CRC Construction Innovation
BUILDING OUR FUTURE

Final Report
Business Drivers for BIM

Research Project No: 2005-033-C

The research described in this report was carried out by:

Project Leader	Ron Wakefield
Researchers	Guillermo Aranda-Mena John Fraser Agustin Chevez John Crawford Arun Kumar Thomas Froese Stefan Gard David Nielsen Martin Betts Debbie Smit
Project Affiliates	Davina Jackson Willy Sher Robin Drogemuller Tom Fussell John Spathonis Paul Crapper

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Authors

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Please direct all enquiries to:

Chief Executive Officer
Cooperative Research Centre for Construction Innovation
9th Floor, L Block, QUT, 2 George St
Brisbane Qld 4000
AUSTRALIA
T: 61 7 3138 9291
F: 61 7 3138 9151
E: enquiries@construction-innovation.info
W: www.construction-innovation.info

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1. EXECUTIVE SUMMARY

This report describes in detail a project aimed at providing a better understanding of the business drivers and barriers to the adoption of Building Information Modelling (BIM) in the Architecture Engineering and Construction (AEC) and facility management (FM) industry sectors.

The objectives of the project were to investigate the nature of economic, process and industry constraints to BIM adoption and then - if possible - to identify business strategies, and cost/benefit models that may support adoption of BIM in AEC/FM industry. The research was based on case studies from the property, construction and facility management sectors as well as other industries and interviews with business leaders and users of advanced applications of CAD in the industry.

Specific projects identified and studied included :

- a prominent high-rise commercial redevelopment in central Melbourne ($300M project; 24 months time-frame – known as case-study “M1”);
- a small, low-rise mixed-commercial development in inner Melbourne ($4M; 6 months - M2);
- a medium-rise office redevelopment of an entire city block in central Sydney ($280M; 18 months - MB);
- a large, innovative high-rise commercial/residential development in Hong Kong, involving a mix of local and international consultants ($300M; 36 months - B1); and
- a characteristic government police and watch-house complex in rural Queensland ($10M; 12 months - B2)

- throughout, the stakeholders were mostly Australian designers, engineers and builders (with a mixture of small and large firms).

The results of the five detailed case studies showed that there are variations in the business case for BIM from one project to another, and no single, consistent business case could be produced. Never-the-less, the results offer significant value to organizations desiring to analyse their own business case for BIM implementation as follows:

- The detailed report of each case study provides much information and opinion that will help readers make more informed predictions of their own outcomes.
- By comparing the results of all the case studies, the cross-case-study analysis evaluates the extent of agreement for the 47 theoretical propositions, indicating the degree of consensus around BIM business case issues.
- Building upon the insight gained from the case studies and an international standard for structuring investment decisions for IT initiatives (ValIT), the report presents a framework that can be used to assemble business cases for future BIM implementation initiatives.

Following the structure of the proposed business case framework, the theoretical propositions (TPs) developed for analysing the case studies were organized into the following nine groups:

- Initiatives
- Alignment Issues
- Efficiency
- Design Functionality
- Collaboration
- Other benefits
- Resources/expenses
- Risks
- Assumptions/Constraints/Conditions

The examination of these theoretical propositions in the cross-case-study analysis leads to the following overall conclusions regarding the business case for BIM :

Despite the wide variety of case-study characteristics previously described, analysis shows that the proposition that “BIM improves information management / flow / sharing” (Collaboration category) was one of the top four propositions most often mentioned across four of the five case studies, while equally strongly, the proposition that “BIM requires appropriate training” (Initiatives category) arose as a topic right across the whole range of five case studies.

Amongst the M1, M2 and MB case studies, both the propositions that “BIM enhances confidence in the design outcomes”, and that “BIM improves design” (both aspects of Design Functionality category) were mentioned often, whereas in the B1 and B2 case studies there was less mention of either of these propositions.

However, the proposition that “BIM requires interoperability standards” (Alignment category) was mentioned more often in the B2 study and somewhat in M2, MB and B1, whilst in M1 the issue of interoperability did not frequently appear. This may simply reflect the critical importance placed on this aspect of BIM by the initiators of the B2 project, and by the involvement of more stakeholders actually exchanging data in the B1 case study than in the other studies.

Again in a similar fashion, the proposition that “BIM is more labour intensive in earlier stages of the project than ‘traditional’ systems” (Resources/Expenses category) was mentioned - and disagreed with - in responses from case study B1, but appeared less often in the other case study responses, while the proposition that “BIM improves efficiency” (Efficiency category) was highly placed in discussions within M2 and B1, but less so in the other case studies.

Following is a summary of key business indicators (ValIT) found in the above-mentioned case studies – M1, M2, MB, B1 and B2.

Initiatives
Analysis of a cross-case-study kind showed that a need for “significant organisational restructure”, “clear understanding”, “appropriate training”, “software selection”, “co-ordination role”, and “process restructure” were all issues brought up in interviews, and agreed with in general (particularly training).
Alignment Issues
In this category, “BIM requires interoperability standards” was an issue with some agreement, whereas there appeared strong levels of agreement and disagreement with the proposition regarding BIM as an foundation for FM. BIM as a prerequisite for government projects did not appear to raise much interest – apart from the B2 case study (which, it should be noted, already had government involvement).
Efficiency
In particular, “BIM improves efficiency” was an issue often mentioned with agreement, whilst the “reduction of rework” proposition was also raised and agreed with. Whilst M1, M2 and MB showed mild evidence that BIM allows the small practitioner to participate in large projects, no comments were ventured from B1 and B2.
Design Functionality
“Design”, “buildability improvements”, and “confidence in design” were issues mentioned in discussions and with agreement. Agreement regarding “creativity improvement” was shown in case-study MB, compared with disagreement on the same topic in B2.
Collaboration
“Improved information management” and “improved consultants co-ordination” were important issues mentioned in discussions and with agreement (but less so in case-study MB than in others).

Other Benefits
Little opinion was ventured on these propositions. However, some level of disagreement is evident as to whether BIM attracts innovative staff (M1).
Resources / Expenses
As could be expected, there appeared general agreement with “BIM requires specialised software”, while discussion of “BIM requires high economic investment”, and “costs outweigh usefulness” indicates that these were issues of <u>dis</u>agreement often mentioned in interviews. However there was also some lesser level of agreement with the “costly investment” proposition in two of the case-studies, indicating high cost may be a factor for some projects/stakeholders.
Risks
“BIM and information ownership” was an issue often mentioned with agreement. However there was also some level of disagreement (B1). In addition, there appeared differences of opinion between case-studies as to whether BIM is considered “sufficiently mature”, and whether “BIM reduces risk in the project”.
Assumptions/Constraints/Conditions
Analysis indicates that it is generally <u>not</u> agreed that “BIM is a short-lived trend”; that “BIM does not improve documentation”; or that “BIM is only a software approach”. The propositions that “BIM can be hindered by legal frameworks”; that its “capabilities must be understood by other stakeholders”, and that it “requires leadership within the implementing company” were generally agreed upon – right across the whole range of case-studies.

2. INTRODUCTION

This Report describes and documents in detail a project aimed at providing a better understanding of the business drivers and barriers to the adoption of Building Information Modelling (BIM) in the architecture, engineering, construction and FM industry.

The objectives of the project were to confirm and investigate the nature of economic, process and industry constraints to BIM adoption and then - if possible - to identify business strategies, and cost and benefit models that may support adoption of BIM in the AEC (Architecture, Engineering and Construction) and FM industry sectors. The research was based on case studies from those sectors as well as other industries and interviews with business leaders and users of advanced applications of CAD in the industry.

A decision was taken early in the project not to embark on a broad mailout-type survey, but to concentrate on a focused set of case studies to illustrate some of the drivers acting for and against the adoption and implementation of BIM in the AEC industry. A number of potential case studies of design and construction projects were identified, and initial approaches made to senior personnel in the firms concerned to ascertain their willingness to be involved and their timeframes.

It was thought that most value would come from taking a quite formal approach to eliciting detailed information from the case-study participants. Five case studies were undertaken which focused on current developments, but from time to time the designers and other staff involved in such projects have moved on and the required information is then not always available. Hence some case study projects were at completion or operational stage – whilst others were still in the design or construction phases.

The case studies required the gathering of both general information regarding the characteristics of the various stakeholders and their businesses, as well as information specific to a particular project that stakeholders had been involved in. Specific projects identified and studied included a small, low-rise mixed-commercial development in inner Melbourne; a prominent high-rise commercial redevelopment in central Melbourne; an innovative large high-rise commercial/residential development in Hong Kong (involving a mix of local and international consultants); a medium-rise office redevelopment of an entire city block in central Sydney; and a characteristic government police and watch-house complex in rural Queensland, while the stakeholders were mostly Australian designers, engineers and builders (although a mixture of small and large firms).

The report sets out the methodology adopted; describes the propositions put forward to shed light on a wide variety of drivers - and also impediments - to the introduction, implementation, and operation of BIM; documents the range of responses from a variety of AEC industry practitioners and support staff (from CEO/finance staff, to engineers, to designers); and analyses the responses for the individual case studies. It also outlines a “Business Case for BIM” model which has been developed - based on a formal, standardised business case model called the ValIT Business Case (developed by the IT Governance Institute) - which may be adopted as a framework to assist individual company’s to build their own range of business cases regarding BIM – taking account of their specific business position, costs, constraints and company strengths.

2.1 BIM definition

The term Building Information Modelling (BIM), popularised by Jerry Laiserin, refers to the ability to use, reuse and exchange information, of which electronic documents are just a single component. BIM is much more than 3D renders or transferring electronic versions of paper documents. By implementing BIM "risk is reduced, design intent is maintained, quality control is streamlined, communication is clearer, and higher analytic tools are more accessible" (AIA 2005).

The literature offers several BIM definitions. However, they all seem to agree that BIM is a digital representation of the building. Following are two alternatives that encompass views of two of the leading organisations in the field.

"A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward."

BuildingSMART website

***"Building Information Modeling** is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a **Building Information Model**, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility. The process of using BIM models to improve the planning, design and construction process is increasingly being referred to as Virtual Design and Construction (VDC)."*

AGC Guide to BIM

2.2 Background Reading

Substantial investigations into "Interoperability" of various systems for Architecture, Engineering and Construction have been undertaken and are documented in some of the following reports :

- HUT (Helsinki University of Technology) Hall 600 project, Senate Properties and CIFE - Centre for Integrated Facility Engineering, "Product Model 4D CAD (PM4D) Final Report", CIFE Technical Report #143, October 2002
  http://www.stanford.edu/group/4D/download/c1.html

- "BLIS (Building Lifecycle Interoperable Software)" coordination project, BLIS organisation, 2002-2004 http://www.blis-project.org/

- "Vera (Information Networking in the Construction Process)" project, Final Programme Evaluation Report, T. Froese, 2002
  http://cic.vtt.fi/vera/Documents/Froese_Final_VERA_Evaluation_020926.pdf

- "The CORENET project (e-Submission, e-PlanCheck, and e-Info)", BuildingSMART Case Study Report, October 2006
  http://new.eic-community.org/index.php?option=com_docman&task=doc_details&gid=17&Itemid=351

- HITOS Project "Experiences in development & use of a digital Building Information Model (BIM) according to IFC standards from the building project of Tromsø University College (HITOS)", Statsbygg (The Norwegian Agency of Public Construction and Property), October 2006
  ftp://ftp.buildingsmart.no/pub/ifcfiles/HITOS/HITOS_Reports/HITOS_IFC_Report_%5BEnglish%5D.pdf

Reports and whitepapers from commercial software and service suppliers for Architecture, Engineering and Construction systems:

- Autodesk Industry Reports and White Papers on BIM
  http://www.autodesk.com/bim
- Archibus/FM example of interoperability
  http://www.archibus.com/asset/0407/assetframeset.cfm?rightlink=asset/0407/interoperability.pdf&vid=13676
- Bentley White Papers - including a response to Autodesk's BIM/Revit proposal for the future
  http://www.bentley.com/en-US/Markets/Building/White+Papers
- Cyon Research. "The Building Information Model: A Look at Graphisoft's Virtual Building Concept"
  http://www.wbh.com/WhitePapers/Graphisoft_Virtual_Building_Model--a_Cyon_Research_White_Paper_030102.pdf
- Graphisoft Whitepapers on IFC's and Virtual Construction
  http://download.graphisoft.com/ftp/techsupport/documentation/IFC/References/whitepaper.pdf
  http://www.graphisoft.com/products/construction/white_papers
- Cadalyst AEC "BIM-related articles", website accessed October, 2007,
  http://aec.cadalyst.com/BIM
- AECbytes "AECbytes Product Reviews" (Revit Structure 2008, Newforma Project Center, Adobe Acrobat 3D Version 8, ArchiCAD 11, Revit Architecture 2008, AutoCAD 2008, Bentley Architecture and Bentley Structural V8 XM, Bentley Building V8 XM Suite, etc.)
  http://www.aecbytes.com/reviews.html website accessed October, 2007

Additional key Reports, websites, and investigations from independent bodies with critical interests in systems for Architecture, Engineering, Construction, and Facilities Management :

- National Institute of Standards and Technology (NIST). "GCR 04-867 Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry", August 2004.
  http://www.facilityinformationcouncil.org/bim/pdfs/04867.pdf
- FIATECH "Capital Projects Technology Roadmap" , FIATECH website, October 2004
  http://www.fiatech.org/projects/roadmap/cptri.htm
- Construct–IT (UK). "nD Modelling Roadmap: A Vision for nD-Enabled Construction", 2005
  http://ndmodelling.scpm.salford.ac.uk/
- The Associated General Contractors (AGC) of America "The Contractors' Guide to BIM, Edition 1", 2006
  http://www.agc.org/page.ww?section=Building+Information+Modeling&name=Building+Information+Modeling+-+Virtual+Design+%26+Construction
- General Services Administration (USA) "GSA's National 3D-4D-BIM Program", Version 0.50, November 2006 http://www.gsa.gov/bim
- National Institute of Building Sciences, "National Building Information Modeling Standard (NBIMS) – Version 1.0 - Part 1: Overview, Principles, and Methodology", and "Introduction to Appendices and References" NIBS Facility Information Council, March 2007
  http://www.facilityinformationcouncil.org/bim/pdfs/NBIMSv1_ConsolidatedBody_11Mar07_4.pdf &
  http://www.facilityinformationcouncil.org/bim/pdfs/NBIMSv1_ConsolidatedAppendixReferences_11Mar07_1.pdf

- National Institute of Standards and Technology (NIST), "General Buildings Information Handover Guide: Principles, Methodology and Case Studies", NISTIR 7417, August 2007. http://www.facilityinformationcouncil.org/bim/pdfs/nistir_7417.pdf
- The American Institute of Architects, "AIA Initiative on Integrated Practice" website http://www.aia.org/ip_default and http://www.aia.org/ip_tech_bim August 2007

Articles of particular interest :

- AECbytes article, "CORENET e-PlanCheck: Singapore's Automated Code Checking System" http://www.aecbytes.com/buildingthefuture/2005/CORENETePlanCheck.html 26 Oct. 2006
- The American Institute of Architects Practice "Which Architecture Firms Are Using BIM? Why?", http://www.aia.org/aiarchitect/thisweek07/0427/0427b_bim.cfm , 27 April 2007
- AECbytes Special Report, "Top Criteria for BIM Solutions: AECbytes Survey Results" http://www.aecbytes.com/feature/2007/BIMSurveyReport.html 10 October, 2007

The interested reader is also referred to the following further lists of background information:

- FIATECH "Industry Research" publications list, October 2007 http://www.fiatech.org/resources/research.html
- National Institute of Building Sciences, "National BIM Standard™ - NBIMS Publications and Resources" website, NIBS Facility Information Council, April 2007 http://www.facilityinformationcouncil.org/bim/publications.php

2.3 Commercial BIM Systems Overview

The following is a brief review of the BIM systems currently available in the local (Australian) market as presented by the industry's main software vendors. A summary of these applications is presented below in Table 2-1.

2.3.1 Autodesk

www.autodesk.com

Autodesk offers two AEC applications: Architectural Desktop (ADT) and Revit. Whilst the former is an object-oriented program, the latter is Autodesk's true BIM solution. Autodesk's introduction of Revit Systems (Revit-based MEP – Mechanical, Electrical, Plumbing –) together with the acquisition of Constructware – an Internet-based construction project management tool and FM Desktop, a facilities management application – indicate Autodesk's commitment to create a true BIM solution from conception to construction to building maintenance (Goldberg 2006).

- Architectural Desktop (ADT): This system is considered to be an intermediate step from traditional CAD software. It is based on AutoCAD and as opposed to other systems, ADT generates its building model through a series of independent drawings – each representing a portion of the complete BIM – which are then put together to simulate a single BIM at the centre. Managing all the loosely-coupled collections of drawings is a source of error in itself (Howell & Batcheler 2005). ADT is a uni-directional system in that any change in the model is expressed in all views, but not all views can change the model. Due to the large installed AutoCAD user base, it is the most widely distributed BIM software and because of its popularity more third-party plug-ins are available for ADT than for any other BIM system (Goldberg 2005).
- Revit: This system is Autodesk's true BIM system. Revit was conceived by programmers who created 3D software for the mechanical design industry. Thanks to its central project

database, Revit is truly a bi-directional system - that is, every building element is managed centrally and users can see immediate results in all views and schedules. Since it is the newest of all mainstream systems, Revit has the smallest user base. However, it is starting to be used in high profile projects like SOM's Freedom Tower at the 9/11 site, in the US (Goldberg 2005; Howell & Batcheler 2005). Revit includes sun studies, a new detail library, material takeoff, keynoting, and IFC import and fully certified export (Goldberg 2006).

2.3.2 Bentley Systems

www.bentley.com/bim

Based on the MicroStation platform, Bentley Architecture is the architectural application within Bentley's multidisciplinary suite of solutions. Through its suite of products – Microstation Triforma, Bentley Structures, Bentley HVAC, and so on – Bentley Systems offers an integrated project model approach. However, in order to achieve the highest level of interoperability, the entire family of Bentley products needs to be used within the project (Howell & Batcheler 2005). After AutoCAD, Microstation has the second largest number of installed seats, and has been used in high profile projects like the Pentagon in the US, the largest office building in the world (Goldberg 2005).

Given Bentley's support of other CAD formats – e.g. DWG –, their's is an appealing option for multidisciplinary teams (Goldberg 2005). Bentley also supports certified IFC import and export (Goldberg 2006).

Due to the acquisition of two of the leading structural analysis and design applications – RAM and STAAD – and aggressive marketing to AutoCAD users, in 2005 BIM adoption in the MicroStation user base passed the tipping point. Bentley's BIM user base has more than tripled during the past two years (Goldberg 2006).

2.3.3 Graphisoft

www.graphisoft.com

In 1984 Graphisoft's ArchiCAD systems for architectural design was the first product to create a virtual model. Since its inception, over 20 years ago, ArchiCAD was conceived using today's BIM concept and embraced IFC file transfer. According to Graphisoft estimates, more than one million projects have been completed using ArchiCAD (Goldberg 2006).

Graphisoft's approach is to create a virtual building model, thus their ArchiCAD application is viewed as one of many satellite applications orbiting a virtual building model rather than being seen as the central repository for the entire model. ArchiCAD's bidirectional associative models keep all the data in a single file. This system uses Geometric Description Language (GDL) to describe 2D and 3D building elements as well as text specifications for use in drawings, presentations and quantity calculations. Due to its compatibility with the Richard Creveling (RCC) database ArchiCAD can be interpreted by Timberline software to create Level 2 cost estimates. (Goldberg 2005; Howell & Batcheler 2005). ArchiCAD 10 is compatible with SketchUp and MaxonForm, which have proven to be useful at the conceptual design and whilst doing organic modelling (Goldberg 2006).

In 2005, Graphisoft introduced the world's first commercially available 5D (that is 3D + Time + Cost), virtual construction system. Graphisoft Constructor 2005 creates 3D construction models with a 4D sequencer that automatically links the construction model to the project schedule to allow schedule alternatives to be analysed more effectively (Goldberg 2006).

ArchiCAD can run on PC as well as on Mac. This characteristic is only shared by VectorWorks ARCHITECT - see below. Mainly due to its early introduction, this software has the most routines dedicated to architecture and construction (Goldberg 2005).

Parallel to ArchiCAD, Graphisoft had also offered ArchiFM for facility management (currently discontinued), as well as GS Constructor and GS Estimator that allow companies to perform model-based calculations for scheduling, estimating and purchasing and provides a comprehensive platform to manage an entire construction project. (Goldberg 2005) (Goldberg 2006)

In early 2007 Nemetschek announced its intention to acquire a majority interest in Graphisoft. However according to its website (http://www.nemetschek.de/de/aktionen.nsf/link/ir-graphisoft_presentations_en.html?OpenDocument#frage4) "Graphisoft will continue to be managed as an independent organisation and will retain its own identity". It has been argued elsewhere that this acquisition will provide more capital to assist with the further development of the ArchiCAD product.

2.3.4 Nemetschek

www.vectorworks.net

Developed in Germany, this system is popular mainly in the German speaking countries of Europe and provides an evolutionary approach from the traditional approach of Allplan. The AllPlan database is "wrapped" by the Nemetschek Object Interface (NOI) layer to allow third-party design and analysis applications to interface with the building objects in their model (Howell & Batcheler 2005).

VectorWorks ARCHITECT is developed by Nemetschek North America, a wholly owned subsidiary of European developer Nemetschek AG. Like ArchiCAD, VectorWorks runs on PC and Mac platforms. Its biggest competitive advantage is its affordability. It is the least expensive of main stream BIM systems (Goldberg 2005). VectorWorks ARCHITECT's mantra is "BIM for the smart-sized firm". There are around 200,000 installed seats worldwide. Its affordable price, USD$1,395 is the result of their business model as the company sells its products directly instead of through resellers (Goldberg 2006). The company's website claims that "more than 400,000 designers in more than 85 countries rely on VectorWorks Technology."

VectorWorks ARCHITECT latest version 12 was released in October 2005, and it is a big update with many improvements. Amongst the new features is the capability to import SketchUp models into VectorWorks ARCHITECT which facilitates the conceptual stage of the project (Goldberg 2006).

Aside from Digital Project, see below, VectorWorks ARCHITECT is the only BIM system with NURBS modelling capability, which allows it to create complex surfaces and organic shapes. This software is available in seven languages and sold in more than 80 countries. It was used by Studio Daniel Libeskind for designing the wining entry in the World Trade Centre competition (Goldberg 2005).

In early 2007 Nemetschek announced its intention to acquire a majority interest in Graphisoft. However Nemetschek have indicated they intend to continue to supply and support the ArchiCAD product lines along with their AllPlan and VectorWorks offerings.

2.3.5 Gehry Technologies / Dassault Systemes

www.gehrytechnologies.com

The Digital Project software is an AEC interface for CATIA developed by Gehry Technologies (Day 2004). CATIA was developed by Dassault Systemes S.A., a company created in 1981 as part of the Dassault Group (Goldberg 2006; Wikipedia 2006). Gehry Technologies (GT) was established in 2002 by Frank Gehry, Jim Glymph and Dennis Shelden (Tenlinks.com 2005). However, Digital Project, currently in its version V1 R2, is the result of 15 years of development at Frank Gehry's office (Goldberg 2006).

Digital Project supports the lifecycle of construction projects in a common digital environment from design and engineering to fabrication, construction project management and on-site construction activities. The software comprises nine modules: Designer, Foundation, Viewer+, Structures, MEP, Knowledge Template, Knowledge Advisor, Project Manager and Primavera Integration (Goldberg 2006). Users can link 3D BIM components to Primavera activities and to simulate these activities in 3D (4D Navigation). Due to its rapid growth in Hong Kong and China, Digital Project includes a Chinese interface (Tenlinks.com 2005).

With its comparatively high seat cost, shortage of CATIA-trained staff and considerable process change required, Digital Project is not aimed at traditional architectural practices. Furthermore, it does not aim to be a mass-appeal modelling tool, but a system targeted at architects that want more control in the building process; who want higher predictability in the cost of complex projects; and at industry players who are looking to adopt a different way of working with project participants (Day 2004).

Table 2-1 : Commercial BIM systems commonly available [Succar, B.]

Product / Developer	Current Version	Mac	PC	Description
AutoCAD Architecture (previously Autodesk Architectural Desktop – ADT) **Autodesk**	2008		✓	• Transitional approach. • Based on AutoCAD • 1300 for network license + 1250 for subscription • Price range: medium
REVIT Architecture **Autodesk**	9.1		✓	• Central project database • Autodesk true BIM system • +1300 for network license + 1250 for subscription • Price range: medium
Microstation / Bentley Architecture **Bentley Systems**	V8 XM		✓	• Integrated project model • Leading structural applications • Autodesk "dwg" compatible • Includes MicroStation, Triforma, Parametric Cell Studio, and Bentley Architecture or Bentley Structural; MicroStation users can add Bentley Architecture or Bentley Structural for ~$1000 • Price range: medium
ArchiCAD **Graphisoft**	11	✓	✓	• Pioneer in BIM • Virtual building model • Compatible with SketchUp and MaxonForm • Timberline compatible • 5D modelling • Cheaper if bundled in three's – network. • Price range: medium
VectorWorks ARCHITECT **Nemetschek**	12.5	✓	✓	• Affordable BIM solution • Imports SketchUp models • NURBS modelling capability • Price range: low
Digital Project **Gehry Technologies / Dassault Systemes**	V1 R2		✓	• State-of-the-art design tool technology • Compatible with Primavera and Microsoft Project • High-end market (suited for complex projects) • Price range: high

3. METHODOLOGY

This chapter is divided into three sections. The first section reviews the overall research design, the second the research instrument and approach, and the third part discusses the tools and techniques developed to analyse data.

3.1 Research Design

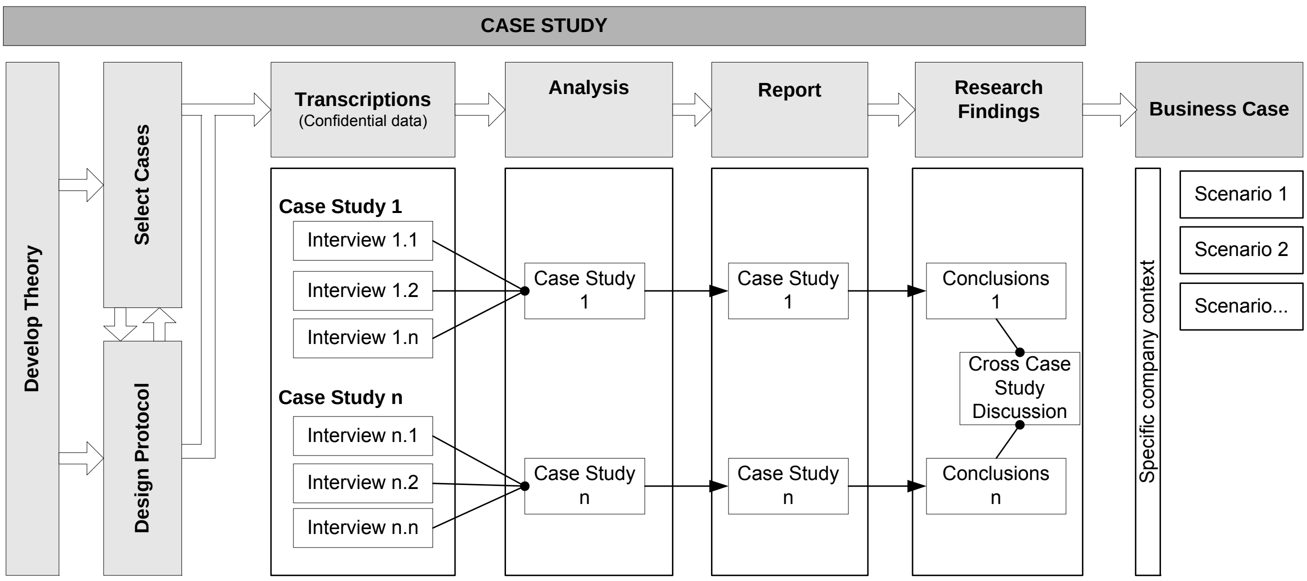
BIM is, at its core, an information technology. This technology impacts work practices, which, in turn, influence business outcomes. This study focuses on the latter level and attempts to explore business outcomes directly rather than addressing technical or work practice issues.

Because BIM technology has far-reaching implications across the entire project team, the issues are complex and inter-related, and an appropriate research methodology must explore the BIM projects in depth, considering both quantitative and qualitative information from many different perspectives. These factors all lend themselves to a case study methodology for the data collection phase of this research.

Since the objective of this research is to contribute to the understanding of the business drivers for BIM for the purpose of helping companies make real business decisions about BIM implementation, this objective is best achieved if the results are presented in a form that mirrors as closely as possible the way that businesses reason about their IT investment decisions – through formal investment business cases. Thus, the analysis results are applied using an industry-standard model for IT investment business cases, the ValIT model (see Enterprise Value, 2006).

