Factors Effecting the Uptake of Building Information Modeling (BIM) in the Auckland Architecture, Engineering, & Construction (AEC) Industry

Christian McCartney

Student Identification Number: 1291784

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Abstract

Building Information Modeling (BIM) is seen as the next big paradigm shift in the building design and construction industry since the move from traditional drafting to 2D computer aided design systems, but although it has been available for a number of years, its adoption and use in the New Zealand, and specifically Auckland Architecture, Engineering and Construction (AEC) industry has been relatively limited.

During the course of this study, a number of interviews were held with industry professionals from the architecture, structural engineering, services engineering, and construction contractor industry sectors, to gain an insight into how they currently use BIM, and what benefits and barriers they encountered in its use and implementation. The interview participants were selected using purposive sampling based on what was already known about the participant's use of BIM. Interviews were semi-structured and semi-formal in nature.

The findings of this research showed that most industry sectors are currently using BIM as a three dimensional coordination tool for coordinating the various design disciplines, as well as for 3D clash detection and 2D document production. Other reasons for BIM use included producing 3D and 4D visualizations and virtual walkthroughs to help non-technical people understand the design intent.

Although the literature describes training and cost of implementation as major factors affecting the uptake of BIM, most of the research participants downplayed these issues, explaining that adopting BIM was a commercial decision made to stay ahead of their competitors, and that the extra training involved actually improved the skill base of their organizations.

Ultimately, what was found by this study is that to progress with the use of BIM, changes must be made to the whole process of design and construction. A truly integrated and collaborative approach must be adopted where the various designers and contractors involved in a construction project work closely together using BIM to achieve gains in coordination, productivity, cost management, and overall project outcomes.

Confidentiality Statement

The author has agreed that all personal and company names of the participants involved in this research will be kept strictly confidential.
Participants involved in the research will be referred to by their industry sector only, and no names of people or organizations will be published in this report.
Any specific project details that could be used to identify the participants have also been omitted from this report.

Publication Agreement

I agree that the Unitec Library and Department of Construction may make a hard copy or digital copy of this thesis available for the purposes of research or private study, provided that due acknowledgement is made where appropriate and that the author's permission is obtained before any material from the thesis is published.

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List of Abbreviations

3D	Three Dimensions
4D	Three Dimensions plus Time Information
5D	Four Dimensions plus Cost Information
AEC	Architecture, Engineering, and Construction
BIM	Building Information Modeling
CAD	Computer Assisted Design/Computer Aided Drafting
IAI	International Alliance for Interoperability
IFC	Industry Foundation Class
KPI	Key Performance Indicator(s)
MEP	Mechanical, Electrical, Plumbing
n-D	number-Dimensions
VDC	Virtual Design and Construction

1 Introduction

Building Information Modeling or BIM as it is widely known is described by many as the future of the design and construction industry and the way in which buildings are both designed and built. Where traditionally, buildings have been drawn on and built from 2D plans, sections, and elevations, they can now be viewed in a detailed n-dimensional model which not only shows the three-dimensional geometry of the building, but can also incorporate construction programmes and sequencing (4D), and cost information (5D), through to sustainable design information, specifications, and health and safety information.

How all of this applies to the New Zealand, and specifically Auckland, architecture, engineering, and construction (AEC) industry is yet to be known, as the extent of BIM use here, and the many perceived benefits and barriers are not yet entirely clear.

An initial literature review will attempt to establish what the current uses of BIM are, to what extent it is used, and also what benefits have been found through its use, as well as the barriers to its adoption. The literature review will be followed by a description of the proposed methodology for this study. The methodology section discusses the choice of qualitative methodology, sampling methods, data collection and analysis techniques, as well as issues such as research ethics, reliability and validity, and data availability.

The actual methodology followed, and the data management process used to collate all the collected raw data is described in chapter four, followed by a discussion of the findings and comparison of these with the literature in chapter five. This chapter explores the actual use of BIM in the Auckland AEC industry, and what industry professionals perceive to be the benefits and barriers of implementing and using BIM.

This is followed by conclusions and recommendations in chapter six, the final chapter of this report.

1.1 Rationale

Literature has shown that significant improvements can be made in time, cost, and quality factors through the use of BIM, however there are also a number of barriers to overcome before BIM will be implemented on a larger scale.

The aim of this research is to explore the factors affecting the uptake of BIM in the Auckland market by asking various architecture, engineering, and construction firms the reasons they do, or do not if that is the case, use BIM. In turn, the results of the research could be used to find ways to achieve higher rates of BIM adoption in the Auckland market, thereby improving project results for all parties involved – clients, contractors, designers, and end users.

1.2 Research Questions

1.2.1 Main Research Question

"What are the factors affecting the use of Building Information Modeling (BIM) in the Auckland architecture/engineering/construction (AEC) industry?"

Many factors come into play affecting the use of BIM in the Auckland AEC industry, both positive and negative. Some of the relevant benefits and barriers have been explored in the literature review, however many of these are based around overseas findings and case studies, because as BIM is relatively new in New Zealand, little empirical data exists surrounding its use.

1.2.2 Sub Questions

a.) "How is BIM currently used by the Auckland AEC industry?"

Before the factors affecting the use of BIM can be understood the current scale and scope of its use in the local industry must first be determined.

b.) "What are the perceived benefits of BIM for the Auckland AEC industry?"

Dawood and Sikka (2009, p. 438) found that the uptake of BIM, and 4D [/5D] planning in particular, was slow despite its numerous benefits, therefore this

study will look into what the perceived and real benefits are for the Auckland AEC industry.

c.) "What are the perceived barriers against BIM uptake?"

The negative factors against the adoption for BIM must be outweighed by the positive for BIM to be used in industry. If the barriers against BIM can be understood, work may be undertaken to minimize these factors.

2 Literature Review

2.1 Introduction to BIM

BIM is described as “one of the most promising developments in the architecture, engineering, and construction (AEC) industries” (Eastman, Teicholz, Sacks, & Liston, 2008, p. 1) since the transition from traditional pen and paper drafting to two dimensional computer aided drafting (CAD) systems, but whilst having been available for a number of years, is not widely used in this New Zealand (Constructing Excellence, 2008, p. 1).

BIM in its most basic form, represents building components as 3D objects, rather than a series of points, lines, and arcs, where these objects contain not only the geometric 3D properties of length, width, and height, but also further information including specifications, finishes, and cost data (Ibrahim, Krawczyk, & Schipporeit, 2004, p. 1). In essence, the BIM model is a virtual replica of the real building, containing all the knowledge and information required to document, estimate costs, construct, and manage the real building.

The use of BIM, and the extent of its use, can vary from 3D geometric models used to produce 2D construction documentation, through to cost estimation and structural analysis. A study by Kunz and Gilligan showed that the majority of users at the time were using BIM as a 3D/4D clash detection tool, or as a visualization tool for presenting architectural design concepts (2007, p. 13). The most common uses of BIM tools are outlined in Figure 1 below.

