions and attitudes, leadership, supply chain integration and collaborative practice, procurement strategies and tendering proficiency, decision tools and technical functionality. A decision framework is outlined related to key drivers. The findings provide valuable insights for researchers and practitioners to understand how a BIM-enabled WHS management system can best be facilitated during the procurement process and supported throughout the entire project lifecycle.

Keywords: BIM WHS integration strategies, Decision framework, Procurement, Tendering, Leadership, Project Information Requirements

INTRODUCTION

Construction is known as one of the most dangerous industries in which to work and many safety incidents, injuries and fatalities could be prevented through improved design, planning and communication. BIM is an enabler technology that involves the generation and management of digital WHS information in construction. It facilitates the separation of people and hazards by the use of technology and data. The purpose of this chapter is to better understand the application of BIM to support WHS management and, specifically, the role the client can play in enhancing its application. Under this overarching aim, this chapter will explore the use and adoption of BIM for WHS management; briefly examine the barriers and enablers for BIM adoption; identify solutions for integrating WHS management in BIM-enabled project planning, design and delivery; and explore procurement frameworks and the client's role in the use of BIM for WHS management. The chapter presents key results of Phase 1 of a four-phase study being conducted in New South Wales a state in Australia:

1. Phase 1: Identify solutions for integrating the WHS aspect in BIM-enabled project planning, design and delivery.
   Understand how and to what extent BIM is used and can be used for WHS management, including identifying the different options of implementation and associated barriers, enablers, limitations, and consequences for WHS risk reduction for the industry, the government and the regulator.

2. Phase 2: Evaluation of WHS management in BIM-enabled project proposals.
   As part of a procurement process and identify preferred procurement models and best practices to evaluate WHS management in BIM-enabled project proposals and recommend the best way for government agencies to evaluate the quality of WHS management in BIM-enabled project proposals.

3. Phase 3: Evaluation of the proposed approach for its adoption
   Understand the implications of the recommended solutions for integrating the WHS aspect in BIM-enabled project planning, design and delivery (objective 1) and for enabling the evaluation

of WHS management in BIM-enabled project proposals at the procurement stage (objective 2).

4. Phase 4: Transfer of Knowledge and Dissemination.
   Disseminate findings to the industry, to NSW citizens, to the students and to the research community.

However even given the local context the international setting is well considered and presented. It is noted that the funder of the study is the multinational company Lendlease a globally recognised 'digital delivery' innovator and so the study has significant international relevance.

BACKGROUND

The construction industry is well known for its hazardous working conditions and association with a concerning number of injuries and fatalities. The issue of WHS is international, with the construction industry responsible for the highest proportion of the 2.3 million work-related fatalities that occur around the world each year (International Labour Organization, 2020). According to the Bureau of Labor Statistics (BLS, 2019) of the United States (US), construction worker fatalities are increasing (from 965 in 2017 to 1003 in 2018). Similarly, construction workers in the United Kingdom (UK) constituted the highest proportion of occupational fatalities in 2017 and 2018 (Garner-Purkis, 2018).

In Australia, the construction industry employs 9% of the workforce 1.16 million people; (Safe Work Australia, 2017) and has the second highest work-related injury and disease incidence rate among all industries. Numerous statistics support the seriousness of this issue. For example, between 2003 and 2013, 401 construction workers were fatally injured (Safe Work Australia, 2017). This is an average of 40.1 workers per year. Over the five years from 2013 to 2017, a total of 153 work-related fatalities were reported in the construction industry, equalling an average of 31 fatalities per year (Safe Work Australia, 2017). While it is promising that the rates are decreasing, the construction industry remains one of the most dangerous and has been listed as a priority industry for improvement in the Australian Work Health and Safety Strategy 2012–2022 (Safe Work Australia, 2020).

Work-related injuries and fatalities have wide-ranging implications. In addition to direct impacts to victims, work-related injury and disease impose significant losses to victims' families, employers and society (Feng et al., 2015). For example, damage caused to productivity, property, equipment and morale can have a detrimental effect on a construction company's profit and loss statement. Effective investment to improve WHS could therefore bring significant returns, both human and economic (Feng, 2013).

BUILDING INFORMATION MODELLING TO IMPROVE WORK HEALTH AND SAFETY

As it becomes crucial to ensure safer working conditions, the introduction and development of new technologies can result in improved building design, project planning and communication. Over the last decade, the use of BIM has risen across the construction industry. The following section explores the increasing role of BIM in construction, its adoption across countries, the barriers and drivers to its implementation and, most importantly, the application of BIM for WHS management.

