University of Southern Queensland

Faculty of Engineering and Surveying

Investigation of Potential Benefits of BIM to Provide Efficiencies in the AEC Industry

A dissertation submitted by

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In fulfilment of the requirement of

ENG4111 and 4112 Research Project

towards the degree of

Bachelor of Engineering (Honours) (Civil)

14 October 2021

ABSTRACT

This research project was undertaken to understand the benefits and efficiencies that can be achieved with Building Information Modelling (BIM) and integrating the BIM methodology into an Architecture, Engineering and Construction (AEC) organisation.

BIM technology has existed for many years, though its widespread adoption into the AEC industry has only occurred in the last decade. It has already had a significant influence on the construction method.

BIM is a process for designing and managing construction projects. This collaborative approach enables stakeholders to engage more effectively, resulting in better project decisions. The BIM process can enable better design and construction, but its benefits extend throughout a building's full life cycle.

BIM has been lauded as a viable technology and approach for tackling the industry's traditional challenges. Certain areas of the industry still lag in adoption rates and full integration into the AEC industry is yet to be achieved.

The purpose of this study is to investigate the advantages of BIM adoption. A literature review and analysis of the findings has been carried out. A case study analysis of a small to medium sized engineering (SME) firm has been conducted.

The literature review found the benefits for organisations that use the BIM methodology are well represented for larger organisations. A gap in the research was identified where SMEs were concerned.

SME businesses comprise most of the construction sector. But are underrepresented in the research on BIM. The case study enabled a better picture of how the BIM methodology is used in an SME.

Recommendations have been made to do more study in the field of small to medium-sized businesses.

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I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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ACKNOWLEDGEMENTS

This research project was carried out under the supervision of Dr David Thorpe. I would like to thank Dr Thorpe for his advice on this topic and guidance for the research project.

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CHAPTER 1 – INTRODUCTION

1.1 Outline of Study

The AEC industry has always sought ways to lower project costs, improve quality, and speed up project delivery. The challenges of tightening time frames and ever-increasing complexity of construction projects have increased the search for more efficient construction processes. Building Industry Modelling (BIM) has shown to make these goals possible. Managing complex builds and client expectations in an increasingly competitive market, has driven the need for improved approaches to project delivery.

There is no official AEC industry implementation framework for BIM. Although the technology that underpins BIM has been available for some time, adoption in some sectors of the AEC sector has been slower than in others.

The aim of this research is to identify benefits that can be gained from BIM and the strategies and methods for wider adoption

1.2 Introduction

One of the most exciting advances in the AEC industry in the recent past is BIM. The technology is used to create a digital model for a project. The model is then used for planning, design, construction, and management. It allows architects, engineers, and builders to see and interact with a virtual representation of the project. This collaborative approach allows them to identify and rectify issues before they become critical.

While BIM is not a new technology, its true potential is only just being realised. It's had a significant impact on how buildings are developed, planned, and built. The origins of BIM can be traced back to the late 1970s and early 1980s. It developed from CAD programs, and it was not until the mid-2000s that the AEC industry widely used BIM, as it's known today (Salman Khalfan Tayyab 2012).

BIM is more than just software or a model of a building, it is a virtual process using three-dimensional intelligent models to design, build and manage a project. It integrates all facets, disciplines, and structures of a project into a single virtual model, enabling all stakeholders to interact more effectively than through conventional methods (Azhar, 2011).

Developing from CAD design programs, BIM solutions like Revit have helped the AEC industry not only envision 3D geometrical models, but also visualize and maintain interactions between objects above the level of knowledge shown in CAD solutions like AutoCAD (Vargehese 2020)

The BIM model centralises all the information and can then be used over the life cycle of the construction project. The model can contain the geometry, spatial relationships, geographic details, quantities and properties of building components, cost estimates, resource inventories, and project schedule. Team members can actively change parts of the model in response to project specifications and design updates, ensuring that the concept is as correct as practicable when the project begins. All project stakeholders should be involved as early as possible for the BIM process to be optimal (Salman Khalfan Tayyab 2012).

1.3 The Problem

The building industry contributes significantly to the Australian economy, both directly and indirectly. It hires about 1 million Australians and produced $212 billion in revenue in 2015-16. This accounted for 12.7 percent of GDP. It also provides the homes, towns, and facilities that makes Australia a more prosperous, liveable, and safe place. While boosting our national prosperity and well-being significantly. However, Australia's building sector has not significantly increased efficiency in decades and can waste up to 30% of its resources. This isn't just an Australian issue. It's a result of the building industry's structure, the increasing sophistication of its facilities, and the existence and function of "silos" inside the system (ACIF 2016)

BIM has been hailed as a promising technology and method for addressing the conventional issues that plague the AEC industry. Despite BIM being used by public and private AEC companies around the globe, complete implementation of BIM is yet to be achieved. Many building companies are concerned about introducing BIM because it can require improvements to their current business processes and involves significant financial investment (Abbasnejad et al. 2016).

Although the technology and process BIM has been around for more than a decade, adoption of new digital technologies has been slower in the construction industry than in other industries such as manufacturing (Chowdury Adafin Wilkinson 2019). The construction industry is grappling with how to incorporate and use BIM. Despite the benefits of the BIM methodology, it is still not universal in the construction industry.

SME organisations make up a significant proportion of the construction industry with small and micro companies accounting for around 98% of the sector in Australia and a similar number in the UK and the US (Hossenini et al. 2016). Large construction firms are usually the prime contractors on large-scale construction and development projects, with many smaller firms serving as subcontractors. Despite accounting for a small percentage of the total number of businesses in the industry, larger firms perform a disproportionate share of the work in terms of value (Brennan Vokes 2013).

These smaller organisations have historically been the slowest to implement BIM into their organisations. This is mainly due to of a lack of resources. Larger organisations have been the early adopters of this technology. While it is the case that the majority of larger organisations use the BIM model and process in their projects, further progress can be made to reach a point where the BIM methodology is the predominant approach. Incentives will continue to be needed to drive growth.

1.4 Research Objectives

This paper seeks to examine the benefits of BIM adoption. A literature review and an analysis of the findings will be conducted. A case study analysis will be completed from an interview with someone in the AEC industry.

Through a literature review, the intention is to identify the benefits for organisations adopting the BIM process. Identifying current best practices for implementing the BIM process and how these can be used in the industry more broadly to facilitate the increased adoption of BIM. The paper will aim to identify benefits in the design, construction, and management phases of a construction project.

1. What are the benefits of BIM use?

2. What efficiencies have already been realised?

3. Identify future efficiencies to be gained.

4. How is BIM being implemented?

5 Barriers to adoption and how to overcome these.

Based on these research questions, the objectives of this study are to:

1. Identify the benefits and efficiencies to be gained from BIM adoption.
2. How to facilitate the implementation of BIM.
3. Identify areas a reluctance in adoption.
4. Explore best practices for implementation.
5. Provide recommendations based on findings.

To reach these objectives,

Identify efficiencies from BIM use.

Identify where BIM is underrepresented.

Identify BIM implementation process.

Discuss findings and make recommendations.

Case study.

Analyse case study results and discussion.

Discuss findings and make recommendations.

1.5 Conclusion

This research project aims to contribute to the literature on the efficiencies to be gained from the BIM process. Through a literature review, this paper aims to understand how the BIM process can be adopted more broadly to a wider variety of organisations. A case study of a small to medium sized organisation has been completed to understand the role of BIM and how a smaller organisation benefits from the BIM process.

A literature review has been undertaken in chapter two to identify efficiencies to be gained from BIM and how these relate to the major areas of a construction project's life cycle. These are, the design phase, the construction of the project and the ongoing management of the assets once the project is completed. The BIM process has already brought significant change to these areas, but further efficiencies could be realised with a better understanding of the BIM process. With universal adoption, the AEC industry could experience better productivity and collaboration.

Chapter three of the dissertation contains the research methodology that has been used to guide the research on this topic. This chapter also outlines the case study research. The resources for the project and the risk management procedure are also outlined here.

Chapter four contains a case study protocol, and the approach taken to the research in this area. The criteria for the case study selection are discussed in this section.

Chapter five is where the case study is presented and the responses from the interviewee are discussed.

The research project discussion and findings are presented in chapter six. The research for the literature review is discussed along with the case study findings to present the benefits achieved by adopting the BIM process.

Chapter 7 contains the conclusions and the further research and limitations of the research project.

The outcomes of this study will add to the literature of the benefits of the BIM process in the AEC industry with an emphasis on how smaller organisation can benefit.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

The intention of this literature review is to analyse the literature on the potential benefits and efficiencies of BIM use in AEC organisations. It will focus on the design, construction, and management phases of a project. This literature review will evaluate the characteristics of the industry, the potential efficiencies to be gained and how implementation can be accelerated.

AEC projects are becoming increasingly more complex. This has been enabled by a combination of technological advances, client expectations and shrinking timelines for projects. This means there is a need for efficiency gains to offset these new normal practices.

The historic challenges that the construction industry has faced, such as limited collaboration and loss of productivity due to rework, are issues that will only be exacerbated by the increasing complexity of projects.

The adoption of the BIM process can enable better collaboration between different stakeholders on a project. This literature review analyses the previous research in this area to help understand where the BIM process is delivering advantages to AEC organisation and how they can further drive adoption rates.

2.2 Development of BIM

BIM is one of the biggest technological changes to be adopted by the AEC industry in recent years. The concept of BIM has been around for decades but only since the mid-2000s has its use become more widespread. It has gone through several developments to become the fully integrated software we know today. The early concepts were developed by allowing more information to be added to CAD programs, for example, time, cost, manufacturer's specifications, and maintenance information (Wierzbicki 2011).

Construction projects prior to BIM development used CAD programs to design the project. These drawings and plans were then shared between stakeholders. This process is one of the major contributors to the siloed culture of AEC industry. Collaboration between stakeholders is hindered by the slow process of sharing documents. Now having developed from the concept of object-based CAD, which could store information on individual objects in the design. BIM now integrates all aspects of the design and model into a central repository (Gerrard Skitmore Zillante Zuo 2010).

As design technology has increased in the last few decades, this has increased the complexity of building and infrastructure design. Introducing CAD software changed the way drafting was done and allowed more complex designs. The continuing development of BIM has allowed the design and fabrication of engineering and architecture that would have not been possible only a few years ago (Aliabadi Mirsharafi 2013).

The broad evolution of CAD to BIM involved several steps. Building Description Systems (BDS) was introduced to allow easier coordination during the design phase of a project. Following BDS, a Graphical Language for Interactive Design (GLIDE) was introduced and incorporated into parts of BDS. This allowed integration of more data associated with some design elements. In 1989, Building Product Model (BPM) was available, and this program allowed further integration of information, including design, estimation, construction processes. Generic Building Model (GBM) expanded on the BPM model and could integrate information from the life cycle of the project. The AEC industry continued to increase in complexity and with the further advances in technology. BIM has been developed to become a fully integrated software which allows improved processes and increased efficiencies from design to post construction (Latiffi Brahim Fathi 2014).

2.3 Role of BIM

BIM is one of the most promising developments in the recent history of the AEC industry. Although the concept and variations of the technology have been around for a couple of decades, using BIM is still far from universal. The technology provides an accurate 3D virtual model of the building and its internal systems. The model can then be used for all the stages throughout the entire project. From planning, design, construction, maintenance, and operation of the building the model is a simulated environment where issues and changes in any of the stages of the project can be identified and managed in real time (Appiah 2020).

A misconception is that BIM is just a software for 3D construction plans. It is a process and a software. It allows all stakeholders in the project to integrate their people systems, business structures into a collaborative process that has the aim of improving efficiency throughout the project (Azhar 2011). The traditional design and construction model in the AEC industry based around conventional CAD describes a building and its components in independent parts. This includes plans, elevations, and separate sections of the building. Revisions to the plans require all other parts to be revised manually or problems will arise because of clashes in the construction phase. In contrast, the BIM process includes all the information and changes can be collaborated on in real time (Salman Khalfan Tayyab 2012)

When the potential is fully realised, the model can represent and show the entire life cycle of a project. The model can give access to building geometry, geographical information, spatial relationships, quantities and properties of building elements, cost estimates and project schedules (Azhar Leung Mok Nadeem 2008).

The aim of BIM is for efficiencies in integrated workflows, this can be achieved by eliminating duplicate and non-contributing tasks and process bottlenecks. Implementation of BIM into a project has been shown to lead to increased productivity among all stakeholders. These gains can be realised not just in the project itself, but along the construction supply chain as well (Abbasnejad et al. 2020)

2.4 Industry Productivity

The construction industry is an important part of the Australian economy. It consistently generates around 9-10% of Australia's GDP (AISC 2020). Efficiency gains in the sector would have significant positive effects on the economy. Despite this large contribution to the economy, the construction industry has historically lagged other industries in efficiencies improvements.

For example, in a report by Procore Technologies, 86 percent of respondents think increasing technology usage is an important means of improving productivity (Everthought Education 2019), they also found 12% of construction time is spent on rework. This is a significant amount of time and has been largely eliminated in other industries such as manufacturing.

This is not a uniquely Australian issue but one of the construction industry in general. There haven't been substantial productivity gains in the Australian construction industry in decades. The Australian construction industry forum has found that promoting BIM is in the top three recommendations the construction industry must improve efficiencies (ACIF 2016).

In the European Union, where the construction sector also makes up around 9 % of GDP, productivity is also lagging other industries. Productivity gains have been non-existent over the last 20 years, while the manufacturing sector has seen gains of up to 3.6% over the same period. (Varghese 2020)

A significant amount of time is wasted in the construction industry. Up to 30% of time can be underutilised on non-optimal activities and rework (Roads & Infrastructure Australia 2018). Even a modest increase in the productivity would realise huge gains in economic output because of the industry's share of GDP. This report highlights the areas of non-optimal work include:

- Looking for project information
- Conflict resolution
- Dealing with mistakes and rework
- Poor communication between stakeholders
- Lack of confidence in data accuracy
- Delays in receiving information

These are all areas that represent possible efficiencies gains from the use of BIM.

2.5 Fragmented Nature of Construction Industry

The AEC industry has many stakeholders that are involved through various stages in the life cycle of a project. This can lead to a siloing effect of certain areas with inadequate collaboration. The sequential nature of a construction project can add to the fragmented nature of the process, where each step is done with brief consultation with the next (Nawi Baluch Bahauddin 2014)

Another symptom of the fragmented nature of the construction industry is poor communication. This occurs throughout the project and can lead to unnecessary work or increase the work that needs to be re-done.

In the literature, communication has been highlighted as a key goal of industry to provide a more efficient process. A barrier to more successful communication between stakeholders is the short time frame of building projects and the more temporary nature of staffing as compared to other types of organisations. Other sectors that have more permanent staff can train their staff over years in effective collaboration techniques (Tobias 2018).

Lack of time has put restraints on the planning capabilities of managers traditionally tasked with this role. Time restraints due to increased workload influences the quality of the planning (Tallgren et al. 2020).

2.6 BIM Adoption in Australia

The adoption of BIM has been uneven among different countries (Ozorhon Karahan 2017). In Australia, BIM adoption is growing, with substantial progress made over the last decade. Despite this development, the bulk of Australian organisations continue to use the most basic version of BIM rather than fully integrating it into their work process (Hosseini et al. 2018). Full integration of BIM into the organisation is the goal of the BIM methodology.

BIM usage in Australia reflects other countries with wide adoption rates, in that larger organisations have higher adoption rates than SME organisations.
Some large organisations have adopted BIM at higher rates because it considered as essential for business growth (Acar et al. 2005,) larger organisations also have more resources at their disposal for training and implementation.

BIM mostly is not mandated for use in Australia. For the most part, Australia has yet to require the use of BIM in significant projects. Other countries offer differing approaches to drive adoption, but mandates are becoming more common. Open BIM standards are used in Norway and Austria. Countries such as the US the UK, Singapore and parts of Europe are at the forefront of BIM adoption, with their governments mandating BIM for construction processes (Hire et al. 2021)

So, while there are no blanket government requirements in Australia currently, the Australian Government's Standing Committee on Infrastructure, Transport, and Cities advocated in March 2016 to make BIM mandatory on government-funded infrastructure projects costing more than $50 million. Queensland has BIM implementation requirements. In 2017, the Queensland Department of Transport and Main Roads issued a draught policy and principal paper, while the Queensland Department of Transport and Main Roads issued a supplementary guidance for utilising BIM in road infrastructure.
In addition, the NSW Government enforced the use of BIM for Sydney Metro Northwest, formerly known as the North West Rail Link (Morrissey 2020)

2.7 Collaboration

A major factor in the successful delivery of a project is collaboration. Traditionally, this has been lacking in the wider AEC industry. It has been shown that a lack of collaboration can cause poor relationships when problems arise. This can mean processes involve waste and can be litigious and antagonistic (Poirier Forgues Staub-French 2016).

The research shows that collaboration in the AEC industry has room to improve and efficiency gains are likely to come from these. Overcoming ingrained practise can be difficult. Many participants in the design and construction process only work together on a specific project and then only when is necessary. For a more collaborative environment, new ideas about collaborative work and new processes need to be adopted (Leeuwen Fridqvist 2006). The research has shown several approaches the AEC industry could adopt to improve in this area.

