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Dissertation

BIM standardisation and its effect on project delivery in the Australian civil design and construction industry

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Abstract

There is little guidance available in the adoption and use of Building Information Modelling (BIM) in the delivery of Australian civil infrastructure projects, including difficulties arising from inconsistencies in the new terminology and standards. According to Schafermeyer and Rosenkranz (2011) there is a high possibility that a nation develops a "constellation of fragmented approaches" if BIM policy processes are reliant on in-house handbooks. This research project explores past studies by way of an extensive academic and industry literature review covering BIM concepts, the benefits and barriers to its adoption and global trends in BIM standardisation, as well as employing a quantitative methodology approach to identify the effect that BIM standardisation and adoption practices has on project delivery.

A survey questionnaire was designed and distributed to 150 stakeholders, consisting of BIM managers, engineers, CAD technicians and other stakeholders, from within the Australian civil design and construction industry to accomplish the outcomes of this project. The research data collected has been analysed using the Relative Importance Index method, and a synthesis of the findings compiled. Key quantitative findings have shown that there is a lack of uniform adoption of certain standards within the industry, noting that the majority of respondents agree that the lack of standardised protocols creates obstacles to the adoption and use of BIM. Training is absolutely essential for the purpose of achieving the successful adoption and use of BIM and to respond to the demand of a growing industry, in the face of inconsistency. Training must not just concentrate on BIM technology, it must also concentrate on the enforcement of standards, and a general strategy concerning data management and project delivery.

This research project is concluded with a reflection on the goal of the project and discusses the strengths and limitations of the research. Recognition of further work to bridge the knowledge gap is also discussed.

Keywords: Building Information Modelling (BIM), standardisation, adoption

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ENDORSEMENT

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Finally, I would like to acknowledge the encouragement and support given to me from my family and friends over the years while I have been studying.

ABBREVIATIONS

BAC	BIM Acceleration Committee	ICT	Information and communications technology
BIM	Building information modelling	IPD	Integrated project delivery
BS	British Standards	LOD	Level of development
BSI	British Standards Institution	NIBS	National Institute of Building Sciences
CAD	Computer aided design	PAS	Publicly Available Specification
CDBB	Centre for Digital Built Britain	RICS	Royal Institution of Chartered Surveyors
CDE	Common Data Environment	SME	Small and medium enterprises
DE	Digital engineering	TfNSW	Transport for New South Wales
EUBTG	EU BIM Task Group	UK	United Kingdom
GDP	Gross Domestic Product	USA	United States of America
GIS	Geographic information system	VDAS	Victorian Digital Asset Strategy

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Chapter 1 - An Introduction to the Study

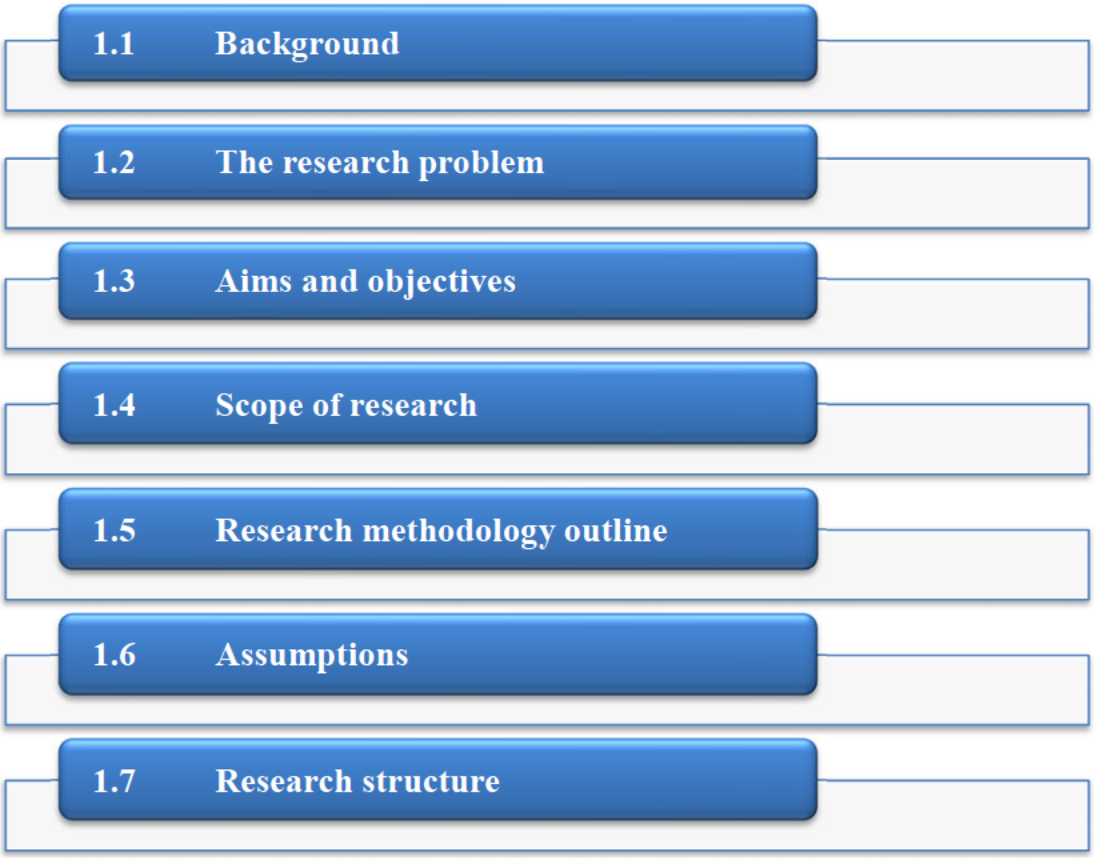


Figure 1: Structure of Chapter 1

1.1 Background

With the change from conventional hard copy design drawings towards CAD in the late twentieth century, crucial changes have occurred in the design and construction industry in the last few decades. Engineers, designers and builders were seen as "walking databases" containing all the project knowledge required and being accountable for all the errors and collisions to be overcome (Czmoch & Pękala 2014). Similar to the shift from manual drawings to CAD, the civil design and construction industry is undergoing further growth in the use of BIM (Kiani et al. 2015). More and more clients require deliverables that have used BIM. The growing use in BIM has transformed the construction industry to manage scope, time and cost, all of which influence a favourable project delivery.