Building Information Modelling

BIM is an integrated, model-based process that is used for creating and managing building projects. It has been variously defined over the last decade. According to ISO 19650:2019, BIM is the:

> Use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions. (ISO 19650, 2019).

For the purposes of this book chapter, the following definition from Gu and London (2010) is adopted as it is more expansive:

> BIM is an information technology enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository. The building information involved in the BIM approach can include both geometric data as well as non-geometric data." (Gu & London, 2010).

BIM facilitates design, visualisation, simulation, collaboration and communication of all project information in an integrated model for better decision-making. It allows all stakeholders to access the same information, at the same time via a common data environment. As BIM allows visualisation of the project in advance of its physical realisation, it provides greater cost certainty, facilitates error elimination and reduces risk.

Existing research indicates that BIM is being increasingly adopted by the architecture, engineering and construction industries (Martínez-Aires et al., 2018), although adoption levels have varied across countries, sectors and supply chains (London & Singh, 2013). The adoption or uptake of BIM by industry, known as BIM maturity, is categorised in four levels according to increasing levels of industry collaboration. BIM Level 0 is the lowest level with no cooperation between participants and mainly involves the use of computer-aided design to make 2-dimensional (2D) drawings. BIM level 1 progresses to the generation of a suite of 2D information with sharing of data using a common data environment. BIM level 2 involves collaborative working and the sharing of information between project participants, whereas BIM level 3 involves total and full integration of BIM in a cloud-based environment (NBS, 2020a).

BIM adoption can also differ in the Level of Development (LOD). BIM LOD is an industry standard that details the development stage of different systems in a BIM environment, specifying the design requirements at each stage. It allows professionals to clearly and effectively specify the content of BIM by articulating the expected LOD of an element's geometry and associated information. At LOD 100 (pre-design), the model mainly constitutes of 2D symbols to define an element's existence. By LOD 200 (schematic design), the elements are partially defined by outlining approximate size, shape, quantity and location. At LOD 300 (design development), the elements have accurate dimensions and location. The LOD 400 level (construction stage) provides basic information about the construction of various elements, including fabrication, assembly and installation. By LOD 500 (as built), the model is field-verified and includes real-life functions of elements in the real building or structure.

Cross country analysis of Building Information Modelling adoption

Although the concept of BIM has been around for some time, the levels of adoption vary between countries, between disciplines and even between clients. Coupled with the varying levels of adoption, the way in which organisations approach adoption across both technical and non-technical aspects plays a significant role in increasing the application of BIM (Gu & London, 2010). Technical aspects refer to the digital functionality, such as software, hardware and IT systems. Non-technical aspects refer to the human aspects of adoption, for example, education and training; cultural, organisational and business support factors.

As the use of BIM has been increasing across countries, governments have developed various BIM regulatory and policy initiatives to guide both private and public sector adoption. Particularly important standards include:

1. BS/PAS 1192 series (UK)
2. The National BIM standards (US) (NBIMS, 2015)
3. Common BIM Requirement (COBIM) (Finland)
4. Singapore BIM Guide (Singapore)
5. National Building Specification (NATSPEC) National BIM Guide (Australia) (NATSPEC, 2011)
6. Statsbygg BIM Manual (EU) (Statsbygg,2013)

At the international level, the International Organization for Standardization (ISO) has developed standards based on the UK BS/PAS 1192 series.

United Kingdom

Up until 2016, the UK Government mandated Level 2 maturity BIM adoption for all government funded projects up to a certain project value in line with the British Standards Institution's (BSI) Publicly Available Specifications (PAS). (Burgess et al., 2018). The BSI PAS documents define good practice for products, services and processes, and help establish consistency and integrity through universal approaches across the country. Of particular note for this book chapter is *PAS 1192-6: Specification for integrated and collaborative sharing and use of health and safety information using BIM (BSI, 2019)*, which supports the development of structured WHS information for construction projects using BIM. However, this mandate has since ceased as the UK has moved to promote BIM Level 2 as part of normal operations and is developing strategies for a fully digitised construction industry (NBS, 2020b).