The large number and variety of stakeholders in AEC involved in a construction project can make effective collaboration difficult. In ‘Understanding adoption and use of BIM as the creation of actor networks’ Linderoth argues that “a characteristic of the AEC industry is the disruptive nature of the networks that make up building and construction projects” (Linderoth 2010). This disruptive nature presents challenges for the AEC industry to overcome. These include the transfer of knowledge from projects to the within the organisation itself. BIM can provide a unique method of overcoming these challenges when implemented successfully.

Linderoth suggests while it’s possible for BIM to address these challenges, the greater challenge is, the benefits from the technology use are not only achieved on temporary basis but are maintained and become permanent structures of the organisation. Linderoth writes “Therefore, the challenge for the permanent organisations involved in a project is to transfer and routinise benefits achieved in one project network with a constellation of actors to a consecutive project network with another constellation of actors” (Linderoth 2010).

2.8 BIM Methodology

BIM is a collaborative working methodology used to create and manage construction projects from conception to completion and into the management phase by project stakeholders engaged in the construction process. The method allows all phases of a building project to be seen in 3D prior to construction and facilitates better collaboration (Munoz-La Rivera 2019).

BIM is process for creating and managing building data throughout the life cycle of a project. This collaborative working methodology is used by all project stakeholders engaged in the construction process. The method allows all phases of a building project to be seen in 3D prior to construction and facilitates better collaboration

(Munoz-La Rivera 2019). The process results in the creation of the building information model, which contains all necessary data pertaining to building geometry, spatial connections, geographic information, and quantities and attributes of building components. Construction technology for the BIM process is always evolving. The construction industry is currently in a transition from a 2D to a model-based environment (Kubba 2012).

With such a shift in the traditional method of working, there can be risks. Azhar identifies one area in the paper 'Building Information Modelling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry', he states "Perhaps one of the greatest risks is the potential elimination of an important check and balance mechanism inherent in the current paradigm. An adversarial stance often brings a more critical review of the project in a kind of mutual guarding of each participant's own interests" (Azhar 2011).

2.9 Innovation

Innovation in the construction industry have led to many important changes. These include innovations in safety, industrial relations, plant technology and regulations. These innovations have produced a safer and more efficient industry. There is still a perception that the construction industry is not as innovative as it could be. AEC organisations need to innovate to win projects, improve the financial results of these projects and to compete in an increasingly competitive market. Development and effective use of new technology can provide important competitive advantages for AEC organisations. These advantages stem from distinctive technical capability, improvements in operations and image as a technically progressive company (Blayse Manley 2004).

Construction practices are rooted in tradition, with many procedures unchanged in decades or more. Some procedures are unlikely to be revolutionised, like in other industries. For example, repeatable tasks in manufacturing can be done by robots, but although there are many repetitive tasks in construction, they often occur in different and inconvenient locations, making automation difficult.

2.10 Industry Adoption

Over the last two decades, AEC firms have increasingly adopted BIM into their operations. This has been led by complex projects and advances in technology. BIM was traditionally used by architects but is now moving toward all disciplines across the AEC industry (Talebi 2014). Implementation of BIM by AEC firms has shown the benefits are reflected in all aspects of the project's life cycle (Yan et al. 2019). Despite these well-documented benefits, there is still some obstacles to BIM adoption in the wider industry. BIM is most used in large-scale projects and has been shown that the implementation of BIM is influenced by the size of the firm. In "Influence and Adoption of BIM with the AEC Industry" Varghese found that in Engineering, 85% of large firms had adopted BIM vs. 71% of small firms. In Construction contractors it was 81% of large firms had adopted BIM vs. only 54% of smaller firms (Varghese 2020).

2.11 Implementation of BIM

Despite the widespread use and accelerating adoption of BIM in the AEC industry, there is still considerable room for growth. In the European Union, 29% of construction firms have used BIM regularly whereas 61% haven't fully transitioned from CAD to BIM (Varghese 2020).

Levels of maturity are used to represent the stages BIM from its entry level (basic form at adoption point) to its most complex and fully integrated form (McCuen et al. 2012)

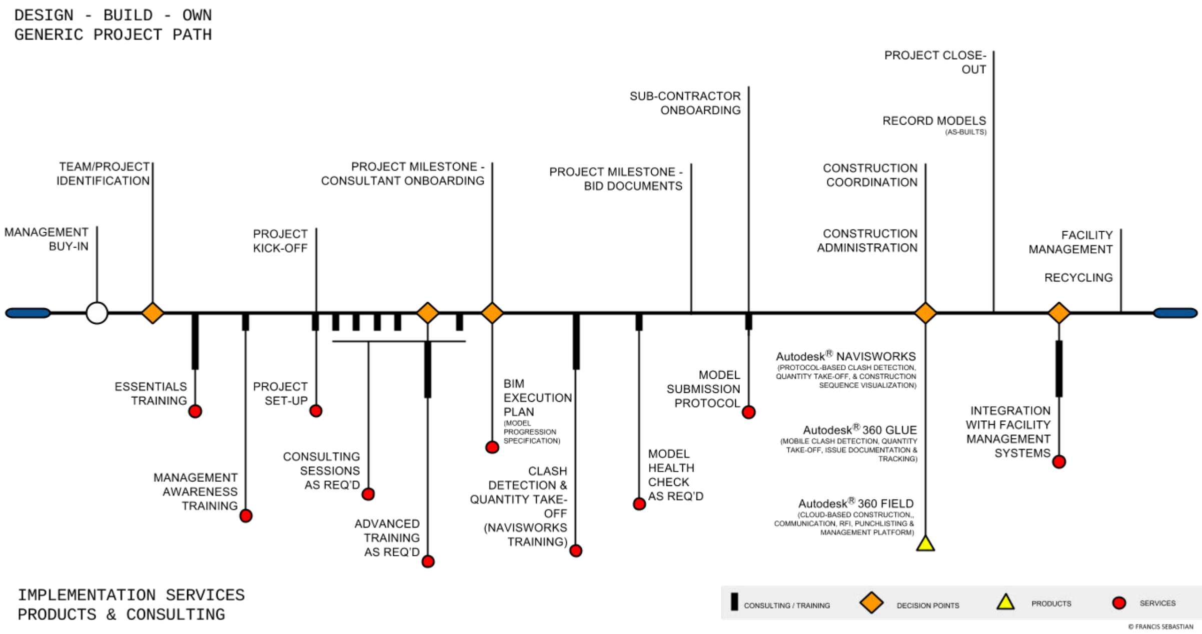
An organisation's willingness, motivation, and capacity to adopt BIM are influenced by a variety of factors, but key areas include the organisation's size, customers, and area of expertise (Hosseini et al. 2018).

The decision to use BIM and adopt the BIM method in AEC firms may be thought of through the perspective of innovation diffusion theory. This theory, developed by Everett Rogers in 1962, explains how and at what rate new ideas and innovations can spread among a social system. (Agarwal et. al 1998). As a result, organisations' first contact with BIM includes deciding whether to utilise BIM or stick with traditional design, construction, and management processes. The deciding factors to move from traditional method to BIM is often due to market pressure, customer expectations, and bandwagon effects, such as pressures resulting from an awareness of the large number of businesses that have already embraced BIM (Hosseini et al. 2018).

Different nations have had varying degrees of BIM adoption (and subsequent implementation). BIM adoption is growing in Australia, with substantial progress made over the previous ten years. (Hosseini et. al. 2018). Despite this accelerating adoption of BIM in the AEC industry, there is still considerable room for growth. In the European Union, 29% of construction firms use BIM regularly, whereas 61% haven't transitioned from CAD to BIM (Varghese 2020).

To establish an analytical framework for understanding the implementation of BIM into an organisation, Succar, in “Building Information modelling framework: A Research and delivery foundation for industry stakeholders” developed maturity stage categorisation for the levels of BIM use in an organisation.

The levels of BIM maturity provide a classification of BIM implementation. These stages are used as a benchmarking tool to offer a clear picture of where an organisation stands in terms of BIM development. The BIM maturity levels are described in the Khosrowshahi et al. in Roadmap for Implementation of BIM in the UK construction industry (Khosrowshahi et al. 2012). These maturity levels are outlined briefly below.



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2.11.1 BIM Maturity Levels

The pre-BIM stage:

Pre-BIM stage refers to traditional construction practices which have significant inefficiencies.

The primary example in this case would be project information stored on paper as drawings and written documents.

This is an inefficient system that can be unstructured and difficult to maintain. Documents can easily be misplaced or destroyed. Inadequate information management systems can cause problems in the construction phase of a project, including incorrect initial work with rework required or avoidable clashes between components. The lessons gained from these issues are then often not taken onboard as records can be difficult to organise.

BIM Stage1:

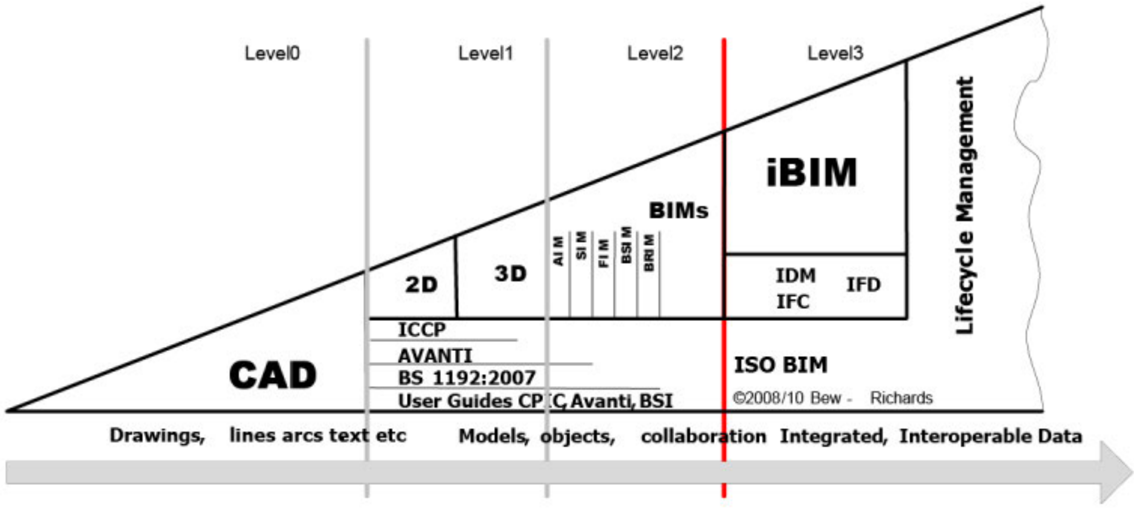
The migration from 2D to 3D, as well as object-based modelling and documentation, referred to as Stage 1. Architectural elements are reproduced properly in all perspectives in the BIM model. Existing contractual ties and responsibility concerns continue in the BIM model, which is still single-disciplinary and produces primarily CAD-like documents (Khosrowshahi et. al. 2012).

BIM Stage 2:

Stage 2 is defined by collaboration and interoperability. Building design and management is a complicated process that causes effective communication and coordination among all project stakeholders. To enable this collaborative approach, Stage 2 maturity causes integrated data communication and data exchange across stakeholders (Khosrowshahi et. al. 2012).

BIM Stage 3:

Stage 3 reflects the true BIM Method. There is a transition from collaboration to integration. Project life cycle stages are reduced significantly at the stage 3 maturity. This happens as stakeholders interact in real time. Eliminating unnecessary back and forth with design changes and revisions. BIM models allow complex analyses at early stages of design and construction. Model outputs at this level include business intelligence, lean construction principles, green policies, and entire life cycle costing (Khosrowshahi et al. 2012)



F g 2 - BIM Matur ty Leve s (b b us 2019)

2.12 Enablers of BIM Implementation

The literature reveals that smaller organisations are lagging larger firms and governments when adopting BIM. This is due mainly to a difference in resources. To increase the usage of BIM, other strategies may need to be employed. One avenue could be to require the use of BIM for certain types of projects. In 2007, Denmark passed a law mandating the use of BIM during labour procurement and commission of projects (Varghese 2020). Other examples in this area are in the US, where an increasing number of large institutional clients now require BIM as a part of the tender process. While in the UK, the government required the submission of a ‘fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016’ (Succar et al. 2012). The literature has shown that without some form of intervention, the take up of BIM will continue to be slow.

The role of government in driving BIM in Australia has mainly been the development of standards and protocols regarding BIM usage (Liu et al. 2015). In their paper ‘The driving force of government in promoting BIM implementation’, Liu et al. conclude that the government can play an important role in laying the groundwork for further BIM implementation. They wrote, ‘The driving force of government can support the industry and academic community in implementing BIM, as government legal and mandatory instructions can promote new technologies directly or indirectly (Liu et al. 2015).

The BIM implementation process involves government staff, university academics, industry staff, and university students. BIM technology connects these related participants. Under the guidance of government responsibility as the driving force, the promotion of BIM technology can be accelerated’ (Liu et al. 2015).

With BIM being a process that requires organisational change, bringing in this change needs to come from the top of the organisation. They need to be open to organisational change in the name of efficiencies and better overall performance. BIM prospers in an organisation that is open to innovation and where mistakes can be seen as learning opportunities (Abbasnejad et al. 2016) Organisations with this culture will see the benefits from the BIM process and continue to edge ahead of their competitors.

2.13 Barriers to Adoption

In Australia, SMEs are classed as firms with less than 200 people, this accounts for most firms in the AEC industry in Australia. Despite the growth of BIM, SMEs have been slower to adopt BIM (Hosseini et al. 2018). In the literature, several reasons have been identified as the most common for not embracing the BIM process. Inadequately trained staff is identified as a barrier to implementing the BIM. Without the resources to train staff or hire more staff, smaller firms continue to rely on the more traditional CAD programs and workflows (Hong et al. 2018). Another barrier to BIM adoption identified by Yan and Damien of Landsborough University was the perceived lack of evidence that it will benefit their business, citing the lack of good case study evidence for the financial benefits (Yan Damien 2008). The initial investment has been identified as another barrier. This reluctance to outlay the significant cost can be related to the lack of good case study evidence for the business case for smaller firms. Cultural resistance, including ingrained practices, is another barrier to adoption. Reluctance to share information or satisfaction with current methods and a lack of desire to change has also been identified (Ademci Gundes 2018).

The lack of client demand was highlighted in the literature to be a barrier to adoption for smaller organisations. In ‘Barriers and facilitators for BIM use among Swedish medium-sized contractors’ Bosch-Sijtsema reported interviewees reported that a barrier for the organisations to adopt BIM was that “the client possessed significant power, and that the clients did not require or request for the use of BIM in the construction projects” (Bosch-Sijtsema 2017).

Because of these varying degrees of readiness to implement the process of BIM. Different approaches will be needed to drive further adoption in the AEC industry in Australia and abroad.

2.14 Current State of BIM

BIM has been available for around two decades now and more organisations are adopting the BIM process, but there is still room for growth. There was early adoption in the USA and other countries have continued to increase their adoption of BIM. Several governments have now set targets for BIM usage on public sector projects (Eadie et al. 2015). Many countries in the European Union now mandate public sector projects use BIM (Smith 2014). This acknowledgement by governments that BIM is the future is a critical step towards further implementation.

In the UK, BIM currently operates under different industry standards. These standards set out common methodologies and codes of practice that ensure that the BIM process is a sustainable approach to design construction and management. In the report ‘A survey of the status and perceived changes required for BIM adoption in the UK’ identifies a number of organisations adopting their own ‘office standards’ for the use of BIM (Eadie et al. 2015). They found in a survey 28.55 of respondents said they had adopted their own standards. The BIM process is one of a collaborative approach. If organisations move to set their own standards and practices instead of operating under a recognised industry standard, it could lead to further fragmentation and inefficacies (Eadie et al. 2015)

2.15 Benefits of BIM

The benefits from BIM are well documented in the literature. BIM has a potential to produce efficiencies at all stages of the project life cycle. It can be utilised by the owner to consider project requirements, the planning team to assess, design, and build the project, the builder to oversee the project’s development, and the facilities manager during the service and decommissioning processes (Bryde Boquetas Volm 2013)

Information sharing and management is a major benefit to using BIM. This collaboration can benefit all stages of a construction project.

The literature shows benefits have been realised in several key areas. In 'Current Use of Building Information Modelling Within Australian AEC Industry', Alabdulqader et al. interviewed several organisations. They were asked about the benefits of BIM in multiple aspects of the AEC industry. The major benefits were organisational, design and economic.