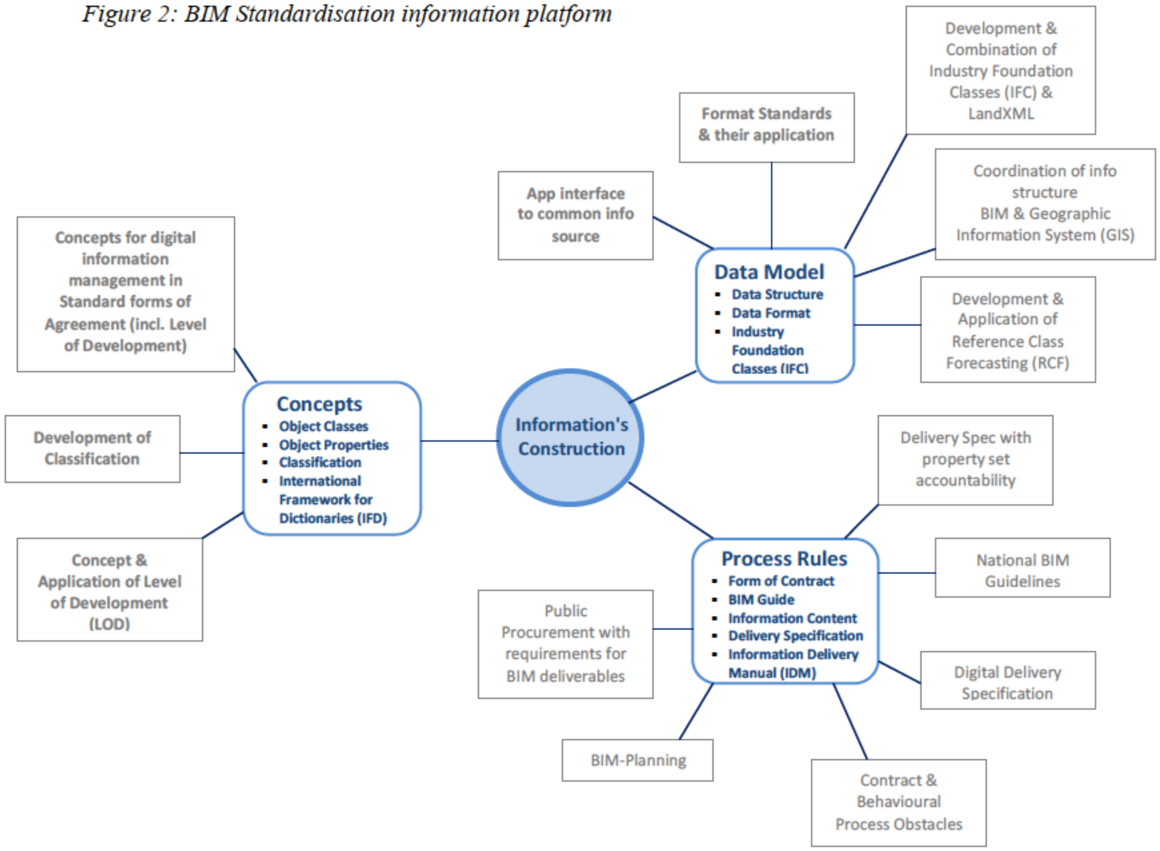
According to GHD (2018), clients and contractors aim to cut down on costs and a 'right first time' design, hence the necessity for precise, clash-free design models is crucial without being costly to produce. For this reason, automated design results for organisation and clash detection is vital. The shift from paper-centric information to parametric, model-based information indicates that the digital design may include details on cost estimates, logistics, simulations, scheduling, energy analysis, structural design, construction, geographic information system (GIS) integration, fabrication, maintenance and facilities management (AIA Trust 2020). Parametric modelling is the core of the thorough implementation of BIM in practice (Czmoch & Pękala 2014), however the failure to provide knowledge and skills are key obstacles to BIM adoption.

The Australian civil design and construction industry is changing as BIM becomes more widely used. Numerous large companies are now operating within the BIM framework however Australia is still trailing other countries in its implementation. The ability to collaborate without difficulty is an important benefit of BIM however inadequate generally-acknowledged standards for BIM content frequently hinders the collaboration process and results in an ineffective workflow and a great deal of additional effort to deliver projects.

Standardisation is the method of establishing standards founded on the consensus of various experts from within an industry. In the civil design and construction industry culture there is a propensity to maximise only at personal or corporate level, not the whole method. For this reason, it is essential to classify and comprehend the strategic disparity between industry standards and organisation standards in relation to BIM. When BIM is examined as a complete project delivery approach, commonalities can be seen with the Information and Communications Technology (ICT) domain. Standards in relation to ICT can be grouped into Concepts, Data Model and Process as shown in Figure 2. These concepts and categorisation of concepts are required for all stakeholders to be all on the same page. A standardised procedure for information delivery and a standard modus operandi is essential (Poljanšek 2017).

Australia needs an integrated and consistent approach, comprising the latest standards and policies, education and a standardised approach concerning data management and project delivery, so that BIM can be implemented entirely across the industry. Consequently, this research aims to identify the effect that BIM standardisation and adoption practices has on project delivery in the civil design and construction industry.

Figure 2: BIM Standardisation information platform



(Poljanšek 2017)

An extensive literature review on international and Australian BIM standards and policy initiatives, an examination of an appropriate industry case study that has already implemented BIM on the project, and a survey of a cross-section of industry stakeholders, will be conducted for analysis. This research project will therefore aim to establish a comprehension of BIM adoption practices, the barriers to its adoption and the impact BIM has on project delivery throughout the Australian civil design and construction industry, with a specific focus on international and national BIM standardisation.

The outcome of this research is likely to determine the impact of unsatisfactory implementation of BIM on project delivery as opposed to the impact of effective implementation, in addition to encouraging stakeholders in the civil design and construction industry to embrace and utilise BIM over the full lifecycle of a project.

1.2 The Research Problem

Preceding BIM adoption, 2D design plans were more lengthy thus projects were allocated additional time for completion. Historically, drafters and designers aimed for their plans to be almost one hundred percent accurate prior to final plans being generated although with the establishment of BIM and federated 3D modelling, plans are currently being drafted in haste to satisfy reduced timeframes. BIM is an essential component of project completion and often demanded by clients. Major stakeholders, particularly clients, strive to minimise costs and a design that is correct at the first attempt, consequently the demand for exact design models is vital without the financial burden of producing them.

Numerous large companies are now operating within the BIM framework however Australia is still trailing other countries in its implementation, especially in small and medium sized design and construction firms. This may be due to inadequate organisational expertise, inadequate training, no client demand and lack of standardised protocols (NBS 2019). Ayinla and Adamu (2018) suggest that a "digital divide" is being formed in the construction industry between large organisations and SMEs even though BIM is intended to assume the role of a merging force in the existing fragmented industry. The findings of Newton and Chelishe (2012) indicate that favourable implementation of BIM requires expert designers although as a result of the considerable expense involved with implementation, the utilisation of BIM would be confined to major projects, thus impeding its use in smaller design organisations.

There seems to be very little guidance available in the adoption and usage of BIM in the delivery of infrastructure projects within the civil design and construction industry, including the difficulties arising from inconsistencies in the new terminology and standards. Therefore, up-to-date uniform standards and policies are crucial to facilitate BIM, however it is necessary for these to be taught and accepted by industry professionals so that they can apply them correctly and routinely. Consequently, the focus of this research is based on the effect that BIM standardisation has on project delivery, which is particularly relevant with the release of the new International Standards for BIM in December 2018 (NBS 2019).

1.3 Aims and objectives

In order for BIM to be implemented completely throughout the Australian civil design and construction industry there needs to be a consolidated uniform approach, incorporating up-to-date standards and strategies in line with international standards, training and a standardised strategy towards information management and project delivery.

The aim of this research is to identify the effect that BIM standardisation and adoption practices has on project delivery in the Australian civil design and construction industry. For the purpose of achieving this aim, the following goals are defined:

- to conduct a thorough review and analysis of BIM concepts, adoption practices, barriers to its adoption and national and international standardisation efforts and initiatives;
- to deliver fundamental data on what is needed to successfully operate and deliver a BIM project over its entire lifecycle; and
- to develop recommendations as to what is required in the industry in order for organisations within the private sector to reach the new international standards for BIM.

This research will lead to a better understanding of what is required in the industry and as a nation in order to reach international standards. It is also expected to show the effects of poor implementation of BIM on project delivery versus the effects of successful implementation, which may assist industry stakeholders in the civil design and construction industry to consider adopting and using BIM throughout the entire lifecycle of a project. Additionally, if the research methodology produces sufficient results, it may push the Australian government to mandate the adoption of BIM across the whole design and construction industry in all states, in accordance with the new International Standards for BIM. It may also assist the global prospects for small and medium design and construction firms to win tenders for projects in new markets more equitably.

1.4 Scope of research

The scope of this project is confined to the Australian civil design and construction industry, incorporating organisations that are involved with both public and private sector projects. The research will be carried out by surveying BIM managers, engineers, CAD technicians and other industry stakeholders, via an internet-based questionnaire, to obtain their views on the effect that BIM standardisation and adoption practices has on project delivery. The scope of this project will incorporate five sections:

- ascertaining participant demographics;
- determining the factors contributing to organisations not adopting or using BIM on projects;
- identifying the beneficial impacts that BIM adoption and use has on project delivery;
- identifying an organisation's standardisation efforts; and
- determining whether or not organisations are working to international standards ISO 19650.

