PCH BIM Case Study

Strategic Projects – Department of Treasury – Western Australia

May 2014

pwc

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Section One

Executive Summary

1 Executive Summary

The objectives of this case study was to capture and record observations and findings which could be used to provide feedback to the State following its decision to mandate use of BIM on the Perth Children's Hospital. The case study deliverable methodology comprised of primary and secondary research work. A revised BIM compliant design deliverable (Schedule 4) is provided in Appendix 2.

Key observations include:

1. Whilst there is no common agreement of what BIM is, most definitions acknowledge its role throughout the life cycle of a built asset (design to decommissioning), utilising information stored in data bases to enable increased collaboration by streamlining interface and communication channels. BIM's role in integrating data into a information rich 3D model is commonly recognised, however, the following points, are less well understood:

- BIM's 3D model is a geographical representation of the information in the databases i.e. only part of BIM not all of it.
- BIM is process driven not a technology.
- BIM comprises of a number of collaborative tools and data bases stored in various software systems, and
- To work well it requires a high level of interoperability

2. Users who receive optimal benefits understand that successful examples of BIM project implementations commence by defining the end in mind, relying on process and governance not technology, address the invisible requirements of the iceberg model (Fig 3.2) and create an organisational structure to reap the benefits achieved by moving the maximum project effort curve from construction to the early design stage (Fig 3.2).

3. BIM is often referred to as the single point of truth of project and asset data and its benefits include:

- Reducing project cost, time and risk by enabling stakeholders to work in a collaborative manner.
- Providing near real time project information to all stakeholders.
- Reducing time wasted checking & chasing the latest information.
- Providing a single auditable record of the assets development.
- Minimising technology platform duplication.

However, throughout the design and construction industry confusion exists surrounding BIM processes and technologies, while there is feeling that software companies are selling BIM to unfamiliar owners as the answer to all project problems.

4. Comparing the use of BIM on the PCH project against established usage frameworks indicates that the PCH project is ahead of what many first time users attempt and pushing towards the limit of what is currently achievable (Fig 3.5).

5. A standard BIM architecture doesn't appear to exist, instead implemented systems comprises of a number of different software packages / tools which in totality meet the users requirements (Fig 4.1). Furthermore, whilst BIM adoption is increasing globally and is often sponsored by national governments, no other instances of fully integrated BIM have been found.

6. Key observations from the SME interviews found that:

- Virtually all the interviewees believed that the introduction of BIM has been a positive step, has improved the working environment and is adding value.
- Model accessibility, BIM's unlimited potential and its speed relative to 2D drawings were viewed positively.
- The additional cost impact, design team competency, understanding the technology and lack of training were some of the negative comments.
- That the State has not yet received any direct value from BIM 4 and 5D due in part to the nature of the contract and a lack of confidence that the initial data was correctly entered.
- That the State does not yet fully understand what BIM 6D is, and that this situation is compounded by the lack of readily available guidance beyond the projects practical completion.

6. In terms of building on the BIM capability platform the PCH project has created, the State could consider:

- Developing a BIM governance model.
- Developing an integrated asset management strategy.
- Modifying the progress claims and cash forecasting process.
- Integrating BIM within the supply chain management process.
- Integration of BIM within lean construction processes.

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Section Two

Introduction

2.1 Background

As a part of the Department of Treasury of the Government of Western Australia, Strategic Projects (SP) is responsible for the planning and delivery of major projects that are considered to be of significant importance to the State. The projects the SP manages are usually unique and complex one off developments and carry a high level of budget and schedule project risk.

The new $1.2 billion project Perth Children's Hospital (PCH) is considered to be a landmark project and is a cornerstone of the State Governments strategy to deliver major social infrastructure for future generations of Western Australians.

At the time of the PCH project award in 2011, SP, with very little previous experience of either the process or the technology involved, took the decision to mandate the use of BIM for the PCH project design and construction teams.

The motivations for this decision were based on:

- A belief that the primary process for making decisions on complex multidisciplinary projects has now shifted away from traditional project management to data and information management.
- A recognition that BIM technology offered an opportunity to drive efficiencies, realise cost savings and increase the value that the State of Western Australia ultimately receives throughout the whole capital project lifecycle development process
- To set an example to WA design and construction organisations of the States intention to demand more of its partners by demonstrating the benefits that can be realised by embracing technology.
- Recognition that owners as the ultimate beneficiaries, must remain involved in the development process and must drive change until it becomes self-sustaining.

As the PCH project has progressed, so too has the SP's understanding of BIM's capability. Rather than seeing BIM as discreet project tool/ process, applied primarily at the design stage, it is now recognised that BIM has significant value to add during the projects construction, commissioning, readiness for operations life cycle phases. It is also recognised that the BIM data will be valuable source of information to be utilised and updated by the facilities management team throughout the completed assets operating phase.

Finally, SP strongly believes that by integrating BIM into future project and facility maintenance processes will result in the creation of a new paradigm of how future major capital projects can be designed, procured, constructed, handed over and operated and maintained.

2 Introduction - 2.1 Background

Project Overview

PCH Project key facts:

- Client: Department of Health
- Delivery agent:- Department of Treasury - Strategic Projects
- Cost: AUD $1.2 billion
- Schedule:
  - Business case approval: Nov 2010
  - MC award: July 2011
  - Stage 2 MC award: Dec 2012
  - PC: June 2015
  - Opening: Nov 2015
- Contractual delivery model: Two Stage Managing Contract with John Holland Group (JHG) as the Managing Contractor (MC).
- Services provided: Tertiary level paediatric health services and key secondary health services.
- Floor area:- Approximately 120.000 sq. meters comprising of:
  - 298 beds
  - 11 operating theatres, and
  - in excess of 35 clinical departments

2.2 Objectives and Scope of the Case Study

The objectives of this report are to:

1. Determine the States initial expectations and anticipated benefits to be gained from mandating the use of BIM.
2. Record the 'as is' situation.
3. Compare the States initial expectations to the 'as is' situation.
4. Capture and record observations, findings and suggestions which could form the basis of lessons learned review process.
5. Review the current PCH Project schedule 4 design deliverable[1] and propose an updated schedule that can be used for future State infrastructure projects which utilise BIM.

Scope

The scope of this commission was limited to the PCH project BIM solution.

Legal and contractual implications are outside of the scope of this report.

1. SP strongly believes from their PCH experience that there is a need to rethink what the current 2D paper based design deliverable specification should look like when utilising the 3D model in BIM.

2.3 Methodological Approach

The case studies methodological approach of this study followed the five step model highlighted in fig 1.1 and comprised of field and academic research work carried out during January and February 2014. The revised Schedule 4 and LOD definitions template were developed during March and April.

Fig 2.1 - Five step methodological approach

<u>Primary and Secondary Research</u>

Primary research was carried out by means of 30 face to face semi structured, open ended interviews based on a concise questionnaire (Appendix A) presentations and demonstrations with:

- Key State stakeholders (State, PCH project team)
- Key John Holland Group PCH project team members
- BIM software providers
- BIM service providers
- SME's from construction and resource organisations
- Academic researchers

Secondary research involved academic and desk top reviews and:

- Visits to the Australasia Joint Research Center for BIM
- Demonstrations of the latest visualisation research developments at Curtin University's Hive and Immersive Reality Center
- Discussions with the innovation director of Woodside's Project Echo augmented reality research program
- Conversations with PwC's BIM SME's in the United Kingdom and USA to understand the latest BIM developments

2.4 Report Structure

This report consists of the following:

- ***Section One: Executive Summary*** The slides are:
    1. Stand alone in nature
    2. Draw on and are supported by the content provided in the main body of the report

- ***Section Two: Introduction*** provides the background context to the case study as well as the objectives, methodological approach and structure of the report.
- ***Sections Three: Background to BIM*** introduces the reader to what BIM is, some of the key terminology and considerations, the value it can deliver and industry criticisms.
- ***Section Four:* SP's BIM PCH Project experience** informs the reader of SP's PCH BIM implementation journey and articulates the responses and findings of the primary research interviews.
- ***Section Five:* BIM around the globe** provides a view of BIM's development around the globe and provides a more detailed view of the direction and challenges in the UK and US.
- ***Section Six:* Proposed Schedule 4 deliverable schedule** articulates the purpose of Schedule 4 and the key changes made to the revision.
- ***Section Seven:* Conclusions and what next for Strategic Projects and BIM?**
- **Appendices.** Contains the revised schedule 4 and accompanying LOD definitions template.

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Section Three

Background to BIM

3.1 Key Observations

There is no common agreement of what BIM is, however most definitions acknowledge its role throughout the life cycle of a built asset, utilising information stored in data bases to enable increased collaboration by streamlining interface and communication channels.

BIM users who receive optimal benefits understand the importance of addressing the invisible requirements prior to commencing a project and understand that many of its efficiencies are achieved by moving the maximum project effort curve from the construction phase into the early design stage.

Analysing the implementation and use of BIM at PCH indicates that the PCH project is ahead of where most first time users are and pushing the limits of what is currently achievable is given existing data security constraints.

Finally, whilst there is much literature promoting its benefits, feedback from the industry points to a number of fundamental criticisms and confusion of process, technology and role of service providers.

3.2 What is BIM?

There is no single accepted definition of what Building Information Modelling (BIM) is, instead it is often described as an information data base which can capture, store and manipulate digital information about a built asset throughout all the stages of its development and operational life cycle from design, procurement, construction, commissioning, readiness for handover, facilities management (FM) operations and decommissioning.

BIM can enable collaboration and be used to create data-rich models in three or more dimensions that facilitate better design, enhance construction efficiency and improve the performance and productivity of an assets development. This is achieved by stream-lining the existing processes and integrating the information found at the different stages of the lifecycle.

It is however, important to understand that:

- BIM's 3D model is a geographical representation of the information in the databases i.e. only part of BIM not all of it
- BIM is process driven
- BIM is not a single piece of software, instead, it comprises of a number of collaborative tools and data bases stored in various software systems, and
- To work well it requires a high level of interoperability[2] to be present between the different software systems allowing the integration of information from software sources.

2. BIM Journal, 2009 defines BIM interoperability as an effective interoperable environment ensuring one-time data entry and the seamless flow of information to all stakeholders throughout the project life cycle. Because multiple stakeholders share the same information improvements interoperability lead s to improvements in the efficiency and competitiveness of each stakeholder. Open international standards are imperative for an efficient information exchange.

3.2.1 BIM and stakeholder communication

The information exchange model adapted from Dinesan, B., 2008 highlights how BIM can improve the information exchange between the different stakeholders involved in the development and operation of a built asset.