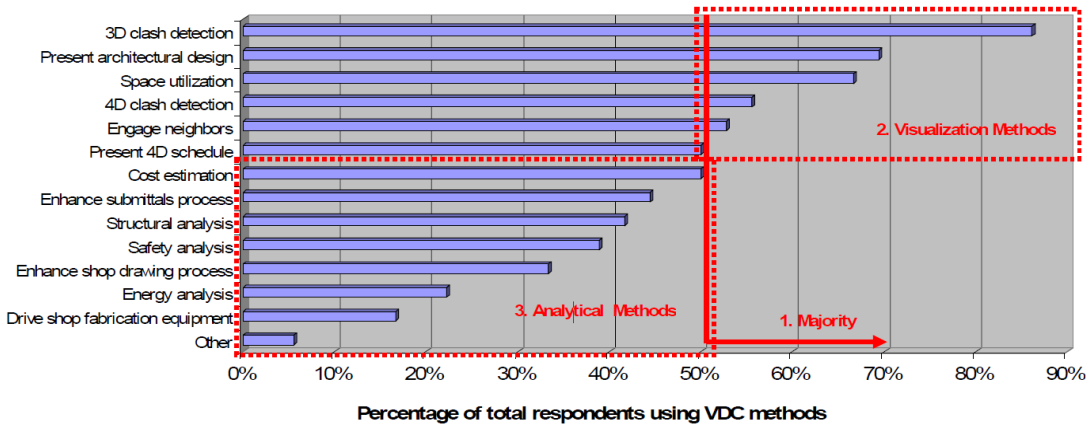

Figure 1 - CIFE Survey Results - Business Purposes for VDC (BIM) at individual organizations. Adapted from Gilligan and Kunz, 2007, p. 13

The findings of Gilligan and Kunz also showed BIM has uses in cost estimating, structural, safety, and energy analysis, and for producing shop drawings (2007, p. 13).

Literature describes numerous benefits arising from the use of BIM technology, but also many barriers against its uptake. These various factors will be further explored throughout this section.

2.2 Benefits of BIM

The benefits of BIM described by literature are numerous, ranging from improved sharing of information and better design (Azhar, Hein, & Sketo, 2008, p. 3), through to higher productivity, improved quality control and better communication (McGraw-Hill Construction, 2008, p. 2).
Some of the various benefits found include an estimated increase in productivity from 15 to 41 percent for structural engineering practices adopting BIM (Sacks and Barack, 2007, p. 1). Other benefits such as improved profitability were also found, with some citing returns on BIM investments of up to 9486% (Azhar et al., 2008, p. 9), caused by the elimination of on-site clashes and the associated saving of valuable time.

The literature describes many more benefits which can be found through the use of BIM, however only the ones most relevant to the Auckland AEC industry, and to this research, have been described in more detail below. “Better quality buildings at lower cost and reduced project duration” (Eastman et al, 2008, p. 1) succinctly describes the key benefits of BIM, as compared with the usual New Zealand AEC industry performance indicators of time, cost, and quality, these being the key measures of a projects success.

2.2.1 Improved Coordination and Clash Detection

A significant benefit of BIM is improved coordination of documents between the various designers and engineers involved in the design phases of a project, as well as the coordination of building structural elements, both with other structural elements and with building services systems. Khanzode, Fischer, and Reed found that labour savings of up to 30% (2008, p. 1) were possible through improved services

coordination due to BIM. The coordination benefits of BIM were also found to apply to specialist trade subcontractors such as precast concrete and structural steel manufacturers, who found that "pre-building" their part of the project could help to significantly "reduce the likelihood of errors" (Kaner, Sacks, Kassian, & Quitt, 2008, p. 3) that could occur on the construction site.

2.2.2 Pre Construction 3D and 4D Visualization

The use of BIM allows for buildings to be constructed virtually in a digital environment prior to physical construction commencing. The use of 3D visualizations in the early design stages, and prior to construction, allow both clients and builders "to feel what their project may look like" (Suermann, 2009, p. 29). BIM software can be used to produce 4D visualizations, which incorporate project construction programmes into the 3D building model. This allows users to see the sequence of construction activities condensed into a shorter timeframe, potentially highlighting logistical issues such as truck movements and crane swing areas.
On one project, Suermann was also able to quantify time savings of up to 19% on project duration when using 4D phasing visualizations (2009, p. 52).

Being able to visualize the building prior to construction, both in 3D and 4D, was also found to speed up the process of obtaining building permits, and reduce any misunderstanding of the design intent (Jongeling, Asp, Thall, Jakobsson, & Olofsson, 2007, p. 18), particularly useful in the types of fast-track projects BIM is often used for. Three dimensional visualizations were also found to be useful for avoiding design errors and issues in regards to "complex and congested arrangements of [embedded objects], reinforcing, and prestressed strands" (Kaner, et al, 2008, p. 4) in precast concrete panels, however this could just as easily apply to other areas, such as complex pipe and services runs, structural steel connections, or even concrete beam to column intersections (Constructing Excellence, 2008, p. 2).

2.2.3 Accurate Cost Estimating and Cost Management

By digitally constructing the entire building prior to starting on site, the use of BIM allows estimators and quantity surveyors to accurately estimate building costs, based on the quantities and schedules generated by the BIM model. These measures are also automatically updated by the BIM software whenever changes are made to the

model (Azhar, et al, 2008, p. 2; Alder, 2006, p. 20) ensuring schedules of quantities are always accurate. If this 5D data is incorporated into a BIM model in the early concept design stages of a project, it can help to quickly show clients the financial effects of change requests and other variations.

The accuracy of cost estimating with BIM however, depends on the BIM model being modeled accurately by the designers (Alder, 2006, p. 50). For example, the BIM model may output a square meter figure for walls to be stopped and painted, however this would not allow for unpainted areas of wall above a suspended ceiling. When takeoffs and estimates are performed using BIM, the quantity surveyor must be careful to understand exactly what the areas and numbers represent.

2.3 Barriers to BIM

Although there are numerous benefits involved when adopting BIM such as those described in 2.1.1 above, there are also other factors which impact negatively on the rate of uptake in the AEC industry. Barriers such as cost, training, interoperability, and changes in the overall design process are found often throughout the various literatures, and as such seem significant in setting back the adoption of BIM in the Auckland AEC industry. The most common of these barriers are described in further detail below.

2.3.1 Cost of Adopting BIM

The initial costs of moving from traditional 2D CAD based approaches to 3D+ BIM modeling are found to be significant, both in terms of the costs of BIM software, and in the upgrading of computer hardware to be able to handle BIM. The initial purchase cost of BIM software is typically a substantial investment, ranging anywhere from $3000 to $10,000 NZD (www.lbms.com.au).