Since 2018, the BSI PAS 1192 series is progressively being replaced by the ISO 19650 series. Three international standards in this series have been published and another two are under development at time of writing:

- BS EN ISO 19650–1: Organization of information about Construction works – Information management using building information modelling – Part 1: Concepts and principles
- BS EN ISO 19650-2: Organization of information about Construction works – Information management using building information modelling – Part 2: Delivery phase of assets.
- BS EN ISO 19650–3: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – information management using building information modelling – PART 3: operational phase of the assets [UNDER DEVELOPMENT]
- BS EN ISO 19650–4: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – information management using building information modelling – PART 4: information exchange [UNDER DEVELOPMENT]
- BS EN ISO 19650–5:2020: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – information management using building information modelling – PART 5: security-minded approach to information management

The three new standards are founded on the UK's standards for information management using BIM: BS/PAS 1192-1 (principles), BS/PAS 1192-2 (delivery phase) and BS/PAS 1192-5 (security).

To support digitisation of the construction industry, two new programs of work were established in 2016-2017. Firstly, the UK BIM Alliance promotes Level 2 BIM as part of normal operations and, secondly, Digital Built Britain (DBB) promotes new initiatives. In 2019, the UK BIM Alliance, BSI

and the Centre for DBB announced the launch of the UK BIM Framework. This framework sets out a guided approach to implementing BIM in the UK and managing information provided by the BS EN ISO 19650 series.

European

According to Ullah et al (2019) in 2014, the European Commission announced directive 2014/24/EU, which recommended member states' use of specific electronic tools such as BIM for public works contracts and design contests (European Parliament, 2014). Research conducted in Germany, France, Brazil and Austria showed that BIM is gaining wide adoption in these countries (Matarneh and Hamed, 2017).

The Scandinavian countries have led BIM adoption (Smith, 2014). BIM was first used in Finland in 2002 and, as early as 2007, it was made mandatory for design software to pass Industry Foundation Class (IFC) certification. IFC is a software file format that can be used across different software applications, allowing teams to share models and collaborate while still working independently. In 2012, Senate Properties migrated the *BIM Requirements for Architectural Design into the Finnish National BIM Guidelines (COBIM)*. Similarly, Norway has been using IFC file formats and BIM in their projects since 2010. In the Netherlands, the Government Buildings Agency mandated the use of BIM for public projects in 2011 (Cheng and Lu, 2015).

United States

The US was one of the first countries to implement BIM (Wonget al., 2010). However, the lack of national standardisation slowed down its progress. It was in 2003, through the Public Building Services, that the General Services Administration established a 3D/4D/BIM program that released limited guidelines for the construction industry. In recent years, the National Institute of Building Sciences has made considerable progress in ensuring the adoption of BIM in the US.

China

The Chinese construction industry became aware of the concept of Building Information Modeling (BIM) around 2002; although only a few projects embraced BIM until 2011 (Herr and Fischer, 2018) when the Chinese government began to strongly support the adoption of BIM. The adoption of BIM in the Chinese construction industry has been expedited since 2011, when the Chinese government started to promote BIM and plan a series of national-level BIM policies and standards. The 2011-2015 Outline of Development for Informationalisation in the Construction Industry issued by the Ministry of Housing and Urban Rural Development (MHURD) is the first national policy to include BIM as an important aspect of informationalisation development (MHURD, 2011). The 2016-2020 Outline of Development for Informationalisation in the Construction Industry specified BIM

as the top of critical information technologies (e.g., BIM, Big Data, Smart Technologies, Mobile Communication, Cloud Computing, Internet of Things) promoted by the construction industry (MHRUD, 2016). A series of national and regional level BIM application guidelines were developed by the central government and local government to comprehensively promote and guide the adoption of BIM in the Chinese construction industry in the last decade (Lin and Zhang, 2018).

Singapore

Singapore's nationwide BIM implementation Roadmap was first laid out in 2011. BIM has since been increasingly used in public sector building-projects, particularly since 2015 when it became mandatory for all building projects larger than 5,000 m2 to use BIM. Another important initiative driving the use of BIM was the Building Information Model Fund administered by the Building and Construction Authority. (BCA, 2013) This initiative aimed to boost the uptake of BIM by construction firms across Singapore by supporting training, consultancy, software and hardware cost for projects.

Hong Kong

The Hong Kong Housing Authority piloted BIM around 2006 and the Construction Industry Council (CIC), a government agency, has since been promoting BIM adoption across the sector. It developed the CIC BIM standards based on international standards like the PAS 1192 and the Singapore BIM guide. Since 2018, all government projects valued over $30 million are required by legislation to incorporate BIM in their design and construction.