1.5 Research methodology outline

Research methodology is a systematic process that involves the theoretical foundation, gathering, analysis and interpretation of data (Patel & Patel 2019). Taking into consideration the type and aims of this research, the research methodology is addressed separately in three phases, that is, determining the knowledge gap, collection and analysis of data, and the formation of a frame of reference. The phases are clarified as follows:

- **Determination of research gap**: This phase consists of an extensive literature review on relevant areas of research. A literature review is an empirical, thorough analysis of a topic in order to develop a research concept, to strengthen what is known about a topic and to determine the knowledge gap (Winchester & Salji 2016). The literature review will give an overview of BIM, including the advantages and disadvantages to its adoption, and BIM standardisation and policy initiatives in Australia, United Kingdom (UK), United States of America (USA) and New Zealand in order to understand the impact BIM has on project delivery throughout the Australian civil design and construction industry. The results of this phase will be a sound knowledge and documentation of the research field and issues in question.

- **Collection and analysis of data**: During this phase, a cross-section of industry stakeholders are canvassed to gather the key research data. These stakeholders are involved in projects that have utilised or are currently utilising BIM on projects. The data will then be collected and analysed for results.

- **Frame of reference**: During this phase, the analysed results will be synthesised to form a frame of reference.

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1.6 Assumptions

Assumptions in any research project affect the conclusions drawn from the whole research process. Assumptions in quantitative research commonly refer to the features and attributes of the data, for example associated developments and trends, variables and distributions. Disregarding these assumptions may cause incorrect findings however this frequently relies on the representative sampling and additional factors. The general assumptions drawn from this study include:

1. Respondents surveyed answered honestly and truthfully in the survey questionnaire in line with their own personal history and experience with the delivery of BIM projects;
2. Respondents were free to reply that they had no knowledge of the topics asked in the survey questionnaire; and
3. The respondents to the survey questionnaire are a true representation of stakeholder perspectives within the civil design and construction industry on BIM standardisation and adoption practices and its impact on project delivery.

1.7 Research structure

Chapter 1 of this dissertation summarises and contextualises the research, including the background; research problem; aims, objectives and scope of the research; research methodology outline; assumptions to the study and dissertation structure.

Chapter 2 examines the literature in relation to the four key aspects of this research: What is Building Information Modelling (BIM), advantages to BIM adoption, global trends in BIM standardisation and the barriers to BIM adoption. It then reviews a case study of an Australian civil infrastructure project that has used BIM in the design and construct. Additionally, it explains the conceptual basis used which supports the development of this research.

Chapter 3 describes the quantitative methodology approach employed in the design and collection of data from the survey questionnaire to accomplish the outcomes of this project. The research data is then organised, responses examined and a synthesis of the findings compiled. Additionally, this chapter explains in more detail the significance of internet-based questionnaires as well as outlining the key resources used to develop the survey questionnaire and any ethical considerations and potential risks to survey participants.

Chapter 4 provides an extensive data analysis of the results from the questionnaire with the aim of determining the relative importance of several key areas in relation to BIM adoption practices and standardisation efforts in the civil design and construction industry and the effect they have on project delivery. A discussion of the findings and lessons learned will also be presented.

Chapter 5 assesses and concludes the research by reflecting on the goal of the project and discussing the strengths and limitations of the research. Recognition of further work to bridge the knowledge gap is also discussed.

Chapter 2 - Literature Review

Figure 3: Structure of Chapter 2

2.1 Introduction

Organisations are developing their own in-house BIM handbooks due to a lack of national leadership in BIM implementation, which may ultimately have a negative impact on the nation's ability to compete (Hooper 2012). According to Schafermeyer and Rosenkranz (2011) there is a high possibility that a nation develops a "constellation of fragmented approaches" if

BIM policy processes are reliant on in-house handbooks. The ability to collaborate without difficulty is an important benefit of BIM however inadequate generally-acknowledged standards for BIM content frequently hinders the collaboration process and results in an ineffective workflow and a great deal of additional effort to deliver projects. BIM standardisation on a national level is something that the Australian government needs to address to ensure the successful delivery of projects industry wide. Statements made that there is inadequate standardisation in the construction sector to assist with BIM procedures are substantiated by Azhar (2011) and Gu and London (2010). Ayman, Alwan and McIntyre (2020) also propose that any doubts in sustainable construction procedures could be managed by using BIM technical skills to oversee resources. Their research observes the future fields of advancement in the alliance between BIM and sustainability and examines the advantages and gaps of BIM at the project level, ultimately giving stakeholders the capability to minimise the time, energy and mistakes on conventional duties.

This chapter presents the concept of BIM, the advantages and disadvantages to its adoption and current global trends towards standardisation efforts. Issues in the design and construction industry and an awareness of their impact on project delivery will be elaborated.

Literature searches were confined to academic journal articles and industry reports, publications and websites, which were sourced from academic databases and search engines. These sources gave an effective representation of the research progress made to date and has shown that more research is required to fill the knowledge gap.

The literature review is divided into six main areas:

1. Introduction
2. What is Building Information Modelling (BIM)?
    - 2.1 BIM Maturity Levels
        - 2.1.1 BIM Dimensions
    - 2.2 Levels of Development (LOD)
3. Advantages of BIM adoption
4. Global trends in BIM standardisation
    - 4.1 United Kingdom
    - 4.2 United States of America
    - 4.3 New Zealand
    - 4.4 Australia

5. Barriers to BIM adoption in Australia and New Zealand
6. Case Study
7. Conclusion

The research conducted in this literature review shall furnish the reader with an increased knowledge of what is necessary to effectively operate and deliver a BIM project over the course of its lifecycle, the barriers to adoption of BIM and current standardisation efforts from both an organisational and national level in the Australian civil design and construction industry.

2.2 What is Building Information Modelling (BIM)?

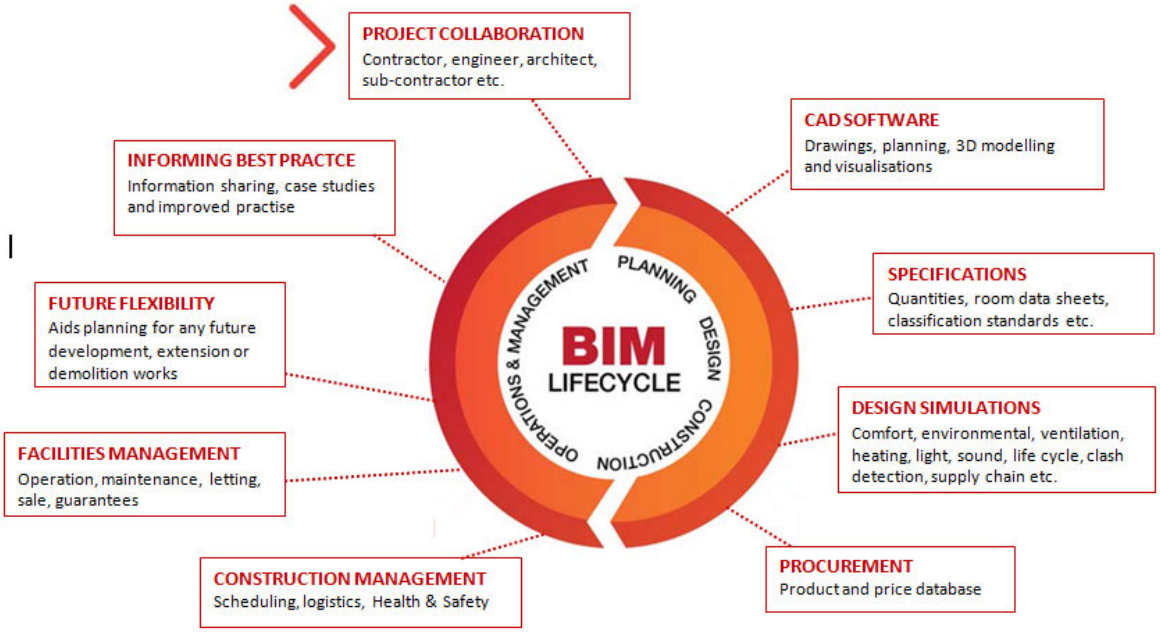
Once BIM is implemented or designated for use at a project, organisational or national level, there is frequently uncertainty and a misunderstanding of how to begin, the actions to be taken and what determines a "BIM project" compared to a "traditional project" (EUBTG 2020).