As is further discussed in 2.1.2.3 and 2.1.2.4 below, the adoption of BIM can bring about the requirement for new staff roles such as an “Interoperability Manager” (Constructing Excellence, 2008, p. 4), and a “Structural Modeler” (Sacks & Barack, 2007, p. 449), further adding to the cost of BIM. These potential staff requirements are over and above the requirements for general drafting staff capable of using BIM. Some other staff requirements are also covered below in 2.3.2, 2.3.3, & 2.3.4.

2.3.2 Training and Upskilling

McGraw-Hill Construction found "training is critical to increasing BIM implementation" (2008, p. 4), showing that without adequately trained users, the extent of BIM use cannot progress forward. This was matched by the findings of Gilligan and Kunz who found that barriers were becoming less about technical issues such as hardware and software, but more about "training and availability of qualified staff" (2007, p. 1) suggesting that the technical development of BIM has come up to speed, but a cultural barrier is now all that is holding back the adoption of BIM.

The issue of training staff also has a great impact on the overall cost of BIM as described above in 2.3.1. The high initial investment cost for training of staff was described by much of the literature (Sacks et al, 2007, p. 446; Ireland, 2009, p. 26), but obviously a necessary requirement in the adoption of BIM.

2.3.3 Software Interoperability

One of the major barriers described by the literature is that of interoperability between the various BIM software packages available. Interoperability refers to the ability of individual BIM packages to be able to open and modify BIM models produced in other software, without the loss of any of the data inherent in that model. Although the International Alliance for Interoperability (IAI) has established the Industry Foundation Class (IFC) standard for BIM models (Suermann, 2009. p. 30), further research has found that the translation of IFC based models into other proprietary BIM systems is not fully accurate and some data is always lost (Amor, Jiang & Chen, 2007, p. 7). Interoperability was found to be a major requirement in ensuring the AEC industry gains further efficiencies in the future use of BIM (Amor, 2008, p. 1) highlighting the importance of different software packages being able to communicate with one another.

Constructing Excellence (2008, p. 4) found the issue of interoperability and software compatibility was being addressed by the software developers, who were working to improve communication between different packages without any loss of the intelligent BIM data. For example the Autodesk Revit software family includes specific standalone packages for Architecture, Structural, and Services (MEP), all of which are fully compatible with each other.

Also suggested was the establishment of a new role; that of an "interoperability manager", to "oversee and coordinate the model's information" (Constructing Excellence, 2008, p. 4). This proposed new role could potentially further add to the cost implications of BIM as identified in 2.3.1 above.

2.3.4 Changes in Design Process

The adoption of BIM requires a complete shift in the design process. Research by Sacks and Barack (2007) discussed a potential shift in workload towards the early stages of a project, when more engineering and design knowledge and skills would be required to produce the initial building model. This skew in workload structure was also found by Ireland (2009, p. 26) and Constructing Excellence (2008, p. 4), who also described the resultant shift in the loading of fees for professional design services.

BIM brings with it the requirement for those producing the building model to have more knowledge of the construction process, such as knowing exactly what is involved in the construction of "the real object" (Ibrahim et al, 2004, p. 1). This requires more skilled personnel, with expertise and experience not only in BIM, but also technical knowledge of the sector in which they are working (Kaner et al., 2008, p. 2).

Sacks and Barack also described the possible emergence of "a new professional role – the structural modeler" (2007, p. 449), with a greater engineering skill set than that of a drafter, but still competent in producing design documentation. These changes would require a shift in the designers/engineers to drafters ratio we currently see in architecture and engineering practices.

Some saw this "process paradigm shift" as a positive, potentially "[improving] quality and cost effectiveness" as well as promoting greater collaboration between project team members (McGraw-Hill Construction, 2008, p. 30), however most agreed that resistance to change was a key factor in preventing the uptake of BIM (Bernstein & Pittman, 2004, p. 8; Constructing Excellence, 2008, p. 4; McGraw-Hill Construction, 2008, p. 43; Yan & Demian, 2008, p. 4).

3 Methodology

3.1 Introduction

The purpose of this research is to develop an in-depth understanding of the current state of Building Information Modeling (BIM) use in the Auckland AEC industry. To achieve this, it is necessary to understand how BIM is perceived by the professionals working in this industry.

For the purpose of this study, the AEC industry will be split into four distinct groups; consultant architecture firms, consultant engineering firms, consultant services engineers, and construction main contractors. Each of these groups will have its own perception of BIM, and therefore will see different benefits and barriers to its adoption. This study will compare the views of each group with one another, as well as with the factors described in literature, to produce a snapshot of the current state of BIM use in Auckland.

Suermann (2009, p. 98) found that when his research began in 2006, there was limited empirical data available regarding the use of BIM, so a qualitative study was first undertaken to determine industry's perception of BIM. The same finding can be applied to the local environment, in that there is very limited existing literature or research in regards to BIM use in New Zealand. This is discussed under the headings research approach and data availability.

Suermann's research (2009) attempted to quantify the tangible benefits BIM had on the construction process, measured against leading Key Performance Indicators (KPI's), however, this research spanned a much longer period of time than is available in this instance, therefore this section will explore the reasons behind the use of a qualitative research approach.

This study will primarily attempt to create a snapshot of the current state of BIM use in the Auckland Architecture/engineering/construction (AEC) industry, and determine the key factors both for and against the use of BIM.

3.2 Research Approach: Qualitative vs. Quantitative

On the subject of BIM, Suermann noted that the amount of empirical data collected was not keeping pace with the rate of BIM implementation (2009, p. 24), perhaps due to the difficulty of quantifying the effects and benefits BIM has on the AEC industry. Currently, there is a limited existing body of research relating to BIM in the New Zealand AEC industry. This research aims to extend the understanding of the reasons for the slow uptake of BIM, specific to the Auckland AEC industry. The limited use of BIM in New Zealand to date means there are too few project examples to study, to be able to develop any meaningful quantitative data on BIM's effects on project key performance indicators.

These factors have led this study towards a qualitative approach, where interview data will be analyzed to discover what the key ideas and patterns are behind BIM use in the Auckland AEC industry. The qualitative methods of data collection and analysis are further discussed below.

3.3 Data Availability

There is a vast amount of literature available on the topic of BIM; a Google Scholar internet search returns approximately 1700 book, journal article, and research paper results for the search term "building information modeling". The issue, however, is that a majority of published research is based on overseas findings, which do not necessarily correlate to the New Zealand AEC industry. If the same search above is extended to '"building information modeling" + "New Zealand"', only 57 results are returned, many of which are not even New Zealand based, but only include the term "New Zealand" somewhere in the text. The only New Zealand based research papers that were found related to BIM model interoperability with fire engineering software (Dimyadi, Spearpoint, & Amor, 2008), and to the IFC interoperability standard (Amor, Jiang & Chen, 2007).