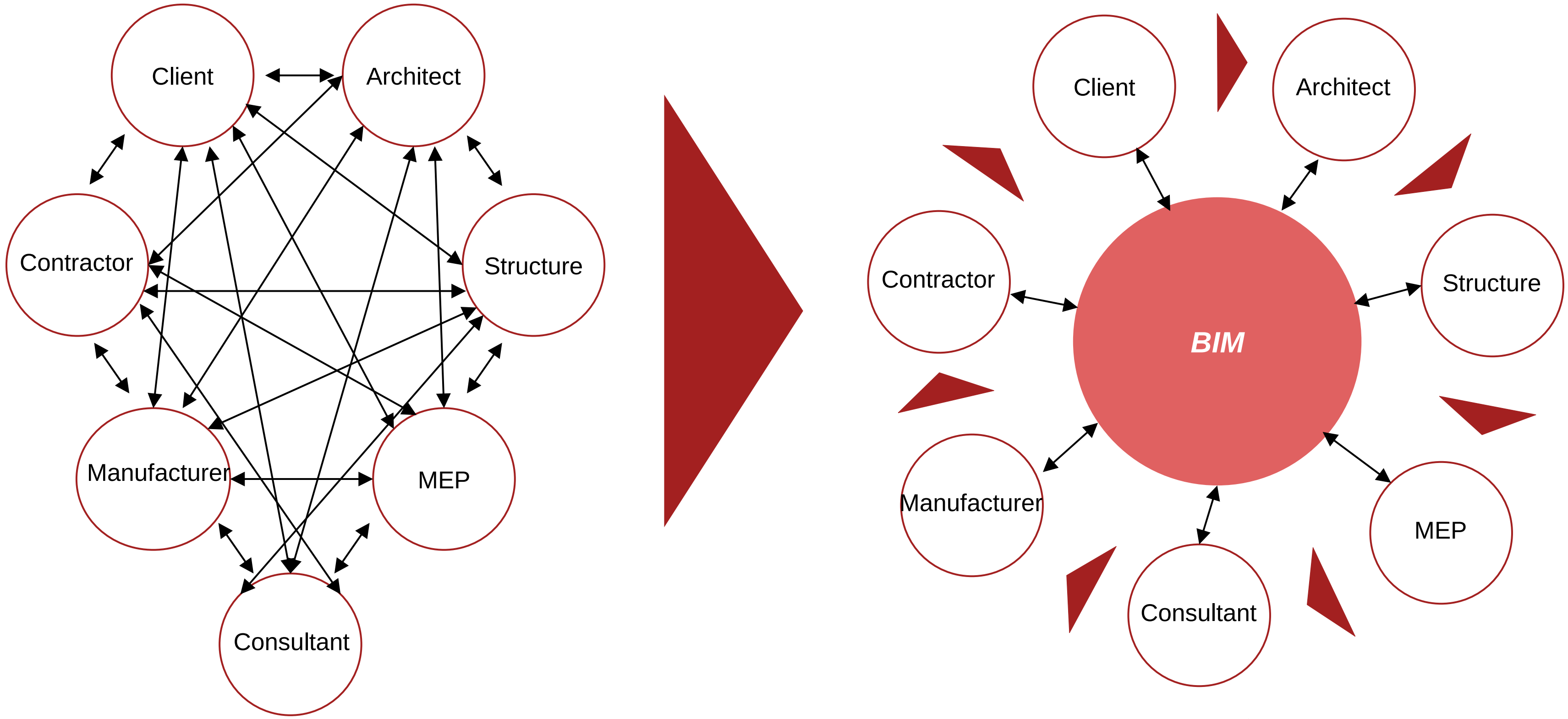


Fig 3.1:- BIM Information exchange model

The left hand side indicates the traditional stakeholders interface and communication channels with each stakeholder having a number of interfaces. Typically data and information is stored on internal systems and exchanged in an uncontrolled manner which can result in confusion and poor project and executive decision making.

The right hand model views BIM at the centre of stakeholders and indicates that they all have a two way informational flow with BIM. This is important because it ensures that all interested stakeholders can contribute to the data base, access the latest 3D model development and have access to the same consistent data[3]. This is why BIM is often referred to as the **'single point of truth'.**

The advantages of the right hand model are that it can improve efficiency by:

- Providing the latest information to all stakeholders.
- Reducing time checking & chasing the latest information (schedules, drawings specification etc.).
- Improves the communication process between key stakeholders by streamlining the number of distribution channels
- Provides a single auditable record of the built assets development.
- Minimizes the need for each party to keep their own records and maintain their own technology platform.
- Makes data and information neutral, and for the benefit of all the stakeholders

The original contributor is responsible for the quality and correctness of the data entered, but does not own it and cannot restrict access to it.

3. BIM is often associated with Industry Foundation Classes (IFC) data structure for representing information. IFCs have been developed by building SMART (the former International Alliance for Interoperability), as a neutral, non-proprietary or open standard for sharing BIM data among different software applications

3.2.2 BIM Deliverables & requirements

Fig 3.2 captures the key elements associated with the use of BIM.

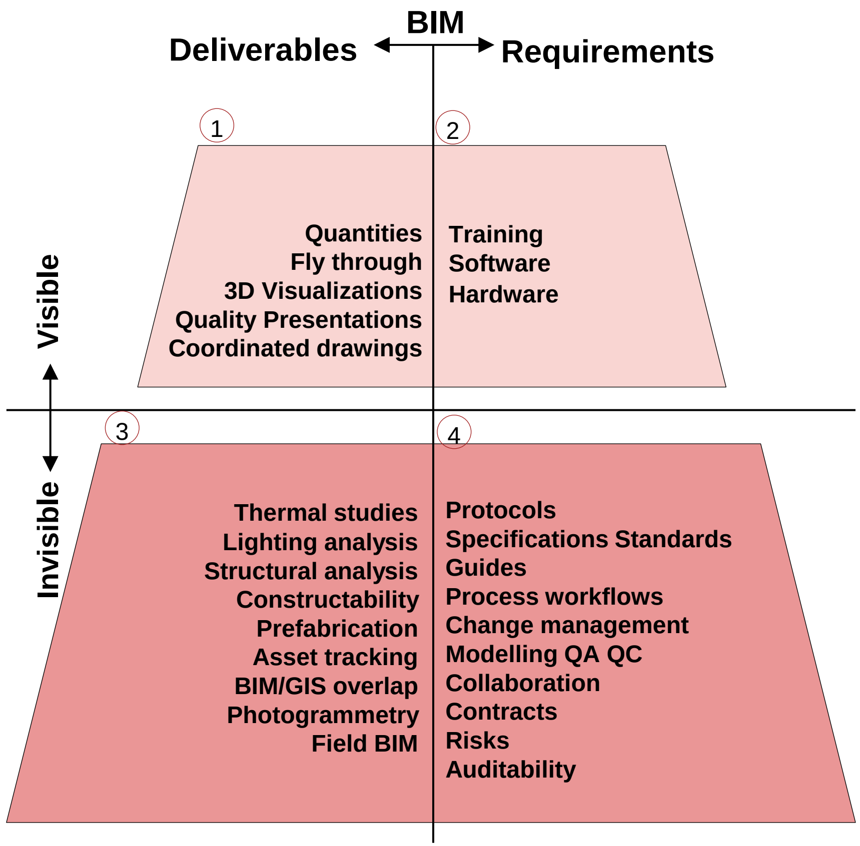


Fig 3.2:- BIM deliverables and requirements "iceberg" model

An effective way of interpreting the model is to considers it similar to an iceberg with the visible elements representing a relatively small part of the whole.

1) and 2) are the elements most closely associated with what BIM delivers and what is thought to be required to provide the deliverables.

However, it is what is invisible 3) which articulates BIM's true capability and, more importantly, the requirements that need to be in place and integrated with existing delivery processes 4) to fully maximize it's capabilities.

Inexperienced/uninformed users are naturally drawn to the contents of 1) and 2) because they are visible and relatively well publicized.

However, successful examples of BIM project implementations:

1. Commence by defining the end in mind i.e. what does the owner really require and what are the real development objectives before working through the contents of 4) to produce an integrated work plan, which:
   - Captures and assigns the contents of 1) and 3), before
   - Detailing how 2) will support.

3.2.2 BIM Deliverables & requirements

Figure 3.3 maps the asset lifecycle project and operational to the BIM information process flow.

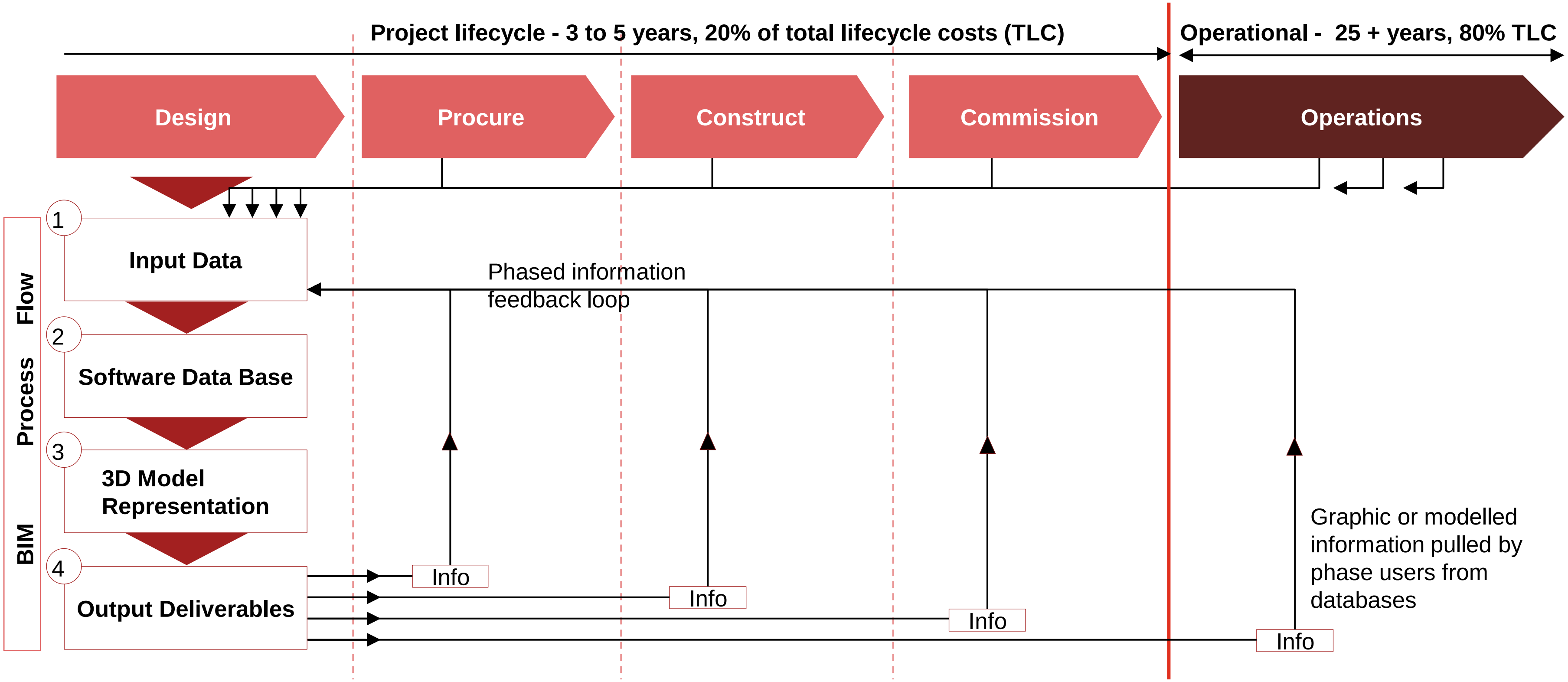


Fig 3.3:- Combined BIM process flow and asset development lifecycle

The BIM information process flow comprises of 4 steps:

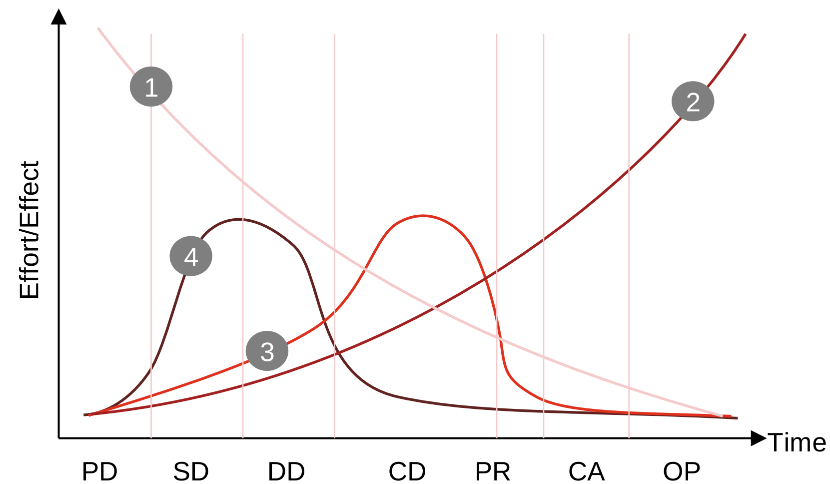
1. Input data. At the commencement of the project, the various design team members (architects, structural, mechanical and electrical, etc.) provide their input in the form of design information (drawings, specifications, schedules etc). It is important to note that as the initial source of the data input, the quality and accuracy of the data entered during this step will have massive ramifications throughout the whole of the project as subsequent BIM users refer to and/or build on the source data. As the main contributor to, and often the leader of the design process, it is imperative to both the overall success of the project and the value that BIM delivers, that the architects design team are aware of their BIM responsibilities in terms of the quality entered and interfacing system interoperability.
2. Software Database. This is where all the inputted data is stored. Typical software platforms include Revit, Archicad, Bentley etc.
3. 3D Model Representation. At this step it is graphically possible to create the 3D information model, these can be fully coordinated or isolated models or views depending on requirements.
4. Output Deliverables. Users are able to draw on the information stored in the tools and databases to prepare a wide range of modelled outputs including:
   - 4D Programmes.
   - 5D Costings.
   - 6D Facility maintenance data.

As the data base is populated, the output deliverables are provided (push or pull) throughout the duration of the asset life cycle. Whilst the above description tends to suggest are linear process flow arrangement this is not the case. New data can be input throughout the life cycle of the whole project to keep the master databases and the 3D model updated and relevant.

There are 3 points of note:

1. The quality of the 3D model representation and output deliverable will be directly proportionate to the quality of the input data.
2. For a typical asset, the operational lifecycle cost is approximately four times that of the initial asset development capital project budget. During the project phase the need for BIM budget and project professionals are readily available, however, this is not typically the case within the operations environment.
3. The creation of the BIM information database early in the assets development lifecycle (ideally early stage design phase) improves the opportunities for information sharing, communication between interested parties and is consistent with controlling project costs.

Figure 3.4 adapted from building SMART UK, 2010 demonstrates the benefits of information sharing and the link to the controlling cost during the project lifecycle.



PD: Pre design SD: Schematic design DD: Design development CD: Construction administration OP: Operation	1 – Ability to impact cost and functional capabilities 2 – Cost of design changes 3 – Traditional design process 4 – Preferred design process

Fig 3.4 BIM Technology:- The benefits of information sharing

As curve 1 indicates the ability to impact cost is at its highest at the start of the asset development lifecycle and diminishes over time.

Curve two indicates that the cost of design changes is lowest at the beginning of the asset development lifecycle and increases dramatically as time passes.

Curve four reflects the effort expanded during the sequential asset development process (i.e. design to procurement to construction etc.) where by information is made available as the proceeding activity winds down. The result of this is that the maximum effort expended during a project typically occurs during the construction phase when the ability to impact cost is declining and the cost of design changes are starting to increase exponentially.

Finally, curve three highlights the benefits to be gained by utilizing the BIM process and shifting the maximum effort curve to the left of the chart. (i.e. from the construction phase to the design phase). These include:

- Increasing the time available to detect potential issues and subsequent solutions.
- Improved planning and scheduling analysis.
- Shortening the documentation phase.
- Potential to accelerate the construction phase schedule.

3.2.3 Levels of BIM

Fig 3.5 :- PCH and levels of BIM framework has been modified from the original Australian Institute for Architects (AIA) and CRC for Construction innovation framework. The model assists with the visualisation of progressive BIM implementations and the positioning of the PCH project.

The model is constructed in 4 stages from level zero (00) isolated through to level three (03) fully integrated. Each stage has two subdivisions ranging from 0A 2D manual, to 3B web service.

Current BIM capability commences at level 1B through to 3A. Fully integrated 3B web based object based sharing is currently used primarily for research.

Level 0 to 1A represents where many projects are operating today.

We consider that BIM @ PCH sits between level 2B and 3A with an aspiration that stretches to between sub stages 3A and 3B, this is:

- Far in excess of where many projects are operating.
- To the extremities of first time users of BIM (1B), and
- Further than the majority of users (1B to 2A).

3.2.3 Levels of BIM

Fig 3.5 :- PCH and levels of BIM framework modified from the the Australian Institute for Architects (AIA) and CRC for Construction innovation.

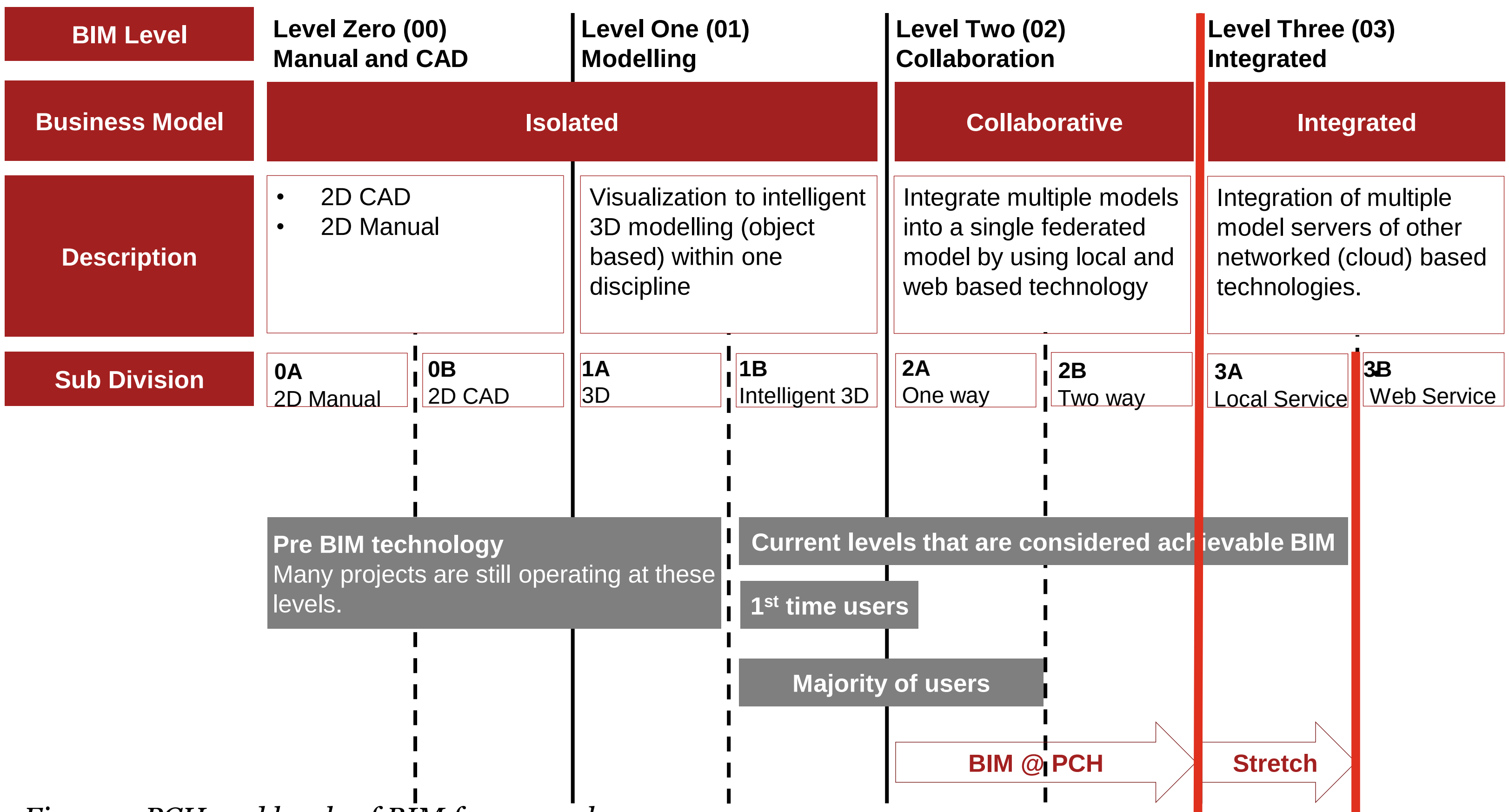


Fig 3.5:- PCH and levels of BIM framework

3.2.4 Levels of Development (LOD)

LOD fundamentally describes how information in a BIM model progresses and how much information will be usable at each stage or milestone of the project.