BIM, as a terminology, serves both as a building information model and a collaborative process utilised by various project stakeholders for creating and managing information on building and infrastructure projects. The model gives the civil design and construction industry the tools to plan, design, construct and manage infrastructure projects. The concept of BIM is depicted in Figure 4. However, regardless of a standard meaning, BIM implies multiple things to various individuals. The inconsistent utilisation of national and international guidelines and terminology for work that needs to be acquired and executed on a project for it to be deemed a BIM project also creates chaos and discrepancies within the industry, producing obstacles for the favourable implementation of BIM.

NATSPEC (2020) describes BIM as a digitised type of construction and asset operations. It unites technological process optimisations and digitised data to greatly enhance client and project outcomes and asset operations. BIM is a calculated facilitator for enhancing the decision-making process for both buildings and construction assets over the entire lifecycle of a project.

British Standards Institution (2020) describes BIM as information handling over the whole lifecycle of a built asset, from original design concept up to construction, maintaining and eventually decommissioning, by using digital modelling.

Figure 4: BIM Concept



(Planning, BIM & Construction Today 2018)

The State of Queensland Department of Transport and Main Roads (2020) defines BIM as a method that concentrates on information management where 3D models and documentation unite to share digital space. The main concept is that BIM is not just one function or method of producing a 3D model separately from using CAD, it is however the information centre for the whole lifecycle of a project.

Ultimately, all definitions of BIM are clearly based on it being a collaborative tool which utilises digital procedures to encourage decision-making and facilitating better productivity in the design, construction, operation and maintenance of assets throughout their whole lifecycle.

2.2.1 BIM Maturity Levels

The recognised standards required for building and infrastructure projects are the levels of BIM maturity. Governments universally are acknowledging that the process of transitioning the civil design and construction industry to completely working together will take a while, and in order to make the process simpler a maturity model to reach the final goal with levels ranging from 0-3 is used. The BIM levels are explained as:

- Level 0 – CAD is used to produce 2D design drawings with output being via paper or electronic means. There is no collaboration involved in this level.
- Level 1 – a mixture of manual 2D design drawings and 3D CAD. There is a limited amount of collaboration of project information across disciplines within the organisation.
- Level 2 – a fully collaborative working environment however each discipline develops its own project information using 3D CAD models but not often working on one shared model. The project design data is shared using a common file format, for example, Industry Foundation Classes (IFC) for generating a federated BIM model (Wildenauer 2020). 4D (time management) and 5D (cost of the project) dimensions are introduced into the project in this level.
- Level 3 – a wholly integrated and collaborative model used by all disciplines via a cloud-based environment. Amendments can be made to the single federated model and updated in real time. A 6D (Project Lifecycle Information) dimension is introduced into the project in this level.

2.2.1.1 BIM Dimensions

Adding additional parameters or 'dimensions' of data to information models allows for further comprehension as to how a construction project will be delivered, the costs involved and its sustainability. BIM dimensions 3D, 4D, 5D, 6D, 7D and 8D relate to the nature of the data and in what manner that data is displayed in a BIM model, however the dimensions used may differ from the expected maturity levels.

- 3D BIM - the third dimension is a shared information model that consists of geometrical and graphical data. It enables stakeholders to collaborate efficiently in order to detect possible errors and rectifying them prior to any construction work commencing.
- 4D BIM - the fourth dimension incorporates timelines and scheduling data into the BIM model which assists with demonstrating how the construction project will develop over a period of time. The visual image of this data is useful in initial clash detection and the effect of modifications made throughout the whole lifecycle of the project.

- 5D BIM - incorporating cost into the BIM model the fifth dimension assists with the budgeting and cost estimation and analysis of the whole project.
- 6D BIM - the sixth dimension centres on a structure's sustainability and energy demands. The inclusion of this data assists with cost estimation of the whole structure throughout the preliminary design phase, hence lowering energy usage in the long term and improving the future operational management of the structure.
- 7D BIM - the seventh dimension focuses on data relating to operations and facility management saved within the BIM model. It enables stakeholders to monitor data and information relating to a structure, for example, structural condition, specifications, warranty, and operating and maintenance guides. The 7D model enhances the quality services provided throughout the whole lifecycle of a project.
- 8D BIM - the eighth dimension, and newest dimension, integrates occupational health and safety into the BIM model. It provides information regarding accident prevention and security on the construction site, including Occupational Health and Safety manuals and emergency procedures.

(Wildenauer 2020)

These levels offer a simple benchmark for evaluating the maturity of BIM involvement within the construction industry (Khosrowshahi & Arayici 2012) however the dimensions used may differ from the expected maturity level. Measuring the maturity of BIM implementation on a project gives an understanding of how to strengthen processes and make the most of the advantages of BIM.

2.2.2 Levels of Development (LOD)

Levels of Development (LOD) is an industry standard that outlines the maturity of each model component during the design phase and enables project deliverables to be more clearly defined. It assists collaboration between stakeholders. Hooper (2015) notes that LOD is a benchmark of a component's reliability and specificity.

There are six levels of development associated with BIM depicting various phases of design in the construction process:

- LOD 100 – Pre-design: a conceptual phase where the model component is graphically portrayed with a symbol or other generic portrayal;
- LOD 200 – Schematic design: a graphically portrayed model component with approximate geometry;
- LOD 300 – BIM: Design development: the model component is graphically portrayed with accurate geometry as well as functional data;
- LOD 350 – Construction documentation: this phase comprises the information as to how the model components interact graphically with different systems and other components as well as written descriptions.
- LOD 400 – Digital construction management: the model component is graphically portrayed with adequate information and precision ready for fabrication; and
- LOD 500 – Asset information management: As built: the model component is geometrically portrayed 'as built' with accurate (relating to the dimensions of data) and functional information.

Accordingly, as highlighted by NATSPEC (2013), LOD is the most critical concept in terms of collaborative working methods.

2.3 Advantages of BIM adoption

Throughout a project's design and construction stages numerous issues arise as a result of problems in communication, organisation and standardisation. This interoperability problem can be relieved with BIM being implemented. BIM allows better design coordination and improves constructability. It offers the construction industry the opportunity to benefit from project cost efficiencies (however not always easy to implement), increasing productivity, better design quality and greater collaboration between project stakeholders, all of which lead to a faster project delivery (Abanda et al. 2018),

According to the European Construction Industry Federation, the broader implementation of BIM will release cost-savings of 15-25 percent to the world infrastructure market by 2025 (Saar 2019).

The advantages associated with using BIM in the civil design and construction industry include:

- providing stakeholders the opportunity to envisage a completed project with all its components and systems before construction starts. This 3D visualisation and the simulation of the surface area enables the improved planning of resources and procedures throughout the construction stage. The thorough outline of the project prior to construction reduces the risk of time-intensive and costly amendments;
- increasingly precise design estimates due to less design revisions as potential problems are seen prior to any errors having occurred. This minimises the necessity for expensive rectifications and design modifications. Effective designs with reduced energy needs at the pre-construction phase can assist in lowering the amount of carbon dioxide emissions created;
- tracking and monitoring resources and the provision of comprehensive information prior to construction commencing. This will enable the correct quantity of materials to be ordered which can then be restocked when required. This gives rise to reduced waste going to landfill and improved modelling for operational energy use resulting in decreased energy needs from the built environment (EUBTG 2020);
- providing greater support and prefabrication as stakeholders can prefabricate elements of the project offsite without difficulty, saving time and money; and
- better project quality due to decreased project risk and improved predictability of project results (EUBTG 2020).

The expected advantage of BIM at the design, construction and operational stages is approximately one percent of capital expenditure, with the major part of savings (60 percent) forecasted to happen at the asset maintenance stage (Artibus Innovation 2019). Private civil design and construction organisations benefit from greater coordination and quicker generation of precise and accurate information to enhance the decision process and the quality of end results. Government organisations reap the rewards from the economic benefits, for example, increased profitability during the delivery stage and better quality of goods and services throughout the lifecycle of the built asset. For those in government who formulate policies and who are interested in the performance of the civil design and construction industry, these cost-effective benefits can be combined to a national level to assist increased levels of productivity [assessed as gross domestic product (GDP)] and opportunity for growth (assessed as exports) (EUBTG 2020). Table 1 shows the benefits of active BIM programs throughout Europe from a 2016 EU BIM Task Group (EUBTG) Survey. The survey suggests that the main benefit to the government sector is purely economical, which comprises increased levels of productivity and competition in international markets.