3.4 Participant Selection and Sampling

The Auckland AEC industry is made up of numerous types of organization, from independent architects, through to nation-wide construction contractors. These can be further sub-categorized into small, medium, and large enterprises, ranging from self-employed builders, through to companies with 500 plus employees.

Because of this large variation of samples within the AEC population, probability-based sampling would not be appropriate, as it may possibly lead to unsuitable participants being selected. This may include independent architects or builders who have had little or no exposure to BIM technology, and would provide little beneficial insight into the research issues.

For the reasons described above participant selection will be based on non-probability sampling, and more specifically, purposive (or judgmental) sampling, where the participants are 'hand-picked' (Denscombe, 2007, p. 17) because of attributes already known about them. In this case, those attributes will be based around the participant organization's previous, current, or future use of BIM, the organizations size, and the industry sector the organization operates in.

The participants will initially be selected from one of each of the following types of organization; Consulting Architecture Firm, Consulting Engineering Firm, Consulting Services Engineers, Construction Main Contractor.

From each of the organizations identified above, interviews will be held with employees at the engineering and design level, as these are the people who will have the most in-depth knowledge of BIM from using it on a day to day basis.

3.5 Sample Size

The sample size for this research will initially be limited to one interviewee from each organization type identified above. If possible, and time restrictions allow, additional participants may be selected based on the attributes described above. Additional participants can be useful as a way to corroborate the data found in the initial interviews, by the process of triangulation.

In regards to the proposed sample size, Denscombe (2007, p. 334) found it is difficult to estimate the appropriate sample size for qualitative studies, compared to quantitative research, where a statistical calculation can provide the exact sample size required. Generally, qualitative researchers aim to achieve saturation of data, whereby no new knowledge is being gained from additional data collected, and no new themes or patterns emerge from the data. Guest, Bunce, and Johnson (2006, p. 61) described how most literature prescribed continuing interviews until saturation was achieved, but noted that the term 'saturation' was often poorly defined, and

carrying out an indefinite number of interviews until saturation was achieved was usually not possible. The study conducted by Guest et al. (2006, p. 66) also found that most new information in their qualitative study (73%) was found within the first six interviews, further supporting the adoption of a small sample size.

Another contributing factor to the small sample size is the availability of appropriately qualified and knowledgeable (in regards to BIM) professionals in the Auckland AEC industry. Business and other commitments often restrict the time that industry professionals have available to take part in studies such as these.

The main determining factor for sample size, however, is the time available to undertake interviews and data analysis. The time required preparing for interviews, undertaking them, and the associated data analysis thereafter, is significant, and must take into account the final completion deadline for this study. It is simply not feasible to continue interviews indefinitely until saturation is achieved in the time available for this research.

3.6 Reliability and Validity

3.6.1 Reliability

Due to this research being based around a qualitative approach, there is an inherent element of unreliability due to the subjective nature of people's responses to interview questions, as well as the researcher being an integral part of the research instrument (Denscombe, 2007, p. 298). To ensure a degree of reliability, the methodology of this research is carefully detailed throughout this section to ensure similar findings could be achieved by other researchers if this study was to be repeated.

3.6.2 Validity

Creswell (2007, p. 206) describes validity in qualitative research as a measure of accuracy of the findings To ensure all findings can be deemed accurate, all interviews will be recorded by means of a digital voice recorder, which will then be transcribed. A copy of the transcription of the interview will then be given to the interviewee to confirm that what was said in the interview is concurrent with what is recorded in writing (Denscombe, 2007, p. 201).

Validity will also be achieved through triangulation of the initial interview findings, both with the findings of other research and literature, as well as time-permitting, further interviews with additional participants.

3.7 Research Ethics

Denscombe (2007, p. 143) discussed three underlying principles relating to research ethics. Firstly, the participant's interests should be protected, entailing that there should be no ill-consequences or repercussions due to their involvement with the research. This principle also considers the participants physical safety.
Secondly, participants will not be deceived or any misrepresentation made about the research and its purpose. All participants will be made fully aware of the reasons behind the research, and what the information they provide will be used for.
The third principle is that all participants provide informed consent to be included in the research. This will be achieved by ensuring participants are completely informed about the research using a project information sheet, and then give their consent on the participant consent form.

Participant confidentiality will be addressed by ensuring only the researcher and supervisor know the identity of those involved with the research. No real names of individuals or organizations will be used. These will instead be referred to by the industry sectors in which they operate, for example, architecture, structural engineering, or main contractor. Care will be taken so that neither individuals, nor organizations can be identified from details contained within the final report, such as identifying details of well known projects they were involved in. Neither will any personally identifying information be published in the final report.

All raw data and interview transcripts collected and collated as part of the research file, will be held by the research supervisor for five years to conform to the requirements of the Unitec Research Ethics Committee. After this period all data will be securely destroyed.

All participants will be made aware that they may end their involvement at any time throughout the research process, and that there will be no consequences to them from their withdrawal.

3.8 Data Collection Instruments

3.8.1 Interviews

Semi-structured interviews will be conducted with all selected research participants at a convenient time and date to both the participant and researcher. Interviews will commence only upon final ethics approval from the Unitec Research Ethics Committee, which is expected to be approximately mid-August 2010.

Interviews will be semi-structured in nature, and will likely be held in the business offices of the selected participants where possible. This will place the participants in a setting in which they should feel comfortable to respond to interview questions openly and honestly.

Interviews will follow a general interview guide as discussed by Turner (2010, p. 755), in that the interviews will be more structured than an informal discussion, but are flexible enough to allow questions to be modified or rephrased depending on the situation to get better responses from participants. This approach "[ensures] that the same general areas of information are collected from each interviewee" (McNamara, 2009).

The general interview guide will contain a number of base questions as outlined below, however if further information is required from the participant, these questions may be elaborated on to gain better responses.

3.8.1.1 Interview Questions

Interview questions will be split into three different stages as detailed below.
Stage one will be used to establish demographic information about the research participant and their organization, such as business size, typical project type, size, and value, and staff numbers. Most of the questions in stage one are closed and will therefore result in short, simple responses, but these are necessary to determine the participant's point of view for later responses. Additional care will be taken with the data collected in this stage, to ensure no details with which the participant or their organization could be easily identified with, are published in the final report.

Stage One Questions

- What type of project is your organization predominantly involved with?
- What type of work do you (and the organization) undertake on these projects?
- What is the typical size (and value) of these projects?
- How many people are employed by your organization?

In stage two the focus of questions will move to discuss how BIM is used by the organization and the benefits found as perceived by the participant. These questions will also become more open-ended allowing the participant to elaborate more on their responses.

Stage Two Questions

- "To what extent is building information modeling used by your organization? 3D modeling, or full 4D/5D time and cost data also?"
- What type of projects (type/size/value) has your organization previously used, or is currently using BIM on?
- "What benefits has your organization found in the use of building information modeling?"
- "Do you think the use of BIM has led to improvements in project time, cost, or quality factors?"