The AIA E202-2008: Building Information Modeling Protocol Exhibit defines the following five basic levels of development which reflect a generic definition of model content and authorised uses of the model for the respective LOD:

- **LOD 100** - Equivalent of **conceptual design**, the model would consist of overall building massing and the downstream users are authorized to perform whole building types of analysis (volume, building orientation, cost per square foot, etc.)
- **LOD 200** - **Schematic design** or **design development**, the model would consist of "generalized systems or assemblies with approximate quantities, size, shape, location and orientation." Authorized uses would include "analysis of selected systems by application of generalized performance criteria."
- **LOD 300** - Model elements are suitable for the **generation of traditional construction documents and shop drawings**. As such, analysis and simulation is authorized for detailed elements and systems.
- **LOD 400** - Model elements are suitable for the generation of traditional construction documents and shop drawings. As such, analysis and simulation is authorized for detailed elements and systems.
- **LOD 500** - The final level of development represents the project as it has been constructed – the as built condition. The model is suitable for maintenance and operations of the facility.

3.2.5 The benefits of BIM

The correct use of BIM technology can improve the approval, design, specification and documentation, as well as the tendering, appointment and contract management stages of a project by increasing data integration and information sharing, as well as reducing design and documentation shortcomings.

Whilst anecdotal information suggest that as a percentage of total project contact value, the:

- Cost of implementing BIM = 0.2 – 2 %, and
- Reduction to project budget = approx. 10 - 15%

Stanford University Center for Integrated Facilities Engineering state that a successful BIM project can:

- Eliminate under budgeted change by up to **40%.**
- Reduce a cost estimate generation by **80%.**
- Ensure cost estimate margin accuracy by ± **3%.**
- Save up to **10%** of a projects contract value by improved clash detection.
- Reduce the project schedule by up to **7%** due to all project stakeholders having access to the same schedule, costing utilization & financial information.

Cooperative Research Centre (*CRC) for Construction Innovation*, state that the primary benefit of BIM is its ability to present integrated data in the form of an accurate geometrical model and that the subsequent benefits include:

- Improved design - building proposals can be rigorously analyzed, simulations can be performed quickly and performance benchmarked, leading to improved and innovative solutions.
- Improved whole-life costs and environmental data.
- Improve existing business processes – as information is more easily shared, it can be value-added and reused.
- Common operational data protocols can be created from the improved business processes, leading to further efficiencies.
- Increased output quality as objects are only modelled once in BIM, meaning that drawings automatically derived from that model are more consistent and accurate, and avoid clashes that may otherwise occur.
- Improved customer service - proposals are understood through accurate visualization and presentations.
- Asset development lifecycle data - requirements, design, construction and operational information can be used in facility management integration of planning.

Hedges, n.d suggests that BIM technology reduces three types of costs:

1. Avoidance costs - by reducing interoperability problems such as maintaining paper exchange systems due to improved information and communication processes:
2. Mitigation costs - by reducing the need to perform redundant activities such as manually re-entering data as professionals are able to work simultaneously within the same 3D model, and
3. Delay costs - for instance, by reducing the waiting times for information exchange.

Finally, *McGraw Hill Construction* found that BIM benefits included:

- Better than expected value - 70 per cent of users who measure return on investment (ROI) saw a positive return on the use of BIM.
- Competitive advantage - BIM is seen as a way of entering new markets, and an additional way of marketing a firm.
- Improved productivity – BIM technology reduces rework and duplication, with 80 per cent of experts saying that BIM brings high to very high value to a firm.
- BIM has the potential to improve productivity and reduce conflicts and changes during the construction stage of a project.
- Improved communication. The use of BIM technology particularly 3D visualization, facilitates improved communication between all members of the project team. 80 per cent of users consider this to be the **most important way** of improving value
- Improved project process outcomes (such as fewer onsite coordination problems). Users rated this as the **second-most important** way of improving value.
- Owner demand. 50% of owners report improved construction outcomes as a result of the use of BIM.

- Improved real time information sharing between all stages of the developed assets life. For example the information required at decommissioning will be available without having to liaise with the original designers.
- Improved information sharing and reduced costs of miscommunications, and
- Improved interoperability and information sharing reduces the costs associated with:
    - Manual re-entry of data between different systems.
    - Time spent duplicating software.
    - Time lost to document version checking.
    - Increased time required for information processing, and money for data transactions.

3.3 Industry criticism

Throughout the design and construction industry a perception exists that software companies are selling BIM as the software that solves all project problems. Consultants and designers stand accused of overselling their services and that, with the benefit of hindsight, these services often don't provide the solution promised.

Other notable criticisms of non adopters include that they:

- Don't understand what integrated BIM is and what it can do beyond their immediate discipline/functional needs.
- Find that value is difficult to articulate.
- Find that that the promised business case benefits are difficult to measure and quantify.
- Find complexities in BIM deliverables.
- Can't get their BIM system to communicate to other project members BIM systems.
- Don't believe that they have received the value and efficiency improvements that they anticipated.
- Are confused as to the true level of investment required.
- Are not aware of the organisational changes that embracing BIM as a core project/business process brings.
- Have a limited knowledge of the products & market.
- Associate BIM benefits primarily in terms of improved visualization and coordination, and
- Consider it a promotional tool.

3.4 The glass corridor anecdote of the value of BIM

The following anecdote provided by the professor responsible for establishing the UK BIM Academy at the University of Northumbria succinctly captures how non project professional see BIM value.

The setting was a design review of a prison project in the UK. During a design review, a senior prison warden was asked to comment on the security separation design for a long common access corridor. When shown the 3D visualisation of the corridor the senior warden asked if the full height metal security barrier could be remodelled using toughened glass. The design team investigated her request and quickly redesigned the corridor replacing the metal barrier with toughened glass.

The senior warden was delighted with this outcome because changing from steel to toughened glass allowed visibility of both sides of the corridor which in turn meant that only one warden was required to patrol the corridor.

This anecdote highlights the benefits of the end user being involved in the design process.

1) The benefits and power of 3D visualisation over 2D paper plans and section drawings, and

2) The speed at which new information can be introduced and assessed to a meaningful outcome.

Section Four

OSP's BIM PCH Project experience

4.1 Introduction

As highlighted in section 2 at the time of the PCH project commencement in 2011, SP, with very little experience or know how, mandated the use of BIM for the PCH Project. It is understood that the starting point was literally an idea and desire to ‘give it a go’ and armed with some internet research is how BIM at PCH got started.

This section provides an overview of what the ‘project within the project’ has achieved since then and covers the current solution architecture, hardware and software schedules.

It also provides the answers and insights to a number of key questions asked of a cross section of the collocated project team, all of who, in the spirit of collaboration took time out their busy schedules to provide their experiences and insights.

4.2 PCH BIM architecture. The implemented system comprises of a number of different software packages / tools, each to fulfil a specific need. The overall system is considered a BIM solution.

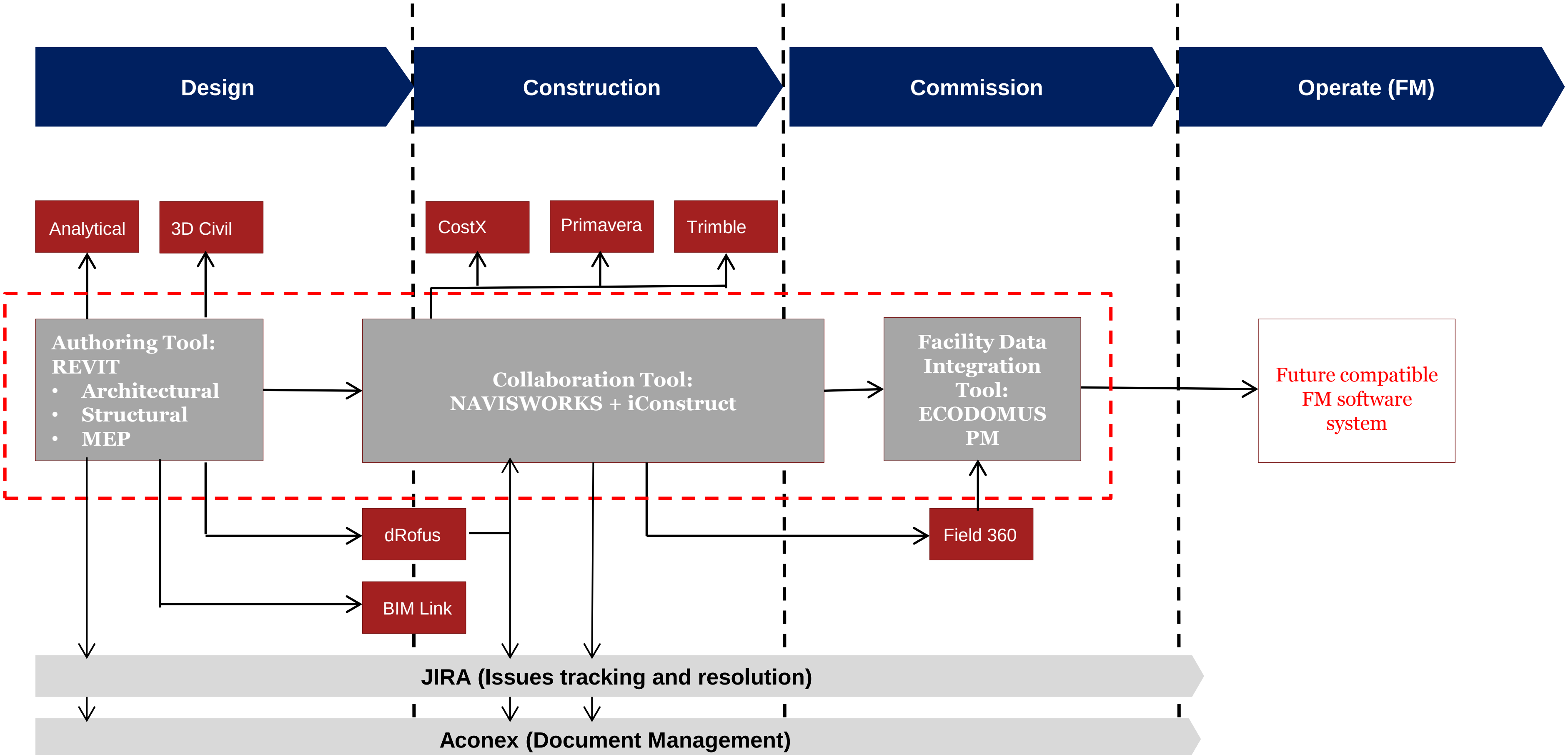


Fig 4.1 - PCM BIM Architecture Model

4.3 Hard and software schedules

Fig 4.2 highlights the PCH BIM software.