These included:

Organisational and operational benefits:

- reduce fragmentation in the AEC industry
- improved efficiencies
- improvement in the exchange of information
- increased communication across the entire project development team

(Alabdulqader et al. 2013)

Design perspective:

- ease of visualisation
- rapid and accurate updating of changes
- clear improvement in engineering design quality in terms of error free drawings

(Alabdulqader et al. 2013)

Economic:

- removal of unbudgeted change up to 40%.
- accuracy in cost estimation within 3%.
- decrease in time taken to produce a cost estimate up to 80%
- decrease in project time up to 7%

(Alabdulqader et al. 2013)

Overall, BIM has improved project coordination, minimised errors, as well as reduced delays and conflicts, which could lead to a potential saving in construction cost alone ranging from 15% to 40% (Alabdulqader et al. 2010)

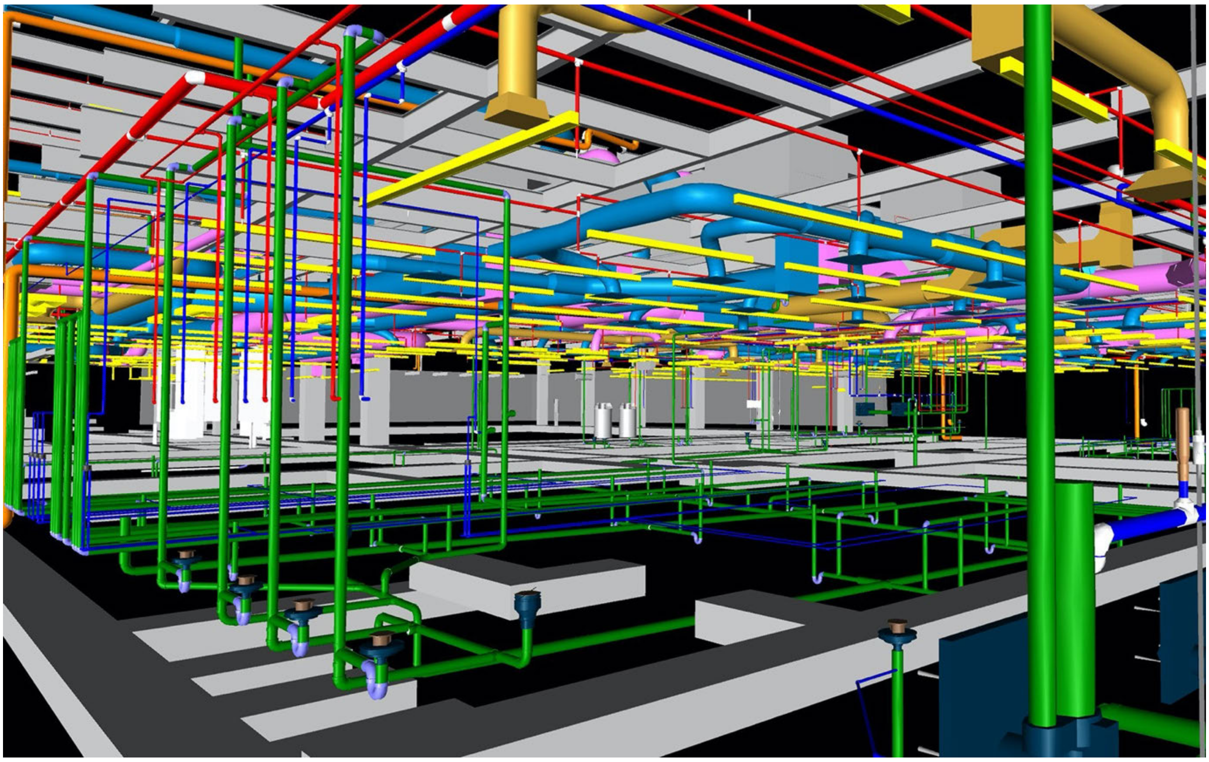
2.16 Planning

The planning stage can enable information and knowledge to be stored in a central BIM knowledge repository (Yamamura Fan Suzuki 2016). The information in the BIM repository will be valuable during the design and construction phases.

2.17 Design

The major aim of the design stage is to assure the production of design and construction documents necessary to ensure that the building is functional and sustainable. The effectiveness of the iterative design process depends on the sharing of information and expertise. At the design stage, BIM creates a collaborative platform for exchanging information. BIM facilitates the seamless exchange of data created during the design phase (Lee Jeong 2012). The flow of information and knowledge promotes the coordinated and collaborative environment required to guarantee the efficient integration of building systems to achieve the desired building performance. The seamless interchange of data from design reviews and building performance analysis will ensure that the optimal design is achieved (Fadeyi 2017).

Elluman and Gilder found that design management decisions should not be limited to one person but involve several professions to consider all outcomes (Elmualim Gilder 2013). This more collaborative approach eliminates much of the back and forth which is the current model.



F g 3 - MEP serv ces des gn n BIM (BakerNow ck 2021)

BIM allows work by multiple design parties. This shortens the design time and significantly reduces design errors and omissions. Clash detection is highlighted in the literature as a major benefit to designers and can also directly benefit from the construction phase. BIM facilitates communication between designers, assuring them that there will be no clashes, conflicts, or errors in later stages (Afsari 2012)

Instead of being created from various 2D views, a 3D model is created. This model can then imagine a concept at any point during the development (Eastman et al. 2018). Accurate and consistent drawings will save a significant amount of time and money. For any set of objects or specified view of the project, these types of drawings may be created directly from the 3D model. When design adjustments are necessary, fully consistent drawings can be produced as soon as the design changes are entered (Eastman et al. 2018).

Through the parametric rules that ensure proper alignment of features of the 3D model, the design can be free of geometry, alignment, and spatial coordination errors. This reduces the user's need to manage design changes (Eastman et al. 2018).

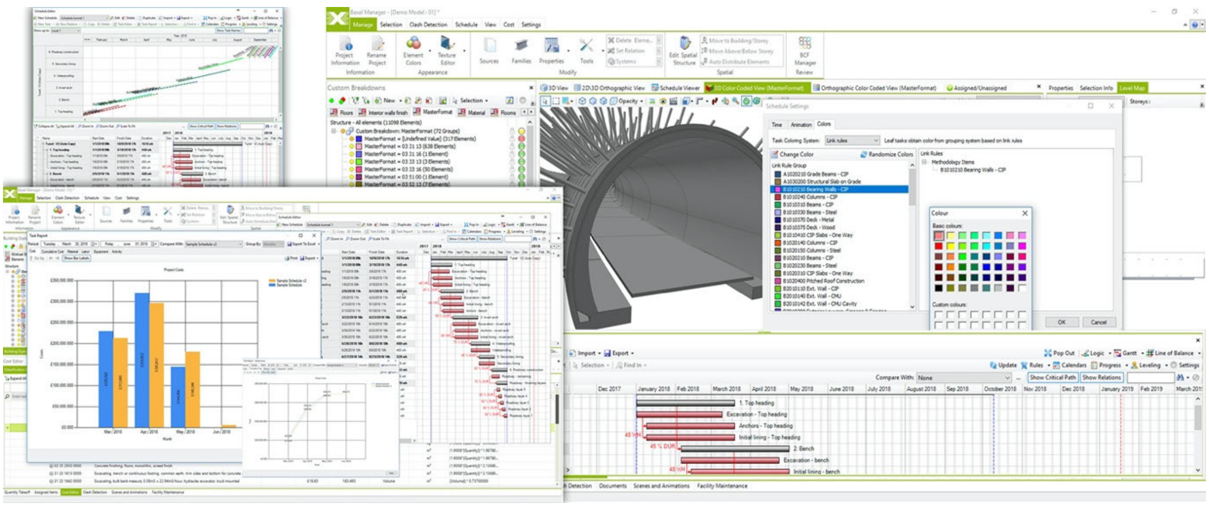
2.18 Construction

The literature reveals there are many benefits from BIM in the construction phase of a project. BIM can facilitate the early assessments of cost, time, and quality implications of the proposed design before construction begins. Risk can also be identified prior to construction (Fadeyi 2017).

BIM is a helpful method for project management, according to the findings in case studies undertaken by Bryde et. al. in "The Project Benefits of Building Information Modelling'. The process can be viewed by the Project Management profession to better plan building tasks. (Bryde Boquetas Volm 2013).

One of the most important parts of the construction stage is materials management. This becomes considerably easier using BIM. A materials list for all structural elements and site features is created from the model. When a model is developed, the associated materials lists can be parametrically linked to each of the objects within the model and then become available anytime (Li et al. 2014). The ability of BIM to generate automatic quantity take-off and cost estimation during the design stage ensures a comprehensive cost projection.

The literature reveals that disputes are recognised as a cause of low performance on construction projects. Disputes on site are closely related to construction processes and site management. Contractors have identified inadequate planning and scheduling, and poor site management as the common causes. BIM can play a crucial role in rectifying these issues. A more efficient construction plan can be developed in 4D BIM software. In '4D BIM for Environmental Planning and Management' Jupp found that, "The use of 4D modelling in conjunction with onsite production control methods to track actual progress and analyse the effects of delays on the overall project schedule has led to higher levels of onsite construction performance" (Jupp 2016). For example, simulation of the working route of a crane can be simulated visually. Scheduling conflicts can then be updated with the BIM model (Li et al. 2014).



F g 4 - BIM Schedu ng (b mcommun ty com 2021)

Waste is a typical problem in the construction process. This occurs because of inadequate collaboration and coordination, late identification of clashes and system conflicts, and inefficient constructability evaluations. The easy access to the integrated information at the design stage will enhance the accuracy of construction phase and a more efficient project delivery (Fadeyi 2017). Research has shown that using 4D BIM for construction planning, scheduling, can enhance the management of construction safety and waste (Jupp 2016).

The literature shows several studies on rework in the Australian construction industry have found BIM can reduce the amount of rework on sites during the construction phase.

In a study by P. Love and D. Edwards based in Australia found, 161 projects were studied, and the average value of direct and indirect rework costs were found to be 6.4% and 5.6% of the original contract value, respectively (Love Edwards 2002)

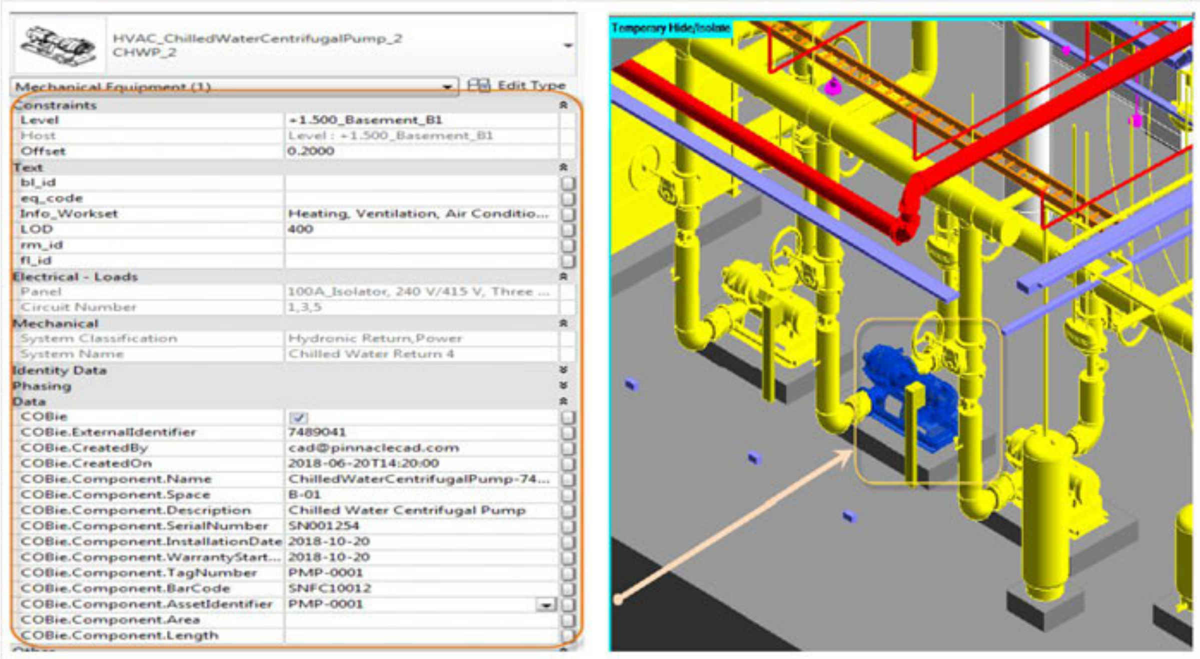
In another Australia-based study concentrating on New South Wales, the rework costs on the average were found as 5.5% of contract value (Marosszeky 2006)

According to the Australian Construction Industry Development Authority, the average cost of rework in projects is 6.5 percent of the contract value. However, for projects with a quality management system, the average cost of rework was determined to be 0.72 percent (Love Edwards 2002)

2.19 Management

The literature shows that benefits in the management sector can be realised from BIM use. In ‘How to measure the benefits of BIM–A case study approach’ Barlish and Sullivan write about their findings that interviewed project managers. They found that “schedule, change orders, and request for information (RFIs) as the most quantifiable project benefits” for project managers using BIM (Hurtado Sullivan 2012).

Facilities management with BIM uses the model and associated data to reduce the owner’s costs over the life cycle of a structure. In ‘BIM and Construction Management: Proven Tools, Methods, and Workflows’ Hardin and McCool write “A common figure that is used to describe life-cycle cost of a building states that around 20 percent of life-cycle cost is designing and building, and 80 percent is operating and maintaining” (Hardin McCool 2015). This highlights the need for effective management of the facility post construction.



F g 5 - Component Management (P nnac ecad 2019)

2.20 Economic Benefits

BIM has also been shown to have substantial economic advantages over traditional methods. The literature shows aspects of BIM use result in economic benefits.

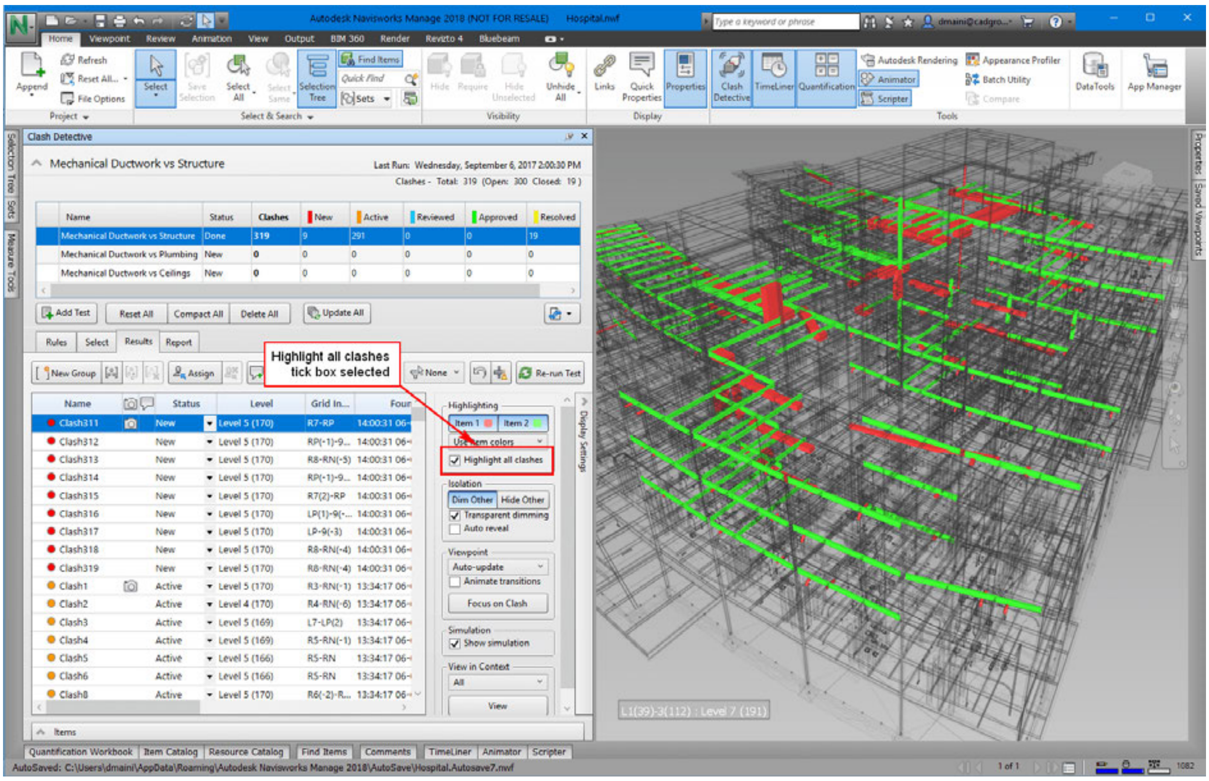
BIM users have identified both short and long-term economic advantages of adopting the technology. The most immediate economic benefit of BIM was the reduction of documentation errors. Fewer contractual claims and reduced construction costs have been identified as long-term economic benefits. Scheduling delays and rework prevention have been identified as short term befits (Ghaffarianhoseini et al. 2017).

Improved collaboration can reduce design errors and omissions. Any changes made to the 3D model can be immediately generated in 2D drawings. Cost estimates can be extracted from the model to keep all stakeholders informed of the cost implications as the design develops. These efficiencies all produce economic advantage to organisation that use BIM (Ghaffarianhoseini et al. 2017).

2.21 Clash Detection

One of the advantages of using this technology is to identify clashes between building components. Early identification of building systems collisions before construction will save time and money. This can prevent significant re-work at later stages of the construction project (Fadeyi 2017). As noted in the previous design phase section, prior to BIM use, the modification to one element of the building meant changing several other drawings. BIM does all the modifications to all the dependent elements automatically (Kumar 2015). If these clashes are detected in the construction phase of the project, significant delays can occur if rework must be done.