Stage three will investigate what the barriers were to the uptake of BIM and how these were overcome by the participant organization.

Stage Three Questions

- "What barriers were found in adopting BIM?"
- "Do the benefits of BIM use outweigh the barriers?"

Throughout these interview questions the participant will be invited to go into more depth with their responses and elaborate further based on their experiences with BIM.

3.9 Data Analysis Processes

a. Collate and Organize

The majority of data collected for this study will be raw text data in the form of interview transcripts. Before any meaningful trends or patterns can be gleaned from the raw data, it must first be arranged and processed so as to improve the ease of analysis. Suggestions made by Denscombe (2007, p. 289), to backup all data, both hard copies and electronic versions, arranging all data in compatible formats, and identifying each piece of data with a unique descriptor or identifying number, will be followed.

b. Familiarize

The next stage of data analysis entails becoming extremely familiar with the collected and collated data. This will involve reading and re-reading the transcripts until a thorough understanding of the data is developed, and any subtle or implied meanings can be picked up. Denscombe (2007, p. 291) found for example that silences or pauses, things that may not normally be noted on the interview transcripts, can be of significant importance in the data analysis process, as they may give entirely new meanings. This same issue was found by Fellows & Liu (2008, p. 188), who suggested keeping notes alongside interview transcripts to remind the researcher of all such pauses, hesitations and interruptions.

c. Coding

As transcript data is analyzed, content showing similar themes or patterns will be given a unique code relating to that particular subject. This will make these areas of similar content and meanings simpler to find and compare at a later time, by matching the codes observed. Codes will be developed throughout the data analysis process as new ideas and patterns emerge. As more codes become apparent these can be grouped into categories of similar ideas.

d. Comparison

Through coding, numerous themes and patterns should develop from the raw interview data. These will then be compared to see if similar ideas are found between the different industry sectors studied, to determine if factors affecting BIM use are

the same or different depending on industry sector. The data will be analyzed using textual (or thematic) analysis.

e. Representing the Data

Data will be represented in a matrix format. The matrix will use the interview questions to form the rows of a table, and the interviewees as the columns. This will make the data easy to compare between the different participants/industry sectors.

4 Data Interpretation and Analysis

4.1 Research Methodology – Proposed vs. Actual

There were no major differences between the proposed methodology, which was discussed in the previous section, and the actual methodology that was undertaken. The key point of difference however, was the number of participants involved. The original proposed methodology called for two or more participants from each of the four industry sectors, however due to time restrictions and the availability of suitably qualified industry professionals, only one participant from each sector was interviewed. It was found that of those organizations in the Auckland AEC industry that actually used BIM, many of the possible participants simply lacked the required time to commit to taking part in this research.

Due to the limited number of participants, this research is merely a snapshot of the current state of BIM use in Auckland, on which future research could be based to create a more in-depth picture.

Other aspects of the methodology were still followed, such as selecting participants using purposive sampling. This sampling method was suitable as all participants were selected based on information already known about them or their organization, such as the organizations previous or current use of BIM. Other aspects of the proposed methodology such as audio recording, transcribing, confirming transcriptions with participants, and thematic analysis of the resulting data were all still followed also.

4. 2 Data Collection

Data collection commenced in the month of September 2010, after gaining Unitec Research Ethics Committee approval, in a series of semi-structured interviews with architecture, engineering, and construction industry professionals. These included a design manager, senior structural engineer, project architect, and a services engineering 3D modeling manager based in practices in the Auckland area. These interviews varied from 35 to 45 minutes in length, and were all held at the participants business offices. The interviews all followed Turner's general interview guide approach (2010, p. 755). The interview guide questions can be seen in section 3.8.1.1 above. In total, the interview guide contained sixteen base questions.

All interviews were voice recorded with the permission of the participants, and were transcribed immediately following the interview. Completed transcriptions ranged from 3292 words and 216 lines up to 7216 words and 401 lines. This variance was mainly due to the depth of answers given by the various participants, and the pace at which the participants spoke, rather than the length of the interviews themselves. An excerpt from one of the interview transcripts can be seen in Figure 2 below.
The interview recordings were generally transcribed within 48 hours of undertaking the interview, to retain a fresh memory of what was said, and any other non-verbal cues.

To maintain a degree of validity, the completed transcripts were sent to the interview participants via email, for them to confirm that what was recorded was a true representation of what was said in the interviews. After checking the transcripts, the participants signed, dated, and returned them for record keeping.

47 then giving those developed drawings to our subs as part of the consultants drawings as well, and getting better
48 prices back from the trades. And the ultimate goal is to [ahh] stop any major issues on site, [umm] and it's a
49 difficult one to quantify because you do the BIM modelling, or you do any sort of coordination work in the office
50 and, hopefully it solves all those problems and you don't have any problems on site, but you don't see any value
51 in it at that point because, but if you hadn't done that process, then [laughs] you know, there could be a twenty
52 grand delay with cranes hanging around steelwork that doesn't fit, so it's kind of a catch twenty-two where
53 you're doing it and the project runs smoothly and it's like well, if we didn't do that would the project run so
54 smoothly, and no one's prepared to step back and not coordinate it and not do that.
55 CMC: So as you're saying, it's harder to actually quantify what that benefit is.
56 MG: Yeah, there's a definite benefit as I said before from us doing 3D little images and sketches and developing
57 the consultants information to the next level, and getting better sub prices, that is quantifiable, the subs are
58 going yep that's great. Some of the subs are actually now asking us to do shop drawings for them, so the terrazzo
59 guys, like the precast terrazzo stair drawings, and the handrail drawings, and [ummm] so the consultants will do
60 a design intent, and normally then we'd ask for shop drawings, you know, and then they get approved. Often
61 what we're doing is doing the shop drawings....
62 CMC: Getting them approved...
63 MG: Yeah, and were taking, say the terrazzo guy might have a fifty grand budget, to do the terrazzo stair treads,
64 and he had a three grand budget for shop drawings within that, we'll take the three grand and we'll give him a
65 forty-seven grand contract, so, you know, we're actually finding we're almost doing the sub trades shop
66 drawings, but that's good because we understand all the other things that are coming in like the glass, like the
67 inserts for the glazing, might be inserted into the terrazzo treads, so we understand the glass and everything, so,

Figure 2 - Interview Transcript Excerpt

4.3 Data Management

The raw data collected from the interview process, in the form of interview transcripts, equates to approximately 18,000 words over 30 pages. To make sense of all this raw text, each of the interview transcripts was broken down into sections, split by question as based on the interview question guide above. From here a table was formed with each row representing the different questions question, and each of four columns representing the interview participant/industry sectors.

From the transcripts, the responses of the participants were distilled down to the basic ideas, making the tabulated results much more concise. From this table, the basic patterns and trends could be made out, and the transcripts referred back to for a more in-depth understanding where required. The table can be seen at the end of this section.