Software package tool	Description
1. Autodesk Revit	Autodesk Revit is a building information modelling software for architects, structural engineers, MEP engineers, designers and contractors. It is a design tool primarily focused on editing geometry and managing the information around an object. It allows users to design a building and structure and its components in 3D, annotate the model with 2D drafting elements and access building information from the building models database. Revit is 4D BIM capable with tools to plan and track various stages in the building's lifecycle, from concept to construction and later demolition.
2. Autodesk Navisworks	Autodesk Navisworks enables co-ordination, construction simulation and project analysis for integrated project review. Navisworks products include advanced tools to simulate and optimize scheduling, identify and co-ordinate clashes and interferences, collaborate and gain insight into potential problems
3. dRofus	dRofus supports the key business processes required in construction projects: • Planning and mapping of areas, rooms and functions • Room Data Sheet (RDS), registration and monitoring of the requirements for each room · • FF&E planning, cost control and procurement of FF&E • Check and visualization of designed model through IFC The introduction of BIM means that the necessity for accurate and accessible information has become even more important.
4. BIM 360 Field	**BIM 360 Field** is construction field management software that combines mobile technologies at the point of construction with cloud-based collaboration and reporting. Turn your field data into information that improves quality, safety, and profitability for construction and capital projects. This is a cloud-based service and allows onsite access to the BIM Model via an Ipad. The Autodesk BIM 360 Field iPad app enables BIM 360 Field users to create and update issues, reference project documents, and run QA/QC, Safety and Commissioning checklists throughout all project phases.
5. Trimble	**Trimble S6 Total Station** provides integrated GPS onsite surveying direct from the BIM 3D model.
6. Ecodomus PM	**Ecodomus PM is** an interface / integration tool for editing BIM and COBie data. It connects to existing BIM database systems and provides an interface to edit, extract and handover BIM data for use in other systems.

Fig 4.2 PCH BIM Software Schedule

4.3 Hard and software schedules

PC Specification

Processor:	Intel® Xeon® CPU	W3690 @ 3.47GHz 3.46 GHz
Installed Memory (RAM):	24.0GB	
System Type:	64-bit Operation System	

Server Specification

• 2 HP DL380 G7 Upgrade – 16GB Memory Module	• 64GB PC2-10600R ECC Memory
• 1 Aspose.Word for .NET. Aspose.Cells (Excel) for .NET & Aspose.Barcode for.NET	• 146GB 10K 6GB 2.5 Hot Pluggable SAS Hard Drives
• 1 Windows Server Standard 2012 – License only	• HP Smart Array P410i/1GB Flash Backed Cache RAID Controller
• 1 Microsoft SQL Server 2012 – Standard Edition – License only	• SATA DVD-Rom Drive
• 5 Microsoft SQL Server 2012 – License only	• 2 HP NC382i Dual Port Multifunction Gigabit Server Adapters
• 1 Symantec Backup Exec 2012 – Application Agent for Microsoft SQL	• HP4GB PCIe Fibre-Channel Adapter
• 1 Symantec Backup Exec 2012 – Agent for Windows Server	• 2 x Hot Pluggable Power Supplies
• 1 EMCVNXe3150 – SAN Storage Solution	• Rack Mount Rails Included
• Includes Dual Redundant Storage Controllers	• HP iLO Advanced License
• 12 x 600GB 15K SAS Drives	• 2 HP V1810 24 Port Gigabit Web Managed Switch – SAN Redundancy – New
• 1 HP ProLiant DL380G7 2U Rack Mount Server	• 1 HP NC522SFP Dual Port 10GbE Server Adapter (SAN Connectivity) - Existing
• 2 x Intel Xeon X5650 2.66GHzSix-Core Processors	

Fig 4.3 PCM BIM hardware

Backup Hardware

- HP X1400 G2 NAS (4 x 2TB, 4GB RAM, 1 x CPU)
- HP MSL 2024 G3 Tape Autoloader (Single LTO5 Drive)

Backup Configuration

Backup to Tape

The tape backup is configured to use a HP Tape Autoloader using Ultrium LTO5 technology. The current HP tape autoloader can utlilize up to 2 tape drives and up to 24 tapes. The PCH project is currently using a single LTO5 tape drive with 30 tapes (2 Tapes per full Friday backup, one tape per weekday Monday-Thursday used for differentials and rotation is over 5 weeks. 6 Tapes x 5 Weeks). Full backup of Exchange Server and data is performed every weekend. Differential backups of all data and full backup of Exchange is nightly.

Backup to Disk

The disk backup is currently running on HP NAS device. There is a full backup for data every second weekend to the NAS and a differential backup of data being performed nightly in between. This is the maximum that can be achieved currently with storage capacity but allows quick restore for data within a 2 weeks window. The retention period may decrease in the future as overall storage requirements increase.

Backup Archive

This backup allows for point-in-time snapshots of the full project environment. Current archiving is being performed by John Holland by removing "Backup to tape" media from rotation and replacing with new tapes. John Holland has implemented and advised that archiving is performed monthly and sent to a third party storage location.

Fig 4.3 details the PCM BIM hardware

4.4 SME Interview and observations

The face to face interviews were held throughout January and February 2014 with three broad groups:

1. Key State stakeholders (State project director, PCH project team (40% of sample group)
2. Key John Holland Group (JHG) PCH project team members (20% of sample group)
3. Industry SME's comprising of BIM software providers, BIM service providers , academic researchers and SME's from 3rd party construction and resource organisations (40% of sample group).

The interviews were conducted face to face on the condition of anonymity and used the questionnaire to provide a structural framework around which the discussions developed.

All the interviewees gave their time willingly and were extremely helpful in providing answers, examples and insights.

Key Observations

- *Question 1.1:-* The majority of the responses focused around the 3D modelling and design aspect of BIM. Other responses allude to it being a tool, process and/or collection of systems for managing data and information. Isolated responses viewed it as a facilities management tool and alluded to its value during an assets operational phase.
- *Question 1.2:-* Responses reflected that for the majority this was their first experience of working with BIM and that those most comfortable with BIM were not project professionals, but came from a software or BIM services background.
- *Question 1.3:-* Positive observations focused on the accessibility that the model allows the client and team members to the design development, its unlimited potential and its speed relative to 2D drawings.
- Negative comments focused primarily the up-front additional cost impact, design team competency and inability to use BIM correctly. Other comments referred to the frustrations understanding technology, lack of training and access to computer hardware in both the State and JHG teams.
- *Question 2.1-2.3:-* Virtually all the interviewees responds indicate that the introduction of BIM was a positive step and this is reflected in the wide range of answers provided. Bullet point five, however, provides a reminder that value hasn't been fully maximised due to data trust issues and of some of the challenges ahead (lack of understanding and embracing change). In terms of the project phase where BIM was seen to add value, interviewees aligned with their own personal areas of competency and as a result, design and construction management figured highly, while procurement was virtually ignored. Regarding the measurement of value, it is apparent that whilst all interviewees recognise that BIM is adding anecdotal value, the are no processes presently in place to measure its benefits empirically.
- In response to *question 3.1* regarding BIM's strengths, many of the answers focused its visual capabilities especially during the design stage. *Question 3.2* (BIM weakness) provided an interesting insight concerning the relative understanding and capabilities of users at different ends of the age continuum. Finally, question 3.3 brought out interesting legal implication relating to professional negligence and also the fact that if BIM becomes a core process then organisational capability will have to change as it did when IT was embraced.

4.4.1 Understanding and previous experience of BIM

The interviewees provided commentary and response to the following three questions:

Question 1.1: What is your understanding of what BIM is and when asked, how do you define it?

- A information structure
- A different way of working
- A 3D model
- A 3D design tool used to resolve issues on screen
- A change management tool.
- An object orientated way of organising data
- A design tool which can be used during the design and build phases of a project.
- A 3D design platform allowing improved coordination.
- Multiple systems brought together in one place where the project design resides
- An informational repository
- A collection of systems which work together in a process
- A number of software packages which can provide project and business information
- An FM management tool used to capture and present project information to the operational team.
- A system to capture the correct information at the correct time and reusing the information during the operational phase of the asset.

Question 1.2: *What experience do you have of BIM, I.e. primary (as a user), or secondary (as an involved party)?*

The answer to this question can be represented in 3 broad groups.

First timers. The majority of interviewees responded that this was the first time working with BIM and that they had little or no previous BIM experience.
Familiar. A small number of interviewees were familiar with BIM terminology and had been around projects long enough to have seen the paper to digital development, but didn't consider themselves BIM experts.
Experts. The smallest number of interviewees and not unexpectedly drawn from the software and service providers. Whilst acknowledging their understanding they also made it clear that developments to software capability are relentless and fast paced.

Question 1.3: Describe your BIM observations to date,

Positives

- Great for creating room data sheets (RDS).
- Positive very leading/bleeding edge.
- It can do anything in the right hands
- BIM is very good, but users need to familiarise themselves with it.
- The model will prove that JHG have done the job requested of them.
- BIM allows client to look at the project for what it is
- No revisions anymore, 3D model is live.
- BIM has taken away the "black box" secretive and exclusive approach promoted by designers.
- Architects no longer in control of design process instead multiple parties able to work direct in the model.
- Able to articulate design details is simpler and quicker than 2D paper drawings.
- Ability to extract data in terms of objects and attributes i.e., Doors Costs.
- Virtual imagining is a very powerful tool and aids understanding

Negatives

- Costly to implement and an extra cost to the project.
- Design team were just not familiar or competent with BIM despite stating otherwise.
- Size of model is now too large and unwieldy to use efficiently.
- Government policy forbidding data being stored in the cloud due to core business confidentiality.
- Little or no training.
- Team is too busy working to understand and utilise BIM to its benefits.
- Pay scale discrepancies between technology & construction personnel.
- Miscommunications due to lack of experience.
- People don't like change so it needs managing better.
- Technology is "too hard to understand" users not confident with it.
- Disadvantage is that costs are upfront and the return is delivered later
- Incorrect set up of design data, object families and libraries.
- Lack of computer hardware in both state and MC project teams
- Short term pain caused by implementing BIM was underestimated.

4.4.2 Value delivered by BIM to the PCH project

The interviewees provided commentary and response to the following three questions:

Question 2.1: How do you see BIM delivering value to a project and the supporting business?

- Adoption by subcontractors.
- Using the same data for ordering, receiving and paying for goods during the procurement process.
- Better understanding what the risks are.
- Design modelling and on site set up using Trimble.
- Value has not been maximised due to a lack of trust in the data contained in the model and project and industry partners not understanding the advantages of working from the model or willing to embrace the required changes.
- To understand value the asset end users (operations and FM) should be involved earlier and to a greater extent than they have been.
- Fly through and virtual modelling should be used to accelerate the familiarisation process.
- Using the 3D model rather than drawings.
- Time saved in finding things in the model vs paper plans and sections.
- dRofus scheduling off the FF&E requirements .
- Build and installation sequencing previously stakeholder had to agree on a vision of what they thought everyone wanted.
- Saving the cost of printing paper copies of drawings.
- Design developed quicker allowing fact based informed decision making.
- Visualization to the non project person.