Table 1: Benefits of active BIM programs throughout Europe

	BUILT ASSETS		SECTORS	
	Delivery Phase	Use Phase	Construction	Digital
Economic	10% savings on time delivery * * * *	Lower maintenance costs Lower operations costs * * * *	Improve sector competitiveness Grow export capability * *	Grow digital services industry Digital single market
Environmental	Less site waste	Optimise operational energy use Assess whole life-cycle analysis *	Resource efficiency Circular economy *	Data infrastructure resource efficiency
Social	Higher standard of health and safety Improved public consultation and engagement	Improve social outcomes (eg. Patient care, pupil learning) *	Cleaner and safer jobs in construction Attract next generation to the sector	Data security Attract digital talent to construction

KEY

* = Targeted benefit of the surveyed public sector BIM programmes

(EUBTG 2020)

2.4 Global trends in BIM standardisation

The construction industry is currently one of the largest areas of the world economy, representing 13 percent of gross domestic product and engaging seven percent of the international labour force (RICS 2020), however it falls behind other areas of the economy in utilising technology and data to improve efficiency, and the results it delivers to the population. Notwithstanding, it is also an area with major development opportunities with world construction set to increase up to 70 percent by 2025 (HM Government 2015).

Performance and predictability are of considerable interest in the design and construction industry, in particular the necessity for major change to industry procedures to overcome these concerns. With increased construction there is a considerable necessity for effective methods of working, as a consequence the 3D model-based concept of BIM in delivering construction projects is acquiring momentum globally. Table 2 presents the developments in BIM adoption and regulation around the world.

Table 2: Global BIM Regulation Evolution

Status of BIM	Country	BIM Regulation
Open BIM standards and mandate	Austria	2015 BIM standards based on IFC
	Norway	2016 Shared on open BIM certification
Mandates in place	Australia	Restricted mandate in place
	Denmark	2012 BIM for all government offices and university buildings
	Dubai	Restricted mandate in place
	Finland	2007 requires IFC for new buildings and operation based on integrated models
	Hong Kong	Mandate in place since 2014
	Korea	2012 BIM Standard of Korea
	Russia	2017 BIM obligatory for all Federal orders
	Singapore	2015 obligatory for all buildings >5,000 sqm
	Sweden	Restricted mandate in place
	UK	2016 BIM obligatory for government projects
	USA	2008 BIM obligatory for government projects
Future mandates fixed	Chile	2020 BIM obligatory for government projects
	France	2017 planned introduction
	Mexico	2017 Standards for BIM projects
	Peru	2022 BIM obligatory for government projects
	Qatar	2017 planned introduction
	Scotland	2017 BIM Maturity Level 2 to be introduced
BIM programmes planned	Canada	2014-2020 BIM implementation programme
	China	Strong government support
	Germany	2017 - 2020 phased introduction
	Japan	BIM Guideline
	Netherlands	2012 based on open BIM
	Portugal	BIM programme in place
	Spain	Going strong in BIM adoption
Planning on BIM adoption	Czech Republic	Plans for BIM adoption
	Belgium	Plans for BIM adoption
	Brazil	Mandate BIM in 2021
	Italy	BIM mandatory from 2019 for projects above €100 million. Full implementation by 2022
	New Zealand	Going strong in BIM adoption
	Switzerland	Going strong in BIM adoption

(Paul 2018)

The push by governments is crucial for BIM adoption by the civil design and construction industry due to the industry being fragmented and subject to rigorous regulations. The governments of the UK, USA, New Zealand and Australia are advanced in their BIM policy development however their approaches to adoption are significantly different.

2.4.1 United Kingdom

Within the framework of the 2011 Government Construction Strategy, the UK Government has been working towards mandating the use of BIM Level 2 for all government projects and in April 2016, BIM Maturity Level 2 was mandated for all public sector projects and a national BIM Maturity Level 3 strategy was launched (HM Government 2015). However, in the construction industry in Britain, there continues to be a tendency for construction projects to exceed their time schedules. In accordance with the UK government's target to accelerate project delivery processes, Gledson and Greenwood (2017) found that there was an increasing rate of BIM adoption but revealed there was a time lag between realisation and first use.

The examination by Lea et al. (2015) of UK BIM Standards and the interconnection to encourage best practice found that the construction industry is continuing to try to adapt to the standardising processes and codes to leverage the fundamental advantages of BIM, with few companies having embraced them. The acceptance of industry standards and a project planning procedure were acknowledged as essential to the favourable delivery of BIM.

With the significant change from paper-centric 2D designs to 3D digital models over the last ten years, the construction industry has made great advancement in creating standards and guidelines for BIM, particularly the 1192 series, with the UK performing a pivotal role. As outlined in the UK 2020 National BIM Strategy Report, the BS PAS 1192-2 focuses on the project delivery stage of construction projects utilising BIM, where the Level of Information and Level of Detail are collected from design and construction activities. Due to inconsistencies of the 1192 series, the UK BIM Framework (formerly BIM Maturity Level 2), an initiative of the UK BIM Alliance, Centre for Digital Built Britain (CDBB) and British Standards Institution (BSI), was started in October 2019 to deliver a collaborative and united approach throughout the industry. The BS PAS 1192-2 subsequently became the international standard ISO 19650 which has been incorporated into many projects worldwide. BS EN ISO 19650-1, outlining the concepts and standards of information management utilising BIM, and BS EN ISO 19650-2, outlining the delivery stage of information management utilising BIM, were first launched as International Standards in December 2018. Consequently, the measuring of the level of BIM maturity has been substituted with information management maturity 'stages' (RICS 2020).

These new International Standards tackle the inconsistencies in the standards and language by supplying a framework where data is taken into consideration from the commencement of a project to minimise the risk and waste linked with information. The standards will also improve the global prospects for small to medium construction firms to win tenders for projects in new markets more equitably. From here on out, the ISO 19650 framework establishes the fundamentals to allow machine-interpretable data to be shared by technology with far greater efficiency, thus enhancing interoperability (NBS 2020).

In addition to the new International Standards, the UK Government released a consistent classification system for the construction industry for the purpose of gaining all the advantages BIM has to offer. Accordingly, Uniclass 2015 is now an element of the UK BIM Framework and advocated in BS EN ISO 12006-2:2020 "Building construction - Organisation of information about construction works". Meanwhile, ISO 12006-2:2015 is mandated by ISO 19650-2:2018 "Organisation and digitisation of information about buildings and civil engineering works, including BIM - Information management using BIM", which has been endorsed in Australia. Subsequent standards in the series comprise Part 3 - dedicated to operations management of assets and Part 5 devoted to security-minded BIM, digital built environments and intelligent asset management (Naden 2019). This means that there will be increased effectiveness in the collaboration on international projects but also provides the design and construction industry with clarity and more productive information management.

According to the UK BIM Report Survey 2020, 68 percent of industry professionals who have adopted BIM have done so effectively. However, historically, the inadequate in-house expertise, inadequate education and training, and cost have become major obstacles to organisations that might want to implement BIM. Since 2019, the number referencing them has fallen, for example, inadequate expertise has dropped from 60 percent to 56 percent, training from 59 percent to 48 percent, and cost from 51 percent to 46 percent (NBS 2020). The survey indicates that small to medium enterprises have emphasised the challenges of managing the daily business performance and project delivery with extra training and investment in BIM, as well as the size of a project remains a challenge.