4.4 Data Analysis and Coding

Data analysis was undertaken using a thematic analysis process, whereby the raw data in the form of interview transcripts was read, and re-read, until the content was familiar and could be recalled easily.

A simple code structure was developed based upon the initial literature review ideas and themes. Each of the key themes from the literature, including coordination, buildability, cost, and training was given a unique code number from 1 through to 10. The transcripts were then re-read, and wherever these ideas appeared, the related code number was written beside to make that area of text easily identifiable.

The codes used were as follows;

- (1) Coordination
- (2) Clash Detection
- (3) Buildability
- (4) Visualization (3D)
- (5) Visualization (4D)
- (6) Cost Estimating (5D)
- (7) Cost
- (8) Training
- (9) Design Process
- (10) Interoperability/Compatibility

Question		Main Contractor (A)	Structural Engineering (B)	Architecture (C)	Services Engineering (D)
1.1.	What type of project is your organization predominantly involved with?	Design and build Negotiated contract Some traditional tendered Public buildings/infrastructure Unique one-off projects	Commercial Health (hospitals) Public works	Commercial Retail (Shopping Centres) Various government projects	Commercial/Residential apartments high rise, 4+ levels, generally concrete or steel construction
1.2.	What type of work do you (and the organization) undertake on these projects?	Design and build – drives whole process from start to finish, employs design consultants, engages subcontractors for construction. Tendered projects, engages subcontractors to build project. Project management only.	Structural design and documentation. Structural design advice.	Architectural design Interiors design Building consultancy	Services design, including mechanical, electrical, hydraulic, fire engineering, acoustic design.
1.3.	What is the typical size (and value) of these projects?	$1.0 million - $20 million Generally around $10 million Generally nothing under $1.0mil	$5.0 million plus Up to $250 million plus	$2.0 million Up to $100 million	Any value at all, take any work available due to economic downturn
1.4.	How many people are employed by your organization?	Approx 15-18 office based staff 7-8 site based staff Auckland based only	30 Auckland based Around 100 NZ wide	Approximately 50 staff Auckland office	Auckland office 30 staff, globally 500. BIM related 4 in Auckland 100 globally BIM related

Figure 3 – Summarized Table of Findings (Page 1 of 4)

2.1. For what reasons does you organization use BIM?	Design and build all risk taken by contractor, better coordination to reduce risk to them.	Better coordination with other consultants	Coordination with other designers Faster production of documents	Explain designs efficiently Reduce mistakes in documentation Efficiently update all documents Better coordination with other consultants
Are other software packages such as AutoCAD used alongside BIM software?	Revit 2011 Revit MEP Evaluation Version ArchiCAD 14 AutoCAD	Revit Structural AutoCAD EMAPS Various structural analysis packages – Microstran etc	Revit Architecture ArchiCAD Artlantis Photoshop	Revit MEP AutoCAD MEP CUBE (Firm specific database) integrates with Revit Services analysis packages
2.3. To what extent is building information modelling used by your organization? 3D modelling, or full 4D/5D time and cost data also?	3d geometry, structural visualization, purely for coordination of Arch/Struct Some 4D visualization by 3rd party	3d geometry for producing construction documentation	Mainly 3d geometry for document production Some use of 4d and 5d currently in development	3d geometry, + object specific data, i.e. mechanical plant data, costs, flow rates etc
2.4. Is additional third-party software such as Navisworks or Vico used to produce the 4D/5D data?	No other software – clash detection done in-house within one BIM model. 3rd party consultant sometimes used to produce 4D virtualizations	Mostly done within Revit as other consultants also using Revit. Revit models being shared between consultants	Mainly done within Revit Vico Office package used for 4d/5d information	Navisworks, used to combine services BIM model with architectural model, structural model, to combine all information
2.5. What type of projects (type/size/value) has your organization previously, and/or	Any design and build projects where cost of BIM use can be absorbed into design fee	All new projects using Revit, currently 3rd party doing additional BIM (4D/5D) on $250mil Hospital project	All projects in previous years done in ArchiCAD. New projects being done 50/50 Revit/ArchiCAD	Not currently using a lot of BIM in New Zealand. Used on around 50% of projects

Figure 3 – Summarized Table of Findings (Page 2 of 4)

	currently using BIM on?				
2.6.	Where BIM has been used, how has its use been perceived by other organizations you deal with?	Clients 'blown away' by BIM use, and contractor stepping up to coordinate project to such a level. Consultants on 'back foot'/nervous of it as it shows up that initial design documents not up to standard when contractor highlights flaws made apparent by BIM use. Sub-contractors	Clients like it for 3D visualization of structure. Especially where non technical people can get better understanding	Clients like BIM use for 3D visualizations and virtual walkthroughs	Some major contractors asking for them to use BIM on projects (design and build). Major architects asking engineers to use complementary [BIM] software. Clients see benefits in using BIM model for building maintenance/management
3.1.	What benefits has your organization found in the use of building information modelling?"	Improved coordination, structural clashes with services, less site issues such as delays. Projects running smoother	Draftspeople get better understanding of how buildings are built. Means most things picked up before issuing documents, leads to better documents. Documents produced faster.	Staff in office upskilling, with better knowledge of building process.	Less mistakes in issued documentation. Less mistakes = less time redrawing = greater profit margin. 3d virtualizations easier for non-technical people (i.e. clients) to understand than 2d drawings.
3.2.	Do you think the use of BIM has led to improvements in project time, cost, or quality factors?	Projects always finished on time generally Quality of junction details possible improved, however not actual completed project quality. High standard usually expected	Possible improvements in time for contractors as RFI's easier to resolve	Yes, more complete documents, less RFI's, leads to smoother process on site	Unsure regarding improvements in time or quality, as only in a design environment. Certainly believes cost of design services lower as faster to produce documentation
3.3.	What barriers were found in adopting BIM,	Cost not a major issue. Always had cost of software/computer	Concept design stage slower as more engineering required initially.	Time required initially for training staff	Small issue in software costs & hardware costs, as slightly more

Figure 3 – Summarized Table of Findings (Page 3 of 4)

	and how were these overcome?	hardware, just increasing use of it to next level BIM software	Before could just draw simple beam outline at concept phase, now must know exactly what beam is. Learning curve for drafting staff		advanced than traditional CAD based systems. Some cost in training staff
3.4.	Was the upskilling and training of staff a barrier to the adoption of BIM?	No, BIM staff already trained prior to hiring, already capable. Some issue with making existing site staff aware of limitations and timeframes of BIM	No, was a commercial decision to be up to speed with latest technology.	Some downtime in initial training phase, but saw the upskilling as a benefit in making staff more multi skilled	Barriers overcome with in house BIM training centre at Melbourne office. 12 dedicated PCs for training only. All engineers given basic Revit training so they understand the requirements and limitations of the software, as well as the drafters
3.5.	Do the benefits of BIM use outweigh the barriers?	Yes, but not as a profit making venture, just to ensure smoother running projects, and less coordination issues	Yes	Yes	Does believe benefits greater than negatives, but participant admits they are biased. Agrees that drafters/modellers of future need knowledge of how buildings are built as well as how to draw them
3.6.	Does your organization intend to increase or decrease its use of BIM in future and why?	Probably stay the same. BIM/design management department/entire company not going to increase in size, so use of BIM will remain the same. BIM to be used on all design and build projects	Aim to increase use to all projects.	Increase use to all projects, and increase use of 4D and 5D through more extensive marketing	Trying to get to a stage where 100% of work is in BIM. However when working on changes to historical job, where work previously done in CAD, easier to redo in CAD

Figure 3 – Summarized Table of Findings (Page 4 of 4)

5 Findings and Discussion

The findings of this research have been related back to the findings of the literature review in chapter 2 above. This will provide a relative comparison between the expected findings as described by the literature, and the actual findings discovered in the Auckland AEC environment.