The case study design is based on Yin 1994. Table 3-1 offers an overview of the overall research design; from the case study to the application of findings.

Table 3-1 : Overall research design

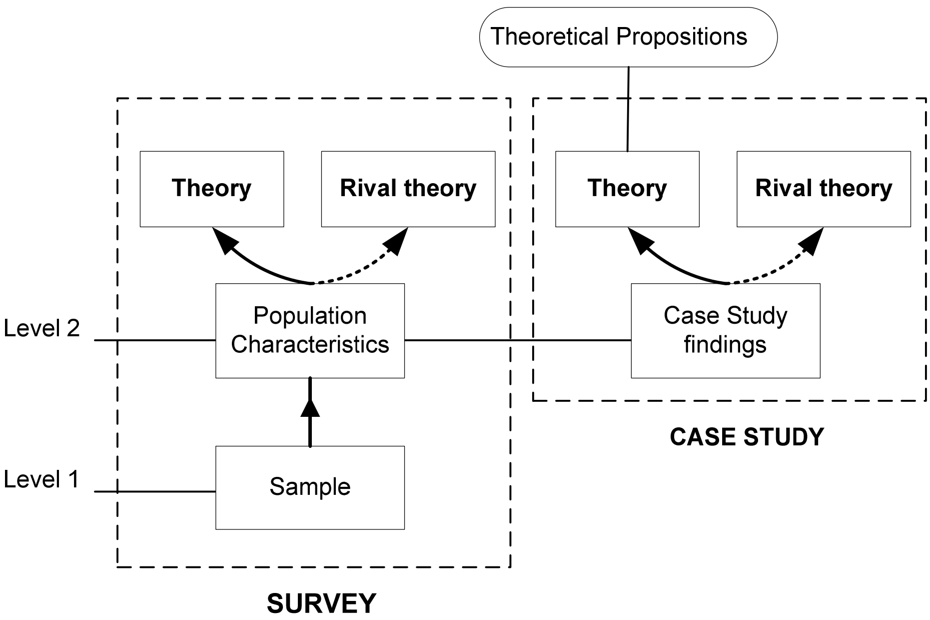


3.1.1 The Case Study approach

Since BIM technology is in the early stages of adoption by industry – at least in Australia - there is limited data available and any research techniques that require large and accurate data sets, such as statistical approaches, are not possible. However, some recent and on-going instances of BIM implementation do exist within our region, which present an opportunity to gather high-quality data about BIM's actual impact on business. The case study approach also offers other benefits like better compatibility with the 'exploratory' nature of the study and the type of generalisation as further explained.

Yin (1994) points out that understanding how generalisation is done in case studies is not only the key to good case study based research, but one aspect that is commonly misunderstood. A fatal flaw in doing case studies is to conceive of statistical generalisation as the method of generalising the results of the case. This is because cases are not "sampling units" and should not be chosen for this reason. Instead, individual case studies are to be selected as a laboratory investigator selects the topic of a new experiment. The selection of case studies depend upon an understanding -or theory- of what is being studied.

Table 3-2 : Case Study generalisation (Based on Yin 1994)



In statistical generalisation an inference is made about a population (or universe) on the basis of empirical data collected about a sample using formulas for determining the confidence with which the generalisation can be made. On the other hand, case studies are generalisable to theoretical propositions and not to populations or universes. Yin refers to this method as "analytic generalisation" as opposed to "statistical generalisation" used in surveys. If two or more study cases are shown to support the same theory, replication can be claimed.

The empirical results may be considered stronger if two or more cases supports the same theory but do not support an equally plausible rival theory, this concept is explained below.

3.1.2 Development of Theory

The development of a theory prior to any data collection is one point of difference between case studies and related methods such as ethnography (see Yin 1994).

Theory development as part of the design phase is essential, regardless of whether the ensuing case study's purpose is to develop or to test theory. Further, Yin, warns about the risks of the too common practice of prematurely proceeding to the data collection phase and making of 'field contacts', without taking into consideration that the relevant field contacts depend upon, amongst other considerations, an understanding (theory) of what is being studied.

However, this theory needs not to be considered with the formality of grounded theory in social science. Rather, the goal is to have a sufficient blue-print for the research, and this requires theoretical propositions. Then the complete research design will provide guidance in determining what data to collect and the strategies for analysing the data.

The research theory is a consequence of the research focus which implies concentration on the business motivations (e.g. economical, competitive, etc.) for adopting BIM.

Research Theory: *"Building Information Modelling (BIM) offers business advantages to those who embrace it."*

Rival theory: *"Building Information Modelling creates business disadvantages for those who embrace it."*

3.1.2.1 Theoretical Propositions

Such a broad theory (and rival theory) is broken down into many theoretical propositions in an attempt to define the possible business advantages offered by BIM.

Forty seven theoretical propositions (TP's) were developed taking into consideration issues raised by key reports and related literature, as well as discussions within the research team and public domain ideas about the advantages and disadvantages of BIM - particularly from a business rather than technical perspective. These TP's were clustered according to nine ValIT groups, namely Initiatives, Alignment Issues, Efficiency, Design Functionality, Other Benefits, Resources/Expenses, Risks, and Assumptions/Constraints . Under each TP is the rationale or question(s) that generated such TP.

Initiatives: Specific action items associated with the BIM implementation.

TP01	**BIM requires a significant organizational re-structure** Tries to explore if BIM requires or demands a reshaping of the company, and if so, to what extent.
TP02	**BIM must be clearly understood throughout the organization** Does BIM require a company-wide culture, or is it only relevant to, and contained within, specific employees?
TP03	**BIM requires appropriate training** What are the training requirements to successfully implement BIM? The word "*appropriate*" refers to the *amount* and *type* of training required to satisfy the specific needs of the company.
TP04	**BIM success is dependent upon selecting the correct software** How much does the selected system impact or determine the outcome? Are there specific characteristics of the software or the reseller that can, positively or negatively, affect the BIM implementation?
TP05	**BIM requires a coordinator role** Once staff are trained and the implementation is mature enough, is there a need for a model manager, or BIM manager, to coordinate future projects from the IT point of view?
TP06	**BIM requires a significant process re-structure (internal and external)** Whilst related to TP01, this TP is more concerned with changes in processes and workflow. Internally, it will try to identify if in-house activities (like design and detailing) are affected and if so, to what extent. Externally, it will try to identify changes on data sharing and flow.

Alignment Issues: Issues relating to the alignment of the BIM implementation program with existing systems and procedures

TP07	**BIM has compatibility difficulties with legacy software systems** To what extent can previous CAD libraries be used in the new system? What if proprietary files, of old projects for example or CAD library, don't translate (cannot be opened) into the new format.
TP08	**BIM requires interoperability standards** How important is interoperability in BIM? Is BIM dependant on interoperability? Is collaboration only possible

when all stakeholders are using the same software?

TP09 **BIM requires all project stakeholders to exchange and use the information**
Does BIM only exist, and it benefits capitalised, when all stakeholders (architect, services consultant(s), etc.) collaborate using a single model? or can partial implementations, by the architect only for example, be called BIM and its benefits experienced?

TP10 **BIM will be required as a prerequisite for future government projects**
Would it be a requirement to participate in Government projects? For example building approval.

TP11 **BIM provides a foundation for FM processes**
Ideally, the information that the model contains at the end of the project is a true representation of the building and as such, it should contain the data required by Facility Managers, making this a natural evolution of the model to FM packages. How easy would it be to maintain (update) the model during the construction phase in order for it to be usable in FM packages?

Efficiency: Improvements to the efficiency of designing and managing building projects.

TP12 **BIM allows the small practitioner to successfully participate in larger projects**
It could be the case that the efficiencies claimed by BIM make projects less labour-intensive, giving small practitioners the opportunity to undertake bigger projects.

TP13 **BIM reduces rework**
The difficulties may be identified and problems foreseen earlier. The consistency of the model can translate into better coordination, which can then provide concise and accurate documentation.

TP14 **BIM improves efficiency**
As opposed to traditional CAD software, BIM deals with the overall model –not unrelated views of the building. Therefore, changes made in the floor plan, for example, will be updated in the elevations, section, etc. which considerably reduces the amount of time and risks involved in making those changes with traditional methods. Further, given the fact that BIM software is bi-directional building components can be managed from non-drawing views like schedules.

Design Functionality: Issues that lead to better building designs.

TP15 **BIM enhances confidence in the design outcomes**
A BIM approach cannot only enhance the management of the data, but increase the confidence in the data's integrity that provides accurate and updated data to the design team.

TP16 **BIM improves design**
This can be achieved by facilitating the design process and matching expectations through a better or more rapid visualisation of the project.

TP17 **BIM improves buildability**
BIM can provide a reality check of the design intent. Theoretically speaking, the design must first be "built" in the computer in order to produce an accurate BIM model. This, in return, will help to promptly identify buildability issues during the documentation phase.

TP18 **BIM improves creativity**
It allows more scenarios to be investigated which should translate to more creative options. Having various options and being able to test them within constraints, and within the budget.

TP19 **BIM increases ability to make changes throughout design**
It is argued that through BIM is possible to make rapid design changes – even during meetings with a client or council. Ability to make changes, communicate and coordinate the changes.

TP20 **BIM improves risk management practices**
Can BIM be used as a risk management and assessment tool by enabling more scenarios to be investigated?

Collaboration: Improved support for collaboration among project participants.

TP21 **BIM improves information management/flow/sharing**

Communication of common information is not only consistent, but easily accessible to all parties.

TP22 **BIM helps to align project stakeholders expectations**
There is more consensus resulting in closer alignment between process and product. As a result of better communicating the design, clients, builders and other stakeholders may more easily visualise and grasp the intent

TP23 **BIM improves co-ordination between some consultants**
BIM offers a common platform for all consultants to work in the same model, all equally understand what the project is, and all the information is in an integrated/singular model - master source of information. Clashes between disciplines could be easily (automatically) detected.

TP24 **BIM improves co-ordination with contractors / fabricators**
Information can be viewed in different formats (schedules or drawings), accurately extracted, and shop drawings can be created directly out of the model.

Other Benefits: Other project and corporate benefits.

TP25 **BIM attracts innovative staff**
BIM might attract equally innovative staff (i.e. profile of people). It can also provide better pay for young professionals; seen as leading-edge workers.

TP26 **BIM enhances company profile**
Use of BIM may provide perception of a competitive edge. It's about being seen as innovative and futuristic.

Resources / Expenses: The resource requirements for BIM, and the corresponding costs.

TP27 **BIM is more labour intensive in earlier stages of the project than 'traditional' systems**
A BIM model requires more information earlier in the project than traditional systems, like sketching and 2D CAD, but once the information is input in the model it is there to be added to, refined and exploited as the project proceeds.

TP28 **BIM requires the employment of additional specialist staff (designers/IT)**
Do existing staff in office(s) have required knowledge? Need additional in-house or outsourced resources?

TP29 **BIM requires a high economic investment**
May require specialised, and possibly expensive, software and/or hardware and training.

TP30 **BIM's implementation and maintenance costs (including underlying IT) outweigh its usefulness**
The overheads required by BIM are difficult to justify and maintain. Could it be that the financial advantages may be more obvious in large or complex projects?

TP31 **BIM requires specialised software**
BIM software may need to have certain advanced and specialist characteristics, unlike others used before. What are the core characteristics that define BIM software?

TP32 **BIM requires specialised IT hardware/infrastructure**
BIM might require specialised network connections and/or servers; large monitors, etc.

Risks: Major risks associated with a BIM implementation.

TP33 **BIM reduces risks to individual stakeholders**
Risk is reduced by having all information in a consolidated model, especially, when one party depends on another. For instance, architect and services consultant(s).

TP34 **BIM reduces risk in the project**
Dealing with accurate, consistent and integrated information reduces the chance for error and replication of erroneous information.

TP35 **BIM requires that a fall-back system be in place since it is not yet sufficiently mature**
'Bleeding edge' vs. leading edge argument. Confidence in the BIM software's implementation or use or levels of customer support may be low. Generally related to the size of the firm.

TP36 **BIM-trained people are scarce**
BIM is seen as new - even for universities. Thus there might be the need to provide training (in-house or outsourced) and bear the consequences (cost, loss of productivity).

TP37 **BIM introduces new issues regarding ownership of information, IP, payment of information, etc.**
On a shared model, who owns the information? Who pays for it? At what price?

Assumptions / Constraints / Conditions: Issues describing assumed preconditions or constraints for BIM implementations.

TP38 **BIM adoption is hindered by legal frameworks**
Traditional legal and contractual issues may not suit sharing information in new ways, or a new collaborative approach to working. Is the current legal framework ready for BIM?

TP39 **BIM adoption is hindered by fee structures**
Fee structure reflects traditional methods and processes. If someone else uses the model 'down the line', later in the project life cycle, should the BIM 'developer' get more payment upfront? Who is the BIM 'developer' (the architect, structural engineer, etc)?

TP40 **BIM is simply an extension of traditional CAD and will be a short-lived trend (vs. BIM is inevitable)**
Is BIM an evolution of CAD? Is it inevitable or is it a current 'fad'?

TP41 **BIM's long-term advantages will outweigh any short-term disadvantages**
Long-term advantages, such as risk reduction, timely delivery and efficiency outweigh the short-term disadvantages such as implementation costs and learning curve.

TP42 **BIM-developer/coordinators increase their role, influence, & risks on the project**
If responsibility is taken for the model it is assumed that you increase influence and risk. That responsibility role becomes fundamental – whether it be a company or an individual.

TP43 **BIM requires leadership within the company**
Does it require a 'champion' - a person with vision within a company - to ensure its successful adoption or implementation within the company?

TP44 **BIM capabilities must be understood by other stakeholders**
Requires communication of a clear statement across all parties of what BIM is, and what it implies.

TP45 **BIM is only a software approach rather than a management one**
How much is BIM just a software? To what extent does BIM require a change in management? Can BIM principles be implemented without BIM software?

TP46 **BIM adoption is hindered by lack of specialised library content**
Libraries of objects determine how you report and how you restructure the model's data. Can generic libraries be successfully implemented in the project? To what extent can existing CAD libraries be recycled?

TP47 **BIM does not improve documentation**
How well can the 3D model, and associated data, 'living' inside the BIM software be transferred ('dumbed' down) to traditional documentation (2D drawings).

3.1.2.2 Scope and Unit of Analysis

BIM is a very broad technology that can encompass all of a project's phases and participants. If taken to its furthest extent, numerous forms of BIM-based software will support many design and management tasks by owners, architects, engineers, general and specialty contractors, and others (e.g., suppliers or regulators). At its present stage of development, however, the predominant form of available BIM software is model-based CAD systems, and the predominant BIM user is the project architect. Indeed, few instances of BIM technologies for applications such as engineering analysis, quantity surveying, construction planning, or facilities management have been found in Australia to date. Furthermore, as BIM continues to spread across the project spectrum, BIM CAD systems and the project architect will continue to play a central role in the BIM process. The scope of this research, therefore, focuses primarily on the use of BIM-based CAD software by project architects, along with the implication of these systems for the other project participants and, in a few cases, the interaction of these CAD models with other BIM-based software.

Decisions to implement BIM technology can be made by a single company for a single project, by a single company across all of their projects, or by a team of companies collaborating on one project. Because it best fits the situation must often encountered in the case studies examined in this study, the unit analysis for the research was taken to be individual projects where the decision to implement BIM was made by a single project partner (the project architect), but the impact was felt and studied for several of the project participants.

3.1.2.3 Case Study Protocol and Selection Process

In order for the research to be reliable (hypothetically speaking, if a later investigator followed exactly the same procedures, they should arrive at the same findings and conclusions) there is the need for standard procedures and elimination of biases in the study.

The research protocol aims to ensure that an acceptable level of standardisation is achieved in the data collected. Given that this research was based on a multi-case studies approach undertaken by several researchers across two geographically separated universities, the research protocol was crucial for the success of the research.

Case studies were selected based on:

a) BIM adopters: The first criteria for selecting a project as case study was that it must had been done using at least one of the BIM systems as previously identified in the literature review by at least one party, in this case the architect. Case Studies where BIM collaboration between consultants occurred were preferred. In parallel, it was considered that interesting contrast could be provided by including an array of successful firms using traditional systems (non-BIM adopters). However, such analysis is outside the scope of the current study.

b) Project Life Cycle: The selected project needed to be at least on, or just about to start, construction. This would allow the study to evaluate the performance of BIM during this critical stage (e.g. reduction in RFI's, generation of "as-builts').

c) Variety of BIM software: Since the research does not aim to study, or promote, any particular BIM application, it was intended that case studies should use different systems. Most of the case studies were ArchiCAD users, one case study used Digital Project and another one a combination of Revit and ArchiCAD as well as other applications.

d) Variety of company / project size: As previously mentioned, projects varied considerably in size in order to allow readers to identify with a particular case study, or between two of them, an array of different size projects was preferred.

e) RMIT's ethics guidelines:

- o The research did not involve the participation from anyone from an ATSI (Aboriginal and Torres Strait Islander) community;
- o No participant under 18 years old was interviewed; and
- o Participants were not in a dependent relationship with the investigators.

Participants were interviewed at their office (or their preferred location) and were asked to provide information as per the interview questionnaire. The interview was conducted by at least one researcher. The following general guidelines were followed whilst conducting the case study in order to comply with RMIT's ethics requirements:

- o Data collection did not involve access to confidential data
- o Participants did not have pictures or video taken of them;
- o Interviews were not tape-recorded;
- o Deception was not used;
- o Interpreters were not used;
- o The research did not involve any tasks or processes which participants may experience as stressful or unpleasant during or after the data collection; and
- o All participants signed RMIT's consent form before the commencement of the interview.

Whilst initial meeting structures included interviewing more than one person at the time in order to benefit from the interaction between the interviewees, this scheme was abandoned. This decision was taken due to two main risks posed to the research.

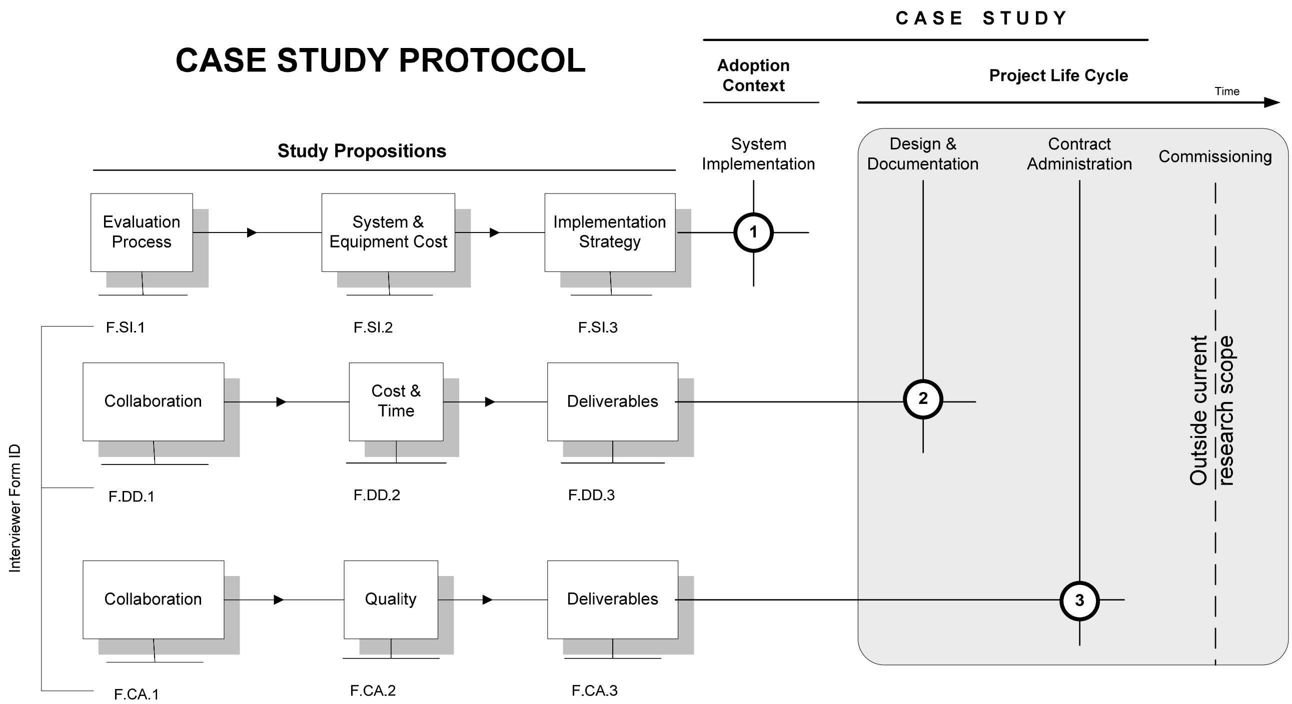
Firstly, as previously mentioned, respondents can withdraw from the project making it difficult to differentiate between the information collected from individual participants during one interview in the case that only one respondent decided to withdraw. Secondly, it was considered that one respondent might be influenced by direct or indirect perceived pressure of the other respondent in the room.

An important aspect of the methodology was that case studies were not to be used to substantiate any preconceived position or agenda. Interviewers were open to contrary findings, and they did not push the interviewee to provide specific answers.

3.2 The Research Instrument

A set of questions was designed in order to gather enough information for the TP's. The main objective of these 56 questions (in total) was to serve as guidelines, or prompts, in an attempt to standardise the nature of the data collected across respondents of different case studies. The questions were divided into nine areas in three different stages: 1) Implementation, 2) Design and Documentation and 3) Contract Administration as shown in Table 3-3.

Table 3-3 : Case Study Protocol



Following is a description of each of the nine areas with tables listing the questions included in each of these groups. This set of questions was applied to the architect's office and consultants as applicable. The tick next to the question identifies the type of respondent to which the particular question was applied; definition of these respondents' profile is further provided.

F.SI.1 Evaluation and Adoption Process

This section aims to unveil the challenges faced by the architect's office whilst trying to evaluate the different systems available and adopt the selected system. This section also tries to identify the concept of BIM within the company and see if there is consistency across the respondents.

	General Manager	CAD Manager	Project Architect	Team Member
1) Concept of BIM within the company How is BIM defined within the company? CORE CHARACTERISTICS	✓	✓	✓	✓
2) Why did the company consider adopting a BIM approach?: 3D-capabilities, Project Documentation, Database capabilities (scheduling), Compatibility with other parties (e.g. consultants), Competitive advantage, Current trend, Other / comments:	✓	✓		
3) Do you think BIM is as much a *software* approach as a *management* one?	✓	✓	✓	✓
4) Who in the company is promoting the adoption of BIM?(staff, partners, new staff, middle management, etc.)	✓	✓	✓	✓
5) Who is delaying or stopping the adoption of BIM? (Consultants, Builder, Legislation, Insurance, etc.)	✓	✓	✓	✓
5a) Consultants:	✓	✓	✓	✓
5b) Contracts / Legal framework:	✓	✓	✓	✓
5c) Other:	✓	✓	✓	✓
6) In your opinion, what are the core characteristics of <u>BIM software</u>? (data interoperability, design collaboration, etc.)	✓	✓	✓	✓
6a) Previous CAD software? [ ] AutoCAD other:		✓		
6b) Is it still in use within the company? [ ]No **[ ]**Yes (_____% of projects / work) for **[ ]** detailing		✓		
7) Is BIM implemented throughout one office, every office, or only on selected projects?	✓	✓		
8) Comparative evaluation matrix for BIM software. Advantages and Disadvantages. ADT, Revit, Microstation, ArchiCAD, Vectorworks, digital Project	✓	✓		

F.SI.2 System and Equipment cost

This section measures the cost of implementing BIM: software and hardware. The hardware cost was identified as a potential issue (it is considered that the specifications required to run BIM applications are higher than those for traditional CAD systems) and as such it is assessed. This section will also identify the role played by the re-seller (software and hardware). An important aspect of this section will be to identify any departures between the estimated and actual costs whilst identifying the causes (hidden costs).

	General Manager	CAD Manager	Project Architect	Team Member
9) Software cost? Impact on firm's budget, rather than $$ value	✓	✓		
10) Departure from estimate? (eg. Extra seats –Licences–, hidden costs such as other software upgrade costs)	✓	✓		
11) Level of involvement of re-seller (support, participation, advice, evaluation)	✓	✓		
12) Hardware cost? Impact on firm's budget, rather than $$ value	✓	✓		
13) Special requirements (hardware / networks)	✓	✓		
14) Departure from estimate? (eg. extra seats –licences–, hidden costs such as other hardware upgrade costs) **expected vs. actual cost**	✓	✓		
15) Level of involvement of re-seller (hardware)	✓	✓		

F.SI.3 IMPLEMENTATION STRATEGY

This section explores the challenges faced whilst implementing BIM, particularly staff related issues (training / hiring / replacing) as well as system customisation. Parallel, it asks about the criteria selection for first BIM project implementation (if not the one of case study).

	General Manager	CAD Manager	Project Architect	Team Member
16) What are the company's BIM objectives? Have they been met? [ ] Yes **[ ]** No, why not	✓	✓	✓	✓
17) Was there a training strategy, and what was it? (complete process) Location, Time, Cost, estimated loss of productivity, Comments.	✓	✓		✓
18) Profile of total staff and staff trained in BIM: CAD operators, CAD Managers, Designer / Architects, Managers/Snr. Architects	✓	✓		
19) Have new people been hired because of their skills using BIM software?	✓	✓		
20) Have people been replaced due to their lack of skills using BIM software?	✓	✓		
21) Overall training experience comments:	✓	✓		✓
22) Software 'out-of-the-box' content: (design components, CD, templates, families)		✓		

23) Customisations / Setup (e.g. blocks, families, pen thickness, etc) Time/effort invested to produce similar deliverables (e.g. drawings). Level of involvement of software reseller: (amount of content provided by manufacturers, sales representatives, suppliers providing BIM components):		✓		
24) When implementing BIM, how did you select the company's first BIM project?	✓	✓	✓	
24a) Was that a conscious decision?	✓	✓	✓	
24b) Was it full; pilot; old & new methods in parallel/tandem. Used as part of the implementation strategy? Plan "B"	✓	✓	✓	
25) First (BIM) project details. Project Name, Project type, Project value, Type of project: (full; pilot; in parallel) Duration of first project, Was the outcome successful? Lessons learnt	✓	✓	✓	

F.DD.1 : COLLABORATION

This section identifies changes, if any, in the way people collaborate and interact within the design team (architect), including consultants and client. Therefore, this section touches on interoperability, ownership of information, spirit of collaboration and risk associated with sharing information. Collaboration with the contractor is explored on section F.CA.1

	General Manager	CAD Manager	Project Architect	Team Member
26) Has BIM changed the way people within the design team collaborate?	✓	✓	✓	✓
27) Has BIM changed the way the firm collaborates with the client?	✓	✓	✓	✓
28) Was the model shared between consultants? Yes, go to Q.34	✓	✓	✓	✓
29) How were the drawings exported? (eg. dwg, dxf, etc)		✓		✓
30) Was information (other than drawings) from the model used by consultants? (Schedules, etc)		✓	✓	✓
30a) Quantity Surveyor		✓	✓	✓
30b) Services Consultant(s)		✓	✓	✓
30c) Civil Engineer		✓	✓	✓
30d) Building Surveyor		✓	✓	✓
30e) Other		✓	✓	✓
31) Under what arrangements was the information shared?	✓	✓	✓	
31a) Economic incentives (fee arrangements)	✓	✓	✓	
31b) Responsibility (who is responsible for the information)	✓	✓	✓	

31c) Other (alliance; spirit of cooperation)	✓	✓	✓	
32) Was information (or data) from other consultants co-ordinated within the model?	✓	✓	✓	✓
33) Other comments: (communication – technical – Design Development)	✓	✓	✓	✓
34) What BIM or CAD-type package(s) were used by consultants? (compatibility; interoperability)		✓		✓
35) Were there tangible benefits from sharing the model? (e.g. eliminate or minimise data re-entry)	✓	✓	✓	✓
36) What were the downsides/disadvantages? (e.g. enormous model / file sizes; Intellectual Property)	✓	✓	✓	✓
37) Has the information been consolidated in a single model?		✓	✓	✓

F.DD.2 : COST AND TIME

This section compares the curves of effort vs. time between traditional (non-BIM projects) and BIM driven projects through the project life cycle. It also tries to establish if BIM actually saves time when compared with traditional documentation.

	General Manager	CAD Manager	Project Architect	Team Member
38) At what stage was BIM implemented? Schematic Design, Design Development, Contract Administration	✓	✓	✓	
39) How would you describe the effort distribution in a typical project <u>before</u> implementing BIM? Effort vs. Time	✓	✓	✓	✓
40) How would you describe the effort distribution <u>when</u> implementing BIM? Effort vs. Time	✓	✓	✓	✓
41) Comments : (risks on the BIM adopted effort)	✓	✓	✓	✓
42) Overall, does BIM save the company time ? (does it take less, more or a similar time to document a project)	✓	✓	✓	✓

F.DD.3 : DELIVERED DOCUMENTATION

This section explores the way BIM generates and communicate project information and compares it with traditional documentation.