Design analysis can produce a more accurate picture of mistakes and omissions and improve the quality of the final works, all of which contribute to fewer design conflicts (Charehzehi Chai Yusof 2017)



F g 6 - C ash Detect on Features (odp anner 2020)

2.22 BIM Tools and Workflows

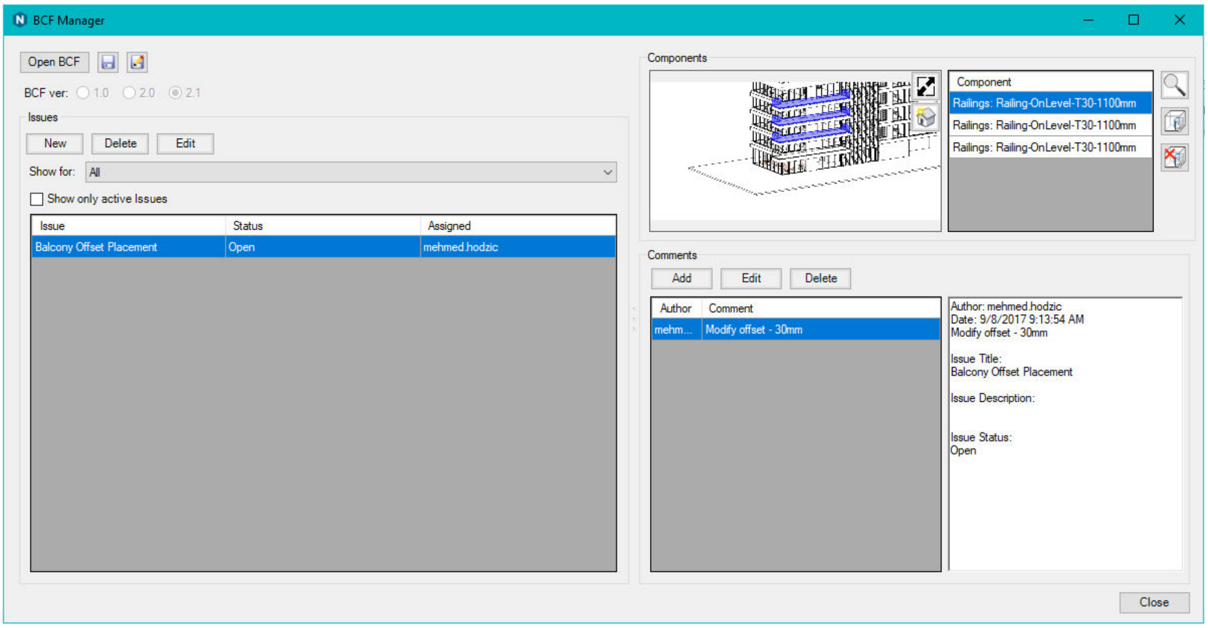
Workflows in the AEC industry are now more integrated because of BIM. The literature shows that the workflow of a construction project can be wholly absorbed into the BIM process. From initial discussions through to design and construction, the BIM process today affects virtually every aspect of the project.

For organisations that have not adopted BIM, current workflows may need substantial organisational change. Such as training, the creation of new positions, and in certain instances, bigger changes, such as department restructuring.

Modelling, visualisation, and simulation of utilities can ensure that the project adheres to the owners', architects', and engineers', requirements. Documentation and coordination activities are carried out using a set of interoperable programs, and information may be exchanged with a wide variety of project team members (Weatherford 2014).

BIM eliminates various problems of legacy workflows like different file formats, disconnected processes. The ability to simulate, create models and visualize allows for the elimination of most compatibility or guideline errors that previously could not be found until the actual construction process. It's also far easier to receive feedback about the current model from different parties within the BIM workflow, making both communication and conflict resolution easier and faster.

Integrating BIM workflows also symbolises the changes in the overall phase distribution when compared to the pre-BIM situation. For example, the conceptualization phase now takes a significant amount of time since most compatibility and clash errors are resolved at this stage and not in the process of construction (Ocean 2020).



F g 7 - Issue reso ut on n BIM (nav ate 2019)

2.23 nD Components

The term ‘nD BIM' (multiple dimensional building information modelling) defines the building information hierarchies. nD BIM processes can improve the efficiency of a project (GhaffarianHoseini et al. 2017).

BIM features go beyond the 3D modelling for which the software is most well know. The most widely used extra components are, 4D BIM, that adds time-related information. 5D BIM adds costs to BIM components. 6D BIM adds life cycle properties to allow for better asset management.

BIM’s 3D capabilities were promoted in the early days to show that it was different from CAD. Which was traditionally used to produce mostly 2D projections, such as floor plans, sections, and elevations. BIM quickly developed from 3D to nD (Koutamanis 2020).

Further dimensions, commonly referred to as nD, up to 10, are used to describe other aspects and uses for BIM, but the literature shows there is a lack of consensus on some nD applications.

As shown in figure 8 nD BIM capabilities involve different phases of the project life cycle and when used in conjunction with each other, are the components of 'integrated project delivery' (IPD) (GhaffarianHoseini et al. 2017)

4D BIM

The different components of a 3D BIM model are associated with time-related information in 4D BIM. Users can create comprehensive time schedules using 4D BIM, which illustrate the lead time, progress, and interdependencies between various work activities. They may also make the most use of space on the job site and see how the project will develop (Ding Zhou Akinci 2014).

5D BIM

Cost data is added to the BIM model using 5D BIM. Each component in the BIM model can have cost data linked. Such as purchase, operating, and renewal costs. 5D BIM can help users produce more accurate cost estimates and evaluate how possible modifications may affect cost throughout the planning and design stages (Ding Zhou Akinci 2014).

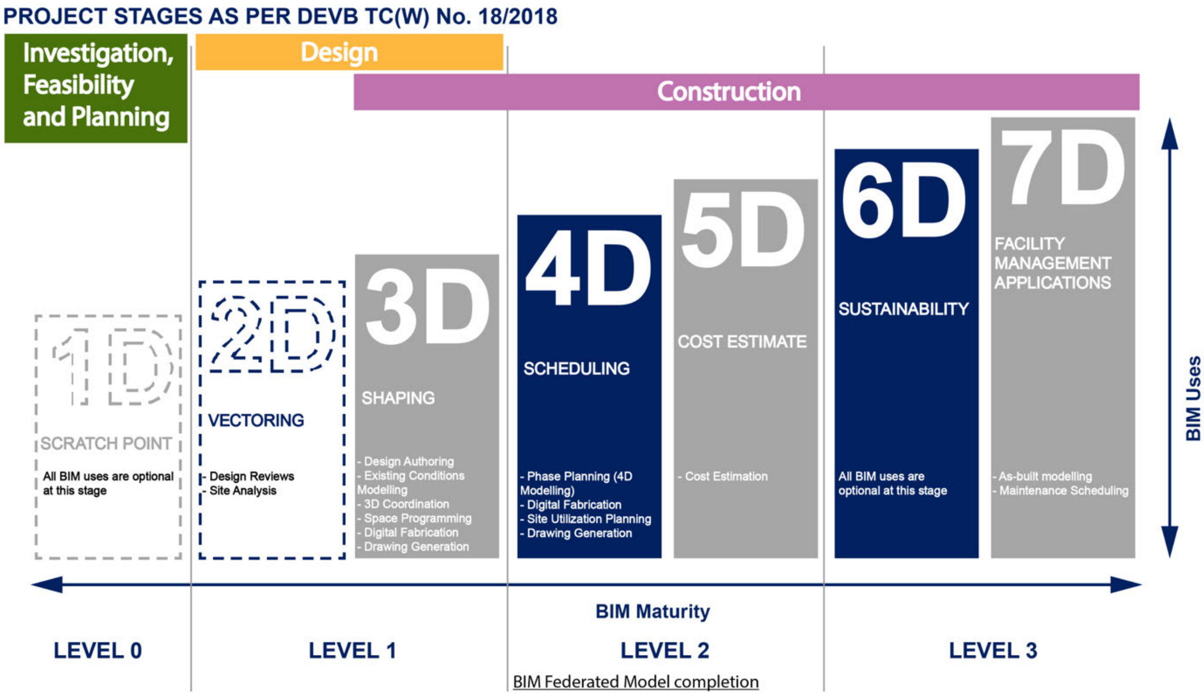
6D BIM

6D BIM adds information on life cycle properties. This data may contain information about the component's manufacturer, installation date, maintenance needs, and expected component lifetime. The 6D BIM model may also be utilised during the design phase to aid decision-making and shift the emphasis away from construction expenses and towards operating costs of the completed project (Ding Zhou Akinci 2014).

7D BIM

Building owners and managers can benefit from 7D BIM because it enhances operations and facilities management. Important asset data, such as status, warranty information, technical specifications, and maintenance and operating instructions, may all be tracked using this kind of BIM model. Everything relevant to facility management can be stored in this model (Ding Zhou Akinci 2014).

The 6D and 7D dimensions are underrepresented in the literature. This could be because they are still relatively new compared to the more established features of BIM. There is still further work that needs to be done to fully define these aspects and their role in the process. In 'Beyond the Third Dimension of BIM: A Systematic Review of Literature and Assessment of Professional Views' Charef et al. found that only 6% of respondents to their survey said they used 6D and 7D features.



F g 8 - BIM nD Leve s (a mgrp com 2019)

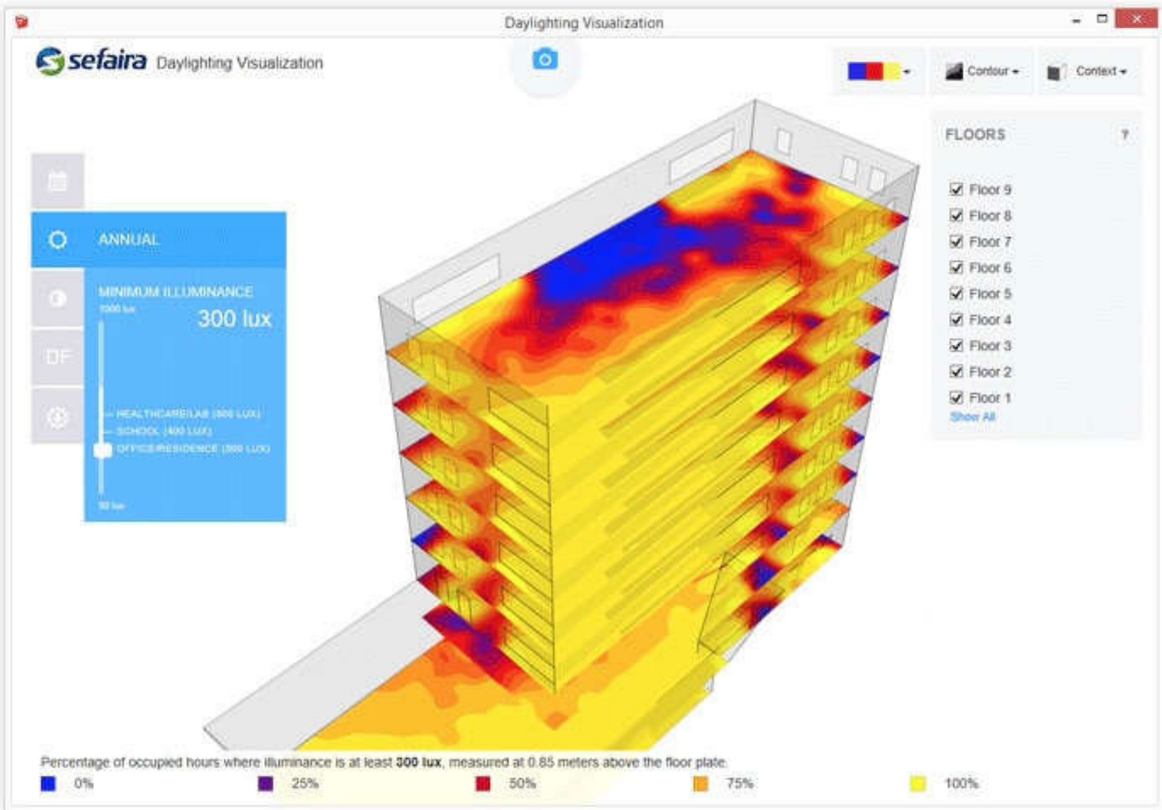
2.24 Sustainability

The literature shows BIM use can contribute to more sustainable building practices. There is no consensus on a specific definition for sustainable construction, but Wong and Qing define sustainable buildings practice in their paper Building Information Modelling (BIM) for Sustainable Building Design as encompassing environmental, social, and economic aspects.

6D BIM enables for the analysis and energy simulation of the building model. As a result, it's possible to simulate the most sustainable solutions in terms of energy savings and efficiency (Francisco Javier et al. 2020)

2.24.1 Environmental Aspect

BIM's contributions to design optimisation are acknowledged as important to minimise the usage of materials and energy. Building performance may be assessed using purpose-built BIM systems and integrated analytical tools. Solutions for reducing resource consumption, such as energy, water, and materials can be found. It is also possible to decrease waste caused by inefficiencies or mistakes in the construction process (Wong Fan 2013).



F g 9 - L ght V sua sat on Feature (Sam C M Hu 2015)

2.24.2 Social Aspect

By increasing communication and collaboration among team members, the BIM method lowers the risk of a construction project. Safety can be enhanced by predicting issues early in the planning process. Using the enhanced design and construction methods can provide a better living or working environment in the final product (Wong Fan 2013).

2.24.3 Economic Aspect

BIM can increase communication and cooperation while also allowing for the early detection of issues, which can prevent the significant problem of re-work. Because of better construction management, less waste is produced, which lowers project costs.

BIM aids in design optimisation, lowering capital and lifetime costs by improving material and energy efficiency (Wong Fan 2013).

The literature shows that the main sustainability benefits come from to the ability of BIM models to produce more sophisticated designs and models, to facilitate better outcomes for sustainability in buildings. For example, Zhang et al. write in 'Investigating the Constraints to Building Information Modelling (BIM) Applications for Sustainable Building Projects: A Case of China, "to improve high-efficiency construction and achieve the goals of cost-saving in construction industry, the United Kingdom (UK), has applied technology of information modelling and visualization to strengthen the applications of sustainable buildings in the last decade" (Zhang et al. 2019)

BIM contributes significantly to sustainable design through design optimisation. This might include things like building orientation, which can be readily simulated in BIM software. External BIM based tools are also available to provide sustainability analysis tools. Revit ECOTECT is one such tool which is a complete building design and environmental analysis tool. For example, ECOTECT can determine shade and reflection percentages and the quantity of solar energy that falls on an object (Wong Fan 2013).

2.25 BIM Education

The literature addresses education and training as an issue. The lack of expertise among workers, the need for up-skilling, and the need to stay current with the continuously changing BIM world are identified as major obstacles to implementing BIM (Puolitaival Forsythe 2016).

Education and training have become an important part of BIM implementation because of the process and technological changes within the organisation. Many of the skills needed to use BIM are transferable from other programs used by AEC organisations. This means professional practise development is another important aspect of BIM education since BIM technology is linked with many profession-specific sources of data, e.g., costing, scheduling and materials flow (Khosrowshahi et al. 2012).

The expanding BIM market means that the AEC sector needs more experienced BIM professionals. Some universities and educational institutions have included BIM training for students in undergraduate and postgraduate construction, engineering, and management programmes to suit industry demands. The bulk of BIM courses are designed for advanced undergraduate or graduate students and include both theory and practice in BIM (Chen Lu Wang 2020)

The literature shows several academics have suggested BIM education frameworks based on the academic process, which can help to shorten BIM learning curves. In response to the above issues, the importance of collaboration between industry and universities in improving BIM education has been increasingly recognised as a solution to the requirement for better training and more industry ready professional with BIM skills (Chen Lu Wang 2020).

Universities and industry, for example, have distinct strengths. One excels in theoretical knowledge, while the other excels in practical abilities. In BIM education, they frequently have emphases, one focusing on the comprehensiveness of the gained knowledge, the other more on hands-on applications (Chen Lu Wang 2020).

The literature shows that collaboration between universities and industry is the optimal approach to achieving the best outcomes for both parties, but ultimately the best outcomes for students and employees learning new skills. In the case study for the paper 'University–industry collaboration for BIM education: Lessons learned from a case study' Chen et al. show that "Through the established university–industry collaboration, the university could recognise industry's needs and practical knowledge necessary regarding BIM implementation. The industry partner also benefited from the academic knowledge and thus from the collaboration" (Chen Lu Wang 2020).

2.26 BIM Legal Issues

Alongside the advantages, BIM use presents new challenges and risks for AEC organisations.

Identified in the literature are these issues that are still be worked through. Some issues have no simple answer at present.

1- Model ownership and IP issues

To what extent can the participants of the project rely on the information in the model to perform their work?

2- Since BIM works best as a collaborative process, will there be a shifting of risk between designer and contractor over means and methods of construction and design?