2.4.2 United States of America

The USA was one of the first countries to implement BIM in the construction industry (Wong et al. 2010) however due to its lack of standardisation and public coordination on a federal scale BIM adoption in the USA has slowed down, unlike many other countries that are making progress in this area. The JB Knowledge 2019 Construction Technology Report revealed that BIM implementation in the USA has been relatively slow, with only 28.3 percent of construction organisations employing BIM professionals (Clayton 2021). While many countries have national regulations that mandate the use of BIM for government construction projects, the USA does not, permitting various systems to stay in competition. This means that the deliverable is decided on a client-to-client basis or a project-to-project basis (Corcoran 2020). Numerous government departments have developed standards and released them to professional bodies, for example the National Institute of Building Sciences (NIBS), however these standards are developed autonomously with no connection to each other.

In 2015, the NIBS introduced the National BIM Standard-United States Version 3, an industry-consensus standard for the creation and use of BIM (Ali 2019). Then, in May 2021, USA's NIBS partnered with the Centre for Digital Built Britain in the UK to establish a National BIM Program for the purpose of aligning the International BIM Standard ISO 19650 with the country's current BIM competencies (Stein 2021).

2.4.3 New Zealand

The New Zealand Government is yet to mandate the usage of BIM however it is accelerating the implementation of BIM principles and methodologies. In 2014, the BIM Acceleration Committee (BAC) alliance was formed to actively encourage the adoption of BIM in line with the UK's BIM Maturity Level 2, as well as the establishment of ISO 19650, and attempt to eliminate the obstacles to its use (NBS 2019). Prior investigation has shown that the New Zealand construction industry has demonstrated that BIM is advantageous to vertical construction projects but there is now a drive to use BIM in major infrastructure projects, not only with BIM ambition, but favourable BIM adoption and delivery being implemented. Government projects that have piloted the use of BIM include the Auckland International Airport and the City Rail Link (NBS 2019). However, appropriate BIM training is essential for the favourable adoption of BIM, and as there is inconsistent utilisation of standards and language, it is damaging to the progress of the implementation of BIM. According to the ANZ BIM Report 2019, 61 percent of respondents would like a federal government mandate on the adoption of BIM (NBS 2019).

2.4.4 Australia

The Australian design and construction industry is changing as BIM becomes more widely used. Numerous large companies are now operating within the BIM framework however Australia is still trailing other countries in its implementation. Sanchez, Kraatz and Hampson (2014) concluded that there is a wide knowledge gap between current technical abilities and those required for the adoption of digital modelling in the delivery of Australian infrastructure projects. Australia needs a consolidated uniform approach, all as a consequence of very little guidance having been given in adopting BIM in the industry.

The Australian civil design and construction industry is approximately one-third of the size of that in the UK, with a workforce of 1.1 million (NBS 2019). The Australian government currently states that BIM is a basic prerequisite in all major tenders, especially those that are difficult or costly, however it is yet to mandate the use of BIM in both publicly and privately funded construction projects across all of the States .

In March 2016, the Queensland Government launched the State Infrastructure Plan which acknowledged the advantages that BIM has to offer, and in November 2018 released The Digital Enablement for Queensland Infrastructure – Principles for BIM Implementation policy which sets out the aims, objectives and principles for all those involved in the adoption and use of BIM throughout the lifecycle of significant construction assets going forward. The Queensland Government then mandated in July 2019 that all projects worth above $50 million are obliged to use BIM in the initial planning stage, with all large-scale government infrastructure projects to complete transition to BIM by 2023. As at April 2021, there were 27 government infrastructure projects worth more than $50 million that were utilising BIM (The State of Queensland Department of State Development, Infrastructure, Local Government & Planning 2021). One of the projects that has successfully integrated BIM is the Cross River Rail, a 10.2 kilometre rail line from Dutton Park to Bowen Hills (NBS 2019). The value added by BIM improved each phase of this project's planning, design and delivery however the level of any collaboration through BIM was solely dependent on the conditions of the project contracts, which is one of the obstacles to BIM adoption.

The Transport for New South Wales (TfNSW) launched a Digital Engineering Strategy in September 2018 which is being released gradually through several significant publications, as shown in Table 3. The strategy is to be adopted in various major infrastructure and pilot projects. The TfNSW has also been instrumental in endorsing the standards of publicly available specification (PAS) 1192-2 and later ISO 19650, in addition to implementing the UK classification system Uniclass 2015 throughout the transport asset management framework. Classification is essential for efficient project scheduling and implementation, with the justification for Uniclass 2015 constantly increasing. Austroads has advocated for the compliance of Uniclass 2015 for road asset classification and the Australasian Rail Industry Safety Standards Board is reviewing the advantages of Uniclass 2015 for national adoption (TfNSW 2019).

In the same way, the Victorian Government published a Digital Asset Strategy to assist with the take up of BIM in line with UK's BIM Maturity Level 2, with the intention of standardising BIM across the government (NBS 2019). The Governments of Western Australia and South Australia have commenced using BIM in various large-scale infrastructure projects and in March 2020 the Tasmanian Government launched its first strategy for digital transformation "Our Digital Future".

Table 3: Standards and guides to be released in each TfNSW Digital Engineering Framework

Release 1 (Sept 2018)	Release 2 (Apr 2019)	Release 3 (late 2019)	Future releases (2020)
Digital Engineering Standard, Part 1 - Concepts and Principles			
Digital Engineering Standard, Part 2 - Requirements			
The Interim Approach, Getting Started			
Digital Engineering Framework			
Terms and Definitions Guide			
Digital Engineering Execution Plan (DEXP) Template and Project Data Schemas (PDS)			
	Updated Project Data Schemas - Model Properties Specification*, Project Data Building Blocks (PDBB)		
	Scheduling for DE-enabled Projects*		
	Digital Survey Requirements Guide		
	Project Data Guides - Application of Uniclass 2015 for Transport, PDBB Guide, PDS Guide		
	Project Management Guides - Project Deliverables Requirements, Using the MIDP, Using the DEXP		
	2D CAD Guides - The DE CAD Concession		
	BIM Model Guides - Setting up for BIM, DE Design Review		
	Asset Data Guides - Master Asset List*, Why not COBie		
		Updated Project Data Schemas - PDBB, ECM, CAD, BIM, System Requirements	
		Systems Engineering Guides - Engineering Standards Mapping	
		Information Management Guides - Master Classification Library	
		Technology Guides - Procurement and Usage, Large File Storage	
		Visualisation Requirements Guide	
			TBC

*Superseded documents

(TfNSW 2020)

2.5 Barriers to BIM adoption in Australia and New Zealand

According to the ANZ BIM Survey Report 2019, 80 percent of participants are either aware of BIM or have implemented it, in comparison to 73 percent in the UK. This indicates that many organisations in Australia and New Zealand are accepting of BIM and recognise that it should be utilised across the entire project timeline, however not all industry professionals and organisations have adopted it for all projects. The report indicates that the four main obstacles to organisations implementing BIM are inadequate organisational expertise, inadequate training, no client demand and lack of standardised protocols. Up-to-date uniform standards and policies are crucial to facilitate BIM, however it is necessary for these to be taught and accepted by industry professionals so that they can apply them correctly and routinely. This survey emphasises the difficulties associated with new terminology and the problems that arise when the terms are interpreted in different ways, hence the necessity for consistency in the way BIM is implemented.

The research findings of Alabdulgader, Panuwatwanich and Doh (2013) show that insufficient expertise in BIM is a result of little comprehension of industry and technical needs, which constituted a main element hindering the progression and uptake of technologies associated with BIM throughout the Australian construction industry. Hosseini et al. (2016) report that the main obstacle in the adoption of BIM is the indifference from stakeholders associated with small and medium enterprises (SMEs) as well as the risks related to an unclear investment return with its adoption. This is also corroborated with research from previous studies. The research shows that knowledge of BIM among SMEs is considerably less than larger organisations and that there is a prejudicial negative view relating to the needs and difficulties of BIM adoption. According to NBS (2020) as little as 40 percent of industry stakeholders state that BIM is the 'norm', with an equivalent number utilising British Standards (BS) and International Organization for Standardization (ISO) standards. Sixty-six percent of SMEs that have not adopted BIM report that their projects are not large enough to use BIM and more than 50 percent report that it is of no interest to them. Additionally, the findings of Newton and Chelishe (2012) show that the adoption of BIM is a critical factor in productivity and global competitiveness of the Australian construction industry. These findings stress the importance of providing quantity data of the advantages of BIM for organisations.