	General Manager	CAD Manager	Project Architect	Team Member
43) Does the 3D model eliminate the need to produce any OTHER document? (e.g. cross-section)		✓	✓	✓
44) Does BIM allow you to present data in new ways?		✓	✓	✓
45) Does the system allow you to have access to NEW information?		✓	✓	✓

46) Is the quality of drawings (2D – printed or PDF) better or worse than before implementing BIM?		✓	✓	✓

F.CA.1 : COLLABORATION

As previously mentioned in section F.DD.1 this section identifies changes and benefits of sharing the model, if applicable, with the builder.

	General Manager	CAD Manager	Project Architect	Team Member
47) Was the model shared with the builder?	✓	✓	✓	
48) Was the builder aware of the architect's use of BIM? (Perhaps more rapid / slower turnaround to queries; etc. ?)	✓		✓	
49) Was there any tangible benefit during the Contract Administration stage due to the use of BIM?	✓		✓	

F.CA.2 : QUALITY

This section explores the relationship, if any, between the use of BIM and a smoother construction stage as a consequence of a better coordinated documentation and client expectations.

	General Manager	CAD Manager	Project Architect	Team Member
50) Following the introduction of the BIM approach, was there a change in the number of RFI's (Requests for Information) lodged? By how much.			✓	
51) Was there a change in the quality of the building? Was the final outcome (building) benefited by the use of BIM? **By how much.**	✓		✓	
52) Were any errors or clashes detected in the BIM approach that previously would only have been 'picked-up' later or on-site? Estimated time savings	✓		✓	

F.CA.3 : DELIVERABLES

This section identifies the level of maintenance required to update the BIM model during the construction phase (for example, when changes arise from variations) required to produce an accurate as-built model and, if applicable, integrate such model with a Facility Management system.

	General Manager	CAD Manager	Project Architect	Team Member
53) Does the BIM model get updated as the building proceeds and variations may become necessary? (ie designed BIM vs. as-built model)		✓	✓	✓
54) What were the types of deliverables provided to the client? (manuals, as-built drawings, x-sections, plans, model,..)		✓	✓	✓

55) Will the model be integrated with a Facility Management package?	✓	✓	✓	✓
56) What will happen to the model after project completion? (Intellectual Property : archived in a proprietary format; neutral format,)	✓	✓	✓	✓

3.2.1 Interviewees Profile

As shown on the previous tables, this research identifies four different players that have an important role in the adoption and successful implementation of BIM and, as such, were systematically interviewed across all case studies. These players are: 1) the architect, 2) the consultants, 3) the builder and 4) the client. Whilst the first two share the same booklet, another set of questions was developed for the last two.

1) The Architect's office

As previously mentioned, currently it is the architect who plays a primary role in the implementation of BIM in building (not the case in civil works). Therefore, four layers of analysis were contemplated to best understand the internal dynamics of BIM adoption within the architect's office. The interview booklet was applied to the following type of respondents.

- **General Manager:** Provides the context of the company as well as the executive perspective, and has a strong knowledge of the costs (financial and non-financial) of adopting a new technology. His / her strategic position allows this person to define the vision for the future of the company.
- **CAD Manager:** The technical knowledge of this person is key to help define the vision and future of the company. His or her understanding of BIM has a direct impact on the initial evaluation of the systems as well as the adoption and ongoing support. As with the General Manager, it is expected that this person is also familiar with the costs involved in adopting BIM (e.g. equipment, training, loss of productivity, etc.).
- **Project Architect:** His or her responsibilities are to deliver the architectural project. Although this person may not participate in the decision to adopt BIM, he or she is directly affected (positively or negatively) by the consequences of such decision. However, it is not expected that this person will directly interact with the system under daily basis or have full technical knowledge of it.
- **Team member:** This person is the drafter, or modeller, who is directly responsible for input of the architectural data (model the building).

2) The Consultant

Any consultant (structural, services, etc) that has a design input to the project and as such needs to interact with the architect's model or documentation.

A specific booklet was developed for the builder and client as described below.

3) The Builder

The contractor responsible for building the project.

4) The Client

The person(s) from the client's end that was exposed to BIM, via 3D visualisation, viewer, etc. This person(s) provides the executive and technical perspective of the client.

3.2.2 Builder / Owner questionnaire

GENERAL QUESTIONS

Question	Owner	Builder
1) Concept of BIM within your company? Does your company have an understanding of the Building Information Modelling concept?	✓	✓
2) Did the design firm introduce your company to the BIM concept, or were you already aware of it?	✓	✓
3) What were your expectations from BIM. Were your expectations (if any) of BIM met during the project?	✓	✓
4) Do you think BIM is a money saving approach?	✓	✓
5) Do you think BIM is a time saving approach?	✓	✓
6) Is this your first project using BIM? If yes? **What has prevented your company embracing the BIM approach previously?** A lack of awareness on your company's part ? Concept not explained well enough? BIM concept/approach perceived as too risky? concept/approach seen as too technical? If not? **For how long / in how many projects has BIM been implemented in your projects?** **Were they successful?**	✓	
7) Is this your first project using BIM? If not? **For how long / in how many projects has BIM been implemented in your projects? Were they successful?**		✓

DESIGN DOCUMENTATION AND TENDER STAGE

Question	Owner	Builder
8) Did BIM improve the understanding of the project through the use of 3D or any other data e.g. schedules, etc.	✓	✓
9) Was the documentation better than other documentation where BIM was not used?	✓	✓
10) Did you have access to the model? If yes **was it before or after tender?**		✓

11) Do you believe that sharing / having access to the BIM model at the tender stage benefits the tender process?	✓	✓
12) Do you believe that BIM fosters better coordination between architect and builder?	✓	✓
13) Do you believe that BIM results in better coordination between architect and other consultants?	✓	✓

CONTRACT ADMINISTRATION

Question	Owner	Builder
14) Do you think that BIM had (will have) a positive impact on the construction stage? (E.g. less problems, smoother process) the construction stage **More rapid resolution of on-site problems?** *For the builder only*: **Less RFIs, faster response time?**	✓	✓
15) Do you believe that BIM reduces the number of RFI's? (estimate – by how much)		✓
16) Do you believe that BIM reduces the amount of time for the architect / consultants to respond to RFI's? (estimate – by how much)		✓

BIM IMPLICATIONS

Question	Owner	Builder
17) Statement: *Suggestions are that BIM adoption means an architect incurs costs earlier in the project than previously.* **Would you be willing to adjust the fee structure to reflect this?**	✓	
18) Looking forward: For your next project, would BIM be a decisive (or a contributing) factor in choosing a design firm?	✓	
19) Looking forward: For your next project, would you prefer BIM being used over traditional methods?		✓
19) Does BIM change the way your company / subcontractors produce 'as-builts'?		✓
20) Would you like to see this model taken to FM packages? (Future projects)	✓	

3.2.3 Post-recollection of Data Procedures

Following each interview, the information registered in the booklet was transcribed into electronic format and then sent to participants to give them the opportunity to correct any of the impressions or information collected prior to analysis or subsequent publication. This action minimised the risk of mis-interpretation by researchers, or of interviewees unintentionally offending a fellow worker or manager through inadvertently mentioning something that others may perceive as distressing. It is noted that no comments to change the transcriptions were received.

The final draft of the report was also sent to all participants for review.

3.2.4 Selected Case Studies

Base on the above-mentioned criteria, five case studies were selected. A total of 20 interviews were done across all case studies. Table 3-4 shows the number, and type of interview, undertaken for each case study.

Table 3-4: Case Studies Undertaken

			Interviewees							
			Architect's office							
Code	**Location**	**Project Type and Value**	**General Manager**	**CAD Manager**	**Project Architect**	**Team Member**	**Structural Engineer**	**Consultant**	**Client**	**Total Interviews**
M1[R]	central-city Melbourne	High-rise office building development $300M 2 years		✓		✓	✓			3
M2[R]	inner suburban Melbourne	Small mixed-use development $4M 6 months	✓[CM]			✓	✓		✓	4
BM[RQ]	central-city Sydney	Extensive office building at wharf-side redevelopment $280M 2 years	✓		✓ ✓			✓ ✓	✓[B]	6
B1[Q]	central-city Hong Kong	Large, high-rise office development on Hong Kong island $300M 3 years	✓	✓		✓				3
B2[Q]	rural town Queensland	Police station/watchhouse complex $10M 12 months	✓	✓	✓	✓				4
									Total (Overall)	**20**

[R] / [Q] : denotes the university that led the case study, RMIT and QUT respectively.

[CM] : In M2, the General Manager and the CAD manager is the same person.

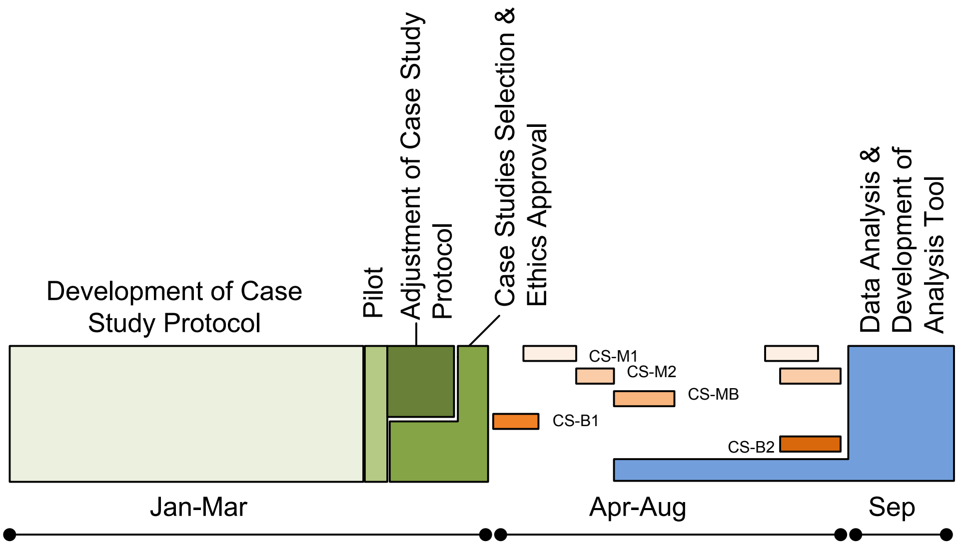
[B] : In BM the client was the developer (builder).

As shown on Figure 3-1, both M1 and M2 were completed in two separate sessions each due to the availability of the participant.

3.2.4.1 Case Study Timeline

The following Figure 3-1, shows key activities leading up to the case studies (including the development of case study protocol, the pilot and case studies section) up to the data analysis and the development of the analysis tool.

Figure 3-1 : Case Study Timeline



3.2.4.2 The Pilot

A pilot case study was undertaken on the 27 of March. The pilot was conducted by four researchers, three in the role of interviewers and one as the interviewee. Whilst the three interviewers have been closely working on the development of the case study protocol, the interviewee was not familiar with the research case study protocol nor being exposed to the questionnaire, but had a sound understanding of BIM.

The pilot simulated the conditions of a real case study, with the exception that on this occasion the interview was being filmed for further analysis. The interview was lead by one of the researcher with spontaneous interventions from the other two interviewers. The case study protocol was applied and the interviewer's booklet followed.

The feedback and overall result of the pilot were positive. With the exception of a few questions (that were later adjusted), the questions seemed to flow and follow a logic sequence.

Based on the outcome of the pilot the Interviewer's booklet was redesign in format and content.

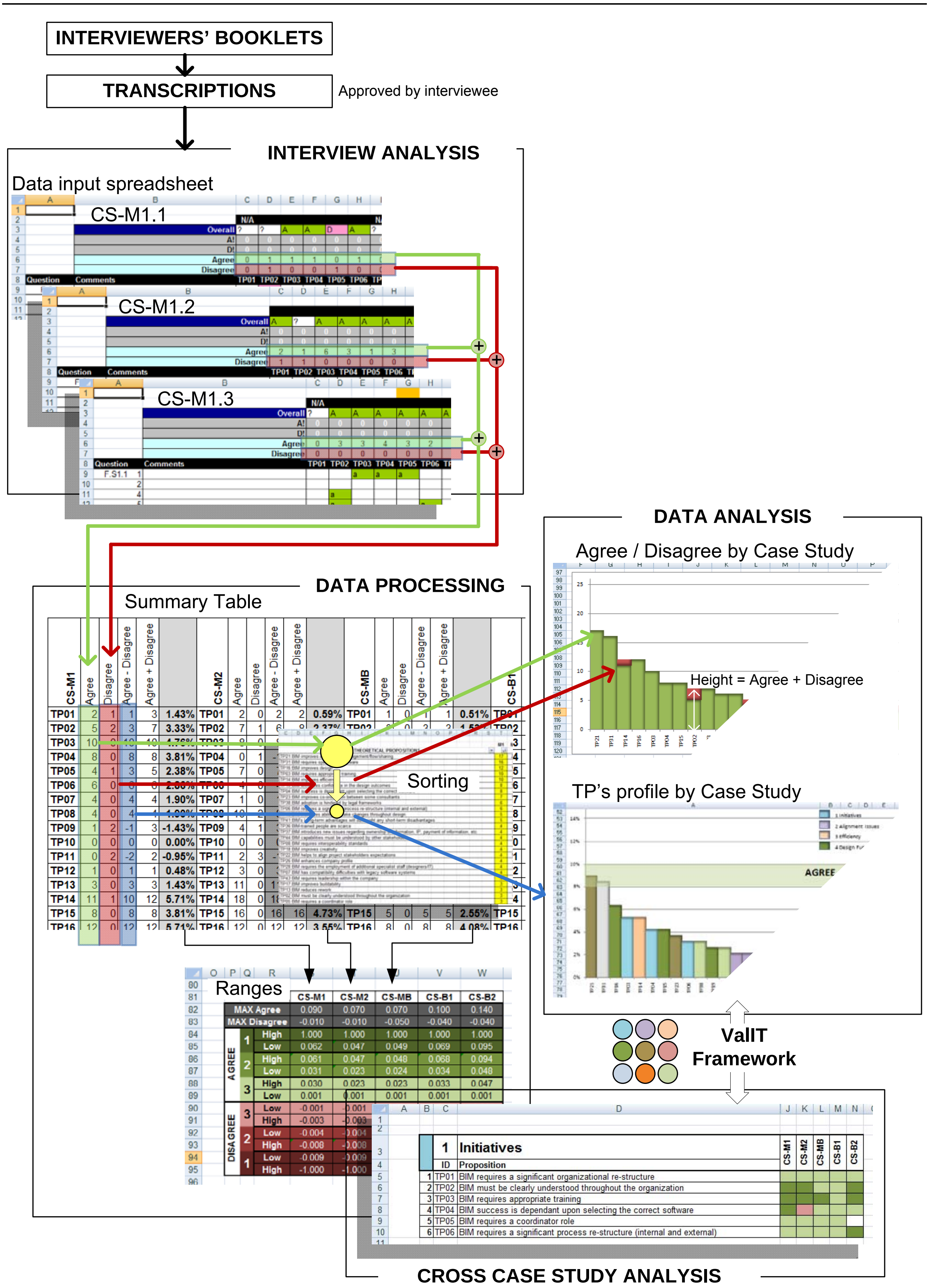
3.2.4.3 The Interview Process

B1 was the first case study to be completed, and then followed by M1 and M2. In the case of these last two, the interview process was divided in two. The architect's office was interviewed first, followed by the interview of engineers and the owner (in the case of M2). Just shortly after the first round of M2 finished, MB started. B2 started almost in parallel with the second round of interviews for M2.

3.3 Analysis System

A system was developed using Microsoft Excel to process data recollected during the interviews and show results in a fashion that would facilitate its analysis. The objective of the system is to move and process data across different stages in an effective way whilst minimising human error and present information in a useful way for analysis and interpretation of results. It is important to note that whilst numbers were used to process the data, this was only a way of coding and 'transporting' qualitative information; it does not however denote a quantitative approach .

The following chart summarises the different sections of the system: Interview Analysis, Data Processing, Data Analysis and Business Case.


INTERVIEWERS' BOOKLETS
TRANSCRIPTIONS
Approved by interviewee
INTERVIEW ANALYSIS
Data input spreadsheet
CS-M1.1
CS-M1.2
CS-M1.3
DATA PROCESSING
Summary Table
Sorting
Ranges
DATA ANALYSIS
Agree / Disagree by Case Study
Height = Agree + Disagree
TP's profile by Case Study
AGREE
ValIT
Framework
CROSS CASE STUDY ANALYSIS
Initiatives
ID
Proposition
TP01 BIM requires a significant organizational re-structure
TP02 BIM must be clearly understood throughout the organization
TP03 BIM requires appropriate training
TP04 BIM success is dependant upon selecting the correct software
TP05 BIM requires a coordinator role
TP06 BIM requires a significant process re-structure (internal and external)

3.3.1 Interview Analysis

The analysis of interviews was done by at least one of the researchers present at the interview to ensure that comments were not taken out of context. The researcher(s) assessed the type of agreement, if any, between the responses registered on the transcriptions and all the TPs. A matrix was composed by putting the case study protocol questions on the first column against all the TPs on the first row. Then, either an "A" for agreement or "D" for disagreement was input depending on the relationship between the data recollected from the questions and each of the TPs. If there was no relationship the cell was left blank.

It is important to note that there is no scale for the level of agreement between the data recollected and the TP. That is, "A", as previously mentioned denotes agreement, but it does not provide details on how much the recollected data agrees with the TP. Therefore, it could be the case that two (or more questions) showed a mild level of agreement within a particular TP, but a third one had a stronger level of disagreement. Since the overall result is calculated just by adding up each occurrence, the system has no way of knowing that a particular question "weights" more than another. Therefore "A!" and "D!" allowed the system to override the sum and automatically put "agreement with disagreement" or "disagreement with agreement" respectively.

Figure 3-1 is a screen shot of the "Data input" spreadsheet. Conditional formatting, green for agreement and red for disagreement, is used to graphically show the type of agreement.

Figure 3-2 : Data input spreadsheet showing full functionality

	A	B	C	D	E	F	G	H	I	J	BA
1											
2			N/A								
3		Overall	?	A	D	?	A	D	Da	Ad	
4		A!	0	0	0	0	0	0	0	1	
5		D!	0	0	0	0	0	0	1	0	
6		Agree	0	1	0	1	2	1	2	0	
7		Disagree	0	0	1	1	1	2	0	2	
8	Question	Comments	TP01	TP02	TP03	TP04	TP05	TP06	TP07	TP08	
9	1			a	d	a	a	d	a	d	7
10	2					d	a	d	a	d	5
11	3						d	a	D!	A!	4
12	4										0
13											

As shown on the above figure, on top of the TPs row, four rows were added (Rows 4 to 7) in order to add up, by column, the type of agreement by TP (Disagree, Agree, A!, D!). On top of these, the "overall" row (Row 3) indicated the result for that particular TP calculated by the highest number of occurrence for the same type of agreement. A question mark, "?", indicated an inconclusive result. However, an inconclusive result can be achieved by either lack of data as shown on column C (no relevant comments from the respondent for that particular TP) or because the different types of agreements were equal (as many A's as "D's) as per column F. To distinguish between these two scenarios an extra row (row 2) indicated "N/A", Not Applicable, when no data was related to that particular TP. In contrast, a question mark on row 3, with no "N/A" on row 2 would denote inconclusive result by contradiction.

At the far right (column BA) an extra column was added to the matrix to show the number of times that a particular question was related to a TP. Although this value is not used for analysis, it is a quality control mechanism. Amongst other things, it indicates with a red "0" that a particular question has not been related to any TP (row 4).

Each interview, of each case study, has one “Data input” spreadsheet. Table 3-5 summarises the number and type of interviews undertaken by case study.

Table 3-5 : Interviews by case studies

M1		**M2**	
M1.1	Team Member	M2.1	General / CAD Manager
M1.2	CAD Manager	M2.2	Team Member
M1.3	Structural Engineer	M2.3	Owner
MB		M2.4	Engineer
MB.1	CEO Architect	**B1**	
MB.2	Project Architect	B1.1	General Manager
MB.3	CEO Consultant	B1.2	CAD Manager
MB.4	Project Engineer	B1.4	Team Member
MB.5	Client/Developer	**B2**	
MB.6	Fitout Architect	B2.1	General Manager
		B2.2	CAD Manager
		B2.3	Project Architect
		B2.4	Team Member

3.3.2 Data Processing

Once all the interviews were coded using the above mentioned method, data was automatically moved across to a summary table. As previously shown in Figure 3-2, this table adds up all the “A’s” and “D’s” (“Ad” and “Da” are converted into A’s and D’s respectively) from each of the “Data input” spreadsheets within the same case study. These data is then sorted (from largest to smallest) to generate the “Agree / Disagree” and “TP’s profile” charts in the Data Analysis.

Parallel, the summary table also calculates the ‘amount of evidence’ gathered for each TP and converts it to percentages. These percentages are then used to generate ranges using colours. Darker colours (green for agreement, red for disagreement) represent higher density of evidence, whereas lighter colours represent less evidence. It is important to note that these ranges are individually calculated per case study.

3.3.3 Data Analysis

The “Agree / Disagree by Case Study” chart is generated by adding up all A’s (green) and all D’s (red) and stack them by TP. TPs are sorted in order of amount of evidence.

The “TP’s profile by Case Study” chart uses the “Agree” minus “Disagree” formula (blue column on the summary table) to calculate the height of the column and uses a colour code to group TP’s as per ValIT framework.

3.3.4 Cross Case Studies Analysis

Automated analyses were produced (one per case study) by grouping TPs as per the ValIT framework and using the previously calculated coloured ranges to indicate the overall result by TP. These automated analyses were then manually overridden to amend specific TPs that because of the limitations of the system (‘cold’ numbers vs. context and source of information) were misrepresented. TPs that required detailed analysis, but not necessarily overridden, were:

M1			
TP	**Comments**	**Automated result**	**Overridden to**
TP05	Difference of view between high level management and middle level technical. Engineer's comments impressions only.	Agree	Inconclusive
TP32	Structural Engineer's comments are only impressions.	Inconclusive	Agree

M2			
TP	**Comments**	**Automated result**	**Overridden to**
TP02	Owner independent from organisation	Agree	n/a
TP09	Structural Engineer requires collaboration from Architect to implement BIM. Architect can see benefits from in-house BIM (justify BIM for own use)	Agree	Inconclusive
TP11	Engineer and Drafter not concerned with long term view. Architect's view reflects current company's situation: unable to tie BIM to FM packages.	Agree	Disagree
TP27	Different opinions between High level architect and drafter	Agree	Inconclusive
TP29	Owner's impression is that BIM will be more costly. Where as Architect/Engineer believes it do not.	Disagree	Inconclusive
TP33	Risk perceived differently from each stakeholder.	Inconclusive	n/a
TP39	Reflects perception of effort distribution.	Agree	Inconclusive
TP45	Drafter unaware of management changes due to BIM implementation.	Disagree	n/a
TP46	Narrow view of content (Drafter) vs. Wider strategic view (CAD Manager/Architect)	Inconclusive	n/a

4. CASE STUDY M1

4.1 Project Background

A multistorey office tower (with several basement levels) development located in the Central Business District of Melbourne at two prominent street corners. The initial tower has recently been completed (2007) as the first stage (estimated construction value AUD$300 million) of a proposed two-stage project for the site. A trend for corporations to seek larger floor spaces rather than skyscrapers was influential in the commercial brief of this new building for which the target market was a range of corporate and government tenants.

4.2 Project stakeholders:

Developer, Architect, Structural Engineer, Building Contractor (‘Design and Construct’), Steel Contractor, Steel Detailing, Services Engineer, Planning Authorities and various consultants.

4.2.1 Architect firm background:

A long established Australian-based architectural firm with offices around Australia and many international commissions. This company was an early adopter of CAD and plotting of drawings as well as CAD techniques in various forms for over 20 years, and more recently as leaders in visualisation, 3D modelling and BIM which they applied in the case study project. ArchiCAD is their main design platform.

4.2.2 Structural engineer background:

A large civil, infrastructure and structural engineering firm with over 80 staff and offices in three states, they have a strong record of using AutoCAD successfully over a substantial number of years, and are on the cusp of implementing BIM but only for selected projects, and not for the case study.

4.3 System Evaluation and Adoption

4.3.1 BIM Concept

Despite, or perhaps because of, the history of the company in using CAD over a long period of time, from the designer’s point of view, BIM is not a word used everyday in the design practice and the BIM concept is not *formally* used - thus many users are not aware of the everyday use of BIM but understand the concept. Whereas from a technical point of view, BIM is seen as a different way of documenting projects more accurately, of achieving a higher degree of reuse of design objects, and a way of reducing RFI’s (Requests for Information).

4.3.2 BIM Objectives

Generally BIM objectives are faster completion of projects / shorter deadlines with fewer staff since fees are getting tighter, and there has been recent major internal CAD review with mixed feelings at the senior levels. Make best use of / exploit the software that is paid for, but current software has some challenges / issues in complex projects, and consideration must be given to migrating to other packages.

4.3.3 Reasons for adoption

Initial primary driver for embracing 3D capabilities was seen as visualisation and marketing. Whereas reasons for BIM adoption were the database capabilities (scheduling), compatibility with other parties, and competitive advantage. BIM is seen as an ideal platform for projects with complex relationship documentation.

Prior to adoption, the architects saw themselves as amongst the leaders in the field, and changed the previous system because it was not compatible with AutoCAD’s dwg CAD format 10 years ago. At that time, ArchiCAD was the only true object-oriented BIM-type product.

4.3.4 Software or management approach

Technical and design consensus suggested more of a management approach, and that BIM is a "different way of working - different from 2D" – not only software but a different way to manage the project. The model is normally set up from project commencement and used throughout the process.

4.3.5 BIM endorsement

Several points of view were expressed - with some senior people convinced of the benefits of BIM and others not necessarily convinced. Mixed feelings apparent with regard to resources, since often staff that have been trained in 2D software applications are much easier to find – and these staff can be less expensive in certain overseas situations.

However some consultants (namely steel subcontractors) were keen to interface with the BIM model as they say it improves the understanding of the shop model, so some people are beginning to be aware of the work put into the BIM model and appreciate the value it can provide.

4.3.6 BIM deterrent

A number of factors were nominated as deterrents to BIM adoption – in particular resource implications (especially finding trained staff, and having staff involved in non-project work setting up object libraries and the like); internal politics (some staff/management don't seem to have a clear understanding of BIM); and regional factors (for instance, many Middle East consultants prefer projects in 2D but they are now starting to be aware of BIM's strengths and weaknesses).

There appeared consensus that factors such as legal frameworks can limit the open sharing of information between companies. It was noted that there are not strong CAD/layering standards widely used in Australia compared with USA, and paper documents still have to be provided, but procedures such as transferring 3D to 2D information can go wrong, so current best practice is to always use a strong disclaimer on any data exchange.

4.4 System Evaluation and Adoption

4.4.1 The software

Several CAD packages have been used across several of the local and international design offices including ArchiCAD, AutoCAD and Microstation – with work almost 50/50 divided between BIM and traditional 2D CAD. As a rule of thumb, the more developed the region the easier it appears to be to use/implement BIM – particularly in Australia and Europe.

The software must ensure that the project information should be accessible electronically in order to be able to provide visual capabilities; access to data built into the model; allow design to start from early 'sketches' in BIM and take it all the way to completion; to generate documentation; and to provide scheduling information. ArchiCAD with its "*ease of use*" and "*excellent support*" (the latter deemed a key factor) was chosen as the BIM vehicle by the design firm. The structural engineers have traditionally used AutoCAD and are still evaluating Revit Structures with a view to BIM implementation if new software releases are deemed suitable.

Interoperability between software packages was another issue raised – with opinion expressed that there needs to be an (accepted) open data format, since if BIM is fully adopted by Government it will (likely) not be as a proprietary product.

4.4.2 Alternate BIM software

Autodesk's Revit has been used in pilot situations but the designers have yet to reach a conclusive opinion, while ADT appeared to have less-than-adequate support - no quick fixes for software bugs. Microstation has been used previously in designers European offices, however the BIM implementation was not yet available in Australia when software was selected, while Digital Project - although appearing expensive – is considered advantageous for complex geometric forms – so its adoption is contemplated for larger, complex projects. The structural engineers are evaluating

Revit Structure with a view to BIM implementation if new software releases have indeed addressed the issues deemed as unsatisfactory by the group in 2006.

4.4.3 System Cost

Introduction of the concept of BIM design software on subscription (rather than initial purchase) has assisted in budgeting for the costs of major design software upgrades, and some discounts are available if large numbers of software licences are involved for the one company. However the initial purchase/licence cost of many alternate design and additional analysis software packages is viewed as ‘high’. For the engineering business, more concern was expressed at the potential cost of having to acquire multiple specialist software for both steel and concrete design.