Australia

Australia has gradually adopted BIM with various initiatives occurring between 2010 and 2020 that has led to the awareness and adoption during this time period. During this time, a number of key organisations, including the Australasian Procurement and Construction Council (APCC), Australian Construction Industry Forum (ACIF) and the Australasian BIM Advisory Board (ABAB), and the Collaborative Research Centre (CRC) for Construction Innovation promoted the use of BIM in the construction industry. As early as 2003, the Collaborative Research Centre for Construction Innovation led many early BIM initiatives in Australia particularly related to government/academic/industry research studies.

In 2010 the Built Environment Industry Innovation Council, one of many industry focused councils created by the Federal government of the day, which brought together industry, academia and government to respond to key challenges, created the Built Environment Digital Modelling Working Group. The Working Group worked in collaboration with the Information Technology Industry Innovation Council to respond to the emerging need to develop an Australian built environment industry capable of adopting integrated digital modelling technologies to improve efficiency, address environmental and life-cycle issues and increase international competitiveness. The working group brought together industry, researchers, policy-makers and industry

associations in the built environment and was chaired by the Department of Industry, Innovation, Science, Research and Tertiary Education, (DIISRTE, 2012).

In 2015, the APCC, in partnership with the ACIF, launched the *BIM Knowledge and Skills Framework* and, in 2017, together with the key standard-setting bodies NATSPEC, buildingSMART and Standards Australia established the ABAB.

The ABAB consists of stakeholders from government, industry and academia who partner to provide expertise and leadership on the adoption of BIM and Project Team Integration (PTI). PTI is an approach that facilitates collaboration among participants at the earliest stages of the project for better efficiency. It supports best practice through advocating a consistent approach to BIM practices, standards and requirements, as well as a holistic approach to the national adoption of BIM in construction. It is through the *Australian Strategic BIM Framework* that all state and territory governments commit to improving procurement methods to allow for the adoption of BIM. As exemplars, they commit to adopt a nationally consistent approach to BIM in the procurement of government-initiated building construction, infrastructure and management projects.

The *Australian Strategic BIM Framework* was launched in March 2017 to incorporate the various guidelines developed since 2010. Included were *the NATSPEC National BIM Guide and BIM Management Plan Template*, which clarify BIM requirements to all project stakeholders, inclusive of clients and consultants, in a nationally consistent manner. Also, in 2017, the buildingSMART National BIM Initiative launched BIMcreds, which provides BIM practitioners with a framework for demonstrating their competence (buildingSMART, 2017). BIMcreds is designed to be used in conjunction with the APCC/ACIF *BIM Knowledge and Skills Framework*.

In 2014, Sustainable Built Environment National Research Council developed a *Towards a National Strategy* that continues to guide the development of an Australian national strategy for BIM adoption. It also developed the *BIM Value Tool* with NATSPEC (2011) to support practitioners who want to understand the benefit and application of BIM and its implementation.

As a result of joint efforts by the ACIF and the APCC, the ABAB has more recently developed the *Framework for the Adoption of Project Team Integration and Building Information Modelling* and *Building and Construction Procurement Guide* with a predominant focus on BIM and PTI. The APCC and ACIF see their role as mediators between industry interests and government requirements, with a focus on legal, procurement, collaboration and process-related topics (ABAB, 2020).

In summary, there is a plethora of BIM documents and guidelines that provide guidance for Australian public and private sector clients and construction industry professionals on BIM implementation. However, regardless of the depth and quality of these guidelines, it is suspected

that there is a general lack of adoption of BIM applied specifically to managing WHS. One reason may be that the material is too generic and lacks specificity in relation to WHS management. Given the critical importance of improving WHS in construction, both nationally and internationally, and the increasing global uptake of BIM, it appears the integration of WHS in BIM is an area that should be further explored to facilitate better WHS outcomes. The general approach to BIM adoption has typically pursued the generic pathway. It is perhaps timely to consider the challenge of integration of WHS management systems into the BIM enabled environment.

Barriers and Drivers to adoption

Despite the numerous benefits, BIM adoption has its own set of challenges. It is useful to understand the significant body of research that has been conducted on the adoption of BIM technologies in construction and the barriers to industry and government uptake when seeking to introduce a BIM-enabled environment. Research studies have categorised barriers according to common characteristics; for example, people, process and product barriers (Lindblad, 2013) or technical, social context, process-related, and work practice issues (Gu & London, 2010). More recent research has added categories such as contractual and legal barriers.