3- Cyber security issues

2.26.1 Model ownership

Who will own the final model after the completion of the project differs from the traditional approach of the past. This issue is complicated because the BIM model can be used in the facilities management of a project (Arensman and Ozbek 2012). Traditionally, the design firm keeps ownership of the model, as this is their intellectual property. The literature highlights the issues of ownership in the sense that the collaborative approach means that multiple parties can contribute to the model's final form.

There is the thought that BIM does not affect the fundamental principles of design, as the designer should retain control. The other approach is that a co-ownership model could be adopted. This raises other issues that would need to be addressed. In 'Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges' Ghaffarianhoseini et al. write "joint authorship of different BIM model developers complicates joint and separate liability for any errors made during the project life cycle (Ghaffarianhoseini et al. 2017).

If multiple parties collaborate on a BIM model, it might be difficult to determine who owns it unless it is specified. Some argued that if a BIM model is created through collaboration, the customer should retain ownership of the final model. This raises legal issues since the BIM model incorporates data from a variety of sources, all of whom want to keep their intellectual property rights to the model they helped build (Eadie Mclernon Patton 2015)

Sharing the BIM model, whilst not restricting the flow of information to other members of the design team and the client, during the design process, can cause plagiarism of ideas and designs. This is because of a lack of protection given to ownership and IP rights of BIM generated data (Eadie Mclernon Patton 2015). To deal with this, BIM protocol may require a more comprehensive intellectual property licensing procedure than currently provided in construction contracts (Ghaffarianhoseini et. al. 2017).

2.26.2 Accuracy of Data

While wider collaboration is a beneficial aspect of the BIM method, some issues can arise from the more collaborative approach. One such issues is the accuracy of data contributed to the model. Parties cannot always be sure of quality of work being added to the model from other parties.

The quality of data underpinning the BIM model carries significant risk, as the reliability of the model ultimately depends on it. The accuracy of this data must be backed up by disclaimers of liability and guarantees from the designers. Where the information is provided by other sources, there can be other legal considerations, such as ownership of data/design or licencing issues (Ghaffarianhoseini et al. 2017).

2.26.3 Cyber Security

Another serious challenge with BIM is cyber security concerns. Because team members can access project data through information sharing, cyber security is a concern because of the risk of unauthorised online access and copyright infringement (Ghaffarianhoseini et. al. 2017).

2.27 Literature Review Summary

The aim of the literature review was to examine the benefits of BIM in the AEC industry. This chapter sought to evaluate some of the characteristics of the AEC industry and the areas where previous research has shown benefits in adopting the BIM methodology.

The literature shows that many of the issues the AEC industry faces can be improved by adopting BIM. Previous research shows adoption rates are not equal among large and SME organisations. The utilisation of BIM in larger organisations is not new and there are many case studies the show the benefits to larger AEC organisations.

The literature identifies the design stage as an area where productivity benefits have been achieved. Design automation features can reduce many time-consuming drafting tasks, such as drafting section details and floor plans. Consistent drawings can be produced from the model. Collaboration in the design stage was consistently mentioned in the literature as an advantage to adopting BIM. Previous case studies show issues such as service clashes and rework can be minimised due to improved communication and collaboration in the design stage.

The benefits for the construction phase of the project are shown in the research to come from several areas. Construction waste going to landfill is a major issue that the construction industry is struggling to find solutions too. The literature has case studies that show construction waste can be minimised with BIM features, such as design optimisation. This can enhance the accuracy of the construction phase. Issues that are discovered earlier in the design phase can mean fewer changes and rework later in the construction phase, which then leads to less waste. Further study needs to be done in this area of waste reduction, but presently, the literature shows BIM can help reduce waste on site.

Automated clash detection is a major benefit to the construction phase of the project. The agreement in the literature research, is significant time is lost to rework and the enhanced collaboration and automatic clash detection features can improve productivity in the construction phase of a project.

The literature shows many organisations face barriers to adoption of BIM. The main issues highlighted are initial cost of investment, training and qualified staff, unwillingness to change current practices and lack of client demand for BIM use. The barriers can mostly be overcome with more resources. The literature highlights many of the benefits to larger organisations, who have the resources to fully integrate BIM. The research shows that SME organisations still face many barriers to adopting BIM.

Mandating BIM is an effective way to increase adoption rates. Cases studies in the literature have shown the mandating BIM use for certain types of projects increases BIM adoption. The countries with the most mandates also have the highest BIM usage rates. These mandates mostly effect larger organisations. Also highlighted in the literature was the lack of client demand as being a significant barrier to adoption in smaller organisations.

The research is not as extensive for the benefits to smaller organisations. This may be because less have adopted the process. Several case studies also identified a lack of literature on benefits to smaller organisations as a reason for reluctance to adopt. With this area being underrepresented in the literature, further research will benefit SME organisations and more research should be undertaken in this area.

The issues of productivity and a lack of coordination were highlighted in the literature as some of the major challenges that the AEC industry needs to overcome. The consensus in the literature is that collaboration is enhanced in all phases of a construction project with the use of BIM. The enhanced collaboration that the BIM methodology can deliver shows the importance of the research into BIM and how it can be fully integrated into and organisation.

CHAPTER 3 – METHODOLGY

3.1 Introduction

In chapter 3, the research approach will be outlined and the time frame for conducting the various components of the research will be set out. This research project will contain multiple methods of research and analysis to gather the required data. Research of the literature and analysis of the findings in this area will be presented. An Interview will be undertaken with an organisation as part of a case study to gather data on specific benefits of BIM in relation to a smaller organisation and the BIM process. A review of the data will be completed and prepared for recommendations on the research.

3.2 Research Phase

3.2.1 The Research Problem

The research that will make up the dissertation will focus on the benefits and efficiencies that can be achieved in the AEC industry. There will also be a focus on successful methods of implementation and how they can facilitate further uptake of BIM. The research for the case study will focus on an SME organisation and how the BIM process has been implemented and the benefits the organisation is realising.

3.2.2 The Research Method

The research and analysis for this dissertation fits into the qualitative approach. This research will mainly be an interpretive analysis of the literature and information got from the interviews. The qualitative research approach is used mainly to take the findings from natural and non-numerical data and to understand concepts and experiences, as Williams explains in ‘Research Methods for Students, Academics and Professionals: Information Management and Systems' that "the interpretivism approach, emphasises meanings created by people and data which are qualitative (or as words), collected by techniques such as interviews and observations" (Wiliiams 2002)

The goal of qualitative research is to undertake research that produces descriptive data (Taylor Brogdan DeVault 2015). This dissertation will take the literature review and interview data and form an analysis that provides in an insight into the benefits that BIM can deliver to an organisation.

3.3 Literature Review

A comprehensive literature review was completed to examine the benefits and unrealised potential to be gained from BIM use in the design construction and management phase of The AEC industry. The review will be undertaken by reviewing literature available online from the USQ library, Google scholar, ResearchGate, Scopus, Web of Science and Science Direct. Once the literature review has been completed, an overview will be presented in chapter two. A further analysis will be undertaken of the literature review to analyse the trends and information that can be used with the interview data to make recommendations.

3.4 Interview

During the research phase of this project, interview will be conducted to gain an insight into an SME organisation in the industry uses BIM. This interview seeks to understand the benefits and efficiencies that they gain from using the BIM process, discover any downsides they have experienced and insights into any improvements they may have to make the process more efficient. Interviewing people who use the software every day as part of their profession gives a valuable insight into the realities of working with BIM that cannot be garnered from a review and analysis of the literature.

The data and findings from the interviews will be analysed and used alongside the findings from the literature to have a more complete picture of the state of BIM usage in the AEC industry.

3.4.1 Interview Method

The interview was conducted via email so the questions can be answered on their time. The interview questions will be split into two parts. The first part will be more general questions about their experience with BIM. It will include the way they use it and if they have any recommendations for improvements or features, they find to be of value. The second part will be more specific and relate to how they use they use BIM on their type of projects. Once all the interviews have been completed and returned, the findings will be analysed.

3.5 Case study

The case study findings which will result from an analysis of the interview will be presented in the broader context of the dissertation, alongside the literature review findings, to create a fuller picture of the benefits of BIM. It will be presented against the predicted outcomes of the research. The literature review will provide guidance for the design of the interview questions that will then be the basis of the case study.

3.6 Data collection

The data will be collected by email and collated in its raw from then analysed and presented in the findings from the literature review.

- Analyse case study/interview data
- Analyse research data
- Comment on findings and make recommendations.

3.7 Resources

The resources required to undertake this dissertation are access to the software necessary to complete the writing of the dissertation and BIM software for reference. To access some of the software, a license had to be got if a student version was not available. The resources required and got and listed in the table 3.1. No other resource is required to complete the dissertation.

Table 3.1

Resource	Timeframe	Source	Priority	Cost
Microsoft Word	Permanent	Student License Purchased	Critical	$120 (Student version Microsoft Office)
Microsoft Excel	Permanent	Student License Purchased	High	Included in Microsoft office
Microsoft Project	Permanent	Student License Purchased	Critical	Included in Microsoft office
Endnote	Permanent	USQ Library	Critical	Nil
Autodesk Revit	Permanent	Student Version	High	Nil

3.8 Risk Management

The risks involved in preparing this dissertation are low, as most of the work will be completed while working on a computer. To complete the case studies, I will conduct some interviews. These will most likely be done over email. Here, the interviews will be conducted in a safe environment and all safety requirements of the workplace or public meeting space will be followed.

Table 3.2

Description of Hazard	People at Risk	Risk Level	Control Measures	Completion Details
Eye and back strain from sitting at the computer for extended periods	Myself	Low	Sit with good posture. Take regular short breaks away from computer	
Site Visits to conduct interview (If undertaken)	Myself Interviewee	Low	Follow Site entry instructions. Conduct interview in safe location.	

CHAPTER 4 – CASE STUDY APPROACH

4.1 Case Study Research

Case studies examine a phenomenon in more detail (Fellows Liu 2015). The general purpose of a case study is to explain a specific scenario (case), such as a person, company, organisation, or institution; identify the case's major problems; Using appropriate theoretical ideas from your unit or field, analyse the situation; suggest a plan of action for that specific situation (WSU 2016)

To accomplish the goals of this Research Project, a case study was used. The case study research approach has the benefit of allowing for a more in-depth evaluation of an organisation and their approach to BIM.

A case study will be conducted that will involve a mix of observations and interviews to gather data and determine the findings. In 'The Case Study as a Serious Research Strategy' Yin describes the case study approach as being exploratory, descriptive, or explanatory (Yin 1981). Yin explains "The need to use case studies arises whenever an empirical inquiry must examine a contemporary phenomenon in its real-life context' (Yin 1981).

Descriptive case study research is aimed at systematically identifying and recording aspects of a specific phenomenon or process. It is not directly aimed at testing a specific theory or hypothesis but attempts to come up with new interpretations or to learn more about current theoretical insights (Fellows Liu 2015).

Exploratory case study research is theory driven, which aims is to test or explore elements of a theory using a hypothesis (Fellows Liu 2015). Explanatory research aims at hypotheses testing which, usually has a causal explanatory character (based on a probabilistic relation) allowing a conclusion to be logically inferred (Fellows Liu 2015).

Many case studies fall between the two extremes of exploratory and explanatory research. This research contains elements of both descriptive and exploratory research. It aims to explore the benefits of the BIM method, and to describe the current practices that are being applied for BIM implementation in the AEC industry.

4.2 Case Study Design

Two basic types of designs are possible when using case studies for explanatory purposes.

The first is a single-case design. This approach can test hypotheses, such as if using BIM for the entire life cycle of a building project is beneficial. A multiple-case design draws inferences from a collection of cases. When the same phenomenon is believed to occur in a range of situations, multiple-case designs can be suitable (Gustafsson 2017).

A single case study is the ideal option when a researcher wants to examine one item (for example, a single individual from a particular group) or a single group (for example, a group of people or an organisation (Gustafsson 2017). The single case study approach is being used in this research project to understand how an organisation use and benefit from the use of the BIM method.

4.3 Limitations

Although a multiple case study approach can be preferable in certain instances. According to Rowley in 'Using Case Studies in Research', "Multiple case designs are preferred, multiple cases can be equivalent to multiple experiments. The more cases that can be marshalled to establish or refute a theory, the more robust are the research outcomes. Lack of access to multiple candidates is a reason in this research project a single case was chosen that represented a part of the industry of interest to the research project and its outcomes.

4.4 Criteria for Case Study Selection

When determining suitable candidates for study, cases must be chosen based on the research goals, questions, and other constraints, such as accessibility, resources, and time constraints (Rowley, 2002).

As this research project aims to understand the benefits of the BIM method to an AEC organisation through the various stages of a construction project. The selection of the organisation for the case study will be based on their representative qualities of the middle range of engineering firms. The literature coverage of SME organisations is not as extensive as larger firms. It is well documented that large organisations have realised many advantages of implementing BIM. Organisations that were too large were therefore not considered because of the access to ample resources for implementation and the benefits for these organisations being well represented in the literature. Organisations that are at the smaller end of the industry have only partially implemented BIM and therefore cannot provide a full enough picture of the potential benefits that can be achieved.

4.5 Case Selection

The organisation chosen for the case study was chosen to fit the following criteria:

- Must utilise BIM
- Have implemented BIM on most of their projects
- Be a small to medium size organisation
- Have implemented BIM in various roles

SMEs usually fall within three categories, micro, small, and medium-sized enterprises. These are defined as, micros with less than 4 employees. Small as having between 5 and 20 and 20–200 employees as a medium sized enterprise (ABS 2009). SMEs represent around 98% of the construction sector in countries such as Australia, the US, the UK, and Canada (Shelton et al. 2016).

4.6 Data Collection

The data collection procedures in this case study will be interview questions presented to an individual in the chosen organisation. The first data collection procedure will be the answering of written questions primarily about the organisation and the use of BIM within the organisation and the benefits that have resulted from implementing the BIM method.

4.7 Analysis of the Data

The case study should be generalised to add to theory. For case studies, analytical generalisation is utilised instead of statistical generalisation, in which a previously established theory is used as a template against which the empirical findings of the case study are compared (Rowley, 2002). The single case study approach is being utilised for this research project, so the data from the interview questions will be analysed as one piece of data.

A comparison will be made between the findings of the case study interview questions and the findings of the literature review, mainly focused on the following areas:

1. Identify the benefits and efficiencies to be gained from BIM adoption.

2. How to facilitate the implementation of BIM

3. Identify areas a reluctance in adoption

4. Explore best practices for implementation

4.8 Case Study

4.8.1 Objective

The objective of the case study is to gain an understanding of the benefits and issues encountered in using BIM on construction projects within an engineering organisation. A director from the chosen organisation will be interviewed and their answers and the findings of the case study will be used to augment the findings from the literature review.

4.8.2 Selection of Organisation

The organisation chosen is an engineering firm that specialises in structural and civil engineering for small to medium-sized commercial projects. This organisation undertakes projects in the education and the aged care sector. The organisation has 25 employees in offices in two locations.

4.8.3 Data Collection

The main data collection process for the case study was an interview conducted by email. This was done to be convenient to the respondent and could be completed in their own time. The answers were returned via email and are presented and summarised in the following section of the report. Further analysis of the response will be presented alongside the findings of the literature review.

CHAPTER 5 – CASE STUDY

5.1 Interview

Software:

What Software do you use?

The literature highlighted several reasons for BIM software choice. By far, the most popular is Revit. The national BIM report 2019 shows Revit is the most popular software by far (NBS 2019)

This organisation uses Revit, saying '*compatibility with AutoCAD'* was the main reason for purchasing this software. Cost was a consideration too, but integration into the systems the company already used was the primary concern.

Training:

Do employees have BIM skills prior to hiring?

The literature identified training as a concern among organisations. Access to qualified candidates and ongoing training of staff were both considerations to the organisation.

The director identified training as an issue within the company. It provides training for some staff, depending on roles, '*some people are hired for their Revit skills'* but goes onto say '*others receive on-the-job training'*. This training is provided by staff in the organisation, saying '*Yes, some Revit drafters and BIM managers provide the training'*.

BIM technology is constantly changing and the role it plays is developing and expanding. For companies with limited resources, this has been identified as a challenge. The literature identifies that with the regular updates, staff may require an additional investment in training and education. The director also confirmed this as something they deal with, saying '*occasionally drafters and Revit mangers attend courses and seminars to further their skills'*.

BIM Adoption:

Were there any barriers to adoption?

Overcoming barriers to adoption have been identified as a concern among some SMEs in the AEC industry. Some early concerns have been eliminated because the benefits of BIM have been largely established. Some concerns remain, though. The manager described they did not really have a major concern in adopting BIM in terms of the business case, but again revealing training as issues saying, '*in terms of the business case there were no real barriers to adoption, but initial lack of candidates and experience was a concern*'.

Was there any reluctance to adoption in the organisation?

Inside the organisation, the majority were on board with adoption of BIM saying, '*not really any resistance other than initial concerns raised about staff*'. Highlighting again that training and access to experience were the primary concern.

Was there a catalyst for adopting BIM?

The reason for adoption here was reflected in the literature that saying '*industry trend*' was the main reason for adoption.

Implementation:

Have you experienced any resistance to its use from clients or partners/other stakeholders (builders, subcontractors etc.)?