4.4.4 Hardware cost

The design firm has implemented an 18-month cycle over which the PC equipment is replaced. With high volumes of business and support agreements in place, all equipment is leased including basic design workstations (with 2Gb of memory) which could cost up to AUD$3,000 to purchase, while a high-end visualisation workstation would likely cost up to AUD$20,000 (including the software) to purchase. The importance of PCs having considerable RAM was again stressed for a successful BIM implementation, and large (24”) monitors are also preferred options. Reliable or robust network connections are seen to affect efficiency (particularly overseas) where licence verification can rely on connectivity. For example, new offices were set-up and moved into in the Middle East within two weeks, and subsequently a shopping centre was designed after two days.

4.5 Implementation Strategy

4.5.1 Training

With around 45 Computer-Aided Design operators within the company’s Melbourne office – all trained in BIM, along with many of the design architects and some senior management, the design company takes training very seriously. Using a mixture of approaches such as developing and utilising in-house training, and outsourcing via training schools, in-house training is seen as more efficient and less disruptive for the say 20-25 hours needed for general BIM software and a further few hours on company-specific issues and other specialised training. None-the-less, training can still be seen as quite disruptive by removing people out of teams which interrupts the whole project, and it remains a large challenge to appropriately schedule the training.

Staff retention and turnover is another issue since loss of expertise and the subsequent need to train new staff members should be factored into the cost of training. Ideally people are trained (in-house) from the time they commence with the company, and it also gives the opportunity for them to ‘unlearn’ old habits which are no longer used. Graduates – as experienced by the design firm - are seen as lacking basic CAD knowledge and university training is not seen as sufficiently BIM-focussed. Therefore, with up to 80% of people currently needing training the design firm actively recruits staff that are already experienced in BIM where it can find them. It is much too early in the process for the engineering business to have made decisions, but training and availability of skills are certainly major factors under consideration.

4.5.2 New working paradigms

With a large number of operators trained in the use of BIM, for most current staff thinking in 3D is second nature, but with new staff, BIM training gives the opportunity for them to ‘unlearn’ old habits which are no longer up-to-date.

4.5.3 Software content:

As a guide, it was estimated that around 80% of the software was usable out-of-the-box, and some 20% needed to be customised. It was considered that too much of the content that was provided with the BIM software products was not likely to be useful – for instance, object libraries of various windows and furniture which the design firm would not use, or libraries focussed on architectural elements that the engineers would not use.

4.5.4 Customisations / Setup

Across the whole design organisation, there is a couple of people developing suitable modelling content on a full-time basis, and there has been much less content available for BIM than for earlier 'simple CAD'. However this situation seems to be improving with companies such as BHP-Billiton now having a BIM library of appropriate (standard) objects that can be accessed.

4.5.5 First BIM project

The engineers are still evaluating BIM software and may try it on a relatively small Sydney project. On the other hand, the first project which the design organisation undertook utilising BIM (circa 1999) was a large hospital project - which in hindsight may have been overly complex as a first project. High hopes were held for BIM to facilitate information sharing, but at that stage (~1999) the software selected was more suited to smaller projects – however valuable lessons were learnt, particularly regarding data formats and information exchange as a result of expectations not matching reality.

4.5.6 Old/new methods used in parallel

Now (2007), as initially, the firm's approach is to embrace BIM rather than any parallel approach (ie in traditional manner, as well as in BIM), since the use of BIM has shown to bring additional value in the information management of projects that the organisation works on – even if other consultants do not (yet) end up exchanging data back and forwards between the firms in a complete loop. Trying to complete projects *in parallel* for the size of projects now involved would be simply prohibitively expensive and difficult (time consuming).

4.6 Collaboration

4.6.1 Within team

BIM has reduced the amount of internal communication required to understand and explain the project. It seems to be easier to get "into" the model, and within 10 minutes of looking around the model, you get the idea. Those architects trained in BIM's use can do the sketch design and CAD development simultaneously. Senior architects that do not know how to use the software are working with the draftsmen as a close team – together looking at the model on the screen. Senior architects might not use the BIM systems but they certainly rely on it. The visualisation helps a lot to communicate with and get ideas across to the client. If senior architects "do not keep up with the software they can be left behind" in what it can achieve.

4.6.2 Collaboration with the client

CAD and BIM has enabled quick visualisations to be produced – which means designers can get feedback from clients straight away - the time savings make it a big advantage. However the 'downside' is that clients are now starting to expect information in 3D - not 2D floor-plans, and to expect 3D models as standard deliverables. Equally though, "*many clients still like physical scale models as well*".

4.6.3 Model shared between consultants

The Building Information Model or sections of it (or at least information from the model) was shared with other consultants at various times, and in particular with the structural engineers, but neither the services engineers nor the quantity surveyors participated in the data sharing.

4.6.4 Drawings export

For the case-study project, the architects produced 2D outlines (.dwg files) from their 3D model, and the structural engineers were able to use these files as templates for the engineering work. On other projects, the engineers had received data from other sources where the projections had been rather unsatisfactory, but the quality and accuracy of the conversion from 3D down to 2D by the architectural firm for the case study project was praised by the structural team as excellent.

4.6.5 Non-drawing information used

Apart from drawings, various schedules were produced from the BIM but these were only for internal use within the design organisation and were not shared with external parties - as a rule, only basic information out of the Building Information Model is provided by the design organisation to external consultants.

4.6.6 Other consultant(s):

From the design firm's viewpoint, the structural engineers appear to be more advanced in accepting electronic information than any other consultants, whereas the services engineer were not ready to accept computer data - more (model) input "from services would be great for clash detection especially in duct work and cabling".

4.6.7 Information sharing arrangements

a) Economic incentives

Key stakeholder felt that the opportunity and incentive to better explain things is huge. However, there is no additional compensation to designers for making the information available and sharing it, whereas it is of real benefit to the organisation which receives the information since their time is much reduced in understanding the project.

b) Responsibility

The sharing (or the provision) of a building information model with <u>basic information only</u> to other stakeholders is seen as assisting designers in reducing risk - since architects are often seen as legally the first party to be blamed in the case of a project dispute. The model can be used as a "reference" or backdrop to support additional work by others, but a prominent disclaimer regarding the data's use by other stakeholders for their purposes is seen as a prudent safety net in case disputes should arise.

c) Cooperative alliances

It was noted that the design and design information (especially for one-off projects) is regarded as part of the architect's intellectual property (I.P.) and often is covered under the terms of the contract with the client, so sharing of a building information model (particularly in its native format) is seen as something that needs strong protection. Hence emerging areas such as Digital Rights Management and the opportunities for protection of I.P. which they may provide will be very important in future, it was noted.

It was felt that the advantages of using information modelling technologies and pushing them forward should be well understood by stakeholders, since the more that the various parties understand about the techniques, the better the outcomes for all concerned.

4.6.8 Data synchronisation with consultants

On the case-study project in Melbourne, the (building information model) data flow was primarily one-way from the designers to some other consultants, and hence there was no consolidated BIM and no direct link back to one. In future, additional resources (time and people) may be needed within one of the key stakeholder's offices to ensure that any added information flows from consultants back to the model are captured, synchronised and enshrined in the BIM to produce a consolidated model.

4.6.9 Communication; technical comments

Tangible benefits of sharing information from a model were seen as improved understanding between the architect and the client; the ability to quickly incorporate changes to the project; and the capacity to undertake clash detection and coordination, while one impediment to sharing was seen to be the sheer size of some of the files to be exchanged. For the case-study, the exchange of digital data allowed clashes to be detected (manually) between the architectural and the structural elements, however the services elements were unable to be included in this process.

It was noted that many engineering and services consultants can select from a wide variety of CAD and analysis packages but use the one they would prefer, since the client (usually) does not dictate what software application(s) should be used. It was also identified that the more automated type of clash detection/collision process “seems well developed in the USA but less so” in Australia.

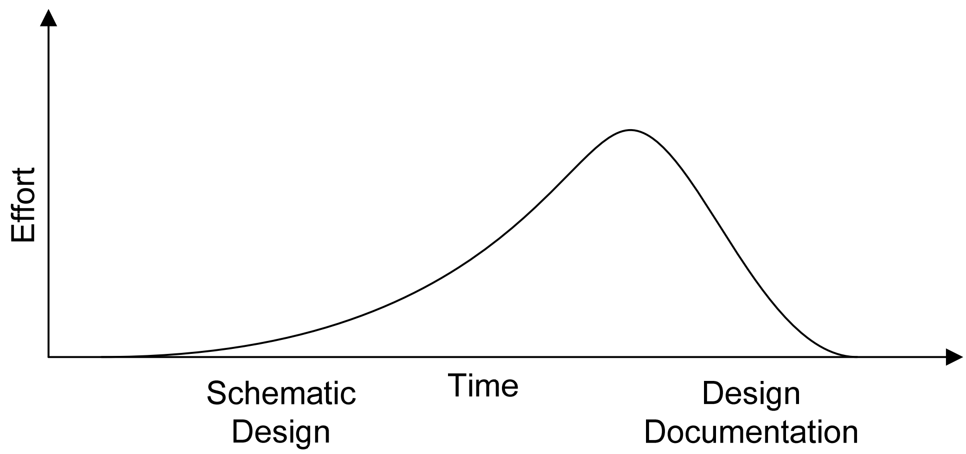
4.7 Cost and Time

4.7.1 Effort distribution when implementing BIM

On the M1 case-study project in Melbourne, the BIM was implemented early in the Schematic Design stage of the project, and respondents confirmed the peak of the effort versus time curve was felt to be steeper and to have been moved to earlier in the project than otherwise would be the case.

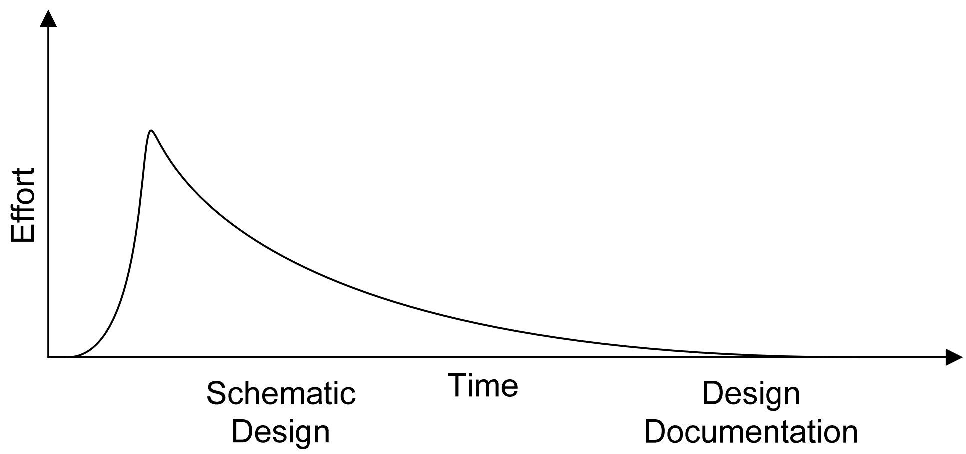
BIM was implemented since schematic design. The effort distribution curve for traditional methods was identified as below in Figure 4-1:

Figure 4-1: Traditional Effort Distribution Curve



Once BIM is implemented, the distribution of effort is shifted to earlier stages of the project (see Figure 4-2) - resulting in more of a straight line at the start of the project.

Figure 4-2: Revised Effort Distribution Curve



However, there was difference of opinion within the design firm. Another respondent believed that with traditional methods the effort was evenly distributed between the two phases but once BIM was implemented, the quicker the data could be put into the model the better (shifting the curve to the left).

4.7.2 Risk on adoption effort

There seemed mixed opinions regarding this – with comments for and against. On the one hand, the cost of change and cost of error increase the further the project develops - for instance, a wrongly designed component (i.e. beam, concrete) will have a higher impact later on - and so the higher initial cost is justified, while conversely there is a risk of the project not going ahead and the additional effort that was put in early may be a unnecessary cost - without the offsetting benefits. The view was expressed that the industry seems increasingly supportive of a fee adjustment to accommodate some of the latter concerns, and that basically the benefits that may be obtained 'downstream' mean that the risk of investing early should be taken.

4.8 Delivered Documentation

4.8.1 Eliminate need for other documents

The prevalent view was that a 3D model does not eliminate the need for other documents but can save time in the creation of cross-sections, for instance, or in the creation of simple rendered views from simple façades and textures at the early stage. As things currently stand, the traditional documentation must still be produced and is often "shared" (or rather exchanged) by using document management systems, so the technology and processes are 'not there yet'. All structural engineering work for the case study was based on 2D drawings

4.8.2 Facilitate new presentation

The BIM and 3D models allow designers to query the model and 'get more information out of it' (it was felt that this was where the 'early efforts pay off'), but also that the visualisation provided to the client (which is usually a range of both BIM-generated images and hand-drawn sketches) needs to be managed.

4.8.3 New information provided

The consensus was that the BIM provided not necessarily new, but better, more accurate and more timely information. Some preliminary environmental analysis could be undertaken more rapidly and this provides new opportunities to analyse options and more real-time feedback on design variations, and the likely implications of contemplated changes. In the past such desired changes could not always be readily incorporated into the design because of delays in obtaining feedback from the analyses.

4.8.4 Drawings quality

Comments were made that the BIM provided better *coordination* of drawings (as opposed to better quality drawings), and an impression that some of the 2D output from BIM was not as good as previously had been achieved from finely-tuned plotting/printing processes.

4.9 Contract Admin. Collaboration

4.9.1 Model sharing

On the case study project, the digital model was not shared with the builder - only hardcopy of 3D drawings.

4.9.2 Builder’s awareness of BIM

Initially there appeared little interest from other stakeholders, however once made aware of the technology and the existence of a model, personnel from the construction company visited the office to view the model. Designers expressed the view that the model helped to explain things better and quicker to the builders than the traditional faxes and hand sketches.

4.9.3 Tangible benefit at CA stage

Again design stakeholder felt the BI model facilitated an easier understanding of the project and emphasised that they felt it assisted the client to better understand the project. Another benefit seen of the use of BIM was that “checking shop drawings is an invaluable tool”, but unfortunately there seems little information available to benchmark against other jobs.

4.10 Contract Admin. Quality

4.10.1 Change in RFI's lodged

The case-study project was successfully delivered on time and within budget, and the design stakeholders perception was that there was a reduction on Requests for Information (RFIs) –but, it was impossible to quantify for the project. It was commented that there appears to be very little (Australian) experience and benchmarks in these areas as yet.

4.10.2 Quality of documentation

Opinion was ventured that designer didn’t think there is a direct relationship between the use of BIM and any change of quality as it is so hard to make comparisons, but it was also commented that “it is not the software, but the people managing the software” that determines outcomes.

4.10.3 Errors detection prior on-site

Covered earlier in discussion of clash detection.

4.11 Contract Administration Deliverables

4.11.1 BIM model updates

In the first Melbourne case-study project which involved a large office-block development, BIM models (3D models) and specifications were treated separately, and components were not specified in the model. Comments were made that normally the model will evolve (visually) but not the database. For legal reasons, when drawings are discussed or issued, the term ‘as-built’ is not used since a design firm cannot control how the project is built, however 2D drawings were issued as Adobe PDF documents.

4.11.2 FM package integration

The case-study BIM was not linked to a Facilities Management package during design and construction. It was felt to be too early in the development and maturing of FM (in Australia) to say whether as a general rule the BIM model will be integrated with an FM package, but one party interviewed felt this link between the two systems is certainly missing after they had explored options to establish such a link.

4.11.3 Project model completion

As the engineers work for the case study was all 2D, the files were archived as proprietary (.dwg) files and stored, while the central document management system utilised for the project was used to archive all documents as .PDF files. The architectural firm’s approach is that once a project is finished, completed models are archived by them in 3D/BIM proprietary (rather than a neutral) format onto DVD or CD-ROM, and retained by them. Comment was made that although archiving in proprietary format may pose some risk, the design software (ArchiCAD) has had a very strong history of backwards compatibility allowing older files to be read by newer software versions. It was also noted that archives can be used as references for future projects so some information and libraries must be able to be extracted from previous models to allow re-use and update where appropriate.

4.12 Analysis of Theoretical Propositions

In Case Study M1 (the multi-storey office-block development in central Melbourne), the ten theoretical propositions which had the greatest "weight of evidence" (i.e. mentioned most often in discussions) to support them, were

TP21 (BIM improves information management/flow/sharing) was most mentioned, then

TP31 (BIM requires specialised software with certain characteristics)

TP16 (BIM improves design)

TP14 (BIM requires appropriate training)

TP03 (BIM improves efficiency)

TP04 (BIM success is dependant upon selecting the correct software)

TP15 (BIM enhances confidence in the design outcomes)

TP23 (BIM improves co-ordination between consultants)

TP06 (BIM requires a significant process re-structure (internal and external))

TP38 (BIM adoption is hindered by legal frameworks)

4.12.1 Concurrence

Based on the interviews and discussions held with staff from various stakeholders, there was consistent agreement (see Figure 4-3) in Case Study M1 with the propositions that BIM:

- improves information management/flow/sharing — associated with the category of Collaboration,
- requires specialised software with certain characteristics — associated with Resources and Expenses
- improves design — associated with Design Functionality
- improves efficiency — associated with Efficiency
- success is dependant upon selecting the correct software — associated with Initiatives
- enhances confidence in the design outcomes — associated with Design Functionality
- improves co-ordination between consultants — associated with Collaboration
- requires a significant process re-structure (internal and external) — associated with Initiatives
- adoption is hindered by legal frameworks — associated with Assumptions/Constraints

It is important to note that in this case study the ten theoretical propositions are the same as the concurrences. This is not the case on the rest of the case studies.

Figure 4-3: Theoretical propositions ranked by weight of evidence for M1

4.12.2 Divergence

Areas where there seemed to be some difference of view amongst respondents were regarding the propositions that “BIM must be clearly understood throughout the organization”, as well as the suggestion of whether “BIM requires appropriate training” and if “BIM requires a coordinator role”. These differences may reflect a “technical versus creative” view of BIM’s role and implementation within a large design business where some personnel are primarily focused on creative design tasks while others must provide the support necessary to ensure any technical systems and processes that support the design are both reliable and efficient.

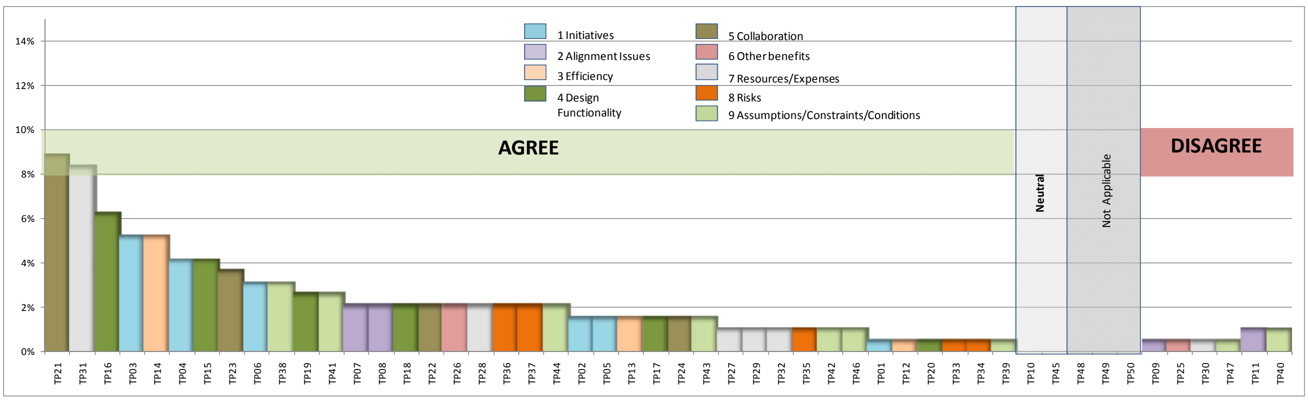
4.12.3 Lack of information

It should be noted that in the case study focused on a commercial office building or in other discussions, the proposition of whether “BIM will be required as a prerequisite for future government projects” was not raised or commented upon by any of the stakeholders interviewed.

4.13 TPs according to Business Case Categories

For this particular large office building case study, as noted in the earlier analysis three of the top ten theoretical propositions were associated with the business driver category called “Initiatives” (see Figure 4-4) whilst a further two were associated with the driver “Collaboration” and another two with “Design Functionality”. To round out the ten, another single proposition related to “Efficiency”, another to “Constraints” and the other to “Resources”. Conversely, in this particular case study, theoretical propositions associated with the categories such as “Risks” and “Alignment Issues” were mentioned less often in discussions than those described in the top few (i.e. had much less “weight of evidence” to support them).

Figure 4-4:Theoretical propositions classified by business driver category for M1



5. CASE STUDY M2

5.1 Project Background

A four-storey mixed hospitality/office development located some four kilometres from Melbourne's Central Business District in a 'suburban shopping strip' at a prominent intersection - surrounded by a mixture of commercial and retail businesses and nearby residential dwellings. Estimated construction value AUD$3.5 Million. Project currently at tendering stage and expected to start construction in 2008. As well as the expectations of normal commercial returns, given that the project was replacing an existing building in a heritage-conscious area, the impact on the streetscape and surrounding buildings was one of the major project considerations.

5.2 Project Stakeholders:

Developer, Architect, Structural Engineer, Services Engineer, Building Surveyor, Planning Authority (Government) and various consultants.

5.2.1 Architect firm background:

Architectural firm has been using 3D modelling techniques since its establishment around 8 years ago. With a staff of some 15 architects and draftspersons, specialising in smaller developments, and having comparatively youthful directors, the company is responsive to innovation and change. Due to their leadership role in CAD/BIM software they have also been involved in the training of staff for other larger architectural practices. They are early adopters and continue to be users of various versions of ArchiCAD.

5.2.2 Structural engineer background:

Allied to the architectural firm through sharing some directors with them, the structural firm also independently consults to other architects on various engineering projects. With a small specialist staff, the company is establishing itself in the innovative structural engineering field.

5.2.3 Developer background:

A relative newcomer to the development industry, experienced in business but with little awareness of CAD or BIM, the developer is looking to produce a building that meets or exceeds his normal commercial return requirements while also meeting the height, façade and setback requirements imposed by local government planners within a heritage area.

5.3 System Evaluation and Adoption

5.3.1 BIM Concept

There appears to be a reasonable consensus about the concept of BIM within the design company, which might reflect the origins of a company which has used 3D CAD and BIM from its conception or 'inception'. In this case study the commitment to a method and way of practising was clear to all staff even clerical employees and reception personnel had a presentation on BIM at the time of commencement with the company.

The case study design consultant refers to BIM as a system that produces clear, accurate coordinated documentation including 3D models, 2D traditional drawings as needed, and schedules as well as take-offs. BIM also enables clear coordination between owners, architects and constructors and allows the company to undertake the modelling of almost any project and the insertion of all data including services, structural, and architectural information into the model. "BIM is not just 3D visualisation; it is about understanding the elements of a building".

5.3.2 BIM Objectives

For the Architect:

- To produce very good architecture; to cover costs, and to make a profit. The company has won many awards for its work, and has had a decade of successes with only one setback. The company themselves considers that their BIM objectives have been met.
- To provide clients with the “architectural intent”, but based on realistic buildability (i.e. the ease with which a building can be built by a contractor).

For the Structural Engineer:

- To invigorate the structural engineering industry. As a reaction to the global competition local engineers have to be much better and a lot more efficient – i.e. same or better quality for a fraction of the price.

5.3.3 Reasons for adoption of BIM.

Reasons include 3D-capabilities, project documentation, database capabilities (scheduling), compatibility with other parties (this refers mainly to the interoperability between the Architect and the Structural Engineer). Aspects like competitive advantage and current trend were not unanimously judged to be triggers of adoption. BIM models are exported to other packages for visualisation enhancement.

The structural engineer saw a clear benefit of the use of standard details (e.g. footing details) to automate repetitive processes. The vision is that “intelligent” objects will be placed into the model and the model will then know how to react to the object.

5.3.4 Software or management approach

The consensus was that BIM is as much a software issue as a management philosophy with support for both arguments (software determines the approach). The need for an “Australian standard” for BIM implementation was mentioned.

5.3.5 BIM endorsement

BIM is strongly promoted by both directors (an Architect and a Structural Engineer) with approval from everyone else in the company. People are hired for their professional ability (i.e. as an architect or engineer) and not just because of their BIM skills, but staff must be prepared to practice in a BIM environment.

BIM adoption is further supported by positive feedback from builders and clients. The consultant proactively promotes the use of BIM.

5.3.6 BIM deterrent

Senior managers felt that many consultants and contractors are not yet in a position to take advantage of the model, and the market is not yet prepared to commit to it. A lack of a national standard is also seen as a fundamental problem. A poor BIM implementation is seen to hinder more widespread adoption.

Some employees believe that adoption is not hindered by suppliers since for example they make available models of their windows, etc. for use within the BIM models.

The opinion was offered that some of the Industry advocates of BIM can still be reluctant to fully share BIM models and information.

One model of the same building to one company is very different to another one. Fixing this problem is more important than having the software talking to each other. For example: the CAD layering arrangement from one consultant can be very different to the other.

5.4 System Evaluation and Adoption

5.4.1 The software

The architectural company has used ArchiCAD (various versions) since its establishment.

The architect's interpretation of BIM is that it does not necessarily imply interoperability, but ideally it would be one model shared across (perhaps) different platforms.

The information should be accessible in order to be able to generate documentation, scheduling, programming, and costing, which will have an impact in the design process. It will all be happening with great speed.

Software should be able to provide "genuine accuracy"; and "good buildability". Design collaboration has been better with (ArchiCAD's) "Teamwork" system. There seem to be many avenues for exchanging data between architectural and engineering consultants.

5.4.2 BIM software

Following are some comments shared regarding various softwares.

The design consultants in this case study stopped looking at Autodesk's ADT when Autodesk released Revit. Opinion was offered that Revit has the advantage of Autodesk's large financial and marketing backing, and they seem to be supporting Revit strongly, but Structures does not seem intuitive at all; not sure about moving individual elements – all entangled.

Bentley Systems Microstation is used by a number of engineering consultants, but there seems a perception that Bentley's product is 'falling behind'.

Graphisoft's ArchiCAD provides a clear, accurate coordinated model - it is good today in what it can deliver today. However, its ability to control database thru Visual Basic is judged rather poor, and the system is not truly interoperable. GDL – a rather dated and relatively 'dumb' language - is used to model individual objects, and ArchiCAD's Programming Interface currently does not appear to be being investigated or improved. ArchiCAD could be in a risky situation, and perhaps it may 'vanish' as we have seen Lotus 123 in the spreadsheet field.

The case study businesses have had little or no experience with Nemetschek's VectorWorks but its worldwide user-base is perceived as larger than that of ArchiCAD.

Gehry Technologies Digital Project – based on Dassault's Catia – may be crucial for aeronautical design, but appears more complex than necessary for most buildings.

With regard to structural applications, "currently none of the BIM applications are able to create schemas – not workshop drawings or blueprints but easy to understand 2D schemas i.e. connecting steel bars. They all print their representation of reality".

5.4.3 System Cost

The cost of the software is not perceived as a major impediment as long as it performs as expected. In fact, it is the training cost and system upgrades which are considered costly. Software costs are factored in as normal business costs. Anticipated subscription licensing might reduce initial purchase costs – for example Graphisoft are considering a subscription approach to ArchiCAD software licensing, and a 12-month (rather than 18) software upgrade cycle.

The level of involvement from the re-seller was limited to marketing purposes only. However, the architectural company has dealt directly with Graphisoft International (Budapest) and is regarded as an API (Application Programming Interface) developer company so they can program the software directly if required or desired.

5.4.4 Hardware cost

The architectural firm has implemented a 3-year cycle over which the high-end hardware is moved from processor-intensive visualisation work; to design BIM modelling and finally to more routine administration and word-processing duties. High-end graphics/video cards (capable of running OpenGL; and having considerable RAM) are essential options, as it is believed that a thorough understanding of the hardware requirements imposed by the software is required for a successful BIM implementation. The initial cost of high-end (expensive) machines is minimized by the quick return. It is normally expected that businesses have good quality machines especially now when your recovery time is so quick.

5.5 Implementation Strategy

5.5.1 Training

The company benefited from their staff profile and were able to provide in-house training to new staff. It was noted that staff are recruited for their design skills – not for their BIM background. Training is considered as a part of staff member's non-billable work (20% approximately), so for this consultant the is no extra cost in sending staff away for training and the loss of productivity that comes with it. For example, new staff are given a couple of days training with an 'in-house guide' through the company's intranet, and then eased into part of a project. This is with support from other team members. Although some staff members have undertaken training at Graphisoft's international HQ, usually there is no further formal training but continual on-going discussions.

"After reading the training manual, newcomers are exposed to projects and learn as they move along. Sometimes, their 2D habits need to be changed. However people with extensive knowledge of 2D have been hired and have proved to be good at BIM."