Since 2006 there have been numerous studies that have sought to understand the barriers to adoption of BIM. As early as 2006, London et al in a national broad based e-business adoption study, identified the barriers and drivers as well as other important outcomes including a) barriers and drivers were clustered and many barriers were inter related to other barriers and then barriers were inter related to drivers b) barriers often turned into drivers c) adoption rates varied which was in itself a barrier d) there were three common identifiable hierarchical pathways to adoption (related to perceptions, compatibility and communication). There were four main interrelated clusters of barriers identified including perceptions and attitudes, communication, compatibility, and market incentives and within each of these clusters there were various underlying interrelated barriers. The overarching barrier of different rates of adoption across the industry largely due to the fragmented industry structure coupled with the project-based nature of the industry played out in various ways. For example the differing rate of adoption and the inherent inertia of the industry impacted attitudes and perceptions through a resistance to change, doubts about benefits, an overwhelming feeling of complexity influenced by a lack of technical compatibility, a lack of desire to change due to supply chain network; and much of this was influenced by top level management and market leaders in particular client and contractor demand.

Over the last fifteen years various studies have identified similar outcomes. It is useful to acknowledge that there is a depth of understanding in relation to barriers to BIM adoption. The following table is a detailed and comprehensive compilation of barriers and drivers which has

been derived from London et al, 2006 and Gu and London 2010; merged with Ullah and Witt (2019) and then updated and complimented with additional literature from more recent studies.

Airtable — BIM4H&S Working-Group PIR Tem... — Sign up

PAS 1192-6 Requirements | Asbestos Requirements | Fire Safety Requirements | Lifting Requirements | APPS

Grid view | Hide fields | Filter | Group | Sort

	Requirement	Requirement Type	Requirement Source	When Used	When Initially Delivered
	Set out a RACI schedule to collaboratively develop the Asbestos ...	Roles and Process Requi...	Works Information	Preconstruction, Construction	CIC 2 - Concept
2	An Asbestos Survey Report to be prepared and accessible to those ...	Roles and Process Requi...	Works Information	Preconstruction, Construction	CIC 3 - Developed Design
3	Ensure all information relating to the management of ACM (Asbestos ...	Roles and Process Requi...	Works Information	Preconstruction, Construction	CIC 6 - Handover
4	Where removal work is carried out copies of clearance certificates and ...	Roles and Process Requi...	Works Information	Construction	CIC 5 - Construction
5	The Principal Contractor will ensure that	Roles and Process Requi...	Works Information	Construction	CIC 5 - Construction

31 records

Figure B1: BIM4H&S Working Group Health & Safety PIR Template, including example requirements in priority areas of risk such as asbestos.

2. How will you use the Common Data Environment (CDE) to share H&S information through the project lifecycle and to make information available to stakeholders beyond the project?

Maturity Steps		
First Steps	**Keeping up with the pack**	**Taking the lead**
Client specifies use of appropriate and accessible IT tools to share information	A project information manager is appointed to manage the CDE.	A CDE is established early, and controlled access is granted to all project participants.
Client specifies who will have access to information	Periodic reviews of H&S File quality, accessibility and content undertaken.	Seamless integration from inception (PCI) to construction phase to handover (H&S File) and operational use from the CDE.
Client specifies format and structure of H&S File	Progressively developing and sharing H&S information within the CDE.	Tools are specified to enable H&S federation and sharing of models
Key References		
PAS1192:6 Section 5		

Transport for London | nationalgrid | Network Rail | Environment Agency | ARUP | ARCADIS | BIM4H&S Client Working Group in conjunction with the HSE

Figure B2: Example Plain Language Question (top) and BIM Maturity Matrix for Clients, Principal Designers and Project Leaders (bottom).