2.6 Case Study

Utilisation of BIM in the design and construction of road, rail or bridge infrastructure will contribute to reaching an economical design result and enhance the effective communication between stakeholders. BIM incorporates the true nature and utilisation of statistical data concerning timelines and cost estimation during the whole project. This is crucial for civil infrastructure projects as a rule in order to cope with the extremely complicated and varied nature of project deliverables. The following case study has been reviewed to investigate the advantages and the overall utilisation of BIM in Australian bridge infrastructure design and construction.

New Grafton Bridge - Grafton, New South Wales

Project description

Client: NSW Roads and Maritime Services

Structural Designer: Aurecon

Construction Contractor: Fulton Hogan

Date of Completion: December 2019

In 2016 major construction commenced on the new Grafton Bridge, a $240 million project funded by the New South Wales Government. The 525 metre, dual carriageway was built 70 metres from the existent road and rail bridge on the Clarence River in Grafton (Hampson et al. 2018), as shown in Figure 5. In addition, the project comprises upgrades to the existing road network in and around Grafton to link to the new bridge. This project illustrates the successful application of BIM and digital engineering that has been utilised in the design and construction phases.

Figure 5: Location of the new Grafton Bridge

(Hampson et al. 2018)

2.6.1 Flood modelling and BIM used for bridge design enhancements

As Grafton is prone to flooding, the main goal of the project is to reduce the flood impact of the new bridge as well as preserving the current level of flood immunity for Grafton and surrounds (Hampson et al. 2018). The initial design included a bridge pier that necessitated eight piles however for the purpose of reducing the flood impact BIM was utilised to improve the design, particularly in cutting down on the number of piles of the bridge. Figures 6 and 7 show before and after optimisation of the bridge pier design. The design enhancements have simplified the structure of the pier, needing just two piles, which provides a more efficient water course.

Figure 6 Bridge pier design with eight piles (before optimisation)

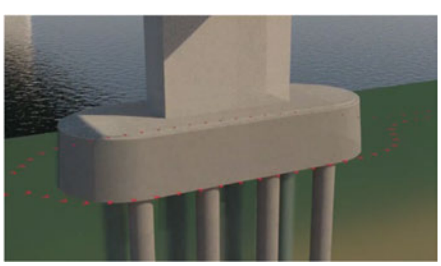
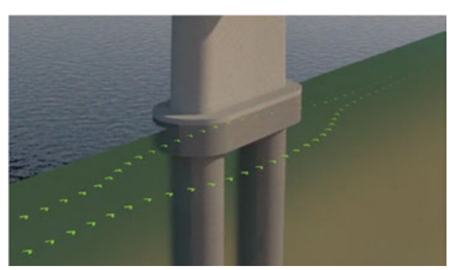


Figure 7 Bridge pier design with two large piles (after optimisation)



(Hampson et al. 2018)

2.6.2 BIM used for bridge construction modelling

The construction procedures were simulated by utilising BIM, the goal of which was to create the bridge virtually prior to it even being built. It is essential that designers determine the practicality of the construction procedures cautiously, such as construction of the abutment, piers and other foundational work. The erection of the framework is often complicated however the 4D modelling of the erection procedures is necessary in improving processes, such as enhancing its efficiency and constructability, in a manner which allows an increasingly competitive design to be generated (Hampson et al. 2018). Figures 8 and 9 show the 4D modelling for the pier installation and segment lifting and installation respectively.

The modelling allows adjustments to be made in order to operate in line with the construction timetable, ensuring construction activities are on track. By utilising the 4D modelling, the quickest and most effective construction processes can be identified and applied on site, which leads to economies of scale on a construction site.

Figure 8: Virtual Construction (4D) Simulation for Pier Installation

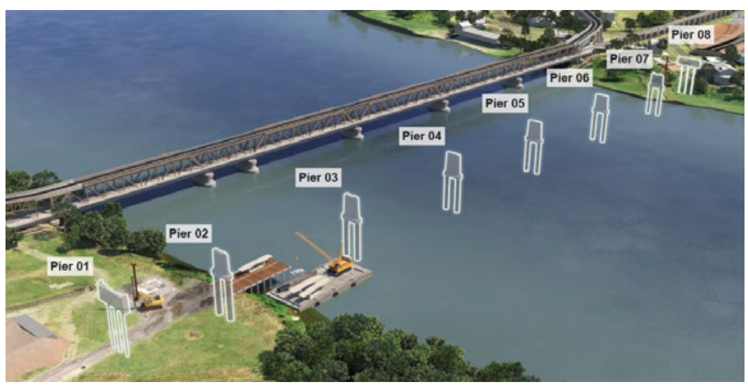


Figure 9: Virtual Construction (4D) Simulation for Segment Lifting and Installation

(Hampson et al. 2018)

The new Grafton Bridge was completed and opened to traffic in December 2019. This case study has shown how BIM has been successfully applied in the design and construction phases as a result of enhancements to the pier design and the addition of 4D BIM (time stages) on the bridge construction has assisted the construction team to discover cost savings.

2.7 Conclusion

Notwithstanding the increasing level of BIM implementation in Australia, the general rate of BIM adoption in small and medium design and construction firms is small compared to larger private organisations. Although the majority of literature has acknowledged the benefits and barriers to the adoption and use of BIM, studies undertaken by the Royal Institution of Chartered Surveyors (2020) showed that the construction industry was falling behind other areas of the economy in utilising technology and data to improve efficiency and asset management. This was also highlighted in research carried out by Sanchez, Kraatz and Hampson (2014) noting that there is a wide knowledge gap between current technical abilities and those required for the adoption of digital modelling in the delivery of Australian infrastructure projects. Lea et al. (2015) also found that the adoption of industry standards were crucial to the successful delivery of BIM, which was supported by the ANZ BIM Survey Report (2019) that emphasised the necessity for consistency in terminology and industry standards.

This literature review has delivered a stronger comprehension of BIM concepts, benefits and barriers to its adoption and BIM standardisation and policy initiatives in Australia, UK, USA and New Zealand. It also has shown that more research is required in order to identify the positive and negative effects that BIM standardisation and adoption practices has on project delivery, especially in small and medium design and construction firms, and this research project will build on that knowledge gap. The following chapters will provide a quantitative methodology approach, using a survey questionnaire with a mix of multiple choice questions and a five point Likert scale, to identify those effects by way of a survey questionnaire to industry stakeholders.

Chapter 3 - Methodology

Figure 10: Structure of Chapter 3

3.1 Overview

Denscombe (2014) notes that a survey strategy is used to analyse trends and gathering information for the purpose of testing a theory, and case studies are used to comprehend the complex association between factors as they function within a particular industry setting. To fulfil the aims of this project a quantitative approach has been employed. Research data has been collected through an extensive literature review of international and Australian BIM standards and policy initiatives, a relevant industry case study has been examined and a standardised questionnaire designed to gather data from a cross-section of relevant industry stakeholders for analysis. This form of approach can be conducted and assessed quickly as well as assisting comparisons between organisations and ascertaining the level of agreement among respondents. Using the comprehensive literature review, the diverse scholarly approaches to BIM standardisation and its impact on project delivery were identified.

3.2 Data collection via industry questionnaires

Questionnaires are a traditional approach for undertaking quantitative research. Quantitative research is presented as a reputable and unbiased means of carrying out research whereby data is numerically examined to extrapolate findings. Questionnaires are the most commonly used research strategies to acquire standardised information from a multitude of individuals (Håkansson 2013).

The various methods to target participants through a questionnaire include (Roopa and Rani 2012):

1. Face-to-face interview;
2. Telephone interview;
3. Postal questionnaire; or
4. Internet based questionnaire.

The accuracy of survey research is credited to the well-structured survey design and questions (Adedoyin 2020). There are various classifications of questions used when designing a survey which are applied depending on the survey's function:

1. Contingency questions;
2. Open-ended questions;
4. Matrix questions; and
5. Likert scale.

Questionnaires must contain identical questions which are in the same format and have identical phrasing to guarantee the information gathered is uniform. A contingency question is one that is responded to on condition that the participant provides a certain reply to an earlier question. Open-ended questions involve the participant responding in their own words devoid of any response constraints (Roopa and Rani 2017). In the interest of this research, contingency and open-ended questions have not been utilised.