A telling comment was made relating to staff retention, viz. "the training of new staff would have a subsequent loss of productivity and this impact is evident to the company – even more than the costs of the software and hardware".

Although there is currently a shortage of skills some staff have not been retained because of their lack of professional design skills as well as because their understanding of BIM remains poor, but this respondent believes that this situation can be avoided if the right attitude is taken by the respondent.

It was noted that "younger architects who are using BIM seem to advance more rapidly than those that are just drawing – they appear to gain a better understanding of the projects in less time".

It was also considered that the introduction of a training manual or national standard will assist the implementation and use of BIM.

It was even suggested that BIM training should be divorced from software vendors in order to separate the generic BIM concepts from the marketing aspects that promote only the vendors' packages.

5.5.2 New working paradigms

"BIM requires a change in current workflows. For example, a conventional 2D approach would require first to solve solutions and then to produce building documentation, whereas the BIM approach requires iterative design and decision making". "This requires more interaction (physical and intellectual) between qualified professionals and drafts people, hence blurring the division between engineers and draftspersons (or modellers)" were comments noted in interviews.

A current issues centres on "changing old habits such as storing and leaving files in the local memory instead of on the server and similar actions that would really slow the project workflow".

And again related to staff training – "sometimes the training problems are not with the skills but with the workflows. For example, BIM can provide feedback on the fly and it is possible – and expected – to make changes and to quickly develop various scenarios than by the more traditional means where decisions were taken in a more lineal manner – thus changes were less iterative".

5.5.3 Software content:

It was observed that "very good content (for architects) is often supplied, however most templates provided with software seem too generic, as most buildings have regional variations or considerations".

There appear a common expectation amongst many in the profession that for "BIM to perform properly all content will have to be entered - this means embedded information will be attached to each object or building component". The case-study has revealed that this is not the case.

5.5.4 Customisations / Setup

It was reported that customisations of BIM systems to particular needs of the case-study respondents were being constantly refined, and this appeared particularly necessary between software versions. Within Australia, there appears to be insufficient effort to support local building component suppliers and this means that individual business normally need to spend time and money making the systems more aware and responsive to the local design and construction process.

Selected objects are and continue to be customised by individuals in-house who have expertise in appropriate programming tools. Customised object libraries are then available for use by other staff, with the end result of improved BIM applications.

In terms of setting up the system this case study indicated that was rudimentary procedure. Little or no support was required by the vendor but on the other hand the director-level staff has extensive experience in setting-up BIM systems within their business and in other businesses.

5.5.5 First BIM project

Directors and staff have used ArchiCAD and BIM since their company was established over 8 years ago. Back in 1999, it was not a financial success but "the project was instrumental to the consulting team getting the systems up and running. The quality of the documentation was not as good as expected".

Lessons learnt: It was observed that "We never knew quite how much to put in and how much to leave out, and this is when the challenge comes in. We definitely improved our understanding as to how detailed a model needs to be – i.e. under-modelling versus over-modelling". A BIM could be too detailed or too generic - sometimes when too detailed the information may be incorrect as it is outside the architect's or designer's domain – and that is when the challenge comes in.

Another point was made thus "We also improved our learning on how to present the outcome – it is one thing to visualise on the computer screen, and a very different one to produce workshop drawings".

5.5.6 Old/new methods used in parallel

In implementing BIM, it was seen as crucial to make a strong commitment to using BIM and to work it through even though it may be a long process. Feedback from other firms that have tried to go “half” BIM and “half” 2D was that they did not appear to be as successful in implementation as the designer – draftsman relationship substantially changes the decision–making cycle. The architectural firm’s approach has been to develop experience on small projects, and then transfer that experience to larger projects.

5.6 Collaboration

5.6.1 Within team

It was observed that “Older/mature-age people coming into projects move from ‘butter paper’ to thumbnails to BIM model. Company and users must recognise that BIM <u>does</u> change the way the design team collaborates”, and from an engineering perspective “Yes, it does change collaboration - people are working on an integrated model - not just individual drawings, so there is much better integration”.

5.6.2 Collaboration with the client

BIM allows the business to work with a client using an actual (virtual) model with rich information – not just a visualisation, and to demonstrate options and collaborate with the client(s) using a mix of 2D and 3D plans and views – straight from the BIM model. According to the design consultant the architectural/structural coordination is much better than in other similar projects and assists to has improved the collaboration with the client.

The architects regularly presented the 3D models and fly-throughs to improve the communication and guide the client, and were also able to make changes “on the fly” – with some understanding of cost and time implications to the project.

5.6.3 Model shared between consultants

The Building Information Model was shared by the architectural and structural engineering consultants. It was felt that Adobe’s new 3D-PDF file structure will promote “sharing” of some information (mainly geometric, and thus perhaps similar to VRML), but not the full model with other ‘intelligent’ information included.

From the structural viewpoint, some exchange of information takes place with small building designers, but many (larger) “practices developing BIM appear reluctant to share the models”. Some staff raised concerns about true sharing of information with regard to the potential loss of Intellectual Property (IP) embodied within any objects developed in-house.

5.6.4 Drawings export

Models are shared in proprietary format (.pln) - as both the architects and the structural engineers were using ArchiCAD, but files for export were mainly DWG files, with a few DXF and 3DS (3D Studio Max) files. In general, files were received and worked with as ArchiCAD .pln files, AutoCAD .dwg files or even Industry Foundation Classes (IFCs). 3D Studio Max, Rhino even Sketch up have been received, but designers then have to do a lot of “rebuilding”.

5.6.5 Non-drawing information used

Apart from drawings, the BI Model was used to produce window schedules, and door schedules, but not finishes schedules because if objects/components are not identified correctly then some items can be overlooked - so finishes were not included in schedules.

One comment was made that BIM is perceived as handing the risk to others (or passing the risk around), and because of the risk implications the market seems reluctant to adopt it.

But the reality is that the client pays for everything – including most project variations. People such as contractors and surveyors simply want to get the building built.

5.6.6 Services Consultant(s):

In general, it appeared that information from BIM models had to be 'dumbed-down' to .DWG files and drawings for exchange with others. Services consultants seem reluctant to interchange data – they do not yet appear to have recognised the market edge provided by BIM and interoperability. Civil engineering information was exchanged because design company and engineering company have some personnel in common – and are, in fact, a "sister company".

5.6.7 Information sharing arrangements

While architectural people felt that caveats/contract clauses could be used to cover any risks of errors in the documents exchanged (user beware – user accepts responsibility), another stakeholder felt (currently) there are still too many "grey areas" where no standard contracts or arrangements can be made.

d) Economic incentives

Respondents felt that economic incentives are enormous with the promise of efficiencies over time, and there are massive incentives at a national and sectoral level but making the transition is going to cost money – sooner or later.

With issues such as shared risk contracts and the role of a Design Manager between the client and the consultants, the role of architects is seen to be changing. Architects no longer seem to be the lead consultant. In addition, various engineers are providing more information – but often the information originates from architects' models.

e) Responsibility

An observation was that "One option for contractual arrangements or risk-sharing is for an independent practice to be fully responsible for project BIM documentation – thus fully liable for the project model".

Risk-sharing contracts are becoming more widespread, and this 'facilitates' the use of BIM - it is seen as an ideal mechanism as under this type of contract information is already shared in the model, and the respondents have the view that BIM use is expected to become widespread as these types of contracts become more popular.

f) Structure: Other

It was commented that " .. knew a case where most specs were branded products (unavailable or too expensive for Australia) but the architects ignored the equivalent – in this case the information was not handled right". This statement clearly highlights one of the shortcomings as once the products are imported and specified the model has to be continuously updated - thus the modelling team needs to be notified of every change.

5.6.8 Other consultants' data synchronised

On the idea of coordinating data / information from other consultants, two alternative views were put forward: one – that literally almost 'everything' should be put into the building model – "terrific really", while another view was that focus for coordinating data is likely to be on individual areas from BIM to fabrication (particularly in steel).

5.6.9 Communication; technical comments

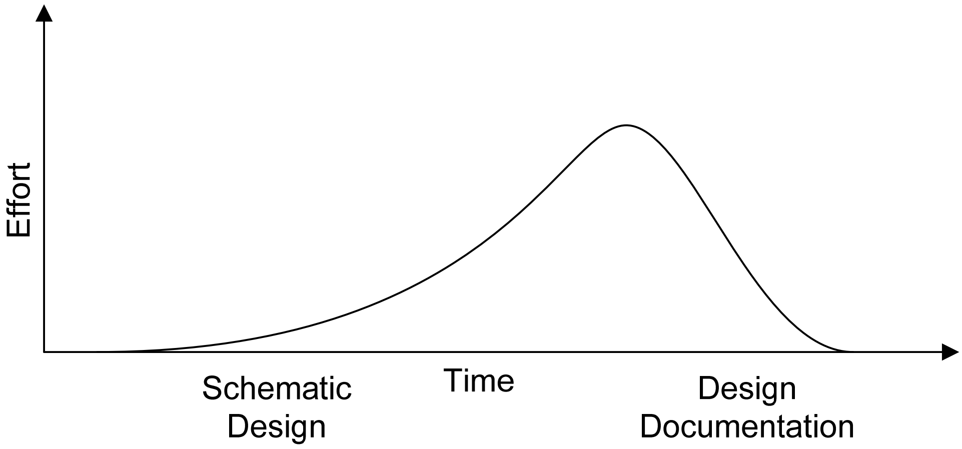
One opinion was "Use of BIM means stakeholders can take a 'proactive' approach rather than reacting afterwards; that is problems can be anticipated and then fixed earlier so more design development can be undertaken rather than documentation (tends to "blur the boundaries" between Design Development and Detailed Documentation production)" while another comment from practicing professional was that the "BIM approach has been very useful for flagging (any) clashes between the architectural and the structural work".

5.7 Cost and Time

5.7.1 Effort distribution before implementing BIM

One respondent believed that the effort distribution before BIM was as per Figure 5-1

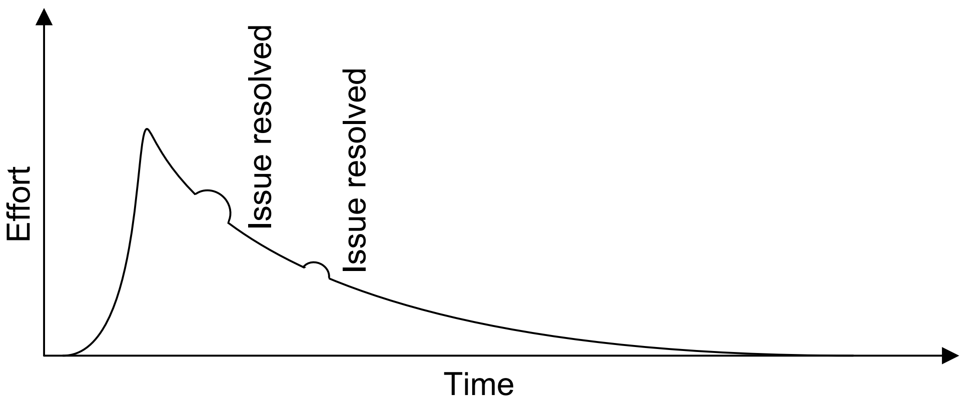
Figure 5-1: Perceived Effort Distribution Curve



5.7.2 Effort distribution when implementing BIM

Architects were of the view that substantial (but certainly not excessive) effort can be required quite early on in the project; but the effort quite rapidly declines until an issue needs clarification or resolution, and more detail is then needed. The issue results in a small increase of effort to resolve it, and the whole process is then repeated (with additional issues needing resolution and consequent effort) but always on a declining curve of effort versus time. – as illustrated in Figure 5-2 below.

Figure 5-2: Actual Effort Distribution, as described by M2 case-study respondents



There were competing views amongst some M2 case-study respondents regarding the cash flow risk allocated by introducing BIM. For instance, the early input of effort could be seen as a cash-flow risk if hourly rates are being used; and over the whole life of the project BIM saved time, but not at the early stages. However, other stakeholders were of the opinion that with the same amount of effort more information was actually captured for use in the project.

5.8 Delivered Documentation

5.8.1 Eliminate need for other documents

Comments were made such as “Still need to provide a wide range of documents to fulfil the contract, but BIM has certainly reduced the need to draw 2D from scratch, and more accuracy in the model results in easier data extraction”. “Often the builder still needs cross-sections, etc. so the architect still needs to produce them. However a risk for the client and/or architect is that if a builder gets data in unfamiliar ways or formats then they may adjust their price to cover their (perceived) risk in using the less-conventional approach”.

5.8.2 Facilitate new presentation

Following observations were noted – “Information has been presented to clients, and also to builders in new ways. Designers have been able to use 3D fly-throughs to explain design intent and project details to three contractors at Tender Stage – this has been most successful for tenderers”. “Also it has been possible to easily produce VR (Virtual Reality) movies/displays of projects for uploading to a website to communicate, clarify and assist in explaining design to any interested parties or potential objectors”.

It was also commented that the BIM approach “facilitated production of a project booklet complementing all documentation - with many axonometrics in A4 format and plenty of images of the model to give clarity - providing detailed information to the builder”.

5.8.3 New information provided

The issue of whether some additional new information became available through instituting BIM was discussed. Two views were expressed: one was that the earlier discovery / finding out of problems is ‘new information’ and extremely useful; while the other view was that a person is basically working with the ‘old’ information – but it is more accurate and coordinated, so this allows fast prototyping and exploration of various options on-the-fly - for example analysis of the mix of architectural and engineering situations including the impact of columns, beams to the space, etc.

5.8.4 Drawings quality

Again substantial comment was noted, viz. “Initially (9 years ago) drawings were not as high a quality as architectural and engineering businesses would have liked – originally better in 2D CAD, so early on a lot of effort was put into ‘getting it right’ and since then quality has been just as good - although obviously the information models need to be precise in order to get accurate floor plans and cross-sections”. Design business has been “able to make universal changes within any BIM-based project and achieve a consistent look to drawings even though they have been done by different draftspersons - who often have differing individual styles”.

5.9 Contract Admin. Collaboration

5.9.1 Model sharing

The BIM model itself was not shared with the builders in the sense of exchange of actual information, however <u>viewing</u> of the model for the office/hospitality project was shared with the tendering contractor(s) where the architects and engineers sat with the builders looking at and discussing views of the model. Feedback provided by the builders was that it definitely gave them more certainty about the project, and that in turn was expected to result in more accurate pricing.

5.9.2 Builder's awareness of BIM

Although initially not really aware of the architect's use of BIM, the builders apparently subsequently saw enormous value as they could see a way to get their shop drawings without having to produce them - but they did not appear prepared to pay for them. Reaction was noted that "if the contracting sector is not prepared to share some of the costs and savings involved in producing BIM this may be a real impediment to the uptake of BIM within the broader industry".

5.9.3 Tangible benefit at CA stage

For projects prior to the aforementioned office/hospitality project (which is still to be built), tangible benefits to the architects during the Contract Admin. stage were seen as the ability to deliver the design intent more easily for contract administration. "A D&C contract allows capture of increased value from using BIM (since risk from unexpected errors can be minimised), however contractors at the tender stage under non-D&C arrangements still factor risk into prices, so the reduced risk (or increased value) is not always reflected/captured in the end price" was noted from designers.

5.10 Contract Admin. Quality

5.10.1 Change in RFI's lodged

The judgement expressed was that there was "not necessarily less RFI's being lodged under a BIM approach, but those that were seemed to be clarified much quicker than normally". To improve clarity, "3D views were used quite a lot in dealing with RFI's".

It was considered by one stakeholder that the use of BIM will reduce RFI's for some time and then, after a period of time they would get back to the same levels, and that perhaps the main improvement wouldn't be "until the contractor has a BIM model on site so that builders could directly query it".

5.10.2 Was there a change in the quality of the building?

It was felt that although an immediate, major breakthrough in quality could not be identified, better quality was being achieved "through 'small wins' along the way at a number of places – all adding up to a 'major win' at the end of the project". It was stated that "everyone seems more committed to the design intent if done in 3D/BIM, but BIM ties the model together better than just 3D" . For example one can "easily change a window in a 3D model, but BIM coordinates and changes the window schedule as well, resulting in better coordination for the same effort". Quality improvements were seen as quite hard to quantify, especially as there are so many factors that can have an impact on this, but the belief was that "certainly less information is likely to get missed".

5.10.3 Errors detection prior on-site

"A number of errors or clashes are often detected using the BIM approach that previously would only have been 'picked-up' later or on-site; often disparities can arise between the floor plan and the elevations/cross-sections", and it was felt that using BIM these are detected earlier in the process. However it is "still a manual process, as things are solved and detected when reviewing and discussing around the BIM model. At this point it is a great communication device, but software is not there yet with fully automated reviewing processes".

5.11 Contract Admin. Quality

5.11.1 BIM model updates

Opinions were offered that frequent model updates are perhaps one of the more important aspects of making BIM of real value in the design and building process, since "as soon as the BIM model stops being updated, then control over the data and the project can be lost. This is because unlike 2D CAD, everything is interrelated so ultimately much more depends on the BIM model". "It can get quite complicated with issues such as site decisions and changes of materials being controlled by the builder, but the model not necessarily being updated accordingly. One solution would be for the builder to take ownership of the model during construction to make sure the model is constantly updated".

It was also observed that "frequency of updates to the BIM Model seems to depend on the job - if a company is engaged to do "as-builts" then the BIM model is usually updated constantly, otherwise updates may be less frequent, in which case the documentation model is used eventually to derive 'as-builts' ".

For the small office/hospitality project, the model is updated constantly, and following updates then an RFI is issued, thus the model is as close to 'as-built' as the draftsperson can get it.

5.11.2 Client deliverables

Respondents were unable to comment specifically on types of deliverables provided to the client for the small office/hospitality project since it has just been through 'tender stage', so haven't reached the stage of deciding on client deliverables, as yet. However designers advised that in general "usually just (AutoCAD) .dwg files are provided, at the moment, and currently the complete BIM model is <u>not</u> normally given to the client".

5.11.3 FM package integration

It was said that "experience suggests FM managers do not (yet) demand this approach, so integration between the BIM model and FM software is not expected for some time". "In future, tight integration would be the ideal scenario to the point where BIM and FM considerations should assist in procuring the building".

5.11.4 Project model completion

Completed models are normally archived in proprietary format (as ArchiCAD .pla files) onto DVD or CD-ROM, and retained by the architectural firm. Feedback suggests that this is the case in most projects and with most consultants known to the firms. There appears to be some reluctance by a number of players in the market to share or give the model away for reasons including intellectual property concerns, and the cost of producing a 'good' model.

5.12 Analysis of Theoretical Propositions

In Case-study M2, the eight theoretical propositions which had the greatest "weight of evidence" (i.e. mentioned most often in discussions) to support them, were

TP21 (BIM improves information management/flow/sharing) was most mentioned, then

TP14 (BIM improves efficiency),

TP37 (BIM introduces new issues regarding ownership of information, IP, payment of information, etc.)

TP15 (BIM enhances confidence in the design outcomes)

TP17 (BIM improves buildability)

TP23 (BIM improves co-ordination between some consultants)

TP16 (BIM improves design), and

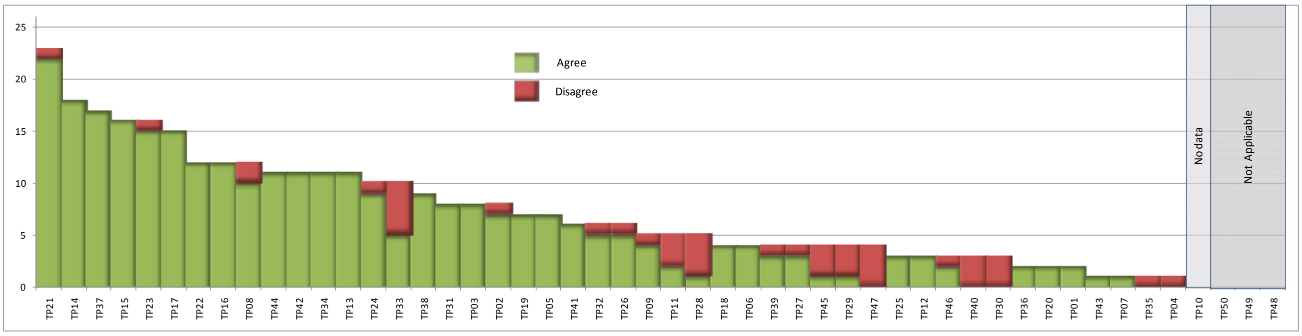
TP22 (BIM helps to align project stakeholders expectations).

5.12.1 Concurrence

Based on the interviews and discussions held with a variety of staff from various stakeholders, there was consistent agreement (see Figure 5-3) in Case-study M2 with the propositions that BIM :

- improves information management/flow/sharing — associated with the category of Collaboration
- improves efficiency — associated with Efficiency
- introduces new issues regarding ownership of information, IP, payment of information, etc. — associated with Risks
- enhances confidence in the design outcomes — associated with Design Functionality
- improves buildability — associated with Design Functionality
- improves co-ordination between some consultants — associated with Collaboration
- improves design — again associated with Design Functionality
- helps to align project stakeholders expectations — again associated with Collaboration

Figure 5-3: Theoretical propositions ranked by weight of evidence for M2



5.12.2 Divergence

There seemed to be a difference of view at various staff and stakeholder levels regarding whether “BIM must be clearly understood throughout the organization”, while there was both agreement and disagreement whether “BIM requires all project stakeholders to exchange and use the information”. Some stakeholders felt that a BIM was well worthwhile / justified solely on the basis of improved efficiency and information management for in-house use — whether or not that information was used by all the ‘players’ in the project.

Another point of divergence seems to be whether “BIM requires a high economic investment”, and here it would seem important that if some stakeholders do believe BIM requires too high an investment, then this perception or reality must be recognised and overcome by those others who feel this may be an impediment to BIM’s successful uptake.

Again there emerged a difference of opinion at different levels on the proposition that “BIM is more labour intensive in earlier stages of the project than ‘traditional’ systems”, as well as on the proposition that “BIM adoption is hindered by lack of specialised library content”. Some charged with day-to-day technical duties and with less responsibility for a strategic overview of many issues felt that BIM was indeed more time-demanding early in the project, and also that specialised library content was not a large issue within current practice. However others who must ensure suitable content is available for use, and with wider strategic responsibilities, agreed with the suggestion that BIM adoption is hindered by a lack of (Australian) library content, but also disagreed with the proposition that BIM was more labour intensive in early stages – provided the implementation is handled correctly and efficiently.

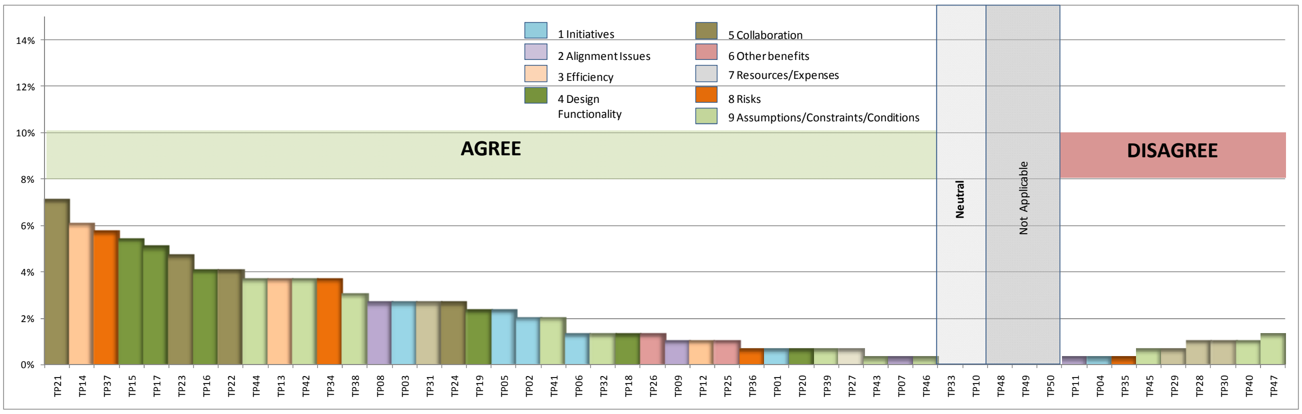
5.12.3 Lack of information

No information was forthcoming — from any of the stakeholders — regarding whether BIM will be required as a prerequisite for future government projects.

5.13 TPs according to Business Case Categories

For this particular case-study, as noted in the earlier analysis three of the top eight theoretical propositions were associated with the business driver category called “Collaboration” (see Figure 5-4) whilst a further three were all associated with “Design Functionality”, with another related to “Efficiency” and another to “Risks”. At the other end of things, in this particular case-study, theoretical propositions associated with the categories such as “Initiatives” and “Assumptions/Conditions” were mentioned less often in discussions than those mentioned above (i.e. had much less “weight of evidence” to support them).

Figure 5-4: Theoretical propositions classified by business driver category for M2



6. CASE STUDY MB

6.1 Project Background:

The project is expected to be completed around February 2009 and will be a 31,000 square metre facility. The building will comprise ground floor and 10 upper levels with footplates ranging from approximately 1,950 square metres to 3,650 square metres. The project value is $280 million, and the property will be initially leased for about 15 years commencing in 2009.

A horizontal development rather than a high rise building, the Sydney scheme is designed blatantly to maximise floor space (33,000 sq m) within an envelope that steps from six storeys to 10 storeys above five floors of underground parking. As an envelope / façade the building will have an innovative aluminium-sheathed steel diagrid which is robustly expressed outside the glazing (a 200mm gap), rather than being concealed inside (making a continuous interior space).

Other innovative features include its cladding systems and environmental green building performance. According to its developer it is to be a showpiece for environmental sustainability. From conception it included a range of initiatives to address environmental sustainable development (ESD) and it is expected to achieve a mark of 5 Star Green Star rating. Sustainable design considerations had an impact on the layout design including direct natural light to all workstations, and flexible workplaces using the benefits of wireless, and will include amenities such as house gym, childcare centre, and cafes.

6.2 Project stakeholders:

The building was commissioned by a large developer, designed by an architectural practice of some 25 designers, an interior design team of workplace experts, an international firm of structural engineers widely known for their landmarks, a nationally know firm of mechanical / electrical engineers, and worked with GIS city mappers and presentation renderers amongst other consultants and stakeholders.

6.2.1 Architect firm background:

Architectural firm has been using 3D modelling techniques since its establishment around 8 years ago. With a staff of 25 architects and draftspersons, specialising in smaller developments, its director has gained extensive knowledge and use of 3D for over 15 years (with experience in cinema 3D effects and visualization also). BIM was considered a natural thing for them, as the practise is responsive to innovation and change. Due to their leadership role in CAD/BIM software they have also been involved in training but are adamant that they employ people for their design skills rather than for their computing abilities with a particular piece of software, viz. “any competent professional would learn any software application on the job”.

6.2.2 Structural engineer background:

This company has been providing consulting services in Australia for over four decades. The company employs engineers, digital modellers, planners, project managers and a diverse range of consulting specialists and its breadth of experience equips them to draw together the right experts internationally - including the best possible team for a given project. The firm has almost 9000 staff working in 86 offices in more than 37 countries. At any one time, it has over 10,000 projects running concurrently. The firm has three main global business areas – buildings, infrastructure and consulting.

The contribution of the engineering firm is to coordinate a holistic approach to solve structural design issues and deliver the best possible results for the project and the client. The structural design was conceived in a rationalised 'diagrid' form which contributed greatly to cost and time of construction. The firm is to provide consultancy services for the entire construction process.

6.2.3 Developer background:

The developer established its property development business in 1989 with a global portfolio valued at more than $16 billion and has accelerated its participation in a range of projects as a sole developer or in joint venture partnerships.

Projects are spread across Australia, New Zealand and the United Kingdom including the property sectors of commercial and industrial; retail; apartments; master planned communities; and mixed-use and regeneration.

6.3 System Evaluation and Adoption

6.3.1 BIM Concept

In this case the BIM concept was not used in a common way across practices and in some cases BIM was understood differently within a single practice. Definitions of BIM ranged from views such as: "tools that allow us to generate object based data", "3D geometric documentation with attached information", "building information sharing", to others who were less aware of BIM - such as the interiors designers. Although the practice is nationally known for its BIM competencies, BIM and being an adopter in another case-study, the input and experience from this Sydney case-study did not illustrate this. At a senior level a respondent offered the following definition: "BIM to me is a 3D geometrical model with as much information as possible attached to it … in this case we are aiming to produce a digital prototype of the real thing".

6.3.2 BIM Objectives

The architects involved in this project has been using ArchiCAD since the 1980's and continue to believe it is a robust design and documentation tool - that is not always used to its potential. For the architects, the original incentive to adopt BIM was the ability to design in 3D - this is still their prime driver as they are well known for their designs and the visual aspect of their work remains the most important factor in their practice. The practice also holds the view that BIM will become the new standard for the building and construction industry.