5.1 Current use of BIM in the Auckland AEC Industry

Of the participants surveyed, all were from medium to large organizations, consisting of approximately 30 or more employees, with between two to ten personnel directly involved in the use of BIM modeling and other drafting tools.

The current use of BIM in the Auckland AEC industry appears to be limited to producing 3D geometry, as a method of creating 2D construction documentation, as well as a basic 3D coordination, clash detection, and visualization tool. Only the main contractor participant had gone to the extent of 4D visualizations that incorporated time and programme data, although it was done on their behalf by an external BIM modeling consultancy. The architectural participant had also used BIM as a method of producing photorealistic 3D visualizations of proposed buildings as a way of showing their clients what the completed buildings would look like. This matches the findings of Azhar, Hein, and Sketo, in that “most companies use BIM for 3D/4D clash detections and for planning and visualization…” (2008. p. 4).

Only the architecture participant had gone to the extent of incorporating 5D, or cost data, into their models. From the other design consultant participant’s point of view, it was the construction contractor’s role on a project to establish construction programmes and costing data, so it was not in their interests to incorporate such data into their BIM models. On the other hand, the main contractor participant stated they were “nervous” about embedding cost data into the model, and preferred to “leave it up to our quantity surveyors” to estimate the construction costs using traditional schedules and take-off methods. This is obviously a cultural barrier to BIM, as although the main contractor participant has been innovative in adopting BIM, they are still hesitant in moving away from their traditional estimating methods, to a full 5D BIM approach.

5.2 Benefits of BIM

5.2.1 Improved Coordination

All of the participants highlighted improved coordination as the most common benefit of using BIM technology. This applies to the coordination of various structural elements, both between each other, and also with building services.

In one situation, the main contractor participant described receiving documentation for a traditional tendered project. “When we got the documentation from the consultants it was a complete mess”, described the complete lack of coordination apparent in the original documents. Due to a tight programme, the main contractor participant decided to take on some of the design risk to completely re-model the project in BIM. Through the use of BIM they were able to completely coordinate “the precast and steel and everything,” and construct everything on site “like a piece of Meccano.” This was all done despite coming to site four weeks late due to the re-modeling process, yet still completing the project on time and within budget. This highlights the benefit of the BIM coordination process, in being able to significantly reduce construction programmes by coordinating all the different structural elements and services.

The main contractor participant also explained how they used BIM as a tool for coordinating their specialist subcontractor’s work. For example, they would sometimes produce shop drawings themselves for items such as complicated precast panels where they also had the experience and knowledge of any other items interfacing with those panels such as glass balustrades.

The structural engineering participant also agreed that the use of BIM had improved coordination, particularly where all the designers involved with a project were using the same software, in this case Revit, but believed the coordination of the complete building including services was more the responsibility of the builder. This finding was matched by the architecture participant who found that coordination between the design disciplines worked much better when compatible software was used.

5.2.2 3D and 4D Visualization

Most of the participants used BIM as a tool for producing 3D visualizations of the buildings they were involved with. This varied from the services engineering participant using it to model complex pipe and duct runs around structural elements,

to the architect participant modeling an entire building to give their client a picture of the finished product. The architecture participant also described the use of the Vico Office software package which allowed them to incorporate the construction sequence into the 3D model and show what the project construction might look like at any given time.

Some of the participants described using 3D BIM modeling to model complex reinforcing details or other complex junctions to "coordinate things out on site" or "show them how everything might fit together."

5.2.3 Faster, More Accurate Construction Documents

Most of the research participants felt that BIM allowed for producing documents quicker and more accurately than previously, as per the findings of Woo (2007, p. 3). The services engineering participant explained that the use of BIM tools, Revit in particular, had reduced the number of mistakes in their construction-issue documents. He went on to explain that, where previously with CAD, "a simple change to one piece of your design, might have meant changing ten to twenty drawings" manually, the change was now being made once to the BIM model, and automatically propagated through all drawings and documents. The structural engineering participant agreed that changes were being made to the model once, but did not believe the reduction in time was so substantial. He suggested the design team and drafting personnel still had to manually check through every plan, elevation, and section to check that labels and other notes were still in the correct positions and that no other mistakes were present. The architecture participant also noted that the speed in which documentation could potentially be issued was a key benefit of BIM use.

5.3 Barriers against BIM

5.3.1 Training

The training and upskilling of staff was only seen as a minor factor in impeding the adoption of BIM by all participants. Methods of overcoming this barrier ranged from having a company in-house BIM training facility with 12 dedicated computers solely for staff training purposes, to hiring staff to the BIM modeling department who already had the skills, expertise, and competence to start BIM modeling immediately. Some of the participants believed that many coming into the industry now, such as

university architectural and drafting graduates, were already competent in many of the BIM modeling packages.

These results are in stark contrast to the findings of Gilligan and Kunz, who found that a “majority [of organizations] now see training and availability of staff as most limiting” (2007. p. 13). This contrast, however, may be attributable to improvements both in the ease of use BIM technology as commented on by the structural engineering participant, or the level of industry personnel training, in the three years since their report was written.

The architecture participant explained that the “time to train people up, and the cost for that” was an initial issue in the adoption of BIM within their office, however believed the continual training of their staff, which was done “in house” and “on the job,” was actually a benefit to the company. Their company’s plan was to train all of their staff in both ArchiCAD, which was already in use, as well as Revit, which they believed was more commonly in use in the AEC industry.

Another issue of staff training that was raised by most participants was that of the education of other staff within their organizations. Not those directly involved with BIM, but others who used the services of the BIM users as part of their day to day business, such as the site and project managers, or project engineers. These indirect users of BIM were required to be trained in the basics of BIM so that they would not expect too much from the BIM users, in terms of what was possible and how long it would take. This was dealt with by the services engineering participant who explained that all of their organization’s project engineers were sent to the training centre described above for basic BIM training.