Question 2.2: During which project phase, design, procurement, construction operational readiness or asset operation and maintenance do you see BIM delivering value?

In the vast majority of cases, answers to this question, were aligned with the interviewees functional design expertise or interest area. The exceptions to this were:

1. The senior respondents of both the state and JHG who unsurprisingly had a wider life of asset perspective.
2. The industry SME group who tended to see the ultimate benefit is terms of asset management during operations.

When interviewees acknowledged other functional areas, design, construction management and FM were highlighted but procurement was ignored.

Question 2.3:How is it possible to quantify and measure the value BIM returns?

- Generally hard but there are some easier instances such as the ordering of FF&E.
- It was never the intent to measure the value delivered. The primary focus was always to get the building built and learn about how BIM can support along the journey. No meaningful measurement indices are currently in place but specific research could be carried out if required.
- Will only be able to do this at the end of the project when the data & information is packaged up and handed over.

4.4.3 Strengths, weaknesses and opportunities

The interviewees provided commentary and response to the following three questions.

Question 3.1: What do you consider BIM's strengths to be?

- 3D virtual modelling.
- Clash detection and avoidance.
- Fly through capability.
- Provides a single point of reference for master data.
- Ability to develop the design faster than the traditional methodology.

Question 3.2: What have you found its weaknesses to be?

- Trust in the data integrity due to poor data input.
- Ensuring its kept up to date.
- Adoption resistance and low user capability within design team.
- General lack of understanding as to what BIM is and how it can be used.
- Main contractors now using BIM but 2nd and 3rd tier don't due to lack of awareness and competitive cost pressures .
- Understanding what associated project & business processes have to change to accommodate the BIM process
- Generational experience: Older project experienced people are not generally BIM savvy, whilst young graduates know how to work the software but don't have project experience.

Question 3.3: What do you believe are the future opportunities for BIM within a capital project development lifecycle?

- Redefining core project processes i.e. design offshore drafting
- Legal Implication: BIM becoming a core design, construction and FM process tool then not using it may be regarded as professionally negligent.
- Could be used for early stage optioneering at pre tender stage.
- Change the risk profile of a construction business by facilitating improved risk identification and management.
- BIM Nirvana:- Full integration between software data bases & systems through the whole project lifecycle.
- BIM will have to come into design, construction & form organisations just as IT did 20 years ago.

Question 3.4: What is anything would you do differently if you could specify, implement or use the PCH BIM again?

- Clearly specify the requirements.
- Provide a comprehensive governance framework.
- Clearly specify the level that BIM is to be used during the different project lifecycle phases.
- Liberate BIM from the design team earlier so that value can be spread around other parts of the project delivery team.
- Better engagement with the MC.
- Clear understanding of what the end will be.
- Provide training, both initial and ongoing.
- Bring BIM capability in house to create bespoke processes & policies.
- Would hold the actual design commencement until BIM governance structures were fully established and object families created correctly.
- Understand what's required as a deliverable and then design the BIM solution to provide it.
- Better understand the choices of software.
- Think through how to better present BIM benefits to tradesmen.
- Improve due diligence of the designer organizations BIM capability down to individual experts capabilities.
- Banish paper altogether to further accelerate use of 3D modeling.
- Targeted random audits of all users.
- Process map the software architecture and the verify and validate it.
- Ensure that organizations can do what they say regarding BIM.

4.4.4 Miscellaneous comments

- The State is very hands on and understands the benefits and constantly promotes BIM which is a positive.
- Both the State and the MC are learning about BIM as the project progresses which is exciting but also challenging and sometimes inefficient.
- The MC appears to be gaining more benefit from the States decision to mandate BIM usage than the State itself.
- People are seduced by the glossy features of BIM such as 3D modelling, clash technology and fly throughs rather than bothering to understand its true capabilities.
- Design & construction contacts do not generally support collaboration team working.
- The construction industry is slow to embrace change and adopt new technology.
- Non BIM specialist organisations will struggle to retain BIM capability due to:
  - Salary expectations
  - Training & development required for BIM experts to stay informed.
- Need to develop strategic partners to provide BIM capability.
- More design is carried out earlier in the project lifecycle but is heavily reliant on the quality of input.
- Contracts from clients look to pass as much risk as possible onto contractors.
- BIM technology will be a benefit to the State as a means of addressing the lack of qualified resources.
- Government to sponsor usage as construction organisation will not implement by choice.
- Current contracts often award lowest price rather than content & capability.
- Design team members (architects & designers etc.) are practitioners and users and not BIM experts, therefore they rarely set up the BIM structure for the whole project.
- Collaboration & not being maximized because of pride and ignorance.

4.5 BIM 4 and 5D

BIM 4D has been utilized on the PCH Project for the following planning activities:

- Locating optimum crane and hoist positions.
- Placement temporary site accommodation.
- Scaffold planning for edge protection and access.
- High level services installation sequencing.
- Planning for installation of major medical equipment (MRIs)
- 4D Scheduling of Structural frame (utilising Primavera & 'Navisworks Timeliner' function).
- 4D Facade construction sequence.
- 4D Roof steel construction sequence.
- 4D typical riser services installation sequence.
- 4D typical fit-out sequence (including, walls, finishes & fit-off items).
- 4D simulation of complex construction areas ie Core B top-out, flue installation and enclosure.
- 4D As-built programme outputs (for assessing time claims)

There is a belief that the State has not received any direct value from 4 and 5D. This is due in part to the nature of the contract, i.e. the MC taking schedule risk, It is understood that it was attempted to utilise BIM 5D to:

- Take-off quantities for development of detailed fit-out programme, and.
- To enable cash flow forecasting.

However, this hasn't eventuated due to:

- The fact that 5D has been used in a limited manner due to unfamiliarity and lack of confidence in its capability.
- A lack of confidence that the initial BIM input values were correct. As a result checking of quantities and traditional cost management is still being practiced.
- Differing views and classification systems across design professionals regarding rules of measurement.

4.6 BIM 6D

The FM teams exposure has been limited to attending some of the on site presentations and discussions with CSI.

They remain to be convinced of the need for, and advantages of, BIM 6D and are presently caught in the circle of being asked what they want BIM to do for them without fully understanding what BIM can provide for FM. Current understanding is that BIM is:

- Information Modelling.
- Graphical Modelling.
- Easy to access and.
- That data can be held against assets.

FM's requirements are practical and pragmatic based on years of experience such as a request that the BIM 3D model should integrate with the:

- Document Management System.
- Works Management System.
- Building Management System.
- Should be able to switch off layers.
- Strip off ceilings so that hidden equipment can be viewed.
- Make it easy for users to find their way around the building.

- How will up skilling of FM operatives occur and how will current proposed operational budget change to effect new process.

Other project teams 6D feedback:

- LOD 5 will contain too much information.
- FM won't know what to do with it.
- Little information exists about the handover process.
- North Metro will ultimately provide FM for the asset, however, the concern is that they don't have the understanding or capability. This requires:
  - Investment
  - Capability upskilling
  - Organisational restructuring
- There is no benefits awareness, coordinated data strategy (project, site, enterprise and state-wide) in regards to 6D.
- BIM 6D is not fully understood or tested and as such there is very little guidance to support the State with 6D beyond practical completion.
- Lack of clarity as to what the data handover and data cleansing process looks like.
- Asset owners need to understand their software and hardware investment decisions.

Section Five

Global Developments

5.1 Key Observations

BIM adoption is on the increase around the globe and is often lead by national governments, however:

1. While aspirational, no instances of fully integrated BIM design, construction and FM have been found.
2. 5D appears more utilised than 4D, primarily via quantity surveying organisations.
3. 6D integration with FM, maintenance and/ or enterprise systems not common.
4. Up skilling tier 2 and 3 contractors is a priority.
5. In both the UK and US BIM is breaking out from building (vertical) construction into infrastructure construction projects.

The information provided in this section has been gathered from document reviews, academic and internal PwC SME phone interviews.

5.2 BIM in the UK

In June 2011 the UK gave a clear message to the whole project development supply chain about the government's BIM programme and requirements by:

- Publishing its BIM strategy, announcing its intention to require collaborative 3D BIM (with all project and asset information, documentation and data being electronic) on its projects by 2016. Initially, compliance will require building data to be delivered in a vendor-neutral 'COBie'[4] format, thus overcoming the limited interoperability of BIM software suites available on the market.
- Calling for BIM adoption on UK government construction projects of £5million and over.

The UK BIM industry can trace its roots back to the publishing of the Latham report in 1994 and the Egan report in 1998 into the state of the UK's then moribund construction industry.

A key finding was that the confrontational and adversarial nature of the industry was detrimental to the overall health of the industry and that teamwork in a ccollaborative environment could increase inefficiencies, benefit stakeholders and delight customers..

By 2005 BIM was being used primarily for structural integration and by 2010 design teams had started to realize that they could generate drawings much quicker and with greater accuracy, with so called little BIM.

The UK government has in the last three years shown a phenomenal amount of interest in understanding how the benefits of BIM can flow through to the wider UK economy. This interest has been matched by UK construction professionals, with a recent survey showing that BIM adoption among UK construction professionals had increased from 13% in 2011 to 39% in 2013.

The UK government's target for level 2 BIM is the major "pull" driver from the client side of the industry and other informed clients are now also asking for BIM but at a relatively immature level.

Initially architects lead the BIM charge, however, this has now changed and many of the BIM projects that occur in the UK are driven by forward thinking MEP organisations who use it as a tool for their own benefit and occasionally in collaboration with other designers.

4 According to the BIM Working Party Strategy Paper, Construction Operation Building Information Exchange (COBie) is a vehicle for sharing primarily non graphical data about an asset. Its purpose is to assist the owner in receiving complete and useful information for the purposes of facility management. Its non proprietary format is based on multiple page spreadsheets easily managed by any size of organisation and by any level of IT.

Tier one contractors are becoming more and more interested as they have the most to lose in terms of saving cost.

There has been a recent move to include phasing information in the models and for main contractors to look to use BIM to understand their construction process.

While many companies claim to be at level 2 BIM that would be a much broader definition and not complying with all the requirements of PAS[5] 1192-2 (a UK BIM 'standard' for design and construction) which was only issued early 2013.