6.3.3 Reasons for adoption

BIM was originally seen as a tool to design and initially used to persuade, but now BIM adoption is viewed as an approach to operate, maintain and procure buildings, and for engaging with the supply chain. It was commented that "don't believe that the model is owned by the client but could make use of it for the life of the building".

6.3.4 Software or management approach

The need for an Australian standard for BIM implementation was mentioned, and that it is considered an important catalyst for BIM adoption across the industry.

6.3.5 BIM endorsement

6.3.6 BIM deterrent

Guidance: According to various responses, a major problem for BIM adoption lies in the lack of Australian and International standards / manual for building BIMs - most respondents in the case-study found that there was little value (currently) in going further than 3D CAD, viz. "Generating 2D drawings from 3D models has great benefits and less chance for error – more accuracy".

Cost: One design respondent was convinced of the need to promote the adoption of BIM, and was unambiguous that 3D CAD is certainly becoming the standard approach but at this point of time, adding any extra information into BIM is costing the practice money. Still, the practice is convinced of its benefits, committed, and certain that this is the way to go but that it is costing.

Risk: Some stakeholders see it as easier to use existing systems and risky to change, and the project manager was viewed as delaying BIM adoption because of those factors. “How do we make money from it – not at the moment. It is about improving our service to the client”.

Backtracking: The structural engineering consultant uses Bentley Structures (on other projects Revit or Digital Project) to include much more detailed engineering data that will allow automated cutting of metal components - after export to specialist fabrication packages. However, when architectural and engineering consultants are asked to provide design information to fellow consultants and building contractors, they are often forced (‘frustratingly’) to backtrack their system to create traditional 2D documents – removing much intelligence from the building information model (BIM).

6.4 System Evaluation and Adoption

6.4.1 The software

In the last few years the engineering practice has adopted Revit in a bigger way as it is seen as less complex than Bentley’s Microstation, and can also export good quality 2D drawings. Microstation though is seen as a good application for parametric modelling, and has scheduling capability – comments were made along the lines that it is “great to view work in its 3D digital format but the problem arrives when printing 2D, especially cross sections as they require extra work”.

The architectural team mainly utilises ArchiCAD, however responses revealed the opinion that first software releases often contain errors, and that to move from ArchiCAD 9 to 10 took “lots of testing and fixing bugs” at the design firm’s expense.

6.4.2 BIM software

For the engineering practice their Sydney office uses 3D CAD including Bentley’s tools, plus Revit and Rhino, with the response “we move data between packages” offered to enquiries regarding specialist packages and interoperability, and “we also use 3D packages for ‘CADduct work’ design and analysis (named ABS) and for electrical installations (ElectroCAD).”

6.4.3 System Cost

None of the case-study respondents considered the cost of software was a real deterrent to implementation of BIM.

6.4.4 Hardware cost

Hardware costs have also not been an issue for any of the respondents – they are factored in as running costs. However there was seen by the architects to be a degree of hidden costs by including things like “the need to do some scripting and to move data across. The concept of interoperability is not there yet”. There is also some level of involvement with the resellers but it is not considered major.

The engineering practice normally purchases hardware every 3 years and tries to move or replace equipment around the office monthly, and have been doing this for the last 10 years.

6.5 Implementation Strategy

6.5.1 Training

Outsourced training is common for the smaller practices. For the larger ones, in-house training schemes seem to be more common. The engineering practice even had an exchange programme to have their employees visiting across offices and continents.

For the architects, training is mainly outsourced - this is mainly due to the size of their business, however it was stated that “The problem with training is that resellers do not necessarily understand design and design workflows. When ArchiCAD took off I was working at another firm and had training and practice with several 3D CAD programs.”

For the engineering practice - which is a much larger organisation - things are done in a different way (including an ‘apprentice scheme’), and when recruiting staff they basically aim to attract and retain good professionals. For instance, “A good person learns quickly. We look for individuals with enthusiasm, preferably familiar with 3D environments – they learn a lot by themselves in their own time”.

6.5.2 New working paradigms

To visualise the building in 3D the architectural offices utilised ArchiCAD, which allowed them to detect structural and service clashes, and to detail cladding and structural components. They could also create accurate and economically efficient databases of materials quantities, but it was commented that because they are not quantity surveyors, insurance limitations would not allow them to truly exploit this capability.

Other aspects of BIM that can be of benefit were seen to include the ability to model and visualise airflows, natural light and ventilation - especially with what is going on with the Green Building agenda. It was stated that it would be great to give the designer the ability to trade-off decisions in real time - with appropriate cost implications, and that “the Green Building Council of Australia should be a party with interest in this. Especially if it can improve the certainty of decisions and costs (i.e. with the point system for 6-star rating - how much is going to cost ?)”.

Engineering responses were also enthusiastic : “We certainly would like to see BIM widely used in the construction industry. We always try to interact with everyone (interoffice and outside the organization), and are especially interested to push BIM into interoperable mode especially in moving from our current 3D standard practice into 4D (3D+time), 5D (4D+costs) and 6D (fully interactive and immersive environment)”.

Responses were obtained around the theme that often the likely costs for achieving a particular Green Star-rating are only estimated to ±10%, while most other costs are to ≤5%, but it can cost tens of thousands of dollars to achieve the last few points in order to get the necessary star rating, so any tool that provides more certainty about the likely cost of achieving a particular star-rating would be extremely useful.

6.5.3 Software content:

Amongst the software used in the engineering respondent’s pilot project included MicroStation, Autocad, Rhino and Studio Max for designing the structure - where most files were saved in (proprietary) .dxf and .dwg formats.

The involvement with the software reseller on the above test project was medium to high for the engineering practice but low for the architectural practice. It appeared the impression of the architects was that as long as one is a large client to the reseller and promote their product, they will provide more support.

6.5.4 First BIM project

For one of the engineering respondents, their first BIM project was a small size pavilion near City Hall in London, and it was commented “This was a test-bed and very successful project where we learnt to integrate the use of MicroStation, Autocad, Rhino and Studio Max for designing the structure.”

For another respondent - from the engineering team - the first BIM project was a Sydney hospital circa 1999, even though a hospital is seen as a relatively high-risk project. The payback return was within a year where “some of the lessons learnt included saving time and producing better drawings”.

For another respondent this case-study is to become their first BIM project – if some of the 4D modelling applications are implemented – and they stated “.. not built yet but so far it has been very successful. The client is happy and they are liking that we will be able to collaborate more easily with other consultants.”

6.5.5 Old/new methods used in parallel

The observation was made that “The old methods and paradigms seem to be well entrenched. This is not only an industry that is under continuous pressure to perform and be more efficient, but also has a client base that might be traditional in their understanding of the design and building process.” This means that new design tools are not always in tune with human communication, for example, interviews indicated that respondents do not necessarily hold the same or even similar views on many key issues.

It should also be noted that physical representations remain well-used in the design process for the case-study - they include a 1:100 working model, a 1:250 presentation model, a 1:500 plastic model for insertion into the Sydney City Council’s physical city model, a 1:1 fragment showing the diagrid frame hitting the ground, a 1:1 node and cladding study and another 1:1 model to test how ball bearings might stop skateboarders assaulting the diagonals.

6.6 Collaboration

6.6.1 Within team

Designers expressed the view that BIM certainly will change the way people within the design team collaborate. For example, the link of structural analysis with modelling provides a more direct path from 3D model into structural analysis software. For this reason, design in 3D would start from day one, it was believed.

They also made the comment that “ …we are always moving towards ‘global working’ and the studio type we are all used to is disappearing. Surely there are enough incentives - expertise is brought to a project from a number of different offices – ‘everyone is everywhere else’ - so if you’ve got the ability to connect people and teams then you’ll have a stronger business case”. Comment was also made on changes to the way work is being outsourced, and the transfer of great technical skills through people living and being trained in the US and Europe returning to Asia and in turn then training local people there.

But it was also clear that how to improve communication and people management remains an issue, since many staff are employed but “to achieve best results they have to be organised into suitable teams, and then we must ensure they work well together”.

Opinion was also put forward that at this point in time there are just not enough examples as to indicate whether BIM radically changes team dynamics since there are currently very few examples of BIM – “there is nothing really to chew on”. Another observation was made that minor exchanges only occurred with 3D – which is seen as not as sophisticated as BIM - but that the challenge would be to have the architects and users ensure that they update the model with enough rigour.

6.6.2 Collaboration with the client

According to a designer respondent, there remains a strong liking by many clients for hand-drawings and for physical models – "The client gets excited when we do hand-drawings, they like the physical models and we find that we can interact more" – and although walkthroughs are seen as a powerful medium, it was also observed that by showing "CAD drawings and 3D's on the computer the media hinders the interaction and decision-making with the client".

Comment was made that there seem less and less 'occasional' clients (clients are mainly developers, trust funds, ..) and that the company must be productive and deliver so BIM would be a good tool to assist in the process, and perhaps even improve the way clients manage their assets – "Many of them have on-going interests in operating and maintaining the buildings they develop, so should have strong interest in facility management aspects".

6.6.3 Model shared between consultants

At this point in the project there has been little (electronic) information exchange or making use of the BIM format and potential, but it is expected to increase in future - particularly in areas of design to builder relationship, viz. ".. most exchanges are with fabricators, joinery and artwork. We have sent 3D data which goes into the router machine and laser cutters. We are in talks with the builder to have 4D implemented in this project. It will be looking mainly at construction sequence."

6.6.4 Drawings export

Revit is seen as less complex than Microstation and able to export good quality 2D drawings which is paramount for both designers and architects. Microstation / Bentley Systems are widely used by the engineering team as it is seen as a good application for parametric modelling, and also has scheduling capability. However, queries were raised about its ability when printing 2D blueprints – especially cross sections – they were said to require extra work, and a "way to alleviate this has been with the use of Revit".

6.6.5 Non-drawing information used

BIM is seen as needing very specific procedures to manage it well in order to get its full potential. For example how the models or components with intelligent data are populated is seen as "the tricky thing".

6.6.6 Other Consultant(s) - Quantity Surveyor

There was a level of data exchange between designers and the quantity surveyor – however this project was the first case of this exchange occurring, and it was agreed that there remain some issues of liability. It was commented that one of the drivers here are standards for documentation across the engineering practice – globally – but that things are different when working with external consultants.

According to the engineering practice, few people have adopted BIM as very few have the rigour to maintain the model. The 3D model is seen as a live document, and thus seen and treated very different from PDFs of 2D and 3D. It was noted that the engineering practice is expected to provide the BIM model at the end of the project.

6.6.7 Information sharing arrangements

Architectural sources expressed the view that it would be difficult to ask for more money to produce a virtual model.

6.6.8 Communication; technical comments

There are also some issues articulated about ownership and responsibility – "it comes down to who is in charge of the model especially as no one knows where it ends and where it begins", and also "Ultimately, it is the team, the full team, who needs to take responsibility over the model, including its accuracy and correct information. It will have to be a collaborative effort".

6.7 Cost and Time

Responses indicated that the immediate objectives of the structural engineers are to "push the 4D agenda, and to collaborate more with the mechanical services engineers and steel fabricators", which are two groups that they wish to see working closer with themselves.

6.7.1 Effort distribution when implementing BIM

Little information was garnered regarding the amount of effort required (and its timing) for the implementation of BIM from any of the stakeholders.

6.8 Delivered Documentation

6.8.1 Drawings quality

Engineers ventured the opinion that there has been little or no need for software customisation such as blocks, families, and pen thickness. However they do have a requirement for customisation to develop applications – especially to export models to analytical software (e.g. GIS information into Revit, but also for fire, acoustics, sustainability and environmental building services). Also, see earlier comments regarding drawing quality.

6.9 Contract Admin. Collaboration

6.9.1 Does builder share model ?

It was felt by a number of respondents that it could be difficult to move away from 2D – although only because all printed documentation is in 2D.

6.9.2 Builder's awareness of BIM

6.9.3 Tangible benefit at CA stage

BIM was seen as a tool to design and initially used to persuade, but now BIM adoption is viewed as an approach to operate, maintain and procure buildings, and for engaging with the supply chain. Comments were also made that BIM has also been good for documentation because of its role in creating and maintaining intelligent data.

The engineering practice has been a staunch user of various Bentley systems which are seen as complex but good to solve laborious tasks, however their ability for creating 2D documentation in the style preferred is viewed as questionable. Rhino is used for massing studies and as a pure modelling tool whereafter the information can be exported (in STEP format) to Microstation or for other analysis. Other applications in use are Tekla Structures for steel detailing and fabrication and a package for building services. Digital Project is seen as a complicated application but particularly good for handling complex geometries - however it is perceived to have a lack of available technical people and operatives available.

6.10 Contract Admin. Quality

6.10.1 Client deliverables?

Designers felt that BIM should also help in the creative process – "tools for creativity – that's always a difficult one to justify. But in the interest of the client this should be justifiable". Perception was that often the client only wants a product – basically to house their business – but for the designers it is about the process.

6.10.2 FM package integration

Engineering responses indicated a prospect to provide a service of web access to a particular BIM which could be updated and maintained for users for a monthly fee, however whether that opportunity should be taken up by that company is the real question.

6.10.3 Project model completion

Some stakeholders responding believed that integrated practice envisages that all building design professionals will work concurrently to produce one virtual model that can be 'mined' and/or manipulated by any consultant, contractor or post-construction facilities manager. Thus the comment was made that "it seems obvious that models will need be owned, updated and sold by, or licensed to, each consecutive owner of the associated actual developments".

According to a senior engineer on the project, "there is no holy grail available now for integrated practice – but in time, hopefully we will be able to work in one 3D geometric environment which allows us all to visualise and test everything before programming construction".

Further remarks were made that the model also needs to live beyond the period of construction to allow future owners of the real building to know how to operate and maintain it, take it apart, recycle it, adapt it or reuse it - "When the technologies are ready, the project manager will need to rule on day one that everyone must use the same software. It goes without saying that the software must be able to engineer the building, not just draw it."

A comment in summary was made by one respondent that "Of course, engineering-capable BIMs are just the beginning of a data modelling revolution which has massive implications for large urban developments and metropolitan planning strategies worldwide. At this scale, the key agenda for researchers and advanced practitioners – will be moving beyond today's static BIMs to develop dynamic integrated simulations".

6.11 Analysis of Theoretical Propositions

In Case-study MB, the seven theoretical propositions which had the greatest "weight of evidence" (i.e. mentioned most often in discussions) to support them, were

TP43 (BIM requires leadership within the company) was most mentioned, then

TP11 (BIM provides a foundation for FM processes),

TP29 (BIM requires a high economic investment)

TP03 (BIM requires appropriate training)

TP16 (BIM improves design)

TP36 (BIM-trained people are scarce), and

TP37 (BIM introduces new issues regarding ownership of information, IP, payment of information, etc.)

6.11.1 Concurrence

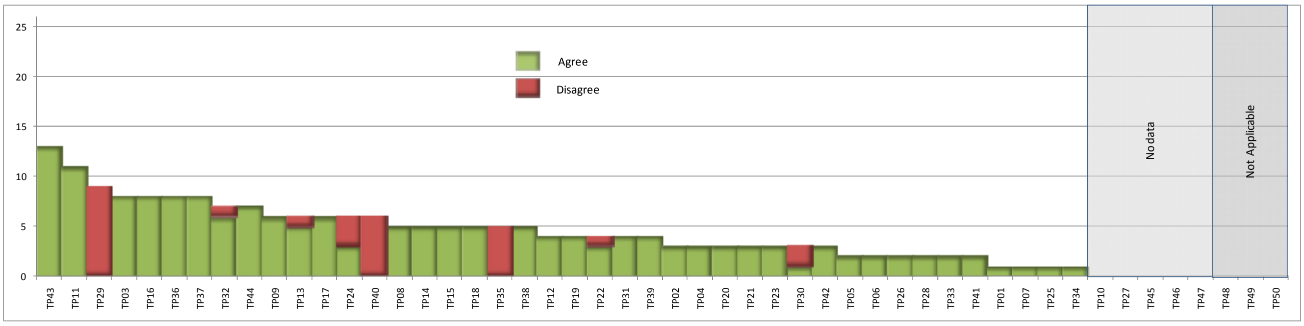
Based on the interviews and discussions held with a variety of staff from various stakeholders, there was consistent agreement (see Figure 6-1) in Case-study MB with the propositions that BIM :

- requires leadership within the company — associated with the category of Assumptions / Constraints
- provides a foundation for FM processes — associated with Alignment
- requires appropriate training — associated with Initiatives
- improves design — associated with Design Functionality
- -trained people are scarce — associated with Risks

- introduces new issues regarding ownership of information, IP, payment of information, etc. — associated with Risks

There was also consistent <u>dis</u>agreement with the proposition that BIM requires a high economic investment — associated with Resources / Expenses

Figure 6-1: Theoretical propositions ranked by weight of evidence for MB



6.11.2 Divergence

For this particular group of stakeholders in Case-study MB, there seemed to be a difference of view at various staff and stakeholder levels regarding whether “BIM requires specialised IT hardware/infrastructure”, and whether “BIM reduces rework” while there was both agreement and disagreement as to whether “BIM improves coordination with contractors / fabricators”.

Another small point of divergence seemed to be whether “BIM’s implementation and maintenance costs outweigh its usefulness”.

6.11.3 Lack of information

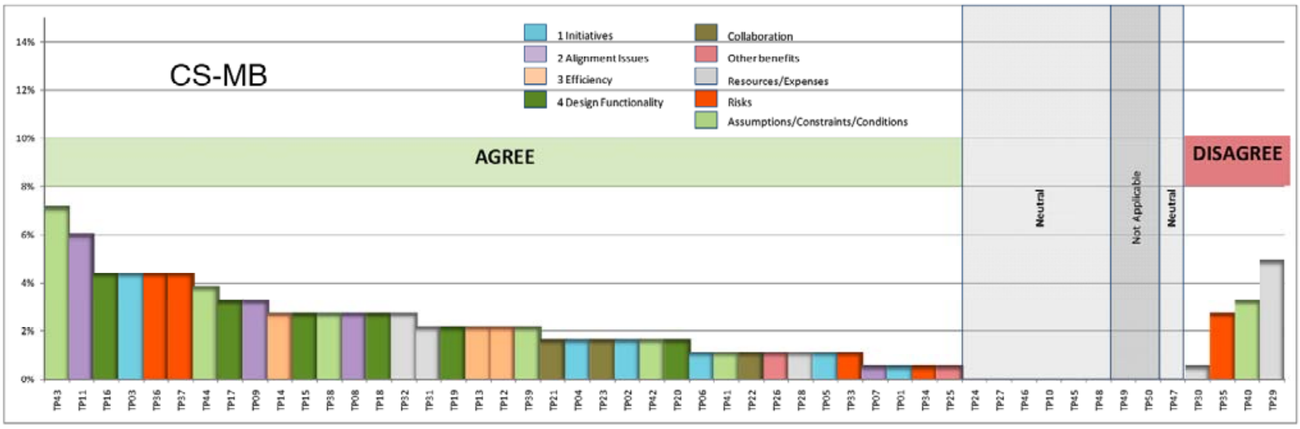
No information was forthcoming — from any of the stakeholders — regarding whether BIM will be required as a prerequisite for future government projects, or whether BIM is considered just a software approach; if more labour intensive at early stages; is hindered by lack of content; or if it results in improved documentation.

6.12 TPs according to Business Case Categories

For this particular iconic private sector development case-study, as noted in the earlier analysis two of the top seven theoretical propositions were associated with the business driver category called “Risks” (see Figure 6-2) whilst “Assumptions/Conditions”, “Alignment Issues”, “Resources / Expenses”, “Design Functionality”, and “Initiatives” were all represented in the top cluster.

At the other end of the scale, in this MB case-study, theoretical propositions associated with the categories such as “Collaboration” and “Other benefits” and to some extent “Efficiency” were mentioned less often in discussions than those mentioned above (i.e. had much less “weight of evidence” to support them).

Figure 6-2: Theoretical propositions classified by business driver category for MB



7. CASE STUDY B1

7.1 Project Background:

Commercial office building located on Hong Kong Island comprising of two basement levels and seventy storeys (59 office floors) with a commanding view over the harbour. The building is next to a train station and part of a comprehensive redevelopment of an established industrial estate at Quarry Bay. Valued at HK$2 Billion (AU$300 Million) the project is due for completion in March 2008. The construction had reached the 66th floor in August 2007.

7.2 Project stakeholders:

Developer, Architect, Structural Engineer, MEP Engineers, BIM Consultant, Planning Authority (Government) and various consultants.

7.2.1 Architect firm background:

Well established group of architectural and engineering practice with over 250 professionals and support personnel. The firm's background goes back to 1957; it is organized into specialised teams according to building types. The teams are dependent on a centralized Design Department. On this particular project, the firm was hired as a design consultant only and played no part in the documentation and construction process. The Architect was not involved in the BIM process.

7.2.2 Structural engineer background:

Large international firm with a vast pool of technical expertise across the world in 86 offices in 37 countries. The firms offers services in Structural engineering, Drainage and sewerage, Façade engineering, Mechanical and electrical amongst others. They provided people to work with the BIM team.

7.2.3 Developer background:

Incorporated in 1972, it is one of the leading Hong Kong developers with extensive experience in the development and management of major commercial, retail and residential properties. The developer was the major driving force behind the use of BIM; it is a company policy that all projects must use BIM methodology. In this case they chose Digital Project and requested that all the consultants be trained and made to use the software.

The developer provided office space and the entire infrastructure, including computers, server, network and software licenses to the project team.

7.2.4 BIM consultant background:

The BIM consultancy is a company that was established to promote CATIA-enabled design and methodology. They developed Digital Project (DP) - CATIA-based software for Architectural design and Construction, and they also provide consultancy services on the implementation of Digital Project; 80% of their revenue is derived from their consulting business.

7.3 System Evaluation and Adoption

7.3.1 BIM Concept

Due to the organisation of the project under a BIM consultant, there is a good understanding of the BIM concept. The BIM or project team is made of people from the BIM consultant, engineer's staff and architect's staff hired especially for that project.

They see it as a management tool to maintain good document's coherency. BIM is working from a single 3D model from which all the data is extracted including schedules; it has been described as a holistic management tool. One that resolves design before construction, improves collaboration, engages the supply chain and provides visibility into the entire project.

It also allows for construction simulation and space/time clashes analysis.

7.3.2 BIM Objectives

Due to the size of the project, the objectives were clearly to save on building time and cost by identifying at documentation stage all the possible clashes and on-site problems and changes that traditionally delay construction time.

The client stated at the beginning of the project that BIM was to be used to save 10% on building cost and 6 month on construction time.

From the client's point of view it was important that the entire team collaborated in real time in order to avoid redraw and back and forth transfer of data with the inherent loss of information typical of traditional approaches.

7.3.3 BIM endorsement

The client sees the necessity and is pushing it. BIM is implemented on all the projects commissioned by that client.

7.3.4 BIM deterrent

The consultants are seen as delaying the adoption of BIM, they prefer to provide standard 2D documentation rather than participating in the 3D model.

Local authorities were also seen as interfering through legislation asking for the submission of 2D documents only.

The availability of cheap, easy to use traditional tools is seen as a deterrent competition by the BIM consultant.

7.4 Software and Hardware

7.4.1 The software

The BIM consultancy is a spin-off company of an architecture firm who have been using CATIA as a 3D modelling and management tool.

CATIA was initially developed for the aeronautic and the motorcar industry and while it provides the 3D modelling capacity and the management functions to be used as an integrated BIM tool, it lacks architect specific functions; Digital Project was developed as a high-end CATIA-based BIM and construction management software by the BIM consultant.

Overall it was found that the software was very good straight out of the box and that customisation was minimal compared with Revit and ADT which had been used previously on other projects by different members of the team.

Installation and setup was all performed by the BIM consultant who provided their own technicians and sales staff. From that perspective, the support and level of involvement of the reseller was seen as very good.

The client chose the BIM consultant rather than the software. The software came with the consultant. One aspect of the software that was seen as important is the complete scalability it provides making possible to use a BIM approach on projects of any sizes.

7.4.2 System Cost

As the system was entirely funded by the client, it is perceived as a cheap solution by the consultants who will return both software and hardware to the client on the completion of the project. The BIM consultant acknowledges that the cost of Digital Project is substantially more than other BIM software such as Revit and Bentley but argues that it delivers value to the industry.

Because Digital Project is a high-end system and incorporates CATIA, it requires high-end hardware and networking; the cost associated is substantial.

7.5 Implementation Strategy

7.5.1 Training

The project team included the software developer who also provided the training to the team members. At the start of the project, 2 weeks were allocated to in house training. Every member of the project and consultant team went through the training. People with a 2D mindset were the most difficult to train, it was identified that an open mindset is the most important quality to have to become proficient quickly.

The same training was given to the Architects, MEP Engineers, Quantity Surveyors and Contractors.

Short term contract people were hired to compensate for loss of productivity during the training period.

7.5.2 New working paradigms

BIM consultants were used to the methodology while for most other project team members this was new.

BIM changed the way people used to collaborate. 3D workshops were organised in which BIM operators took part in design sessions which was a new thing for them.

Also because the software is seen as particularly good at detecting clashes, analysis sessions were organised involving members from different firms where field solutions were tested and implemented with everybody participating. “Having every stakeholder under the same roof is as new as the BIM method itself”.

It was commented by one of the respondents that “We had infused a very precise discipline into the whole design process where architects, engineering consultants, structural engineers, all had to design to the same precise vocabulary”. “I think it has been an incredible process of intuitive collaboration. It is all about project certainty. We know what we’re designing, we know how much it’s going to cost, we know how it’s going to be built, and for us as a developer that is paramount to total success”.

7.5.3 Old/new methods used in parallel

It was noted that “The client was ‘pushing’ for BIM so the emphasis was placed on the new method, some documentation was drawn in AutoCAD but that was exceptional”.

7.6 Collaboration

7.6.1 Collaboration with the client

BIM allowed for more than simple visualisation, it provided a tool to demonstrate solutions, construction process and design alterations in real time due to the parametric aspect of the software. Parts of the 3D model are regularly exported to XML which provides the client with a virtual model that they could explore at their own leisure using “3D XML Player” a software making possible to access information such as the product structure in an immersive mode and perform cross highlight with the 3D geometry.

7.6.2 Model shared between consultants

All the consultants worked under the same roof on the same model in real time eliminating the need for drawings export. The only kind of data interchange was exporting to XML.

7.6.3 Non-drawing information used

At tender stage, the quantity surveyors used excel spread sheets reformatted for their specific needs. Doors, windows and other schedules are all integrated within the BIM solution. Once tender was complete, the quantities and prices were incorporated in the BIM model.

7.6.4 Information sharing arrangements

The structure with a common project office and a common server solved most of the problems traditionally associated with information sharing. The Design team is responsible for incoming data and the BIM consultant is responsible for the outgoing data.

7.6.5 Other consultants' data synchronised

Views differed within the team, according to the project leader all the information, including shop drawings were included (imported) in the BIM model, while the BIM operator was under the impression that everything was included in house and no information came from outside.

7.6.6 Communication; technical comments

Performance by MEP engineers was better and more important than the Architect's.

Due to the nature of Digital Project the size of the model and the amount of information is never a problem. The 3D model for this project is rather complicated with over 300,000 objects. Digital Project loads in the computer memory only the objects the user is working on.

The complete model is visualised through 3D XML.

There was no problem with Intellectual Property as BIM was instrumental; a traditional contractual agreement was used.

7.7 Cost and Time

7.7.1 Implementation of BIM

BIM was implemented from the Design Development stage right through the documentation stage; it is planned that it will be used until completion of the project.

7.7.2 Effort distribution when implementing BIM

Before (Drafter): In previous practice, closer to (b) curve (see Figure 7-1), while Figure 7-2 below indicates the revised distribution curve.