5.3.2 Cost

Cost did not rank highly as a barrier to BIM to any of the interview participants, in terms of software cost, computer hardware cost, or training cost, as most participants saw the use of BIM as a natural progression of the business. The structural engineering participant described not using BIM as “falling off the back of the bus,” as it would see them fall behind the advancements of other engineering consultancies, and potentially lose future business because of it. The architecture participant also agreed it was a business decision to go forward using BIM, therefore the cost did not impact greatly on them adopting BIM.

The main contractor participant explained that they had always had license fees for CAD software, and always had the computer hardware associated with it, so there was no “spectacular” cost difference in license fees between CAD and BIM and the minor hardware upgrades required to run it. They saw BIM as “a tool of the job,” something that was needed, so therefore the cost of moving to a BIM approach was insignificant for them.

Much of the literature that described the cost of implementing as an issue (Holness, 2006, p. 42), is now a number of years old, therefore the cost of both BIM software and the related hardware may have reduced significantly since then, lessening the impact that cost has on the adoption of BIM.

5.3.3 Lack of Empirical Data Supporting BIM Adoption

Yan and Demian found that there was a “lack of case study evidence of the financial benefit of BIM” (2008. p. 4), which is matched by Suermann’s findings that there is a lack of empirical data to back up the adoption of BIM (2009. p. 24). The responses of the construction main contractor participant further support these findings, as they believed it was difficult to quantify the benefit of adopting BIM, both in terms of gained profit margins, or accelerated project durations. The only actual evidence the main contractor had supporting its use of BIM was anecdotal suggestions from site supervisors and project managers that the projects where BIM was used had run more smoothly. The likely reason behind this lack of data is that BIM is relatively young technology in New Zealand. Suermann’s report of 2009 made an initial step into producing quantitative data on the benefits of BIM, and was successful primarily due to the large number of potential BIM case study projects available in the United States and elsewhere overseas. Based on the services engineering participants estimate of approximately only 50% of their projects using BIM, and the main contractor using it only on their negotiated design and build projects, it would appear the number of projects in New Zealand making use of BIM is still too small to produce any meaningful quantitative data that could be further researched.

5.3.4 Change in Design Process and External Drivers

The use of BIM shifts more design and engineering work towards the front end of a project, as was pointed out by the structural engineering participant. Whereas previously during the concept design phase, an engineer could have used a simple

series of lines with an appropriate label to represent a beam in two dimensions, they must now know exactly what size and profile that beam is in order for the modelers to create an accurate BIM model. This is in line with the findings of the Constructing Excellence pathfinder project case study, which goes on to explain a "shift in fee structure will be required to reflect this" (2008. p. 4). Such a change in fee structure has already been undertaken by the architecture participant, who explained "we're changing our feeing structures now….. but it's a learning process for the clients to realize they're going to be paying a bit more upfront…." Further to this, the architecture participant went on to describe how with "some of the commercial clients it does take a bit of encouragement" to get them to agree to a higher proportion of fees near the start, compared to government clients, who are "very much knowledgeable and interested" in the use of BIM on their projects, and are willing to meet the costs of BIM to gain its benefits.

6 Conclusions and Recommendations

6.1 Conclusion

At this stage it appears that the Auckland AEC industry is only scraping the surface of what BIM is capable of. Instead of making use of the full n-D capabilities of BIM, most users are currently using it only as a 3D and basic 4D visualization and coordination tool with only some venturing the step further into 5D cost modeling.

The most common benefit found by the participants of this study was that of improved coordination between design disciplines, and the production of more accurate construction documents in a faster timeframe. The improved coordination also ensures the construction process runs more smoothly through fewer clashes, better buildability, and fewer requests for information from the construction contractors.

The main barrier preventing the uptake of BIM at this point is the change in design and construction process required. Commercial clients like and appreciate the use of BIM but in many cases require “encouragement” to invest in the higher design fees near the start of a project that BIM will cause. This is unlike government clients who were found to be “knowledgeable and interested” in having BIM used on their projects. Obviously as the knowledge of BIM that various clients have of BIM increases, more will become aware of the benefits associated with its use. The barriers of cost and staff training were not as significant as was described by literature (Gilligan et al., 2007; Holness, 2006) as for most sectors it was a commercial business decision to adopt BIM that would improve productivity and profit long term.

What has been made clear is that to make full use of BIM in the Auckland AEC industry, the whole process of design and construction must change. Fee structures must be skewed to match the greater workload of BIM near the start of a project, staff must be further trained and upskilled in the use of BIM, and a more collaborative approach must be taken to design, shifting to an integrated process where the various design disciplines work together more closely, both between themselves and the construction contractors. Currently, the most common method of

procurement in New Zealand is the traditional tender (58%) (Zuo, Wilkinson, Le Marusier, & Van der Zon, 2006, p. 3) which does not lend itself as much towards integration and teamwork as procurement systems such as design and build, or partnering/alliancing. This type of procurement system leads to those involved in the design and construction teams "[working] towards individually defined objectives that are often in conflict with one another" (Baiden, Price, & Dainty, 2006, p. 14), in stark contrast to what BIM aims to achieve.

6.1.1 Key Benefits of BIM in the Auckland AEC Industry

- Better construction document coordination.
- Faster document production.
- More accurate document production.
- Improved clash detection.
- 3D/4D visualization.
- Designers becoming more knowledgeable in the construction process.

6.1.2 Key Barriers to BIM in the Auckland AEC Industry

- More substantial design and engineering work required earlier.
- Drafting staff require more knowledge of the building process and require more design and engineering skills.
- Design process paradigm shift.

6.2 Recommendations

For the use of BIM to take off in the Auckland AEC industry, a further paradigm shift must take place, in making the design and construction process truly integrated and collaborative in nature. Procurement methods such as design and build, promote such an integrated design and construction process where the construction contractor is also the entity driving the design process. Similarly, project alliances also have such benefits of integration and collaboration.

The recommendation is for the industry to more frequently adopt such procurement methods so as to promote the integration of the design and construction teams. Also required is more education for potential clients on the benefits possible through the use of BIM.

6.3 Further Research

As the use of BIM in the Auckland AEC industry, as well as the rest of New Zealand, increases, more and more case studies and quantitative data will become available to study further. This will vastly expand the possible scope of future research, to extend from qualitative surveys to in-depth quantitative studies.

Possible ideas for future research include:

- A quantitative study into percentage of design and/or construction organizations using BIM in the Auckland and/or New Zealand AEC industry.
- A quantitative study to measure the actual effects of BIM use on construction key performance indicators of time, cost, and quality. This would be similar to Suermann's (2009) study, but in a local context. A study of this type would need a larger number of BIM enabled projects to be able to gather meaningful quantitative data.
- An in-depth case study into an Auckland or New Zealand design or construction organization which has adopted BIM, to fully detail all the benefits found by that company, as well as the barriers to BIM and how they were overcome.

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