The literature showed that resistance to implementing BIM mainly comes from inside the organisations and that the outside forces such as clients and other stakeholders were driving organisations to adopt BIM. This is the case with the manager saying they had received '*none, no resistance from others*'.

Where did the major push for implementation come from? Organisation or client?

This was further highlighted by the direct requests the organisation received from clients, saying '*fee requests from projects would often say that it was a prerequisite*' to use BIM.

Benefits:

What have you found are the major benefits of BIM?

A finding from the literature review was that automation of tasks was a benefit of the BIM method. Here the director confirmed that the automation of previously time-consuming tasks, was the major benefit to the organisation saying that, '*auto generation of sections and member size schedules'* is the biggest benefit.

Has BIM improved productivity?

Productivity gains are proclaimed as industry wide benefits from the use of BIM, most often from large organisations. In terms of smaller organisations, access to resources and training can dictate the extent of the benefits. With this organisation improved productivity is achieved but the manger qualifies it by saying '*yes it improves productivity in areas, but mainly if the users are experienced*'.

Responding to questions about major areas of productivity gains that were repeatedly identified by larger organisations, the director revealed that in some of these areas they yet to see any noticeable gains or don't expect to in their sector.

Has there been noticeable improvements in the following areas?

Looking for project information?

The director said this applied to them in some areas but was less relevant to the structural engineering sector, saying '*Yes, in certain instances, but this is more of a building services thing, for example hydraulic/electrical/mechanical'*

Conflict resolution?

This is another area that the director revealed does not affect their work directly, saying other parties benefit from their work in this case, saying others '*often use our model for clash detection*'.

Dealing with mistake or rework?

The director said this is an area they haven't yet considered, saying they were '*undecided on the benefits of this at present'*

Communication between stakeholders?

Communication between stakeholders was confirmed as being another area of productivity gain. The manager revealed '*yes, notable improvements have been made in communication*'

Confidence in data accuracy?

Here, the director said he was '*neutral*' on the case data accuracy need further consideration on this question.

Delays in receiving information?

Reducing delays in receiving information areas was confirmed by the director as being an area where BIM had improved productivity. The time-consuming back and forth between parties has been reduced saying '*a BIM model can be used quicker than waiting for architects to send requested sections and details'*

Efficiencies:

What area has the biggest efficiency gain?

The areas that produced the biggest efficiency gains for the organisation were again confirmed to be the reduction in time of completing previously labour-intensive tasks. The director says their biggest efficiency gain has been '*producing general layouts and models quickly*'.

Has it reduced delays in areas that would have happened before?

The reduction in time taken to produce plans and models again was an area the director identified as being an area of improvement. In terms of areas that could cause delays, the time-consuming production of models and plans was identified saying '*Yes, quick production of floor plans and 3D model for clients and stakeholders*'.

Have you reviewed BIM performance?

The director said '*no, not at this stage'* that any performance review of BIM had been done. This is something a larger organisation would be more likely to undertake.

Do you have any goals for efficiencies to be gained?

This director said this area is somewhere they haven't considered yet, saying '*no, not really, no specific goals*'. This is another area a larger organisation will probably consider.

Is there any area that you expect to provide further efficiencies in the future?

Although the director said they had no specific goals set at his stage, they were expecting some more improvements to be available in some areas in the future. These were specific improvements related to their field of structural engineering, saying he expected '*Add-ins for structural steel detailing, concrete detailing, integration with structural design software' to be available in future updates'.*

Collaboration:

Has BIM enabled more collaboration outside the organisation, with clients or other project stakeholders?

Collaboration was shown in the literature to be an area where BIM can play a major role in delivering benefits to the AEC industry. The director confirmed this was the case for their organisation, saying '*yes more collaboration with clients and others is possible*'.

Has BIM improved communication improved with clients?

As well as enabling more collaboration on projects with other stakeholders, the director said '*yes, communication with clients and others has improved'* revealing not just only more collaboration and communication but theta BIM also facilitates better quality communication.

Has BIM enabled more collaboration within the organisation?

As well as collaboration with clients and other outside stakeholders, internal communication and collaboration was identified in the literature as being improved by the BIM process. This was confirmed by the manger as an area of improvement in their organisation as well saying '*yes better internal communication is easier'*.

Project Phases:

The main phases of a project that the organisation is involved in are the design and the management of a project. Their major role as structural and civil design consultancy is to design entire projects or aspects of projects for a variety of clients. The first stage of their involvement in a project is in the design phase. The director confirms what the literature shows, saying, '*yes, the design of a project is made easier with BIM tools'.*

Has it made management of projects easier?

After the initial design phase and while the project is in construction, the organisation provides support and management in some areas of the project, this phase has also been improved by BIM. The director says '*yes management of the design while in construction is also easier with the improved collaboration'*

BIM Stages:

The stages of BIM were developed by Bilar Succar in a paper called 'BIM Maturity Stages'. Succar defines stages for capabilities as 'BIM maturity' and is the basic ability to perform a task, deliver a service or generate a product. BIM Capability Stages (or BIM maturity levels) define the major milestones to be achieved by teams and organisations as they adopt BIM technologies and concepts' (Succar 2009).

What BIM Stage is the organisation at out of the following?

The manager described stage 3 as the maturity stage that the organisation had reached, saying '*from conception to delivery BIM is used*', and that '*yes, communication is in real time with others involved*'.

Limitations:

What is the main negative of BIM use?

The literature shows some limitations or perceived negatives to BIM. For this organisation, these positives far out way the negatives, but the director explains something they have found limiting and would like to see improved in the future saying, '*It's good for general modelling, but 1:10/1:20 details still need to be produced'.*

5.2 Interview Summary

The questions in the interview conducted with the manager at the engineering firm were planned to compliment the main findings of the literature review. The interview process has validated many findings from the literature review. A key finding of the literature review was that benefits achieved from BIM are more efficient process that were time-consuming and labour intensive previously. The interview revealed for the organisation that this process was the major benefit achieved by adopting BIM.

The increase in collaboration was identified and a key area of benefit that BIM can deliver. The interview revealed that communication and collaboration has improved for the organisation with the use of BIM. This improvement occurred with outside stockholders on their projects and within the organisation itself.

Also well represented in the literature is the implementation and barriers to adoption of BIM. Here, the organisation faced few barriers to implementation and adopted BIM based on the trend of the industry toward BIM use. Training and availability of qualified staff was the only real challenge that they have had to deal with.

There are several stages of BIM maturity identified in the literature in which different levels of efficiency and benefits can be realised. Is this case, the organisation has fully integrated BIM into the final maturity stage, and this is reflected in its use of BIM for conception phase through to the delivery of the project.

The findings of the interview have confirmed some of the primary findings from the literature review and the benefits that BIM can deliver to an organisation and the wider AEC industry.

6.0 Discussion and Findings

6.1 Introduction

The preceding chapter presented the case study questions to look at the potential benefits of BIM for the chosen organisation. In this chapter, the results of the literature review and the case study are discussed in relation to the research questions.

The chapter takes the findings for the literature review and the case study and discusses what were found to be the primary benefits of BIM.

The literature review revealed the use of BIM has improved the AEC industry's overall performance on construction projects. Investigations into the use of BIM have mainly focused on larger organisations and projects. This chapter contains the findings of the case study interview, which was conducted to see if SME businesses have benefited from BIM.

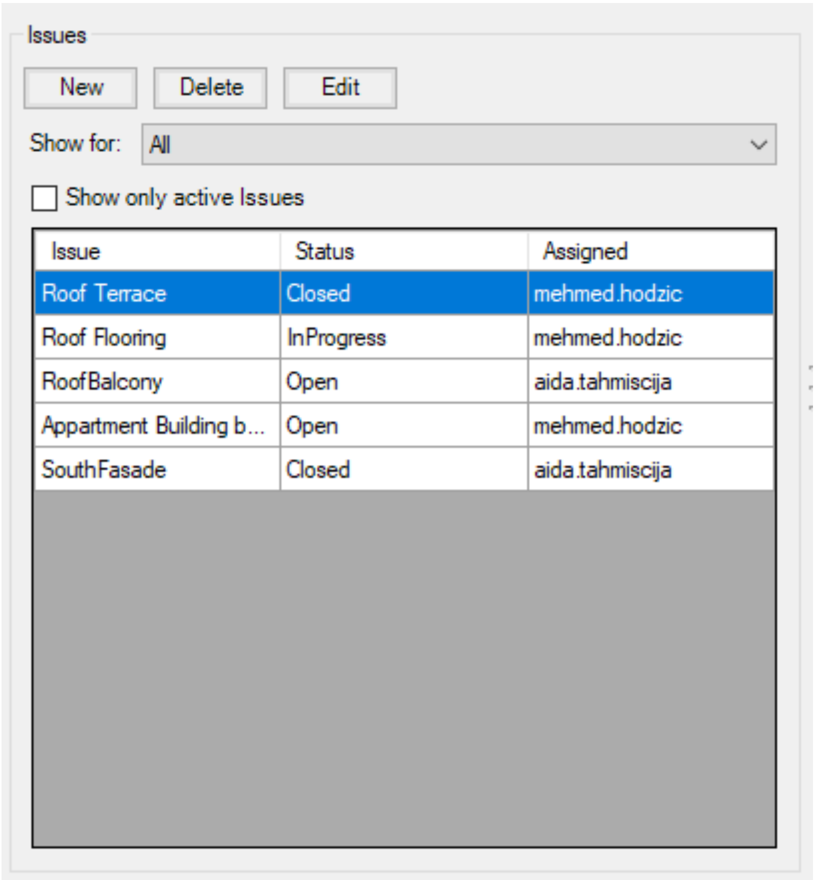
6.2 What are the benefits to BIM Use?

The benefits of BIM use are well represented in the literature review. When compared to traditional design and construction methods, BIM adoption can enhance workflows, collaboration, and communication, minimise costly rework, and manage a project throughout its life cycle. Findings from the literature review and the case study, show these benefits to have a positive influence on productivity and efficiency.

6.2.1 Collaboration and Communication

The collaboration and communication between stakeholders throughout the life cycle of a project were identified in the literature as key benefits from the BIM process.

BIM is a process that encourages collaboration and communication. All stakeholders engaged in the project can effortlessly cooperate and communicate due to cloud-based BIM tools. Access to all the information required, as well as the most up-to-date models and from any location. All project stakeholders may work on the full scope of the project. Estimates, models, and design notes are all generated and saved in a single location.



F g 10 - BIM Commun cat on (nav ate 2019)

The literature review shows how a more collaborative approach to a project facilitates improved productivity. Elluman and Gilder found in 'BIM: innovation in design management influence and challenges of implementation', that this more collaborative approach eliminates much of the back and forth which was a feature of the previous model. Which still exists in many organisations (Elluman Gilder 2013). In the case study, the director highlighted communication had improved from the use of BIM, saying that ‘*noticeable improvements have been made in communication’* had been achieved with BIM.

Benefits are realised from the ability to communicate and make design modification in real time. For example, Architects can make modifications to designs which are then immediately updated in the model. The ease of data exchange was highlighted by the manager in the case study as a key benefit to his organisation. Requesting and waiting for the exchange of documents and plans has become a thing of the past with BIM. From the case study the director said ‘*a BIM model can be used quicker than waiting for architects to send requested sections and details*’. A more efficient process is the consequence of improved communication and collaboration facilitated by the BIM methodology.

6.2.2 Clash Detection

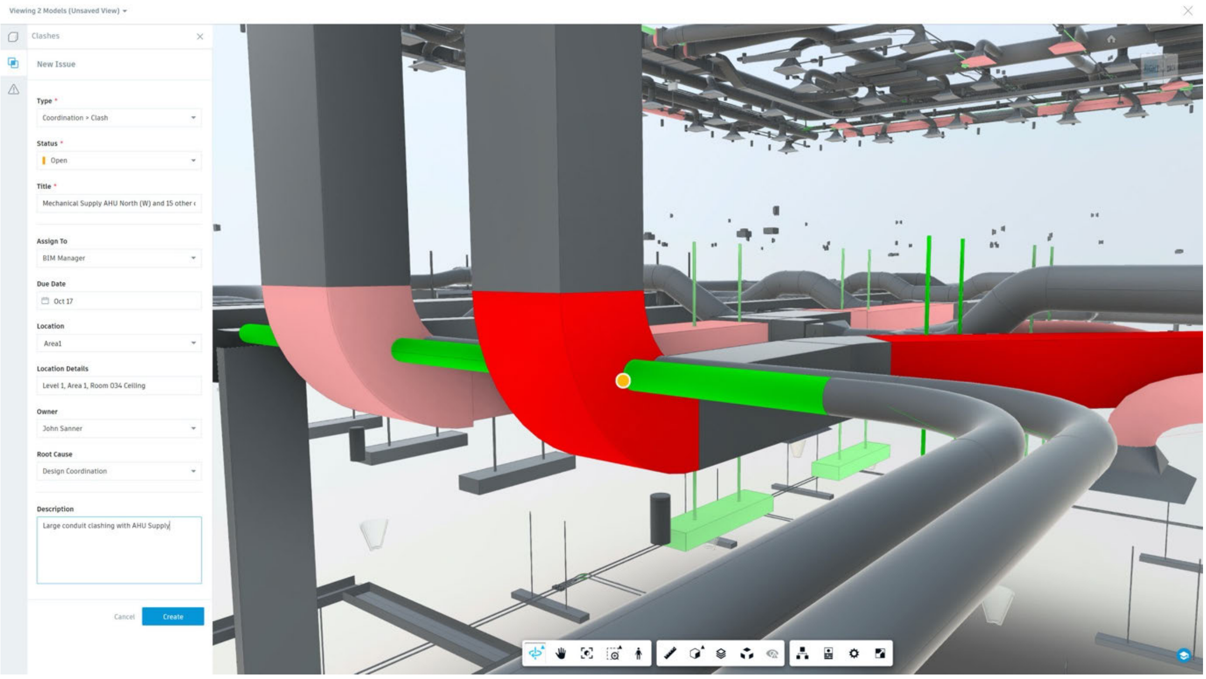
Clash detection is regarded by many as a major benefit of BIM. The literature review shows BIM facilitates effective coordination between design teams that allows internal or external clash detection. The automated clash detection feature can prevent clashes by automatically determining if there will be any conflicts between service trades or major structural elements.

The number of repairs or costly rework will be limited through clash detection. BIM facilitates proper planning before construction. Unexpected problems and last-minute modifications can be prevented through simple evaluation and communication between stakeholders.

As highlighted in the literature review, if a clash in services is detected once a change has been made, the model is updated, and the BIM software does all the modifications to all the dependent elements automatically (Kumar 2015).

In ‘The role of building information modelling (BIM) in delivering the sustainable building value’ Fadeyi states that early identification of building systems collisions before construction will save time and money can prevent significant re-work at later stages of the construction project (Fadeyi 2017).

In the case study, the director revealed clash detection was not a major concern for them directly but that other stakeholders in the design process often used their model for clash detection on projects, saying others '*often use our model for clash detection*'.



F g 11 - C ash Detect on Feature (Construct on Junk e 2020)

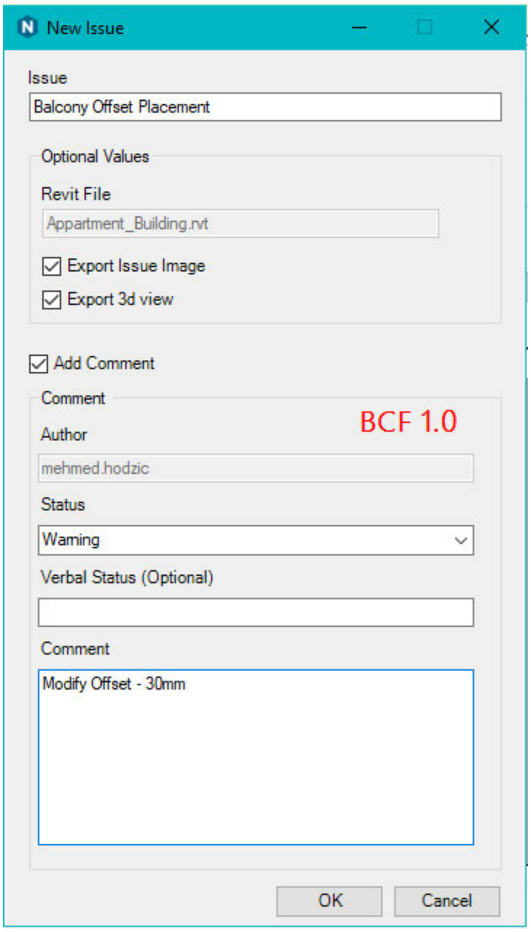
6.2.3 Design

This phase of the construction process has traditionally been fragmented. Greater cooperation, by including all stakeholders in the design stage, can resolve issues early before costly rework or significant re designing must be done.

BIM facilitates the seamless exchange of data created during the design phase (Lee Jeong 2012). Which limits the back and forth of document sharing and manual updating design changes.

Conceptual design, analysis, detailing, and documentation are all done in the design phase using BIM. BIM design data can then guide scheduling and logistics in the pre-construction phase.