Figure 7-1: Previous effort distribution curve, for case-study B1

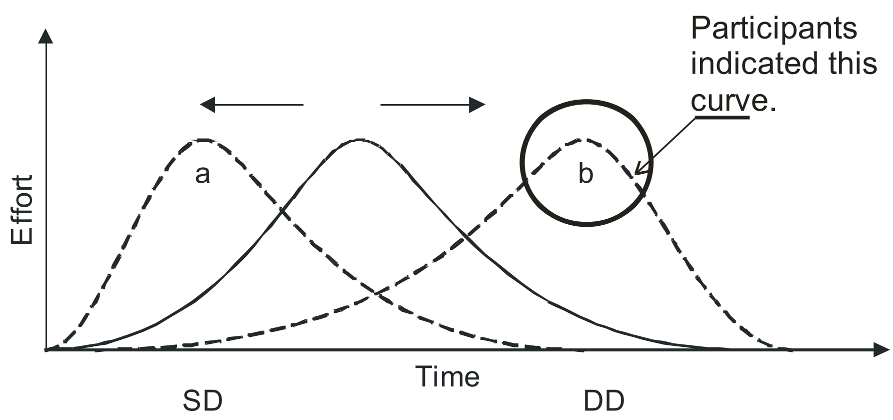
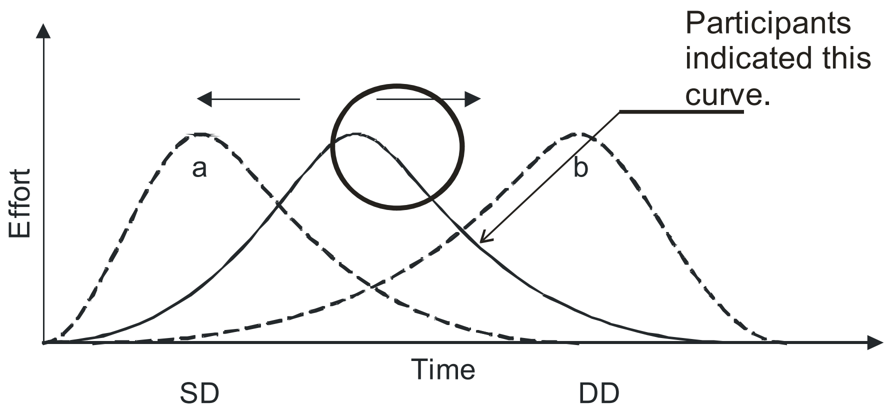


Figure 7-2: Revised Effort distribution curve, for case-study B1



BIM should have been implemented earlier, the method did not save the company time but risks have been reduced by eliminating speculation; changes in 3D take less time than in traditional documentation.

7.8 Delivered Documentation

7.8.1 Eliminate need for other documents

BIM does not eliminate the need for other documents, detail drawings, shop drawings are still produced in 2D.

7.8.2 Facilitate new presentation

BIM allows for the presentation of cohesive 3D as well as different views of the model sorted by Digital Project layering system. EG. Building with MEP services or without them or even just the MEP model by itself. Quantity data can be presented in new way thanks to the accuracy provided by the 3D model. It was stated that BIM did not allow for new information to be presented but rather for new ways of presenting that information.

7.8.3 Drawings quality

Thanks to the coordinated information, the quality of the documentation is improved when compared to traditional ways of documenting a project.

7.9 Contract Admin. Collaboration

7.9.1 Builder share model?

The model was made for the builder; it is the all point of BIM according to the manager. However the 3D model had to be partially re-built before it was made available to the builder. Sharing the model with the builder substantially improved the communication between construction and documentation teams.

7.9.2 Tangible benefit at CA stage

The software was used to identify over 3000 clashes after the structural engineer made some alterations to the core structure. The documentation was amended in a very short time compared to traditional methods and no clashes have been detected so far during construction, this is one of the biggest advantages of BIM.

The model was also used to test building sequences, a number of problems have been identified during simulation and fixed before construction; for example the size and position of scaffoldings was modified after it was found that it would clash with structural columns, a substantial saving in construction time.

It is estimated that since construction has started, the company is saving approximately 1 day a week in construction time compared to similar projects before the implementation of BIM.

7.10 Contract Admin. Quality

7.10.1 Change in RFI's lodged

Because the builder had access to the BIM model and 3D visualisation, there was a reduced need for RFIs

7.10.2 Was there a change in the quality of the building?

The most important improvement in building quality is due to early detection of construction and design problems allowing for un-compromised solutions to be designed on time. In this regard the building is of a much better quality.

7.10.3 Errors detection prior on-site

Thousands of errors were detected and solutions designed and implemented before the drawings were delivered to the builder.

7.11 Contract Admin. Quality

7.11.1 BIM model updates

The single 3D BIM model is constantly updated by the BIM consultant. The aim is to be at least 2 or 3 floors ahead of construction with an updated BIM model.

7.11.2 Client deliverables?

On contract completion, a full "as built" BIM model will be delivered to the client. It is not clear which facility management software will be used, but the model in proprietary format (DP) will be handed in to the client for that purpose.

The complete BIM solution will be archived in Digital Project proprietary format as well.

7.12 Analysis of Theoretical Propositions

In Case-study B1 – a large international commercial property development - the six theoretical propositions which had the greatest "weight of evidence" (i.e. mentioned most often in discussions) to sustain them (see Figure 7-3: Theoretical propositions ranked by weight of evidence for case-study B1

), were

TP14 (BIM improves efficiency) was most mentioned, then

TP13 (BIM reduces rework)

TP08 (BIM requires interoperability standards)

TP21 (BIM improves information management/flow/sharing), then

TP44 (BIM capabilities must be understood by other stakeholders)

TP47 (BIM does {not} improve documentation)

while others included :

TP17 (BIM improves buildability)
TP23 (BIM improves co-ordination between some consultants)
TP27 (BIM is {NOT} more labour intensive in earlier stages of the project than ‘traditional’ systems)
TP30 (BIM's implementation and maintenance costs (including underlying IT) {DO NOT} outweigh its usefulness)
TP31 (BIM requires specialised software)
TP43 (BIM requires leadership within the company)

7.12.1 Concurrence

Based on the interviews and discussions held with a range of staff from various stakeholders, there was generally steady agreement in Case-study B1 (see Figure 7-3) with the propositions that BIM :

- improves efficiency **[d]** — associated with the category of Efficiency
- reduces rework **[d]** — also associated with Efficiency
- requires interoperability standards — associated with Alignment
- improves information management/flow/sharing — associated with Collaboration
- capabilities must be understood by other stakeholders — associated with Assumptions/Constraints,

  Note [d] denotes some level of disagreement.

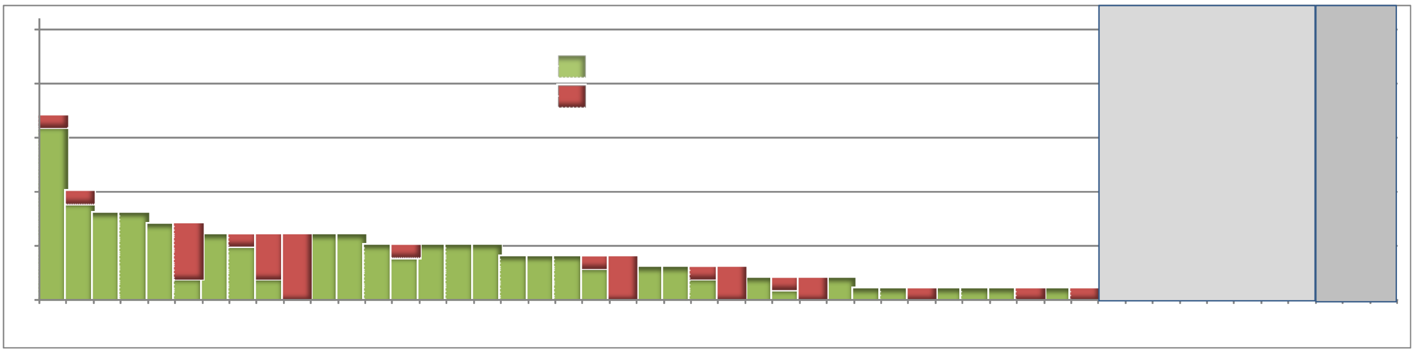
There was also steady **dis**agreement with the proposition that BIM :

- does not improve documentation — associated with Assumptions/Constraints

Other propositions often mentioned included :

- improves buildability — associated with the category Design Functionality
- improves co-ordination between some consultants — associated with Collaboration
- implementation and maintenance costs (including underlying IT) outweigh its usefulness — associated with Resources/Expenses. Note : **dis**agreement here
- requires specialised software — associated with Resources
- requires leadership within the company — associated with Assumptions/Constraints

Figure 7-3: Theoretical propositions ranked by weight of evidence for case-study B1



7.12.2 Divergence

There appeared to be some larger differences of opinion between respondents regarding the proposition of whether "BIM is more labour intensive in earlier stages of the project than 'traditional' systems", – with the bulk disagreeing, and also disagreeing on whether or not BIM improves documentation.

7.12.3 Lack of information

No responses were ventured, from any of the stakeholders, regarding whether BIM:

- will be required as a prerequisite for future government projects
- allows the small practitioner to successfully participate in larger projects
- improves creativity
- improves risk management practices
- attracts innovative staff
- enhances company profile
- is simply an extension of traditional CAD and will be a short-lived trend (vs. BIM is inevitable)
- its Long-Term advantages will outweigh any short-term disadvantages

7.13 TPs according to Business Case Categories

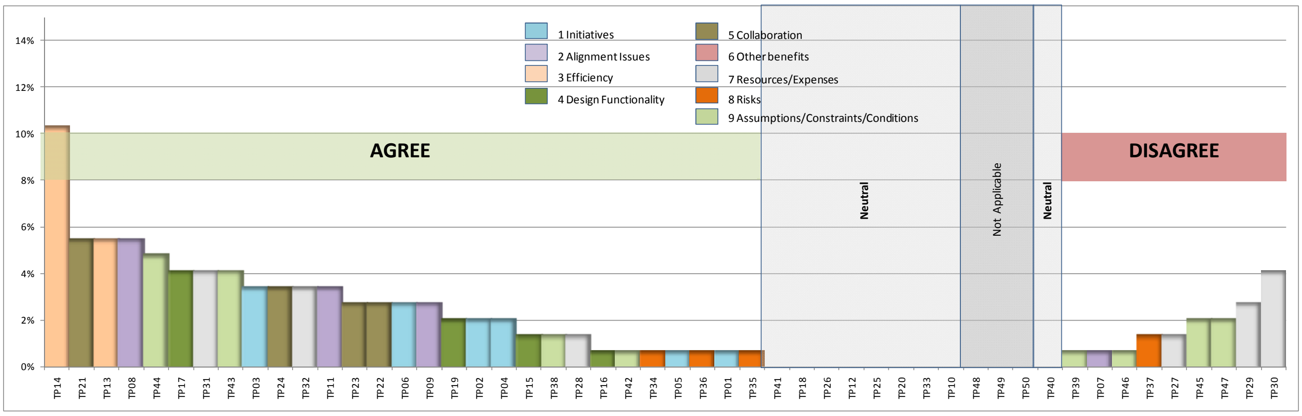
The nine categories or groupings of theoretical propositions (TPs) for the business case are :

- Initiatives
- Alignment Issues
- Efficiency
- Design Functionality
- Collaboration
- Other benefits
- Resources/expenses
- Risks
- Assumptions/Constraints/Conditions

For this particular Hong Kong-based case-study, as noted in the earlier analysis two of the top nine theoretical propositions were associated with the business driver category called “Efficiency” (see Figure 7-4) whilst a further two were associated with “Assumptions/Constraints”, another two with “Resources”, and one other with each of “Collaboration”, “Alignment” and “Design Functionality”.

At the other end of the spectrum, in this particular case-study, theoretical propositions associated with the categories such as “Risks”, “Initiatives” and “Other Benefits” were mentioned far less often in discussions than those mentioned above (i.e. had much less “weight of evidence” to support them).

Figure 7-4: Theoretical propositions classified by business driver category for case-study B1



8. CASE STUDY B2

8.1 Project Background:

The identified project comprises a Police Station and Watch House, located 60 km inland from Cairns in northern Queensland. The project is being executed through Project Services which is Queensland's Governments internal professional department responsible for the built environment. The estimated project value is AUD$10million. The BIM aspects of the project were implemented primarily to test the ability of IFC (Industry Foundation Classes) in the reliable import/export of data between various diverse built environment specific computer applications. IFC's are an initiative of the IAI (International Alliance for Interoperability) in an attempt to establish a uniform code for the assembly of a virtual simulation of a proposed project.

8.2 Project stakeholders:

Queensland Police Service, Queensland Department of Justice and Attorney General and Queensland Department of Public Works ("Project Services", or "PS")

8.2.1 Project Services background:

Employing over 700 staff and located in seven offices, Project Services is the commercialised business unit of the Queensland Department of Public Works. Professional Services, being a subset with Project Services is the lead agency primarily responsible for architectural, engineering, landscape architecture, interior architecture and CAD (Computer Aided Draughting) services. Professional Services pride themselves on being early adopters of technology.

8.3 System Evaluation and Adoption

8.3.1 BIM Concept

Project Services refers to BIM as a system that offers traditional CAD three dimensional (3D) abilities, but at the same time overcomes CAD's shortcomings by being both integrated across the project scope and informational in its shared content. The primary aim of BIM adoption is to ultimately run the Integrated Practice Model.

8.3.2 BIM Objectives

Project Services strongly agrees that BIM is inevitable for the wider construction industry. BIM is being adopted for its abilities to improve documentation, capability to accurately and promptly produce 3D information, a distinct commercial competitive advantage, and BIM's potential to integrate, interpret and extract information through databases.

8.3.3 Reasons for adoption

As the proportion of total building budget devoted to professional fees is gradually declining over time (currently at about 12%), so the professions involved compete for increased potions of this fee pool. Project Services proposes that by adopting BIM they are able to work 'smarter rather than harder' by reducing repetition of electronic documentation through the use of a singular integrated model.

8.3.4 Software or management approach

The consensus was that BIM is much a software issue as a management philosophy.

8.3.5 BIM endorsement

BIM is being strongly promoted by the senior management of Project Services. The adoption of BIM by non-senior management is mostly favourable.

8.3.6 BIM deterrent

Senior managers felt that contractual legalities were of concern, and that builders generally were unaware of BIM. Non-senior management, and those more intimately associated with BIM through actual use, felt that software vendors through their focus on vendor specific integrated product offerings, delayed adoption by ignoring the need for wider interoperability and exchange of information between diverse applications.

8.4 System Evaluation and Adoption

8.4.1 The software

As mentioned before, Project Services (PS) pride themselves on being early adopters of technology, and the project was intended as an IFC test. Project Services have been using both ArchiCAD and Revit for a substantial period of time. Most of the actual building modelling was produced using Revit 9 and 9.1 with Revit proving ultimately unable to accurately export to IFC format; thus ArchiCAD was used to import the Revit model and export to IFCs – ArchiCAD effectively becoming the IFC export engine that Revit lacked.

8.4.2 Alternate BIM software

Senior management has adopted the approach that what software might be considered the most appropriate at a given point might no necessarily be so in the future. That being said, staff responsible for software implementation consider ArchiCAD a good alternative in that is an excellent modeller and has good BIM capabilities. On the down-side ArchiCAD is considered as hard to learn and less intuitive in its operation than Revit. ArchiCAD is also seen as much better than Revit at IFC's. PS has also used Autodesk's Architectural Desktop (ADT), which they found to be good if customised and has good 'depth'. However, ADT is additionally considered too complex and files can easily be corrupted. It should be noted that ADT is less object orientated than true BIM.

8.5 Software and Hardware

8.5.1 System Cost

The cost of the software is not considered as overly prohibitive. Senior management considers the cost of BIM aware and able people as more important than that of software. As PS has been using Revit sine before Autodesk acquired it, cost is additionally considered as less significant. Additionally, PS has reported appropriate involvement of the resellers.

8.5.2 Hardware cost

PS replaces all hardware on a three yearly basis. However, the cost of BIM capable hardware is considered as higher that CAD capable hardware; this is due to BIM having greater demands for memory (system and graphics), as well as network ability in terms of increased storage space (server and workstation) and ability to transmit the larger BIM files over a Wide Area Network (WAN); a WAN being essential to PS as it operates across the state of Queensland from 7 diverse locations. Additionally BIM has necessitated the procurement of a dedicated BIM server to facilitate the sharing of single BIM files between diverse users. An interesting observation was that hardware cost, from the perspective of workstations, was more of a choice rather than an obligation. Most workstations currently available already have a high specification and increasing memory and graphics ability is insignificant if taken within the cost of the total workstation cost.

8.6 Implementation Strategy

8.6.1 Training

PS has implemented a loose strategy of deploying and/or developing key individuals in the training and support of BIM applications. It is perceived that these key persons will act as knowledge base for all matters concerning BIM. There if further an acknowledgement that BIM, owing to its current evolutionary process, should be self-taught. BIM has additionally 'taught' externally at selected periods and to selected audiences. The cost of the training is considered as moderate in terms of actual cost and productivity loss.

8.6.2 Software content:

'Out-of-box-content' of BIM software is considered as adequate. However, as BIM currently lacks maturity, the effort required in terms of customisation of Families, etc. is considered as substantial.

8.6.3 Customisations / Setup

It has been reported that the time demands to populate data sets is considerable if compared with the production of similar deliverables using traditional CAD. 'Considerable' needs to be contextualised as the number of people involved is only two.

8.6.4 First BIM project

As the project was initiated to primarily test IFC ability, the project was consciously chosen according to manageable and controllable size, involvement of all construction industry professionals, and simply, it was the next to be executed.

8.6.5 Old/new methods used in parallel

As IFC's could be argued as symbiotic with BIM, the use of other softwares traditional CAD was not considered. However, owing to Revit's inability to produce IFC's, ArchiCAD was used in this role.

8.7 Collaboration

8.7.1 Collaboration

BIM has changed the way people within the design team collaborate. Rather than each member of the design team recreating and producing information, now a single model is proposed. Users commented that BIM allowed more detailed information to be available at an earlier stage.

8.7.2 Collaboration with the client

BIM allows us to work with a client using an actual (virtual) model with rich information – not just a visualisation, and to demonstrate options and collaborate with the client(s) using a mix of 2D and 3D plans and views – straight from the BIM model.

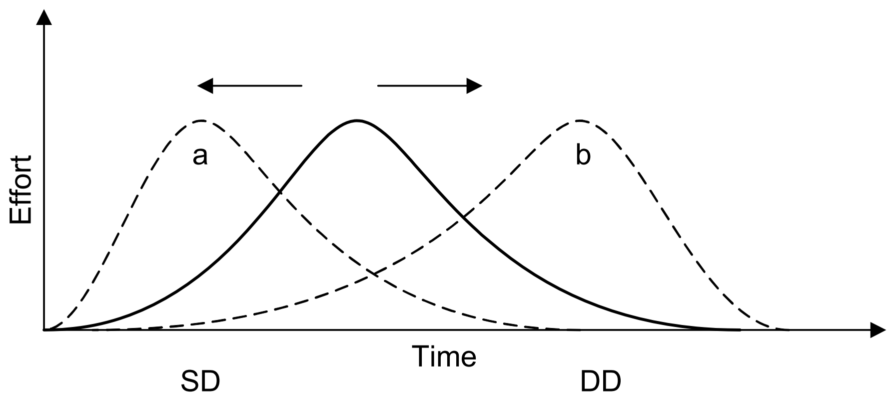
8.7.3 Model shared between consultants

The Building Information Model was shared by consultants within PS. As mentioned before the whole aim of this 'project' was to test the ability to share IFC's in the sharing of information. PS experience in this regard revealed that the sharing of the model between the Architect and Mechanical Engineer (use of DDS and Riuska) was relatively easy, while sharing between the Architect and Structural Engineer proved more problematic owing to file sizes. (An interesting note that Revit Building and Structures were use, and due their lack of IFC support these problems supposedly arose) The end result of the process was an understanding that IFC's need further dramatic development.

8.8 Cost and Time

8.8.1 Effort distribution before implementation of BIM

Figure 8-1: Effort distribution curves, for case-study B2



Three of the four participants interviewed indicated that in a tradition 'before BIM' project, the effort was primarily distributed towards the end of the project - as indicated by curve 'b" in Figure 8-1 above). The fourth and dissenting view offered, stated that as PS was already modelling in three dimensions, rather than 2D, and using traditional CAD to do this 3D modelling, the effort distribution was earlier in the project (as indicated by curve 'a').

8.8.2 Effort distribution when implementing BIM

All those interviewed indicated that in a BIM project the effort distribution was earlier in a project (as indicated by 'a' in the diagram above). Comments concerning the risks associated were that work with outside consultants becomes problematic, risks of project delay or cancellation, 'forcing' deign earlier can result in a design process that is insufficiently resolved, and software compatibility. The overall consensus form a management perspective was that BIM can conceivably save time. However others interviewed felt that as the project was an IFC trial, it could be premature to comment. While others proposed that as BIM is still evolutionary, at this stage it will still take a similar amount of time.

8.9 Delivered Documentation

8.9.1 Eliminate need for other documents

BIM does not eliminate the need for other documents.

8.9.2 Facilitate new presentation

Data (or rather information) has been presented to clients, and also to builders in new ways. Architect was able to communicate complex BIM generated 3D views to the client. However it could be argued that as PS is already using 3D CAD as their foundation to produce subsequent documentation, the earlier point is irrelevant. What BIM allows is a more efficient manner to create the associated 3D views. BIM further allowed more detailed and concise information to be available at an earlier stage for the consultants.

8.10 Concluding Remarks

At this stage, owing to client brief changes, the project has gone back to initial design stage. Project Services fully intend that if the project were to proceed, that any final information would be consolidated into a single model in an IFC format and be compatible with a facilities management tool.

8.11 Analysis of Theoretical Propositions

In Case-study B2 – the small State Government justice complex - the nine theoretical propositions which had the greatest "weight of evidence" (i.e. mentioned most often in discussions) to sustain them, were

TP08 (BIM requires interoperability standards) was most mentioned, then

TP14 (BIM improves efficiency) then

TP21 (BIM improves information management/flow/sharing),

TP03 (BIM requires appropriate training)

TP06 (BIM requires a significant process re-structure (internal and external))

TP02 (BIM must be clearly understood throughout the organization)

TP09 (BIM requires all project stakeholders to exchange and use the information)

TP29 (BIM requires a high economic investment)

TP27 (BIM is {NOT} more labour intensive in earlier stages of the project than 'traditional' systems)

8.11.1 Concurrence

Based on the interviews and discussions held with a range of staff from various stakeholders, there was generally steady agreement (see Figure 8-2) in Case-study B2 with the propositions that BIM :

- requires interoperability standards — associated with Alignment
- improves efficiency [d] — associated with the category of Efficiency
- improves information management/flow/sharing — associated with Collaboration
- requires appropriate training — associated with Initiatives
- requires a significant process re-structure (internal and external)) — associated with Initiatives
- must be clearly understood throughout the organization) — associated with Initiatives

  Note [d] denotes some level of disagreement.

Other propositions often mentioned included :

- requires all project stakeholders to exchange and use the information — associated with Alignment
- requires a high economic investment — associated with Resources
- is {NOT} more labour intensive in earlier stages of the project than 'traditional' systems — associated with Resources

Figure 8-2: Theoretical propositions ranked by weight of evidence, for case-study B2

8.11.2 Divergence

There appeared to be some larger differences of opinion between respondents regarding the proposition of whether "BIM is more labour intensive in earlier stages of the project than 'traditional' systems", – with the bulk disagreeing, and also disagreeing on whether or not BIM improves documentation.

8.11.3 Lack of information

No responses were ventured, from any of the stakeholders, regarding whether BIM:

- requires a coordinator role
- allows the small practitioner to successfully participate in larger projects
- helps to align project stakeholders expectations
- implementation and maintenance costs (including underlying IT) outweigh its usefulness
- adoption is hindered by fee structures
- BIM-developer/coordinators increase their role, influence, & risks on the project

8.12 TPs according to Business Case Categories

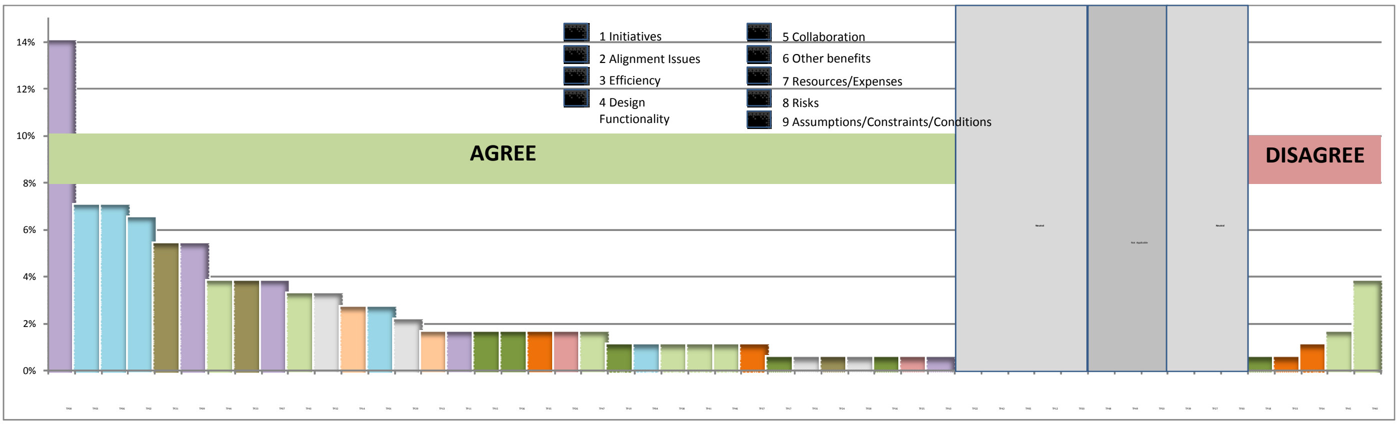
The nine categories or groupings of theoretical propositions (TPs) for the business case are :

- Initiatives
- Alignment Issues
- Efficiency
- Design Functionality
- Collaboration
- Other benefits
- Resources/expenses
- Risks
- Assumptions/Constraints/Conditions

For this particular north Queensland-based case-study involving a Government justice complex, as noted in the earlier analysis three of the top nine theoretical propositions were associated with the business driver category called “Initiatives” (see Figure 8-3) whilst a further three were associated with “Alignment”, another two with “Collaboration”, and the other with “Assumptions/Constraints”.

At the other end of the scale, in this particular case-study, theoretical propositions associated with the categories such as “Risks” and “Other Benefits” were brought up far less often in discussions than those mentioned above (i.e. had much less “weight of evidence” to support them).

Figure 8-3: Theoretical propositions classified by business driver category, for case-study B2



9. CROSS CASE-STUDY ANALYSIS

9.1 Background

The case studies varied from a large commercial development in central Melbourne and another – even higher - commercial development on Hong Kong island; to an iconic building designed for a wharf-side redevelopment in inner Sydney; to a smaller mixed-use development in inner-suburban Melbourne; through to a government complex in a small town 60km from the coast in Queensland.

At one end of the scale, some of these projects involved small groups of architects, structural engineers, developers and builders, while others extended the stakeholder base to include quantity surveyors, several additional engineering disciplines, a metal fabrication group, and up to an IT group focussed on BIM implementation and management. Most projects were largely private sector based, while B2 had Government-involvement as a client and also as the project manager.

Table 9-1: Summary of Fundamental Characteristics of Case Studies

	M1	M2	MB	B1	B2
Major stake-holders	Architects Stru'l engin'rs Mech engin'rs Q.S. Developer Metal fabric'r Builder	Architects Stru'l engin'rs Mech engin'rs Developer Builder	Architects Stru'l engin'rs Mech engin'rs Elec. engin'rs Developer Builder	Architects Stru'l engin'rs Mech engin'rs IT manag't Developer Builder	Architects Stru'l engin'rs Mech engin'rs Developer (gov) Builder
Est'd cost (AUD)	$300M	$4M	$280M	$300M	$10M
Timeframe	2 years	6 months	18 months	3 years	12 months
Location	Central city	Inner urban	Central city	Inner urban	Rural town
Extent of data exchange	Architects, (Stru'l engin'rs)	Architects, Stru'l engin'rs	Architects, Stru'l engin'rs Mech engin'rs Developer	Architects, Stru'l engin'rs Mech engin'rs IT group, Developer Builder	Architects, Stru'l engin'rs Mech engin'rs Developer (gov) Builder

Note: (Stru'l. engineers) - brackets indicates that electronic data flow was one-way only

Despite the wide variety of differing characteristics indicated by Table 9-1 above, analysis shows that Theoretical Proposition 21 (BIM improves information management / flow / sharing) was one of the top four propositions most often mentioned right across four of the five case studies, while equally, TP14 (BIM requires appropriate training) was also a topic that arose frequently right across the whole range of five developments.

Amongst the M1 and M2 case studies, both the propositions TP15 (BIM enhances confidence in the design outcomes), and TP16 (BIM improves design) were both mentioned quite often whereas in the B1 and B2 case studies, there was much less mention of either of these propositions.

Conversely, the proposition TP08 (BIM requires interoperability standards) was mentioned more often amongst the B1 and B2 studies, whilst in M1 and M2, the issue of interoperability did not appear so much. This may simply reflect the critical importance placed on this aspect of BIM by the initiators of the B2 project, and by the involvement of more stakeholders exchanging data in the B1 case-study than in the M1 and M2 studies.

Again in a similar fashion, the proposition TP27 (BIM is more labour intensive in earlier stages of the project than 'traditional' systems) was mentioned - and disagreed with - in responses from case studies B1 and B2 but appeared much less often in M1 and M2 responses.

TP03 (BIM improves efficiency) was a proposition highly placed in discussions within M1 and B2, but much less so in the other case studies.