There is an industry-wide aspiration in the UK to take BIM through the full life cycle of a project to asset management and a lot of publicity around it. However PAS 1192-3 which covers the asset management usage of BIM was only issued at the end of 2013.

While there are companies who claim to have the capability and the knowledge to take BIM through asset management we have not yet found a compelling case study, or anyone who knows of one, to show a BIM model taken from the design phase all the way through to FM. There are separate BIM solutions for asset management but nothing demonstrating seamless integration at present.

Other big challenges in the UK industry are:

- getting lower tier (2/3) contractors up skilled on BIM. There are a few suppliers who have started to embrace BIM and modelling their products but low tier contractors are currently resisting as they don't have the physical capacity or resources available.
- Retaining BIM literate employees who once proficient leave for higher paid positions is becoming a retention issue within the academic and construction sectors alike.
- BIM 6D and operational readiness:
  - Disparate software hampering seamless data handover to the FM operational teams is a big concern as the construction industry has not traditionally been good at handing over information and operational teams don't ask or can't articulate their requirements.
  - This issue is exacerbated by the fact that FM personnel are not typically as highly trained as designers and other construction experts.

To overcome this issue, recent academic studies have focused on identifying what are FM's minimum operational requirements and then stripping out all additional functionality contained in the 3D model..

5.PAS is a Publicly Available Specification written by industry bodies under guidelines from the British Standards Institute (BSI). It's a fast track way of issuing guidance and if approved/endorsed can become a full British Standard in a couple of years

While there are companies who claim to have the capability and the knowledge to take BIM through asset management we have not yet found a compelling case study, or anyone who knows of one, to show a BIM model taken from the design phase all the way through to FM. There are separate BIM solutions for asset management but nothing is seamlessly integrated at present.

Benefits realization

- Subcontractors are more likely to receive benefits from BIM 4 and 5 D.
- Suppliers and product manufacturers are providing prefilled equipment templates as part of tender returns to make subcontractors work processes easier and improve their win rate.
- Owners are benefitting from being more engaged in projects and with the main contractors and are saving money by using the BIM process to enable:
  - Sophisticated risk management modelling.
  - Cultural change. Indirect project savings – single no blame insurance coverage resulting in 15% reduction in premiums and 12 years operational coverage for free.

5.3 BIM in the United States

In the US, BIM is seen to be closely related to Integrated Project Delivery (IPD) where the primary motive is to bring the teams together early on in the project with a reliance on database technology as the foundation. While the concept of BIM and relevant processes are being explored by contractors, architects and developers, the term itself has been questioned and debated with alternatives including Virtual Building Environment (VBE) and virtual design and construction (VDC) also considered.

The official use of BIM in the US is synonymous with the GSA (General Services Administration) BIM initiatives. The GSA are responsible for the construction and operation of all federal facilities in the US and are responsible for in excess of 300 million square feet of space.

As far back as 2007, the GSA mandated the use of BIM for spatial program validation to be submitted prior to final concept presentation. This allows design teams to validate spatial program requirements such as required spaces, areas, efficiency ratios, and so on more accurately and quickly than traditional 2D approaches and better manage its space over the long term.

Because of its government standing and very active presence at BIM technology conferences it is thought that its strong advocacy of BIM is likely to become a defining influence on the entire design and construction management industry in the US.

McGraw-Hill Construction 2013 SmartMarket report summarises

1. BIM Users

- Industry-wide adoption of BIM now stands at 71%. Contractors (74%) have surpassed architects (70%) and engineers (67%) are close to parity with the two other groups.
- Size matters in BIM adoption: About 90% of large and medium-to-large organizations are engaged with BIM, compared to less than half (49%) of small ones.

2. BIM Resistance

- Although there are fewer non-users, more of them are hardening their resistance, especially amount non-using architects where 38% say they will not use BIM.

3. Further BIM Growth

- All BIM users report that more of their projects involve BIM, and they are forecasting even greater implementation of it over the next two years.
- BIM expertise increased from 2009 to 2012, with the ranks of advanced and expert users growing 33% and 20% respectively.
- There are also more highly experienced BIM users in the industry: Half (49%) of 2012 BIM users have five or more years' experience, twice the proportion of 2009.

4. BIM Investments

- Users are favouring BIM investments that improve collaborative processes over ones in technology, especially among contractors, aligning well with their increasingly integrated role on BIM projects.
- Highly engaged firms are most committed to BIM investments, demonstrating that despite their already significant levels of skill, experience and implementation, they see more value available.

5. Design

- Design is the longest-standing application of BIM.
- Modelling the building envelope by architects is the most frequently used BIM design activity.
- Analysing mechanical system performance by mechanical engineers rates as the most difficult design activity.
- Structural analysis rates among the most difficult activities, but is frequently used as tool to make this critical analysis easier.

6. Construction

- Construction-related activities are more recent applications of BIM.
- Spatial co-ordination for pre-construction activities.
- Constructability analysis and job site planning/logistics are contractors' top uses, demonstrating their innovation in applying BIM.
- All users report struggling with 4D and 5D.

7. Processes

- BIM processes are the ways companies and teams leverage BIM to bring value to projects, including collaborative modelling and model-sharing, Integrated Project Delivery, BIM-generated visualisation to expedite review and approval cycles, and using BIM for close-out and facilities management processes.
- The highest level of model-sharing activity is taking place among contractors and fabricators, further indicating the growing BIM leadership from this sector.
- Most owners, architects and engineers give good ratings to accuracy, completeness and quality of models they receive from others. Contractors are less positive.

5.4 BIM developments around the globe

Around the globe there is a simultaneous push, often lead by the Government, for an integrated adoption of BIM standards, in order to improve software interoperability and cooperation.

France	Examples include the FFB (Fédération Française du Bâtiment), and the French arm of buildingSMART
The Netherlands	In 2011, the Rijksgebouwendienst, the agency within the Dutch Ministry of Housing, Spatial Planning and the Environment that manages government buildings, introduced the RGD BIMnorm.
Norway	BIM has been used increasingly since 2000. Several large public clients require use of BIM in open formats (IFC) in most or all of their projects. The Government Building Authority bases its processes on BIM in open formats to increase process speed and quality, and all large and several small and medium-sized contractors use BIM.
Iran	The Iran Building Information Modeling Association (IBIMA) shares knowledge resources to support construction engineering management decision-making.
Hong Kong	The Hong Kong Institute of Building Information Modelling (HKIBIM) was established in 2009. The Hong Kong Housing Authority set a target of full BIM implementation in 2014/2015.
Singapore	The Building and Construction Authority (BCA) has announced that BIM would be introduced for architectural submission (by 2013), structural and M&E submissions (by 2014) and eventually for plan submissions of all projects with gross floor area of more than 5,000 square metres by 2015
South Korea	It was not until late 2000s that the Korean industry paid attention to BIM, after which, BIM has been spread very rapidly. Since 2010, the Korean government has been gradually increasing the scope of BIM-mandated projects.

5.5 What does good look like?

- Optimal BIM architecture. A standard architecture doesn't appear to exist instead users should start with the end in mind in terms of deliverables, understand the data standards and structures and use the deliverables and requirements to drive the technology selection, interoperability and process integration.
- The BIM community and the market place. BIM is a hot topic in the design and construction sectors, and governments around the globe (UK, US, Germany, Singapore, etc) are starting to mandate it use on their projects.
- Common standards. There is now a focus towards creating and implementing common standards, specifications and frame works. In the UK the Construction Industry Council (CIC) have been heavily involved as have National BIM Standard (NBS). In the US, the National Institute of Building Science appears to be pushing the agenda and NatSpec is taking the lead in Australia. BuildingSmart - who are international, pan industry and not for profit are considered by many to be a potential unifying body but are considered by their detractors as being too academic.
- Technology. BIM strategy, process and governance is more important than the hard and software.
- Users and potential adopters are confused by the profusion of BIM software and speed it is being developed.

Major software vendors (IBM/ OP) looking at ways to integrate current offerings.

- BIM confusion. Would be users of BIM are being confused by misrepresentation and inconsistencies between BIM consultants, software providers, end users throughout the major phases of an assets development lifecycle. Many organisations now profess to have BIM capability….

How your golf swing?

The following anecdote expresses the difficulty finding examples of excellent integrated (design construction management and FM) BIM projects in the form of a golfing analogy.

In response to the question what does leading practice BIM look like? the interviewee explained that leading practice examples of BIM is like a golf swing. Many different individual components have to be considered and improved for the stroke to be regarded as impressive. It is relatively easy to find amateur players to advise you about what needs to be improved, without them really knowing what they are talking about.

Taking this and aligning it with our own observations:

- An excellent golf swing comprises of many different parts however, its very difficult to get them all working together at the same time.
- Often the less people know, the more they talk; real experts and advisors don't need to talk so much and are able to differentiate themselves by demonstrating relevant credentials and experiences.
- The perfect swing, like excellent examples of integrated BIM projects are so rare as to be practically non existent.

In summary, whilst we should never stop striving for perfection (fully integrated, interoperable, end to end lifecycle BIM), we have to understand the issues to be overcome, the limits of our own capabilities, the imposed constraints and:

1. Continue to work on improving the individual components within he overarching process, and
2. Acknowledge and take advice from true experts to speed the learning and development process.

Section Six

Proposed Schedule 4 deliverable schedule

6 Proposed Schedule 4 deliverable schedule

6.1 Introduction

The continuous development of the BIM virtual 3D design model is causing a huge disconnect with the traditional paper based fixed milestone review process within the phased lifecycle.

From their direct experiences of utilising BIM on the PCH project, the State's Strategic Project (SP) leadership believes that there is a need to rethink what the current 2D paper based design deliverable specification should look like when utilising the 3D model in BIM.

The purpose of a design review is to:

- Identify risk.
- Check and measure design progress.
- Allow the owner to assure themselves that they are getting what they want.
- Identify areas of concern and focus on specific issues.
- Check cost against program milestones.

Disadvantages of this approach include:

1. That the design review milestones suit the major early starting disciplines such as architecture and structural.
2. In some instances, the early starting disciplines may have to stop working and wait for the subsequent disciplines to catch up, and in the process demobilise or continue to work at risk.
3. The later starting disciplines scramble to produce information that is not necessarily required and may well be revised depending on the out come of the design review.
4. The traditional paper based review process creates an illusion that all of the project is present at the same place during a stage review milestone. In reality the design teams often keep working in the hope of anticipating the outcomes of the review or, if this is not the case, try to win the client around to their way of thinking.
5. Often there is limited time for conceptual design with the project progressing straight to the detail design phase.

6 Proposed Schedule 4 deliverable schedule

The original Schedule 4 details the various design work stages comprising of:

- Concept.
- Schematic; and
- Design.