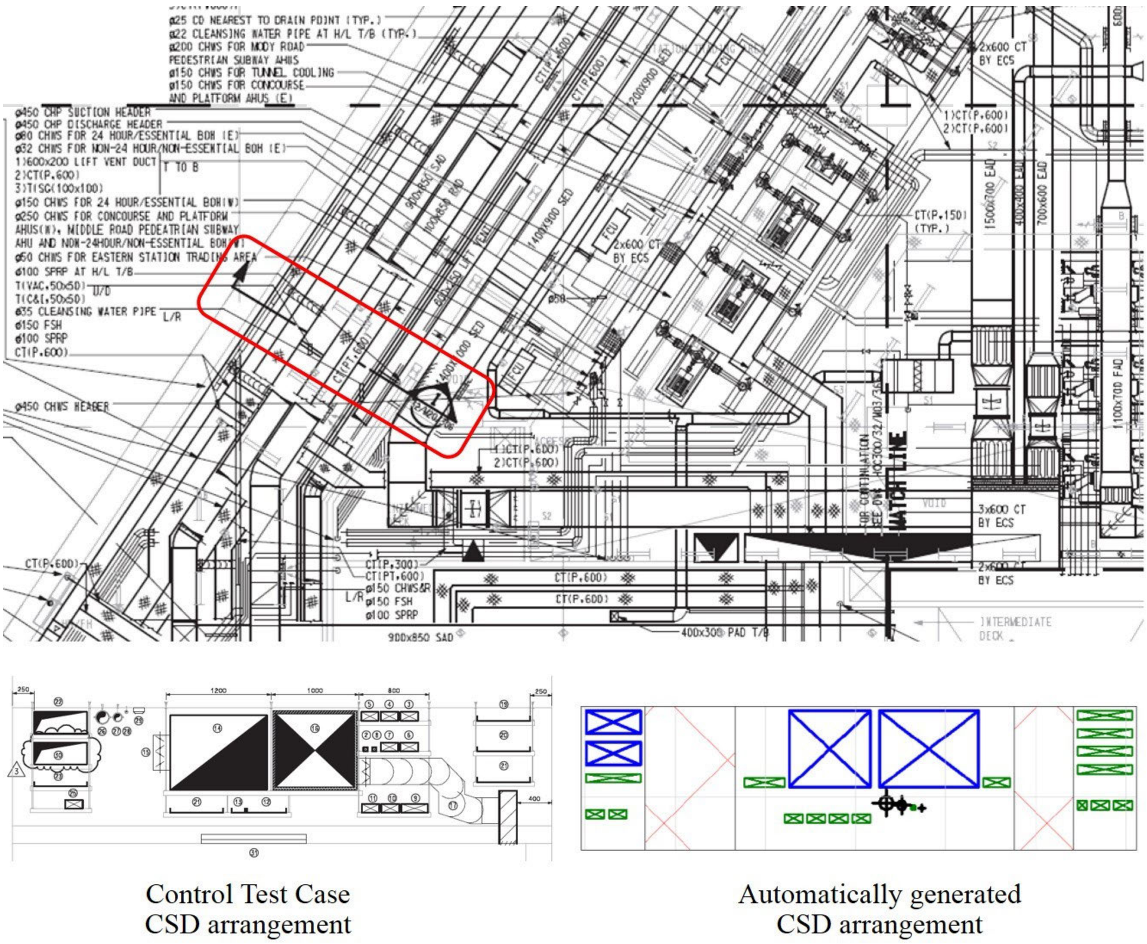
As an engineering consultancy, the major role of the organisation in the case study is to design projects or structural elements for projects. The organisation has fully implemented BIM, and the director confirmed BIM is a benefit in the design phase, saying '*the design of a project is made easier with BIM tools*'.



F g 12 - Commun cat on through BIM (nav ate 2019)

The literature shows design automation features as a BIM capability that benefits users. Having consistent drawings with updates in real time saves a significant amount of time and resources. When design adjustments are necessary, fully consistent drawings can be produced as soon as the design changes are entered (Eastman et al. 2018).

Visualisation of designs from the client's perspective is an area where BIM is a vital tool. Building owners, for example, like to see their structures in 3D rather than 2D, since this technology provides a more complete and “real world” perspective. A virtual walk-through of the building is possible to gain an even better perspective of the building not possible before. This allows the approval and feedback to process to be completed with less back and forth and less confusion. Resolving problems at this early stage will result in significant cost savings throughout the building phase.



F g 13 - Automat c sect on generat on (A bany Tam 2016)

6.2.4 Construction

While BIM is most often associated with design and pre-construction, it is beneficial in the construction phase of the project as well. BIM enables projects to be created digitally before they are built physically, removing many of the inefficiencies and issues that often occur during construction.

Rework in construction projects is referred to as the unnecessary redoing of a task or process. In construction projects, rework can result from many factors, such as errors, omissions, changes, poor communication, and coordination. Rework adversely affects the performance and productivity and ultimately the profit margins of a project.

The literature shows that rework can have a significant impact on the cost of a project. The construction industry operates on relatively small margins, so reducing the amount of rework and delays can improve productivity and profitability. The literature review identified the cost of rework for a project a significant problem.

A Swedish study revealed the cost of defects determined from seven building projects ranged between 2.3% to 9.3% of the total contract value (Josephson et al. 2002)

Several studies on rework in the Australian construction industry have found similar results where the rework costs on the average were found as 5.5% of contract value (Marosszeky 2006)

Before construction starts, BIM enables trades and subcontractors to better coordinate, identifying any Mechanical, Electrical, Plumbing (MEP) internal, or exterior conflicts. By allowing quick review and discussion across different disciplines in real time, you can prevent last-minute modifications and unexpected problems.

6.2.5 Management

Management of construction projects through their various stages is one of the most important aspect of a project being successfully delivered. Planning and scheduling elements of BIM alongside the communication and collaboration are used to facilitate better management of construction projects.

F g 14 - Schedu ng (b mcommun ty com 2018)

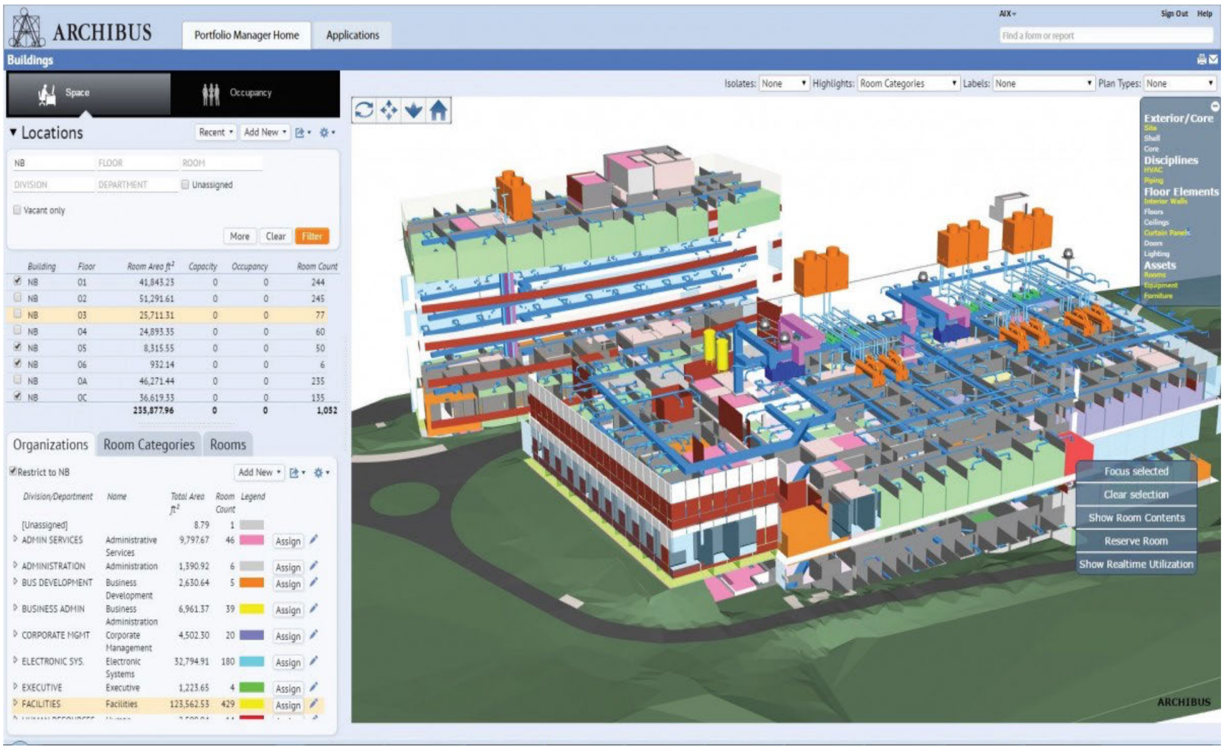
A well-executed construction project management plan can prevent project underperformance, mitigate, and resolve issues before they arise.

Using BIM as a technology is a way to optimise and streamline these processes while creating a better flow of information. BIM as a management tool can help stakeholders to adopt new ways of working and collaborate more effectively.

Integration of the model with schedule information produces collaborative opportunities with subcontractors to ensure schedule accuracy, as well as create efficiencies through better management. Integrating schedules into BIM is commonly referred to as “4D BIM” Model information for scheduling can be used several ways (Hadlin McCool 2015)

Facility managers utilise BIM to plan maintenance and manage daily operations. Inconsistent updates can make project monitoring and navigation more difficult, increasing the risk of team members losing track of critical works. BIM allows efficient team cooperation by providing real-time updates and visualisation (Hadlin McCool 2015)

Scheduling and improved collaboration and communication make BIM an important tool for management a construction project from conception through to project delivery and onto the management of the facility.



F g 15 - Schedu ng Features (Co umb a Un vers ty 2019)

6.2.6 Sustainability

Through the literature review it shows that BIM improves the sustainability of a construction project through 3 aspects.

6.2.6.1 Environmental

BIM's contributions to design optimisation are widely recognised as critical to reduce material and energy consumption. With material waste and the volume of construction waste that goes to landfill this is an important area.

6.2.6.2 Social

The BIM method reduces the risk of a building project by improving communication and cooperation among team members. Predicting problems early in the planning phase improves safety, leading to better workplace environment for workers.

6.2.6.3 Economic

Less waste is generated because of improved construction management, lowering project costs. By increasing material and energy efficiency, BIM helps in design optimisation, reducing capital and lifetime costs.

BIM users have found both immediate and long-term financial benefits from using the technology. The elimination of documentation mistakes was the greatest immediate economic advantage of BIM. Long-term economic advantages have been recognised as fewer contractual claims and lower building costs (Ghaffarianhoseini et al. 2017).

6.3 Limitations

While a more collaborative approach is regarded as a positive of the BIM Method, some problems may still emerge. The accuracy of data fed into the model is one such problem. Parties cannot always rely on the quality of work contributed to the model by others. This requires due diligence by contributors.

An ongoing issue that is highlighted in the literature review is the ownership of the final model and related data. It may be difficult to identify who owns a BIM model if several parties work on it unless it is mentioned clearly. This can create legal concerns, since the BIM model includes data from several sources, who may wish to keep their intellectual property rights to the model they helped create (Eadie Mclernon Patton 2015). This legal concern can be overcome by the issue being explicitly acknowledged prior to design.

Cyber security concerns are another potential issue with BIM. Because of the model being stored in the cloud, issues with internet access and copyright infringement can occur since many stakeholders may access project data via information sharing (Ghaffarianhoseini et al. 2017)

6.4 What Efficiencies Have Already Been Realised?

As building projects increase in size and complexity, the construction sector confronts many challenges.

Technology and other advancements have the potential to boost output and efficiency, but construction projects continue to underperform, run over budget, and suffer delays regularly.

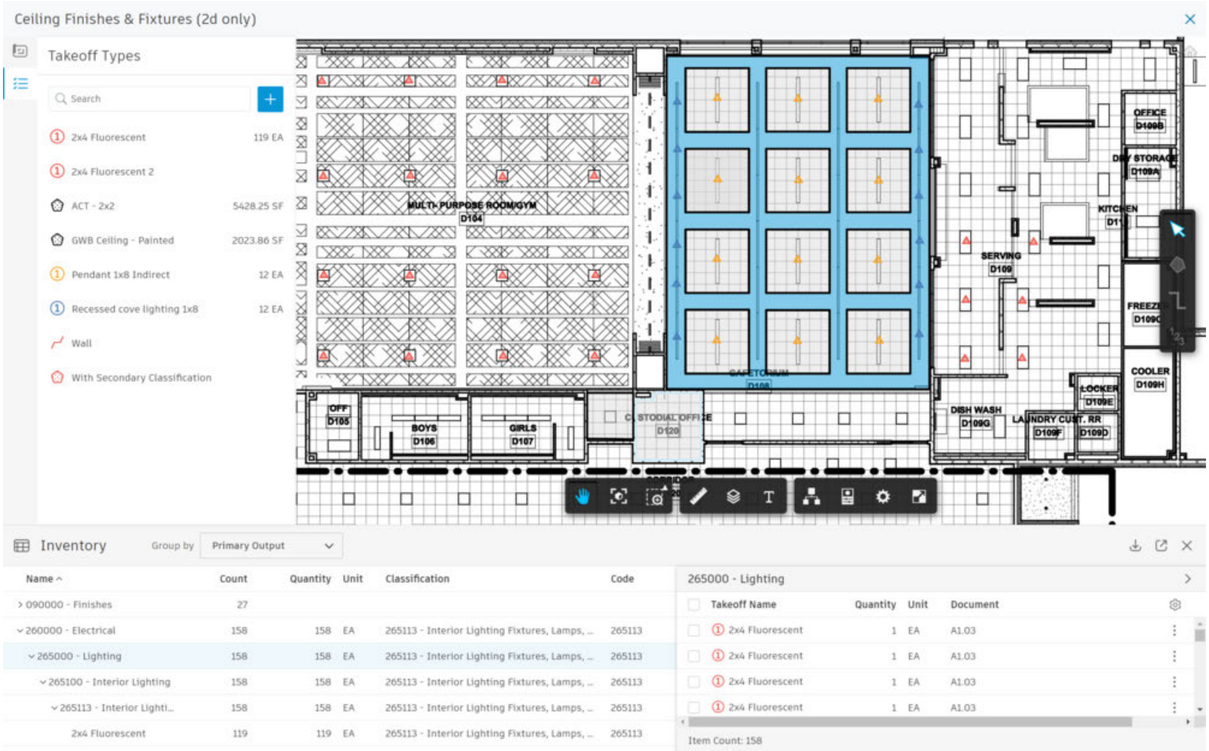
The comprehensive literature analysis and case study revealed that BIM can help the AEC sector adapt. It has been shown that using the BIM method can make the building process considerably more efficient.

6.4.1 Design

Production drawings and details have always been a time-consuming process. BIM has improved this process by allowing architects, engineers, and other project stakeholders to combine and merge models more easily. The working drawing production process is significantly reduced, creating a much more efficient process. The manager is the case study stated the major benefit that the organisation achieves is ‘auto generation of sections and member size schedules’.

6.4.2 Construction

Optimisation of schedule and cost estimation is an ongoing problem in the AEC industry. Inefficiencies because of inadequate collaboration and coordination, late detection of clashes and system conflicts, and poor constructability assessments are common, and all can be mitigated by implementation of the BIM method. BIM offers the data required during the design phase to detect and remove waste throughout the building phase. As stated in previously, the elimination of rework on construction projects can deliver enormous costs saving and productivity gains.



F g 16 - Automat c nventory take-off (Construct on Junk e 2020)

6.4.3 Management

Real time communication between stakeholders of a project is shown in the literature to be the primary efficiency and productivity gain with BIM. In the case study, the manager confirmed delays in sending and receiving plans and updates had largely been eradicated, stating ‘a BIM model can be used quicker than waiting for architects to send requested sections and details’. This access to new data in real time for all in the design and construction process is one of the main benefits to BIM.

6.5 Identify Future Efficiencies

BIM has produced a more efficient workflow but additions to BIM can further benefit the construction industry in the future. Automation of some design features is already used and recognised buy BIM users as a beneficial process. Further automation of design elements will be introduced. Artificial intelligence and virtual reality features of BIM have been identified by Autodesk as future additions to BIM.

Using data for design optimisation is a major potential for BIM in the future. The literature review found applications for the data from data mining applications to be applied for design optimisation was within reach and will benefit many aspects of the design process and ultimately the final product.

The utilisation of measurable performance data to enhance the accuracy design input, simulations, and hence output has been studied by using monitored building data for model calibration and parametric simulation to improve the performance in the design phase (Tronchin et al. 2018)

Design, construction, sustainability, and energy analysis, have the potential to benefit from data mining applications. This process has the potential to further accelerate many of the productivity gains already realised by BIM.

6.6 How is BIM Being Implemented?

BIM implementation must extend throughout an organisation to realise the full potential. It cannot be used in isolation, for example, just a design aid. While this approach to BIM can provide some positive outcomes initially. It won’t change a company and only offers a fraction of the advantages promised by BIM.