Table 9-2: Theoretical Propositions most often mentioned, by Case-study

	M1	M2	MB	BS1	BS2
Propositions most often mentioned	TP21 31 16 14 03 04 15 23 06 38	TP21 14 37 15 17 23 16 22	TP43 11 29 03 16 36 37 44 17 09	TP14 13 08 21 44 47 17 23 27 30 31	TP08 14 21 03 06 02 09 29 27

9.2 Summary

The nine categories or groupings of theoretical propositions (TPs) for a business case view are :

- Initiatives
- Alignment Issues
- Efficiency
- Design Functionality
- Collaboration
- Other benefits
- Resources/expenses
- Risks
- Assumptions/Constraints/Conditions

and following analysis of interview responses and clustering across a range (see Methodology chapter) of dark-green through mid- to pale green; to white; to pale-red through mid- to dark-red, the results from the five case studies were tabulated, and are shown in the Tables below.

Table 9-3 Initiatives: Specific action items associated with the BIM implementation.

1	ID	Initiatives — Proposition	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
1	TP01	BIM requires a significant organizational re-structure					
2	TP02	BIM must be clearly understood throughout the organization					
3	TP03	BIM requires appropriate training					
4	TP04	BIM success is dependant upon selecting the correct software					
5	TP05	BIM requires a coordinator role					
6	TP06	BIM requires a significant process re-structure (internal and external)					

It can be seen from the prevalence of mid- and pale-green cells in this table above (Table 9-3) that the propositions (TP01-06) in this group were mentioned in interviews, and agreed with in general.

Table 9-4 Alignment Issues: Issues relating to the alignment of the BIM implementation program with existing systems and procedures

2	ID	Alignment Issues — Proposition	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
1	TP07	BIM has compatibility difficulties with legacy software systems					
2	TP08	BIM requires interoperability standards					
3	TP09	BIM requires all project stakeholders to exchange and use the information					
4	TP10	BIM will be required as a prerequisite for future governement projects					
5	TP11	BIM provides a foundation for FM processes					

This second table shows from the range of dark and mid-green cells relating to "BIM requires interoperability standards" that this was an issue with some agreement, whereas the mixture of red and green cells for TP11 indicates there appeared strong levels of agreement and disagreement with the proposition regarding BIM as an foundation for FM. The white cells indicate that BIM as a prerequisite for government projects did not appear to raise much interest – apart from the B2 case-study (which, it should be noted, already had government involvement).

Table 9-5 Efficiency: Improvements to the efficiency of designing and managing building projects

3	ID	Efficiency — Proposition	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
1	TP12	BIM allows the small practitioner to successfully participate in larger projects					
2	TP13	BIM reduces rework					
3	TP14	BIM improves efficiency					

Again the table is dominated by dark and mid-green cells – particularly for TP14 (BIM improves efficiency) – indicating that this was an issue often mentioned and with agreement, whilst the "reduction of rework" proposition was also raised and agreed with. Again, the white cells for B1 & B2 indicate an inconclusive result regarding participation in larger projects.

Table 9-6 Design Functionality: Issues that lead to better building designs

	4	Design Functionality	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
	ID	Proposition					
1	TP15	BIM enhances confidence in the design outcomes					
2	TP16	BIM improves design					
3	TP17	BIM improves buildability					
4	TP18	BIM improves creativity					
5	TP19	BIM increases ability to make changes throughout design					
6	TP20	BIM improves risk management practices					

The fourth table with a strong incidence of mid-green cells – particularly for "design" and "buildability improvements", and "confidence in design" – indicates that these were issues mentioned in discussions and with agreement. Again, the white cells indicate an inconclusive result, while the pale-red indicates some disagreement in case-study B2.

Table 9-7 Collaboration: Improved support for collaboration among project participants

	5	Collaboration	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
	ID	Proposition					
1	TP21	BIM improves information management/flow/sharing					
2	TP22	BIM helps to align project stakeholders expectations.					
3	TP23	BIM improves co-ordination between some consultants					
4	TP24	BIM improves co-ordination with contractors / fabricators					

Again the table is highlighted by the presence of dark and mid-green cells – particularly for TP21 (improved information management), and TP23 (improved consultants co-ordination) – these were issues mentioned quite often in discussions and with agreement.

Table 9-8 Other Benefits: Other project and corporate benefits

	6	Other benefits	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
	ID	Proposition					
1	TP25	BIM attracts innovative staff					
2	TP26	BIM enhances company profile					

The range of pale-green cells indicate little opinion on these propositions, whilst disagreement is evident with "attracting innovative staff" proposition in case-study M1.

Table 9-9 Resources / Expenses: The resource requirements for BIM, and the corresponding costs

	7	Resources/Expenses	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
	ID	Proposition					
1	TP27	BIM is more labour intensive in earlier stages of the project than 'traditional' systems.					
2	TP28	BIM requires the employment of additional specialist staff (designers/IT)					
3	TP29	BIM requires a high economic investment					
4	TP30	BIM's implementation and maintenance costs (including underlying IT) outweigh its usefulness					
5	TP31	BIM requires specialized software					
6	TP32	BIM requires specialized IT hardware/infrastructure					

Strong dominance of dark and mid-red cells – particularly for TP29 (BIM requires high economic investment), and TP30 (costs outweigh usefulness) – indicates that these were issues of disagreement often mentioned in discussions. However it should be noted that there was also some lesser level of agreement with the "costly investment" proposition in two of the case-studies.

Table 9-10 Risks: Major risks associated with a BIM implementation

8	ID	Risks / Proposition	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
1	TP33	BIM reduces risks to individual stakeholders					
2	TP34	BIM reduces risk in the project					
3	TP35	BIM requires that a fall-back system be in place since it is not yet sufficiently mature					
4	TP36	BIM-trained people are scarce					
5	TP37	BIM introduces new issues regarding ownership of information, IP, payment of information, etc.					

Again the dominance of dark and mid-green cells – particularly for TP37 (BIM and information ownership, IP) – indicates that this was an issue often mentioned and with agreement. However it should be noted that there was also some level of disagreement with this from case-study B1. In addition it should be noted that with the mix of red and green cells, there appeared differences of opinion between case-studies as to whether BIM is considered sufficiently mature, and whether BIM reduces risk in the project.

Table 9-11 Assumptions / Constraints / Conditions: Issues describing assumed preconditions or constraints for BIM implementations

9	ID	Assumptions/Constraints/Conditions / Proposition	CS-M1	CS-M2	CS-MB	CS-B1	CS-B2
1	TP38	BIM adoption is hindered by legal frameworks					
2	TP39	BIM adoption is hindered by fee structures					
3	TP40	BIM is simply an extension of traditional CAD and will be a short-lived trend (vs. BIM is inevitable)					
4	TP41	BIM's Long-term advantages will outweight any short-term disadvantages					
5	TP42	BIM-developer/coordinators increase their role, influence, and risks on the project					
6	TP43	BIM requires leadership within the company					
7	TP44	BIM capabilities must be understood by other stakeholders					
8	TP45	BIM is only a software approach rather than a management one					
9	TP46	BIM adoption is hindered by lack of specialised library content					
10	TP47	BIM does not improve documentation					

Again the incidence of dark-red and mid-red cells – particularly for TP40 (BIM is a short-lived trend) – indicates that this was an issue often mentioned but by disagreement, as well as disagreement with the propositions that BIM does not improve documentation, and that it is only a software approach. The presence of mid-green cells indicates the propositions that BIM can be hindered by legal frameworks; it requires leadership within the implementing company, and that its capabilities be understood by other stakeholders were also mentioned quite often with agreement.

10. BUSINESS CASE FOR BIM

10.1 Introduction

The objective of this report is to identify the business drivers for BIM via examination of a number of case studies. Having collected and analysed a series of case studies, this section presents a promising framework which may be used to study the resulting business cases at a future date.

A business case presents the analysis of some business opportunity in order to support decision-making about proceeding with the initiative. There are many ways to present a business case, but they should generally assess the benefits, resources/costs, and risks for the initiative. Rather than using an arbitrary format for the BIM business cases, this report adopts a formal, standardised business case model called the ValIT Business Case, developed by the IT Governance Institute (ITGI).

This Business Case model is a part of the ValIT initiative, which provides a framework for measuring, monitoring, and optimizing the realisation of business value from IT investments. ValIT is based on ITGI's COBIT (Control Objectives for Information and related Technology), a framework for IT management processes. According to ITGI (ITGI, p.7), ValIT focuses on the investment perspective—the strategic question "Are we doing the right things?" and value question "Are we getting the benefits?", while COBIT focuses on the execution perspective — the architecture question "Are we doing them the right way?" and the delivery question "Are we getting them done well?". The ValIT framework presents processes for value governance, portfolio management, an investment management based largely on data and analysis captured in business case documents. The ValIT objectives and methodology were found to be in very good alignment with those of this study, and the ValIT business case provides a suitable model for the future documenting of these findings.

10.2 The Business Case Scenarios

The business case presents the data and analysis for a particular business initiative in some business context. The specific details of the initiative and the context can have a decisive bearing on the outcome of the business case. Therefore, it was found to be of limited value to present a "generic" business case for BIM adoption by all companies across all sectors of the building industry. Equally, it was not practical to present the business cases for the specific case studies reported here, since not all of the necessary information was available, and it would not necessarily be relevant to other situations in any event.

10.3 The Business Case Format

10.3.1 Overview

10.3.2 Fact Registry

The Fact registry is a tabulation of all the of the relevant facts that make up the business case analysis, and the ValIT Business case format decomposes the wide range of issues along several key dimensions. While these dimensions could be considered in any order, we have organized them into the following hierarchy to provide a specific sequence to the analysis. Not all items at all levels are required, but should be included in the fact registry as appropriate.

- **Level 1: Analysis Components**

At the top level, the information is organized according to the overall flow of the analysis, as follows:

- ❖ Initiatives
  The business, process, people, technology, and organizational actions/projects undertaken to achieve the outcomes. Also, the contributions of each initiative to

individual outcomes (where appropriate). Specific action items associated with the BIM implementation.

- ❖ Alignment Issues
  The degree to which the program aligns with existing systems and practices, regulations, policies, and business strategies. Issues relating to the alignment of the BIM implementation program with existing systems and procedures

- ❖ Efficiency
  Improvements to the efficiency of designing and managing building projects.

- ❖ Design Functionality
  Issues that lead to better building designs.

- ❖ Collaboration
  Improved support for collaboration among project participants.

- ❖ Other benefits
  Other project and corporate benefits.

- ❖ Resources/expenses
  Resource requirements for delivering the program, and Expenses incurred to provide the necessary resources, from reduced efficiencies, etc. The resource requirements for BIM, and the corresponding costs.

- ❖ Risks
  Critical risks facing a program, including risk quantification and mitigation information Major risks associated with a BIM implementation.

- ❖ Assumptions/Constraints/Conditions
  Issues describing assumed preconditions or constraints for BIM implementations

- **Level 2: Capability Layers**

The analytical components can be applied at each of three layers of business scope/focus:

- ❖ Technical Capability
  The specific technological capabilities delivered by the program.

- ❖ Operational Capability
  The operational capabilities that are supported by the technological capabilities.

- ❖ Business Capability
  The overall business capabilities enabled by the operational capabilities.

- **Level 3: Life cycle phases**

The analysis information can be organized according to the life cycle phases required to build/create, implement/deploy, operate, and retire the program.

- ❖ Build
- ❖ Implement
- ❖ Operate
- ❖ Retire

- **Level 4: Stakeholder**

Building projects involve large scale collaborations of stakeholders from many different organizations, and since collaboration issues are central to BIM technologies, the business case inevitably involves multiple stakeholders. The value propositions become considerably more complex since the parties that reap the benefits may differ from those that incur the expenses and risks. Thus, although not considered in the ValIT framework, it may often be relevant to define specific stakeholders' interests in each element of the program.

- **Level 5: Outcome Range**

Often, the expected results of the program cannot be forecast with much precision, and can be described in terms of the best case and worst case extremes from a range of probable outcomes.

- ❖ Best case
- ❖ Worst case

10.3.3 Analysis

Overall cumulative analysis of:

- Financial benefits
- Financial costs
- Non-financial benefits/alignment
- Risk Analysis
- Change impact?
- The impact (positive and negative outcomes) of not doing the program. Including the opportunity costs-i.e., the net cost of foregoing the next best/status quo alternative]

10.4 Application of Business Case Framework

Because of the widely varying array of alternatives regarding company size, industry sector (architectural, engineering and construction firms); experience with BIM, CAD and Information Technology in general; the differing sets of skills within the companies; the size, nature and strength of their relationships with other consultant firms; and whether the various stakeholders are private or public sector or a mixture, we have not attempted to come up with a generic case-study to apply the framework. Following, we outline the approach and hopefully provide a sufficient framework for individual companies to apply the Business Case process to their own (much more specific) situation.

10.5 Business Case Framework

In order for a business case to be reliable it must be developed to achieve specific objectives or outcomes taking into consideration the particular needs and characteristics of the company. The clearer the objectives are defined and the specific circumstances of the company analysed, the better the business case will be. Therefore, it is not possible to define a typical business case to adopt BIM. Furthermore, a single company could develop more than just one business case based on different scenarios. For instance, a scenario might assume that there will be no model sharing with third parties (Architects office only) whereas another might define a variation where collaboration between consultants is considered.

The following Business Case Framework aims to help companies interested in adopting BIM, gather the required information to do a business case. It is not, however, a business case in itself.

Outcomes

Outcomes are the clear and measurable results sought. The outcomes are divided into: operational, technical and business capabilities. There can be more than one outcome on each of these capabilities.
Following are examples of outcomes expected when adopting BIM. These expected outcomes are based on results from the case studies.

- **Technical Capability**
  - **Technical Outcome 1:** Ability to produce the necessary drawings and documentation from the BIM model.
  - **Technical Outcome 2:** Ability to exchange BIM models with consultants (structural, building services, and quantity surveyor).
- **Operational Capability**
  - **Operational Outcome 1:** Ability to design in a 3D environment throughout the entire design process.
  - **Operational Outcome 2:** Ability to use BIM to support design collaboration / information exchange with consultants.
  - **Operational Outcome 3:** Ability to reduce error in documentation through better coordination between consultants.
- **Business Capability**
  - **Business Outcome 1:** Ability to complete larger design projects with greater efficiency than present – this is particularly important for the smaller practice.
  - **Business Outcome 2:** Improved design outcomes through better understanding of design alternatives by clients and designers. Measured by client satisfaction levels and designers qualitative opinions of design outcomes.
  - **Business Outcome 3:** Reduced risks associated with information-related errors. Associated with information consistency in drawings, errors introduced during information exchanges, etc.

In order for the above-mentioned outcomes to be achieved the following issues need to be considered. Again, it is reiterated that this is not a comprehensive list of issues to consider, as every business case would have particular and specific items, but should be considered as a useful starting point for developing the business case.

Initiatives
Technical Capabilities
Acquire BIM software Assess different software options. Consider not only upfront cost, but yearly subscriptions (if applicable) as well as support for resellers.
BIM customisation / libraries Consider time and resources required to customise the system and develop library of components.
Required IT infrastructure

Assess current IT infrastructure (CPU's, monitors, network, etc.) to see if it will perform as required. Considered specialised hardware like model servers, etc.
BIM data exchange capabilities How is information going to be shared between the design team (eg. Consultants)? Is the model going to be shared? Or, is the model going to be exported in other format (lose intelligence).
Operational Capabilities
Develop / implement revised design procedures Development of in-house manuals and procedures
Conduct pilot project Choose a project that is suitable to be used as a pilot project based on its size, type, delivery time, allocated resources, fee structure, etc.
Business Capabilities
Position firm as technological leader
Pursue new market segments
Seek strategic partnerships with compatible consultants / contractors

Alignment
Technical Capabilities
Data integration with existing systems
Data interoperability with key standards (IFC)
Interoperability with key partner Assess current IT infrastructure (CPU's, monitors, network, etc.) to see if it will perform as required. Considered specialised hardware like model servers, etc.
Business Capabilities
Alignment with corporate strategy issues • Match the technology aggressiveness / conservativeness • Target markets / segments • Growth / size • Risk attitudes

Efficiency
Technical Capabilities
Reduce errors and rework Aim to reduce errors and rework through early detection of potential clashes between services and the structure - in advance of actual construction
Operational Capability
Deliver on time Aim to increase ability to meet project deadlines in an efficient and timely manner
Reduce number of RFI's Aim to reduce the number of RFI's lodged during construction phase, due to a better co-ordinated documentation and improved buildibility of designs.
Business Capability
Access to larger / more complex project Become involved in larger projects through better and more efficient information management on projects

Design Functionality
Our Firm
Increase ability to make (managed rapid) changes throughout the design phase
Provide improved design innovation and creativity
Our Partners
Improve buildability for contractor (ensure smooth transition from design through to constructed facility)
Our Clients
Enhance confidence in the design outcomes

Collaboration
Our Firm
Improve information management and sharing
Our Partners
Improve coordination between consultants – more timely and accurate information
Improve coordination with building contractors, etc.
Our Clients
Improve client collaboration with 3D visualization

Other benefits
Our Firm
Heighten staff morale through working with innovative approaches to varied projects
Ensure firm is perceived as leaders by other designers, engineers
Our Partners
Maintain and improve high standard of accurate data and timely interchange of data with partner firms
Our Clients
Strengthen perception by clients of firm as technological leaders

Resources and expenses		
The analysis should be organized according to the life cycle phases required to assessing, implementing, operating, and retiring program.		
Assessing Staff time to evaluate, acquire, & customise hardware, software, & communications networks		
Acquire software:	$$$ Best Case	$$$ Worst case
Customise software:	$$$ Best Case	$$$ Worst case
Upgrade hardware:	$$$ Best Case	$$$ Worst case
Upgrade networks:	$$$ Best Case	$$$ Worst case
Implement		
Cost of initial training (Include loss of productivity):	$$$ Best Case	$$$ Worst case
Cost of on-going training (include loss of productivity):	$$$ Best Case	$$$ Worst case
Operate		
System not in productive use while periodic software updates (or unscheduled software patches) are installed and tested	$$$ Best Case	$$$ Worst case
Software updates (6; 12; 18 months ?)	$$$ Best Case	$$$ Worst case
Loss of productivity (During pilot / first projects)	$$$ Best Case	$$$ Worst case
Re-balance labour requirements at different phases than pre-BIM	$$$ Best Case	$$$ Worst case
Retire	$$$ Best Case	$$$ Worst case
Maintain access to BIM model (neutral, or proprietary format ?):	$$$ Best Case	$$$ Worst case

Retain previous copies of software (& hardware) if back-up is in proprietary format, or on obsolete media	$$$ Best Case	$$$ Worst case

Risks	
Our Firm	
Inability of software to perform as required	Likelihood ( ) X Impact ( )
Difficulty of staff to learn / adopt new practices	Likelihood ( ) X Impact ( )
Difficulty of recruiting staff already trained in BIM	Likelihood ( ) X Impact ( )
Counter lack of understanding of BIM's capabilities within firm	Likelihood ( ) X Impact ( )
Our Partners	
Problems with technical capabilities of project partners.	Likelihood ( ) X Impact ( )
Unresolved issues regarding ownership of information, intellectual property, and the like	Likelihood ( ) X Impact ( )
Un-resolve legal issues with information sharing (IP)	Likelihood ( ) X Impact ( )
Our Client	
Change in fee structures	Likelihood ( ) X Impact ( )
Inability to deliver project on time	Likelihood ( ) X Impact ( )

11. CONCLUSIONS

The results of the five detailed case studies showed that there are variations in the business case for BIM from one project to another, and no single, consistent business case could be produced. Never-the-less, the results offer significant value to organizations desiring to analyse their own business case for BIM implementation as follows:

- The detailed report of each case-study provides much information and opinion that will help readers make more informed predictions of their own outcomes.
- By comparing the results of all the case studies, the cross-case-study analysis evaluates the extent of agreement for the 47 theoretical propositions, indicating the degree of consensus around BIM business case issues.
- Building upon the insight gained from the case studies and an international standard for structuring investment decisions for IT initiatives (ValIT), the report presents a framework that can be used to assemble business cases for future BIM implementation initiatives.

The results of the research indicate that BIM offers advantages to those businesses that embrace it. These advantages include improved efficiency and collaboration by reducing re-work and early detection of potential problems as well as improving the management and communication of information generated by the model. There were some other benefits that seem specific to a certain type of project or group of stakeholders, for instance the need for interoperability; an enhanced confidence in design outcomes; or the ability for small engineering and architectural practices to become more efficient and competitive thus increasing their ability to bid for larger or more complex projects.

Whilst some case studies only implemented BIM within the one company, that is the model was not directly shared with other consultants, there were still some benefits reported which could justify this type of limited implementation. Furthermore, attempts to fully implement BIM between stakeholders reported issues of compatibility not only between different packages, but even within different solutions from the same provider.

Another finding was that the cost of the software and hardware are not considered as serious impediments; however it is the issue of cost of training current staff and the lack of available trained recruits which is viewed as the largest deterrent for adoption of BIM by the Australian AEC Industry. This issue was followed by the lack of ready-to-use BIM parametric libraries (architectural and engineering content), which demands time and money to develop in-house.

Case studies indicated that implementation should be undertaken in a fully committed fashion since 'fall-back' strategies (e.g. design and document in the traditional way, but in parallel) were not seen as financially viable. However, this should be done in a staggered manner beginning with smaller projects which are more easily managed and controlled.

12. BIBLIOGRAPHY AND REFERENCES

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Refer to earlier (Chapter 2.2 in this Report) for Background Reading for Bibliography.

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13. GLOSSARY

The following explanations are provided as a guide to acronyms, names and terms which may not be familiar to or readily understood by some readers.

- **3D, 4D and 5D** Techniques that use spatial dimensions of width, length, and depth (3D) to represent an object, or these dimensions plus time (4D), or space plus time plus cost (5D).
- **AEC/FM** Abbreviation often used to refer to the Architecture, Engineering and Construction (and Facilities Management) industry sectors as a group
- **ArchiCAD** BIM software produced by ***Graphisoft*** which allows the user to work with data-enhanced parametric objects, often called "smart objects" by users. The product allows the user to create a "virtual building" with virtual structural elements like walls, slabs, roofs, doors, and windows.
- **BIM** Building Information Model is a digital representation of the building process to facilitate exchange and interoperability of information in digital format, or as the American Institute of Architects has defined: "a model-based technology linked with a database of project information" – see also Virtual Building, Virtual Design and Construct, etc.
- **Buildability** term sometimes used to describe the ease or complexity with which a built facility can actually be constructed in the real world, or as the review of design by the building contractor(s) or others familiar with construction techniques and materials.
- **CAD** Computer-Aided Design covers a wide range of computer-based tools that assist engineers, architects and other design professions in their design activities. Current packages range from 2D vector-based drafting systems to 3D solid and surface modelers.
- **dwg; dgn** older ('drawing') data formats - originally proprietary - but extremely widely used as 'de-facto industry standards' in the past, these formats were implemented by Autodesk and Bentley for their earlier AutoCAD and Microstation CAD products, and are being largely superseded by Open (non-proprietary) versions, or by more 'intelligent' data structures such as IFCs.
- **Digital Project** BIM software product by ***Gehry Technologies***, Digital Project is a powerful new software platform, utilising Catia to support the lifecycle of construction projects in a common digital environment, from design and engineering to fabrication, construction project management and on-site construction activities.
- **IFCs** Industry Foundation Classes are data elements that represent the parts of buildings, or elements of the process, and contain the relevant information about those parts. IFCs are used by computer applications to assemble a computer-readable model of the facility that contains all the information of the parts and their relationships to be shared among project participants.
- **Microstation** widely-used CAD platform of ***Bentley Systems*** which is used by teams of architects, engineers, contractors, and GIS professionals to integrate work on buildings, civil engineering projects, power plants, and geospatial information – see also Bentley Building, Bentley Architecture, GenerativeComponents, etc. in the allied BIM field.
- **NavisWorks** the developer of JetStream - a collaborative 3D/4D Design Review software system used in the project lifecycle of Building, Plant and Marine construction.
- **QS** Quantity Surveyor has the role of managing and controlling costs within construction projects and may use a range of management procedures and technical tools to achieve this goal.
- **Revit** **'**Successor' to ***Autodesk*****'s** AutoCAD/ADT, it is a range of BIM software produced in three versions for the varying building design disciplines: Revit Architecture, for architects and building designers; Revit Structure, for structural engineers; and Revit MEP, for mechanical, electrical and plumbing engineers.

- **Rhino** Rhinoceros 3D is a stand-alone, commercial (NURBS-based) modeling tool developed by ***McNeel & Assoc.*** The software is commonly used for industrial design, architecture, marine and automotive design, CAD/CAM, rapid prototyping, reverse engineering as well as the graphic design industry.
- **STEP** Standard for the Exchange of Product model data, and more accurately known as ISO 10303 - a (neutral, non-proprietary format) ISO standard for the computer-interpretable representation and exchange of industrial product data.
- **Tekla Structures** a BIM software tool by ***Tekla*** that integrates with architectural models, yet encompasses specialized configurations for structural engineers, steel detailers and fabricators, precast concrete detailers and manufacturers, as well as contractors.
- **VectorWorks Architect** Software product by ***Nemetschek*** (US) for design, detailing, dimensioning and presenting of an architectural design. VectorWorks is used in a diverse range of professions that includes architecture, exhibition design, interior design, industrial design, landscape design, naval architecture, and mechanical engineering.
- **Virtual Building** (proprietary) term used by Graphisoft to describe the modeling approach established in ArchiCAD – similar in intent to the generic acronym BIM
- **Virtual Design and Construct** general term used to explain the modeling or simulation on a computer of the design and production of a facility in the built environment – prior to full-scale construction

14. AUTHOR BIOGRAPHIES

Prof. Ron Wakefield

RMIT University, School of P, C and PM
Ph +61 03 9925 3448, email Ron.Wakefield@rmit.edu.au

Ron is currently Head of the School of Property, Construction and Project Management at RMIT University, Australia. He is also one of the three Program Directors of the Cooperative Research Centre for Construction Innovation.

Prior to joining RMIT, Dr. Wakefield was the William E. Jameson Professor of Building Construction in the Department of Building Construction, and the Associate Director for Building Technology Research at the Centre for Housing Research, Virginia Tech.

Dr Guillermo Aranda-Mena

RMIT University, School of P, C and PM
Ph +61 03 9925 9512, email Guillermo.Aranda-Mena@rmit.edu.au

Guillermo is currently a Lecturer in Property, Construction and Project Management at RMIT University, Australia. He holds a PhD in Construction Management and Engineering from The University of Reading and Masters of Science in European Construction Engineering from Loughborough University of Technology, both in the United Kingdom.

Since moving to Australia in 2003 Guillermo has been a principal investigator for the Cooperative Research Centre for Construction Innovation research projects in ‘Construction Planning Workbench’, ‘eBusiness Adoption in Construction’, ‘Mobilising Construction’, ‘Automated Estimator for Civil Concrete Structures’ and currently ‘Business Drivers for BIM’.

Mr Agustin Chevez

RMIT University, School of P, C and PM
Ph +61 03 9925 1724, email S3032925@student.rmit.edu.au

Since completing his Master in Project Management at RMIT, Agustin has been involved in the Construction and Architecture Industry in Melbourne. His work combines academic research with industry practice. He is currently implementing BIM at Balcombe Griffiths Architects.

Agustin is currently undertaking Doctoral studies as a Cooperative Research for Construction Innovation scholar within the School of Property, Construction and Project Management at RMIT and co-supervised by Director of Workplace at Woods Bagot on the topic of evolution of workplace architecture.

Mr John Crawford

RMIT University, School of P, C and PM
Ph +61 0408 808 544, email John.Crawford@rmit.edu.au

Prior to establishing his Allor consulting company, John was a senior Scientist with the building and urban planning divisions of CSIRO for 30 years. He has been deeply involved in design research and in working with public and private industry in the innovative usage of ICT in planning, building, construction, and engineering for many years.

John co-authored the key Technology Review for On-Line Remote Construction Management (ORCM) project report, as well as more recently undertaking research on Wayfinding Systems and Technologies in the Built Environment, on Successful e-Tendering Implementation, and on Early-Stage Parametric Building Development, and has most recently been working as a Senior Research Fellow at RMIT University in Melbourne.

Mr Stefan Gard

Queensland University of Technology, School of Design
Ph +61 07 3138 9008, email sgard@qut.edu.au

Prof. John Frazer
Queensland University of Technology, School of Design

Prof. Thomas Froese
University of British Columbia, School of Engineering

Mr David Nielsen
Queensland University of Technology, School of Design
Ph +61 07 3138 7044, email dnielsen@qut.edu.au

Cooperative Research Centre
for Construction Innovation
9th Floor, L Block
QUT Gardens Point
2 George Street
BRISBANE QLD 4001
AUSTRALIA
Tel: +61 7 3138 9291
Fax: +61 7 3138 9151
Email:
enquiries@construction-innovation.info
Web:
www.construction-innovation.info

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