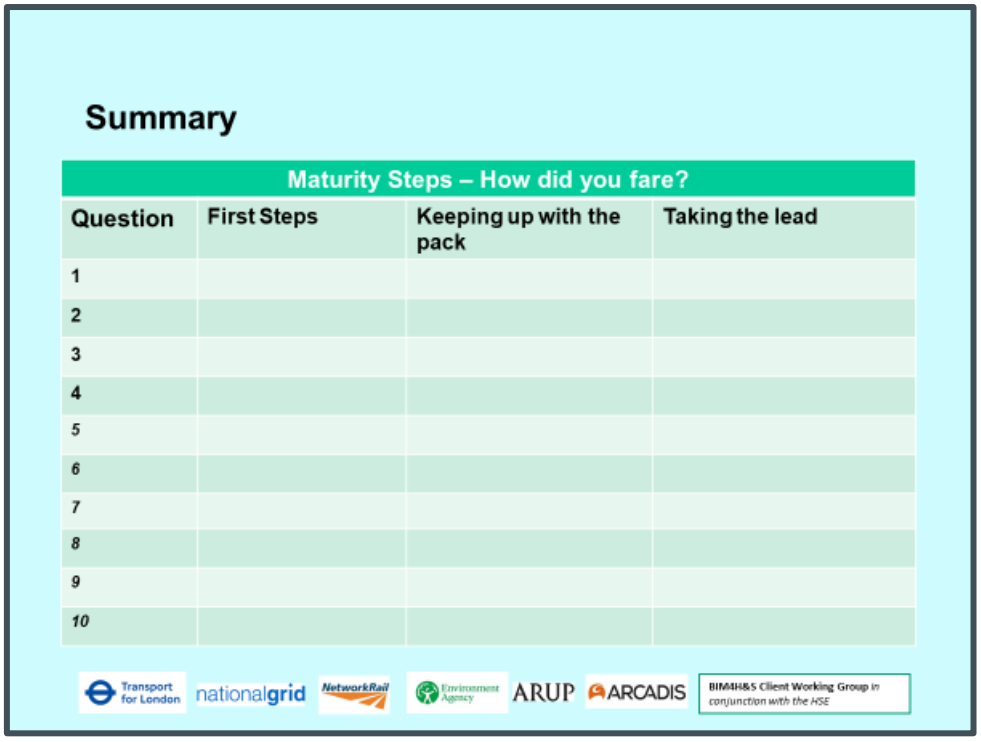

Figure B3: In-depth analysis of standards, guidelines and frameworks provided a scaffold for organising project documents and for discerning threads of BIM for WHS management in the case studies.

INTERVIEWEE 1
RESEARCH TEAM MEMBER 1

QUESTION	CL	TP	BP	SCM	THEME	QUOTE	SIGNIFIC-ANCE
In many ways that is what we're looking for, you know, that formal link and that formal relationship between the work health and safety management systems and the BIM models. However, sometimes that doesn't happen... in practice, did you use the model to help you - - - the formal and the informal. Happy to hear about anything		X			BIM and WHS requirements are well-defined, but kept separate	Yeah. It's really interesting direction. Because, officially, I'm not really aware of any requirement or emphasis from the builders to use their modelling for WHS. They're totally aware and totally specific on what they want for both of those elements. But I've never seen a link between the two. So very, very specific on both of those two elements but they don't establish a link between them. As far as I'm aware, there's never been a necessity to use one or the other to benefit the other.	3
		X			WHS requirements are clearly specified at tender	So they very clearly specify the site WHS requirements.	3
	X				WHS requirements are comprehensive and exceed required legal standards	And the company, like Lendlease for example have their global minimum requirements which is a list of, very comprehensive list of rules and regulations that go in excess of the Australian standards or whatever applicable stand there is, which totally covers WHS issues.	3
		X			BIM requirements are clearly specified at tender	Then they, also, are very specific in their contracts and tendering documents on the building information management aspects. They clarify the type of modelling they require, the level of model development they require, the software that they will use, the file types they will incorporate.	3
			X		Contractor takes initiative and makes use of BIM for WHS even when their integration is not specified	But we do, so we use them in their entirety to — so we'll thoroughly develop our models to, like a LOD500 level which is full, as-built documentation. And we will use our models to work through the methodologies, to skill our installation teams up on exactly what they're going to be facing well before the building exist. And that is, I guess, the nuts and bolts of what	3

Level-1 Analysis template 1

Figure B4: Example of Research Team Member 1's Level-1 analysis of Interviewee 1, including the question asked, links to Phase 1 recommendations, first-order themes, quotes and significance.