It also outlines the review requirements corresponding with the above work stages and highlights in detail the expected minimum content of information to be reviewed, including:

- Drawings and scales.
- Schedules of accommodation; and
- Room data sheet's .

Appendix B details the proposed Schedule 4 Design Work. Appendix C provides the accompanying Level of Development (LOD).

6 Proposed Schedule 4 deliverable schedule

6 Proposed Schedule 4 deliverable schedule

Section Seven

Conclusions and what next for Strategic Projects and BIM?

7.1 Key Findings

1. The role of the architect and wider design teams is vitally important in terms of design quality assurance and visible cross functional collaborative leadership.
2. Many of the PCH project team members are very enthusiastic about the benefits BIM delivers, particularly the collaborative working environment.
3. The vast majority of project team members exposed to BIM believe BIM has changed the way they work and is delivering value, however, empirically measuring the value delivered remains a challenge.
4. Would be users are confused by the range of technology and disparate advice available.
5. BIM is generally misinterpreted by project stakeholders (clients, consultants and contractors) who don't understand the difference between integrated BIM and BIM for design, construction etc.
6. While BIM deliverables are different for every project, the chances of a successful outcome are enhanced by ensuring that the BIM strategy and processes are integrated and consistent with the overarching project delivery and asset operation strategy.
7. Integration with project supply chains need to advance in parallel with BIM developments if the overall project and asset benefits are to be captured and realized by the State.
8. BIM has changed the project information exchange model from multiple individual data bases to a single point of truth.
9. Improved communication via collaboration, particularly 3D visualisation is regarded as the highest value deliverer. Improved project process outcomes is the second.
10. Little direct value has been received by the State from BIM 4 and 5D.
11. 6D presents a future opportunity for FM teams to deliver value throughout whole of the operational lifecycle phase, however, confidence is low that the State is sufficiently prepared for the major operational changes this will entail.

12 Globally, governments are leading the BIM standardisation effort and are mandating usage to encourage adoption.

13. Optimal BIM architecture doesn't appear to exist instead users should start with the end in mind, in terms of output requirements, and work backwards to create the desired systems architecture.

14. BIM is a hot topic globally and quality service providers and operatives are in demand.

16. In terms of technology, BIM strategy, process and governance is more important than the supporting hard and software .

17. Up skilling of tier 2 and 3 subcontractors is a concern.

18. Owners must set the example for BIM adoption by staying engaged throughout the whole delivery process and mandating its use.

19. Owners are benefitting by being more engaged in project process and with the other project stakeholders. They are saving money by using the BIM process to enable:

- Sophisticated risk management modelling, and
- Driving cultural changes – Eg single no blame insurance coverage resulting in up to 15% reduction in premiums and 12 years operational coverage for free.

7.1.1 How does BIM at PCH compare?

Considering the genesis of its own in house BIM strategy and the fact that the PCH project would have been in a better shape had BIM been understood by the design team from the start, the use of BIM on the PHC project (Fig 3.5) compares very favourably to other case study examples both in Australia and further afield.

This conclusion is supported in part by the fact that we were not able to easily find a more advanced example of an integrated end to end BIM case study.

However, there are a number of areas demanding improvement:

- Data input: As a collaboration tool, its is imperative to the success of the project that data is consistent and trusted.
- Governance. From the onset, all parties need to understand the project's overarching BIM strategy, structure and standards and participants should be able to readily demonstrate knowledge and capability.
- Audit. All parties should be frequently audited as part of the BIM governance procedure to ensure compliance to the BIM strategy, structure and standards.
- Familiarisation. Training and development, both initial product familiarisation and ongoing structured on the job refresher sessions.
- Lack of appropriate hardware (both State and MC).

7.2 What next for Strategic Projects and BIM?

With the rapid development of hardware and software, BIM's performance is now essentially constrained by the imagination, familiarisation and capability of its users. There are a number of areas where SP could use future projects to build on the start made by the PCH Project.

1. Progress claims payments. Use the 3D model with appropriate estimating and cost systems to develop a 5D process with an initial focus on verifying planned versus actual work progress and drive:

- Interim progress payments.
- Cash flow forecasting.

2. Integration with lean construction processes. Investigate the benefits to productivity and cost to build to be achieved by:

- Utilising the 3D modelling information for value engineering, lifecycle productivity and optioneering exercises, throughout, the development lifecycle.
- Linking the 3D modelling information with offsite modular fabrication and assembly site activities during the projects construction phase.
- Trialling the use of radio frequency identification devices (RFID) to improve delivery, onsite storage logistics, materials management and on site work scheduling.

3. Supply chain management. Drive a wider integration into related supply chains, for example by linking client fit out (FFE) works directly into supplier processes. As a minimum, this should deliver both procurement and quality assurance benefits as expert suppliers bring the benefits of their expertise, systems and processes to the State in a competitive environment.

4. Integrated asset data management strategy (IDMS). Assist with the development of this strategy by:

- Educating the State's asset management teams as to how BIM can support them in delivering ongoing facility management value throughout the assets lifecycle.
- Utilising the QEII campus to develop and trial the future IDMS. This location is unique in that upon completion of the PCH Project, the campus will provide the FM teams with an opportunity to:
  1. Monitor a completed mega project with fully loaded 3D model.
  2. Tie back data and information from future capital projects
  3. Retrospectively scan data from exiting assets into an integrated site wide asset data model, and
  4. Trial a localised FM remote operating center.

5. Potential State sponsored activities. By demonstrating ongoing collaboration and owner involvement, the State, using as its basis the PCH Project and the content of this report, has a opportunity to develop its leading integrated BIM position by:

- Publicising, promoting and articulating its experiences and the adoption journey (intentions, observations, outcomes and intended next steps) via various forms of media.
- Using future major capital project tender responses (pre award documentation reviews) to further develop innovative and collaborative BIM solutions.
- Utilising the findings of this report to develop a lessons learned BIM knowledge management process to facilitate the embedding of the lessons learned into the States formal asset development process. The facilitated process would be a mix of fact gathering and brainstorming with stakeholders, SME's and other interested parties.

6. Training and development. Work with academic institutions and businesses to guide education providers in respect to BIM the learning curriculum. Whilst an in-depth understanding of BIM and its associated technologies is important. It is also necessary that graduates and students understand the broader context in which BIM is applied and how it interacts with:

- Cost estimating and management.
- Planning and schedule development.
- Contracting structures.
- Legal implications.
- Risk identification and management.

7. Integrated BIM architecture. A two step approach is suggested. Step 1 could see the integration with the issues tracking and document management tools, while Step 2 could include full integration with project controls, systems, specifically cost and schedule.

8. Modify existing specifications between stakeholder. As BIM drives collaboration it will be necessary for the State to understand what form of project contracting is best suited to creating a collaborative project environment.

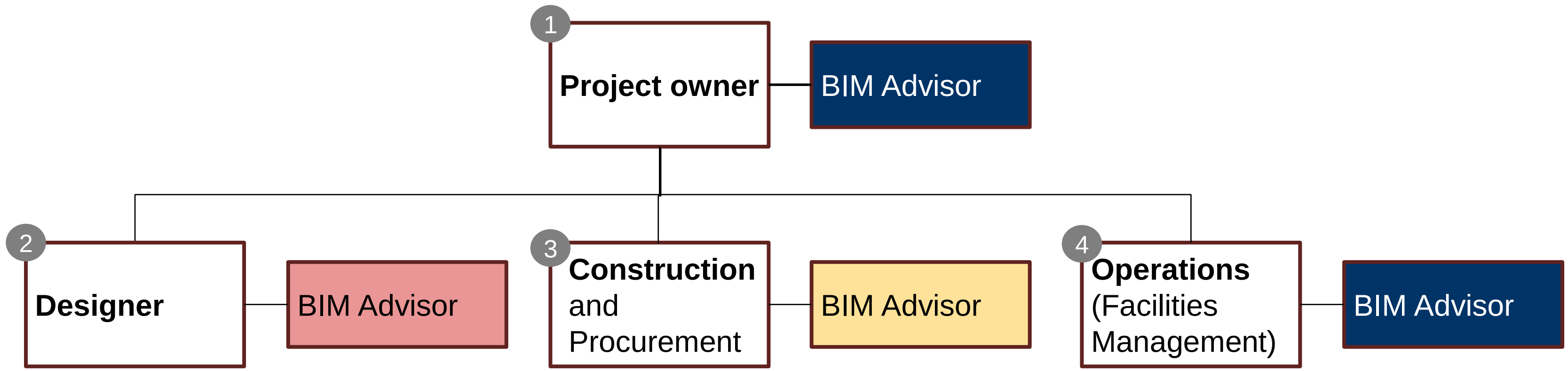


Fig 7.1 – Proposed BIM governance model

9. Define the BIM governance structure. Recognise that the above model represents the key functional stakeholders of a project and is the starting point to contractually capturing what is expected from each party and how they will interact together.

It is important that:

- The project owners (the State) BIM advisor sets the specification, standards, protocols and interoperability requirements which all BIM functions follow.
- The owners BIM advisor is responsible for random auditing of the BIM process during the design and construction phases.
- All stakeholders are familiar with the concept of starting with the end in mind in terms of both the final project model and the data to be handed over to operations at project completion. This will aid the operational start-up process and facilitate a smooth and continuous data transfer to operations throughout the project development lifecycle.
- The assets operational user requirements are captured early in the project development lifecycle.
- The projects teams BIM architecture (design and construction) is compliant and interoperable with the operations BIM system requirements and that this in turn complies with the State wide integrated asset data management strategy.

Appendices

BIM Case Study Questionnaire

1.0 Introduction

1.1 What is your understanding of what BIM is and when asked, how do you define it?

1.2 What experience do you have of BIM, I.e. primary (as a user), or secondary (as an involved party)?

1.3 Describe your BIM observations to date, (I.e. in terms of the software / hardware performance, its place in the overall capital project process, the structure of the model, how partner organisations integrate etc).

2.0 Value

2.1 How do you see BIM delivering value to a project and the supporting business? This can be in the context of your individual role, the wider project delivery and/ or the final asset end state.

2.2 During which project phase, design, procurement, construction operational readiness or asset operation and maintenance do you see BIM delivering value?

2.3 How is it possible to quantify and measure the value BIM returns?

3.0 Observations

3.1 What do you consider BIM's strengths to be?

3.2 What have you found its weaknesses to be?

3.3 What do you believe are the future opportunities for BIM within a capital project development lifecycle?

3.4 What is anything wold you do differently if you could specify, implement or use the PCH BIM again?

Appendix B – Proposed Schedule 4 Design Work

Content is provided in a separate word document

Appendix C – Level of Development (LOD) Definitions

Content is provided in a separate word document