The implementation stages are often referred to as maturity stages. Succar developed 4 stages of maturity to define the level an organisation has reached. This can provide a framework for an organisation to progress to the ultimate goal of BIM, which is full integration into the organisation.

Level 0 - encourages no collaboration and relies on paper-based 2D CAD drawing methods. This is an out-of-date level that is no longer utilised by industry experts.

Level 1 - BIM Both 3D CAD and 2D drawing are used. While 3D CAD is utilised for conceptual work, 2D is used for documentation. Because everyone generates and maintains their own data, there is little or no coordination between the many stakeholders at this level.

Level 2 - Encourages collaboration by each stakeholder using their own 3D model. This level is distinguished by collaborative working, which necessitates efficient information sharing.

Level 3 - Is also known as 'Open BIM.' The Level 3 stage allows all participants to work on the same model, eliminating the possibility of contradicting information. Level 3 is the fully integrated use of BIM within an organisation.

Implementing BIM is critical for the AEC sector, and promoting BIM requires the backing of a national policy. The high cost of application and the lack of trained people are major roadblocks for SME's The initial expense of investing in new technology, as well as the time required to educate people, is substantial. Governments, the AEC sector, educational institutions, and BIM suppliers should collaborate to lower BIM implementation costs, develop BIM implementation methods, and promote BIM education.

6.7 Barriers to Adoption

There are many well-documented barriers for adoption of BIM. Many of these now only relate to smaller and medium firms as larger organisation have the resources to fully implement BIM.

This research project concentrated on the barriers for adoption in SME organisations.

The high initial cost of BIM adoption is a barrier to adoption. In the case study the director confirmed that the cost of BIM software was a consideration when determining their product choice but that other factors such as compatibility with other programs was more important. While cost is identified in the literature review as a factor, it is not the major deterrent it once was, with companies now accepting it as another operating cost.

Another concern raised by the director in the case study was the lack of trained candidates available, saying '*in terms of the business case there were no real barriers to adoption, but initial lack of candidates and experience was a concern*'. The cost of training staff has a larger impact of smaller organisations. To meet business needs, a growing number of universities and educational institutions have incorporated BIM instruction for students in undergraduate and postgraduate construction, engineering, and management programmes this will help to provide the skills to the organisation with the increasing adoption and complexity of BIM.

Lack of client demand is a barrier to adoption for smaller organisations. If the there is no willingness for the client to pay for the extra work, it is often does not make economic sense. This can be because the client does not have the awareness of BIM and does not see therefore does not recognise the benefits.

The role of the main BIM developers is another component of the BIM education process. These businesses will have a vested stake in the outcome. This might be done to persuade a younger generation to use their BIM products.

Therefore, BIM education should not be bound to a specific BIM software product, but the BIM process. Although they are, to an extent, unavoidable, efforts should be made to mitigate vested interests in certain software vendors to better instil BIM practical knowledge. Though these issues are minor and manageable (Chen Lu Wang 2020).

Incentivising BIM use is the effective way to increase adoption rates. Countries with high industry penetration and mature usage have some of the most incentives to implement BIM. The industry trend will push organisation in the adopt BIM and integrate it into the businesses but additionally help will need to be provided to smaller organisation if adoption is to increases to match the larger organisations. Training will need to be addressed to further integrate BIM into the AEC industry.

As shown in the literature review, one of the most effective ways to implement BIM into an organisation is to mandate its use. This incentivises companies to adopt BIM and to increase the industry penetration. Many countries have BIM mandates of public.

Denmark has enacted legislation requiring the use of BIM in public projects (Varghese 2020). Other places where the business sector is promoting BIM include the United States, where a growing number of major institutional customers are requiring BIM as part of the tendering process.

With governments and other larger players in the industry mandating or encouraging BIM, smaller organisation will follow the industry trend of BIM adoption. BIM is the future, and this is what is driving most organisations to implement BIM into their organisations.

This was identified by the director in the case study as the reason for their organisation BIM, saying '*industry trend'* was the main reason for adoption.

6.8 BIM Methodology

BIM can provide benefits and efficiencies throughout all phases of a construction project. All these efficiencies and productivity gains can be seen as examples of how the BIM methodology can improve the construction process.

The adoption of the BIM methodology into AEC organisations can increase productivity in the sector. This will require adjustments in how certain parts of the industry approach the construction process. The BIM methodology is a process that integrates people, systems, and business structures into a collaborative process to minimise waste and maximise efficiency throughout the project's life cycle (Azhar, 2011). The BIM methodology can require significant changes to an organisation's workflow and operations. But it allows the integration of all project stakeholders' roles.

From the literature review it was shown that the AEC industry can struggle with collaboration. This has been identified as a source of some problems that adopting the BIM process can improve. A more collaborative process can change the mindset of parties working against each other and to working towards a common goal, which is ultimately the successful delivery of the project. This method allows a better understanding of each party's position and will help develop a more collaborative environment.

A risk that was identified in the literature review is that a more collaborative approach could encourage a less critical view towards the construction process. Allowing a complacency towards critical analysis if everyone feels like they on the same team (Azhar 2011). From further analysis of the literature, this concern seems to have not been realised and the enhanced collaboration of the BIM methodology has produced productivity gains and better relationships in the AEC sector.

The increasing use of BIM will enhance collaboration and reduce fragmentation in the AEC industry, leading to further improved performance and lower project costs. The BIM methodology overall is about enhanced collaboration in all aspects of the construction process. It is the source of the benefits that can be achieved. The BIM methodology is the idea and the process that needs to be adopted to realise the individual benefits from BIM.

6.9 Recommendations and Summary

The results of the research project have shown that there are many benefits for an organisation in adopting the BIM process. The research project has shown benefits can be achieved and how adoption of BIM can address some issues that the AEC industry faces today.

When implementing BIM into an organisation, full integration should be the goal. BIM outcomes for each organisation a likely to be different. Setting clear goals on the expected outcomes will make implementation an achievable process. Implementation can sometimes require changes in how an organisation operates. Changes that are hard to make can be a deterrent, therefore, implementation strategies and goals from another organisation should be considered.

The barriers to adoption for larger organisation have been overcome largely because of their resources. BIM mandates and requirements from certain clients on larger projects has also driven adoption rates among larger organisations. The research shows that barriers to smaller organisations are still an issue, and this is reflected in the lower adoption rates. Despite many smaller organisations being aware of the benefits and being open to implementing the BIM process, a lack of client demand on smaller projects remains to be a significant barrier. If an organisation is ready to adopt BIM, it may need to convince clients of the benefits that it can achieve not just in the design and construction phase but with the ongoing facility management.

The research shows that mandating BIM has been a successful method to increase adoption rates. This has largely been done by governments on large public projects and projects above a certain value. Further mandates in other areas could drive continue to drive adoption.

The future of BIM is to build on efficiencies already achieved by adopting the BIM process. Further automation and predictive design features will enhance the productivity of design teams that use BIM. BIM will play a role in improving the sustainability of the AEC industry. Construction waste is a major issue that needs to be addressed properly and the research shows that BIM can help in this area. The energy analysis and other features to encourage sustainability is an area where the performance of buildings will be improved because of BIM.

The case study confirmed many of the findings from the literature review. The research found that the benefits to large organisations were well documented. The case study was completed to gain a better insight into the benefits that could be achieved in an SME organisation. Design automation and better collaboration with outside stakeholders and within the company itself, show that the benefits in the literature for large organisation can be achieved at a company with fewer resources. This company worked on projects that had client demand for the use of BIM, so they could avoid a barrier that can still limit the use in some organisations.

The way BIM can improve the workflow and productivity of each phase of a construction project is linked to the enhanced ability for collaboration. This is an area that the construction industry has historically struggled in and causes some of the issues identified in the literature review. By facilitating better communication between all stakeholders, the BIM methodology can improve the outcome for all parties involved in a construction project. A more collaborative AEC industry is better for the industry and the community.

CHAPTER 7 - Conclusions

7.1 Introduction

The aim of the research was to identify the benefits of BIM and how adoption can improve issues faced by AEC industry. The research project was motivated by a desire to investigate the potential of BIM after experiencing the benefits it can bring to a project.

A literature review was completed to analyse the previous research in this area and to identify the advantages achieved by organisations that have adopted BIM. The research revealed that benefits to an organisation can be achieved in all phases of a construction project. The review of the literature revealed that majority of the previous research had been on the use of BIM in larger organisations. The research had gaps in relation to smaller organisations and that further research could be completed in this area.

To get a better understanding of the benefits a smaller organisation could achieve and to add to the literature on this topic, a case study was completed. The findings from the interview process show that for a small organisation there are benefits in line with the larger organisations. Adopting the BIM process is shown to be beneficial to smaller organisation as well.

7.2 Conclusions

The outcomes of the research objectives of the research project were to identify the benefits and efficiencies to be gained from the BIM process. The areas where there were barriers to adoption and to explore implementation practices. The research objectives were achieved by the combing a literature review and a case study analysis of an SME organisation. The case study and findings for the literature were analysed to report the findings and recommendations.

The research identified where the benefits from BIM are achieved in large organisations and to a lesser extent in smaller ones. The review of the literature showed the use of BIM can provide efficiencies at all stages of the construction project life cycle. The facilitating of better collaboration is how the BIM process enables most of the productivity gains. The consensus in the literature was that all phases of a construction project is more productive with better communication with the BIM process.

The cases study was successful in identifying benefits and efficiencies that a smaller engineering firm can achieve. The projects the company undertakes are small to medium-sized commercial projects, which meant there was a demand from the client on most of their projects. This allowed the company to avoid a major barrier to adoption for smaller companies, which is a lack of client demand. The company did not face any barriers to adoption. Only concerns about staff training. This area of adoption reluctance in smaller organisations is something the case study research did not cover comprehensively. Discussions with a SME organisation about the barriers identified in the literature was not fully achieved and could be enhanced by interviewing more organisations.

By identifying that the literature was skewed towards larger organisation and projects, the aim of the research and case study was to add to the literature of SME organisation adopting the BIM process.

Ultimately, the goal for large and smaller organisations is to become more efficient in their output, become more sustainable and to provide a safe working environment for their employees. By adopting the BIM methodology and aiming to fully integrate this process into the organisations, the efficiencies and productivity benefits discussed in this paper are achievable.

7.3 Further Research and Recommendations

The research shows that the BIM process is not just beneficial to large organisations. It has been shown that organisations of all sizes would benefit from adopting BIM. The literature is well represented with case studies of large organisations and how the BIM process has been implemented successfully. The gap in the literature was regarding SME organisations. Further research could be done to examine in more depth, the BIM process regarding smaller projects. The feasibility of small organisations to adopt BIM, which undertake small projects in the commercial and residential sector, would enhance the understanding of the BIM process in this area and help further drive BIM adoption rates.

7.4 Limitations

The research achieved the aims set out, although there were some limitations that would have provided more in-depth findings. The case study was conducted by completing an interview with the subject. Access to documents and a further in depth an analysis of one their projects would have provided more in-depth analysis of the benefits the BIM process provided to the case study organisation. Repeating this approach with several case studies would provide further depth to the results and could have been achieved with more access to other organisations.

Appendices

Appendix A – Project Specification

University of Southern Queensland

Faculty of Health, Engineering & Sciences

ENG 4111 / 4112 Research Project

Project Specification

For: Drew Eager

Title: Use of Building Information Modelling in the Design, Construction or Asset Management of Buildings and Infrastructure

Major: Civil Engineering

Supervisors: David Thorpe

Enrolment: ENG4111 – EXT S1, 2021

ENG4112 – EXT S2, 2021

Project Aim: Investigate the potential benefits of the use of BIM software to provide efficiencies in the design construction and management phases of a project.

Programme: Version 1, 18th March 2021

1. Literature review
2. Review BIM software in use in Australia
3. Research the expected outcomes and efficiencies of BIM
4. Analyses procedures prior to BIM use
5. Investigate current take-up/usage of BIM. Identify proponents and opponents. Compare Australian use to world use
6. Comparison of outcomes with BIM use and without
7. Investigate potential to improve the design, construction and facilities management or a project
8. Investigate suitable projects for a case study/s
9. Case study of infrastructure project including the potential to save time and costs, improve quality, and improve the ongoing life cycle management
10. Cost/ benefit study of the use of BIM in case study project
11. Demonstrate BIM advantages and negatives for wider industry
12. Final recommendations on use of BIM

If time allows,

13. Potential BIM outcomes in the future

Appendix B – Timeline

Semester	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	B	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Activity																															
Projec Proposal																															
Projec Plan																															
Projec Resources																															
Li era ure Review Research																															
Wri e Li era ure Review																															
Research B M Use in Aus ralia vs World																															
nves iga e Expec ed Ou come of B M Use																															
Analyses Expec ed Ou comes From B M																															
nves iga e mplemen a ion B M																															
nves iga e Possible Projec for Cases S udies																															
n erview B M Users																															
Case S udy 1																															
Case s udy Comparison																															
Wri e Up Draf																															
Projec Conference																															
Review Draf																															
Wri e Up Final Disser a ion																															
Submi																															

Appendix C - Interview Questions

Organisation:

Number of employees?

Primary work discipline?

In which sector of construction are most projects?

What BIM Stage is the organisation at out of the following?

- Pre-BIM stage - Traditional CAD based methods.
- Stage 1 – Migration from CAD to BIM, use of BIM modelling, no collaboration with other stakeholders, single discipline approach to BIM use.
- Stage 2 – Design and management, collaboration with other stakeholders,
- Stage 3 – Move from collaboration to integration in the organisation, interaction in real time with stakeholders, BIM integrated into full life cycle of the project.

Do you use it from conception to delivery or only in certain aspects of a project?

Software:

What software do you use?

Why did you choose that software?

Is cost a consideration?

Training:

Did employees have BIM skills prior to hiring?

If needed does the organisation provide training to staff?

Adoption:

Were there any barriers to adoption?

Was there a catalyst for adopting BIM?

Was there any reluctance to adoption in the organisation?

Implementation:

Have you experienced any resistance to its use from clients or partners/other stakeholders (builders, subcontractors etc.)?

Where did the main push for implementation come from? Organisation or client?

Benefits:

What have you found are the main benefits of BIM use?

What is the main negative, if any of BIM use?

Do you view BIM as a software program/tool or a process/complete method of working?

Has BIM improved productivity?

Efficiencies:

What area has the biggest efficiency gain?

Is there any area that you expect to provide further efficiencies in the future?

Do you or have you reviewed BIM performance?

Do you have goals for efficiencies to be gained?

Has it reduced delays in any areas that would have happened before?

Productivity:

Has there been noticeable improvements in these areas?

- Looking for project information?
- Conflict resolution?
- Dealing with mistakes and rework?
- Undecided on the benefits?

- Poor communication between stakeholders?
- Lack of confidence in data accuracy?
- Delays in receiving information?

Collaboration:

Has BIM enabled more collaboration within the organisation?

Has BIM enabled more collaboration outside the organisation, with clients or other project stakeholders?

Have clients requested BIM use?

Has BIM improved communication improved with clients?

Design:

Has it made design phase easier?

Has BIM prevented any issues regarding rework on site or in the design phase?

Management:

Has it made management of projects easier?

Appendix D – Ethics Approval

[RIMS] USQ HRE Application - H21REA216 - Expedited review outcome -Approved Inbox ×

human.Ethics@usq.edu.au   Tue, Sep 28, 11:31 AM

[redacted]

Dear Drew

I am pleased to confirm your Human Research Ethics (HRE) application has now been reviewed by the University's Expedited Review process. As your research proposal has been deemed to meet the requirements of the National Statement on Ethical Conduct in Human Research (2007),
ethical approval is granted as follows:

USQ HREC ID: H21REA216
Project title: Investigation of Potential Benefits of The Use of BIM Software to Provide Efficiencies in The Design Construction and Management Phases of a Project
Approval date: 28/09/2021
Expiry date: 28/09/2022
USQ HREC status: Approved

The standard conditions of this approval are:

a) responsibly conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal;.

(b) advise the University (email:ResearchIntegrity@usq.edu.au) immediately of any complaint pertaining to the conduct of the research or any other issues in relation to the project which may warrant review of the ethical approval of the project;

(c) promptly report any adverse events or unexpected outcomes to the University (email: ResearchIntegrity@usq.edu.au) and take prompt action to deal with any unexpected risks;

(d) make submission for any amendments to the project and obtain approval prior to implementing such changes;

(e) provide a progress 'milestone report' when requested and at least for every year of approval.

(f) provide a final 'milestone report' when the project is complete;

(g) promptly advise the University if the project has been discontinued, using a final 'milestone report'.

The additional conditionals of approval for this project are:

(a) Nil.

Please note that failure to comply with the conditions of this approval or requirements of the Australian Code for the Responsible Conduct of Research, 2018, and the National Statement on Ethical Conduct in Human Research, 2007 may result in withdrawal of approval for the project.
Congratulations on your ethical approval! Wishing you all the best for success!

If you have any questions or concerns, please don't hesitate to make contact with an Ethics Officer.

Kind regards

Human Research Ethics

University of Southern Queensland
Toowoomba – Queensland – 4350 – Australia
Email: human.ethics@usq.edu.au

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