AXIAL CODING FOR: CLIENT LEADERSHIP
PREPARED BY: RESEARCH TEAM MEMBER 1

PROJECT	INTERVIEWEE	QUESTION	CLIENT LEADER SHIP	THEME	RESEARCHER	QUOTE (BOLD HIGHLIGHTS MADE BY TEAM MEMBER 1)	SIGNIFIC-ANCE	EMERGING SECOND LEVEL THEME	POSITIVE OR NEGATIVE EXAMPLE
2	7	Tell us a little bit about the Environment Health and Safety Management System that you have at Lendlease.	X	Separate EHS plan as a subset of a holistic project management strategy	2	**We have an Environment Health and Safety Management System, and a Project Management Plan.**	2	CLEAR COMMITMENT TO WHS GOALS; DECIDING ON VALUE OF WHS RELATIVE TO OTHER GOALS LIKE COSTS AND QUALITY; ESTABLISHING ROBUST WHS SYSTEMS, PROCESSES AND STANDARDS CUTTING ACROSS PROJECTS	(+)
2	7	Tell us a little bit about the Environment Health and Safety Management System that you have at Lendlease.	X	A digital source to access project information covering it lifecycle summarised in GMRs	2	**The plan talks about everything from designing a project, right through the project life cycles to monitoring onsite. What the key deliverables are through that life cycle. That Management System is online.**	2	CLEAR COMMITMENT TO WHS GOALS; DECIDING ON VALUE OF WHS RELATIVE TO OTHER GOALS LIKE COSTS AND QUALITY; ESTABLISHING ROBUST WHS SYSTEMS, PROCESSES AND STANDARDS CUTTING ACROSS PROJECTS	(+)
2	7	So in those digital platforms and things, are the 3D models involved in that as well?	(-)	Planning using visualisation prepared the workers to better response to risks	2	construction is very dynamic, **there's so many problems to solve. And if all the problems are left to the workers onsite, we rely on the human factors, and we're all human.** (ZP Comment: which is why they rely on an online system)	3	CLEAR COMMITMENT TO WHS GOALS; DECIDING ON VALUE OF WHS RELATIVE TO OTHER GOALS LIKE COSTS AND QUALITY; ESTABLISHING ROBUST WHS SYSTEMS, PROCESSES AND STANDARDS CUTTING ACROSS PROJECTS	(+)
2	4	since this project has the great model in place, does the project have any guidance documents or plan to direct the health and safety, or do you think such a kind of plan or guidance document is necessary? Not everyone or not every project is quite good at using BIM to improve health and safety.	(+)	Good to set up guidance for use of BIM models for projects.	3	I think, if you look at a post review of what we've done, in hindsight it's probably good to set something up. I think like what Tim said, because of the complexity of the building, **this originated based on how we are going to put it together and it's us wanting an understanding to make sure that everyone who comes to our site understood the same thing from both program methodology and a safety point of view.** how are you going to install it. How you put that together as a document, you could do it.|| **It's probably important to understand that we haven't necessarily don't anything different. To what we**	1	CLEAR COMMITMENT TO WHS GOALS; DECIDING ON VALUE OF WHS RELATIVE TO OTHER GOALS LIKE COSTS AND QUALITY; ESTABLISHING ROBUST WHS SYSTEMS, PROCESSES AND STANDARDS CUTTING ACROSS PROJECTS	(+)
2	8	We've seen some of the documents from Normoyle, I think, for the façade contractor and so they were quite detailed. But we haven't seen anything from the end of Kengo Kuma. And I was just wondering, was there any process where Lendlease and Kengo Kuma, sort of, went back and forth about the	X	WHS is not a concern for concept architect. || Concept architect would be happy to accept if they understand the clients safety requirements.	3	So the concept — so to be brutally honest, so Kengo Kuma, world renowned, famous international architect, works in — out of Japan. One of the — so to answer your question, the first instance. || Yes, there was a lot of back and forth and they stay involved all the way to the end of the project to ensure that the concept and the design intent was maintained throughout the process. **They — I wouldn't say they had any contractual, maybe safety or — there was no, yeah, obligation, I believe, from them to do so. But they stayed involved because they wanted to ensure that the**	3	CLIENT-DRIVEN INVOLVEMENT OF SUPPLY CHAIN PARTICIPANTS IN MUTLI-STAKEHOLDER DISCUSSIONS AT KEY PROJECT STAGES, FOR A HOLISTIC APPROACH TO WHS	(-)

Figure B5: Example of Team Member 1's Level-2 analysis of Client Leadership including project, interviewee, question asked, link to Client Leadership, first-order themes, Level-1 researcher, quote, significance, second-order theme and whether the quote was a negative or positive demonstration of the theme.