3.2.1 Benefits of internet based questionnaires

Online questionnaires have several advantages compared to alternative data collection techniques, including (Adedoyin 2020):

- Cost effectiveness - able to survey a multitude of participants with the data being delivered in a format that is already prepared for analysis;
- Accessible to the majority of intended recipients;
- Fast turnaround time between dissemination of the questionnaire and responses;
- Reliability - prevents researcher bias and misrepresentation and not socially influenced; and
- Versatility - the questionnaire can be applied in any discipline.

3.2.2 Disadvantages of internet based questionnaires

Online questionnaires also have disadvantages, including (Adedoyin 2020):

- Inadequate selection of participants results in biased data and poor response rates;
- Confidentiality - there is a risk of disclosure of confidential information when information is delivered online;
- Inadequate control over respondent's understanding of questions;
- Honesty and accuracy of the respondent's answers; and
- The questions portray what the researcher considers significant.

3.2.3 Ethics and risk assessment

Participating in any questionnaire there are only minor risks, for example, the possibility of disclosing confidential information; the design of the questionnaire may be incorrect and the findings could be biased and immeasurable; or the gathering of online data cannot be guaranteed as safe due to the possibility of hacking or malicious activity. Buchanan and Hvizdak's (2009) study into research ethics explores various concerns pertaining to confidentiality, informed consent, investigation and scientific integrity of online surveys. The study reveals that online questionnaires are an economical method of carrying out research provided that the methodology is in accordance with ethical decision-making, not just for convenience and ease of use.

Pursuant to the National Statement on Ethical Conduct in Human Research (2018), human ethics approval is required if the research involves people participating in surveys. As such, ethics approval was required from the USQ Human Research Ethics Committee to endorse the online survey prior to disseminating any information to potential participants (see Appendix B). As a result, and as Denscombe (2014) reiterates, research ethics are a major concern relating to the selection of strategies. Measures have therefore been taken to ensure that those participating in the research project maintain their anonymity, the data is kept confidential, those participating realise the nature of the research and their contribution, and those participating voluntarily approve to taking part.

As there are minimal risks to a researcher's personal health and safety in conducting an online survey, a risk assessment has been developed to mainly measure the risks relating to the time involved in completing this research project throughout the various phases of the project. Appendix C outlines the possible risks to the project and the measures to minimise those risks.

3.3 Survey design

3.2.1 Introduction

Survey quality is essential for precise, dependable and valid results. Survey findings rely primarily on the execution of the survey including solid sampling procedures and appropriate management of the questionnaire. To ensure the survey quality, each phase of the project has been examined and steps carried out, including:

- ensuring the survey sample size is indicative of the target demographic, and that the information is complete. If the survey design is flawed the results will then be prejudiced and frequently unquantifiable; ensuring close attention is paid to the execution of the questionnaire and checking immediately so that issues can be resolved while the questionnaire is underway; and
- transferring and backing up the data immediately after it has been collected so that any mistakes can be resolved while the questionnaire is still underway.

The result of this quality assurance procedure is that the survey strategy will produce quality information. The findings can then be recorded to be valid, dependable and comparable.

3.3.2 Key resources

Various resources were required to guarantee this research project accomplished its objectives. With the aid of a desktop computer and access to the internet, online survey software programs are required to produce, distribute and analyse results gathered from the research data. In this instance, LimeSurvey software, via the USQ Survey tool, has been used to design the questionnaire at no cost. Online surveys allow a quick and cost-effective method of sampling a cross-section of participants with the data being delivered in a format that is prepared for examination and evaluation. They also minimise the turnaround time between disseminating the survey and receiving replies.

The survey strategies chosen for this research project necessitate meeting strict deadlines and to conclude the research within a given amount of time. Nonetheless, as the strategies are somewhat predictable with regard to their timeframe they are able to accommodate quite strict timetabling. Consequently, the benefit of using an online survey tool for the questionnaire means that more data can be collected faster, with greater accuracy and the need for data input is therefore removed. To guarantee that the research project goals can be met within the allocated time limit and to ensure that all tasks and benchmarks can be tracked and checked, a weekly plan of the research project timetable is shown in Appendix D.

3.3.3 The Questionnaire

The questionnaire was designed from an extensive literature review and the researcher's work experience in the civil design and construction industry. The literature review revealed several key areas in relation to BIM standardisation and its effect on project delivery. These areas were the foundation for this questionnaire.

Each participant targeted in the questionnaire is employed in a significant role within their firm in the Australian civil design and construction industry and is involved with the use of BIM on projects to some degree. To obtain a wider and more representative coverage in order to give credibility to the findings, assistance was sought from members of the Australasian Procurement and Construction Council and the Australasian BIM Advisory Board, which consist of alliances of key industry leaders from both government and private sectors in Australia and New Zealand, that encourages best practice and uniform approaches by government and industry to

BIM practices, standards and requirements. Appendices E-G set out a Participation Information Sheet and covering letters in the form of survey invitation emails to prospective participants and industry associations, with a link to the questionnaire, that has been forwarded to potential participants for their information and completion prior to undertaking the questionnaire, as approved by the USQ Human Research Ethics Committee. Prior to undertaking any survey research involving human participation approval must be first sought from the USQ Human Research Ethics Committee for ethics clearance.

The questionnaire was divided into five sections, each section consisting of the main research questions, for the purpose of accomplishing the goals set out in this research project, as follows:

(i) Demographics

Section one was aimed at ascertaining the capacity in which each participant was employed, their competency level in using BIM and the type and value of the BIM projects their organisations have been involved with;

(ii) Obstacles to BIM adoption and use

Section two sought to determine what factors contribute to an organisation not adopting BIM on their projects;

(iii) Benefits of BIM adoption and use

Section three was aimed at identifying the impacts that have been beneficial on projects since an organisation's adoption and use of BIM;

(iv) BIM implementation

Section four sought to ascertain the number of projects that organisations have achieved BIM Maturity Level 2 and Level 3; and

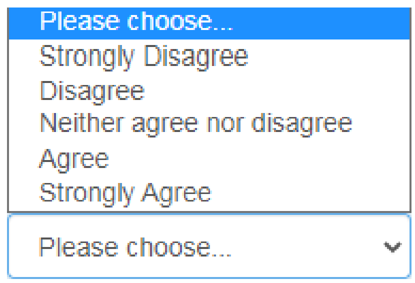
(v) Standardisation efforts

Section five asked participants to identify whether current standardisation initiatives are beneficial in their organisations and to rate their experience of International Standards ISO 19650-1, 19650-2 and 19650-3.

The questionnaire has been designed to measure a participant's opinions on current standardisation efforts from both an organisational and national level, as well as their BIM practices, its impact on project delivery and any obstacles that need to be overcome in order to adopt BIM over the entire lifecycle of a project. Appendix H sets out the questions that have been provided to participants for their responses.

Participants were invited to answer the questions by using a mix of multiple choice questions and a five point Likert scale. The scale was designed and customised using the USQ Survey tool which allows for drop-down menus in order to rate the degree of a respondent's agreement to a particular question or statement, ranging from "Strongly Disagree" to "Strongly Agree" with a neutral option as a choice. The main advantage of the Likert scale is that it permits the researcher to easily quantify and code the responses. Figure 11 displays the five point Likert scale.

Figure 11: Likert scale drop-down menu



The questionnaire targeted 150 Australian civil design and construction industry stakeholders from 26 July 2021 to 9 August 2021 with a projected response rate of 20 percent, being 30 questionnaire responses. Sixty-four responses were however gathered and analysed, depicting a 43 percent response rate. Research indicates that online surveys often have a targeted response rate of less than 20 percent and it is not unusual for online surveys to even have a response rate of below 10 percent (Mol 2017).

The Relative Importance Index (RII) method was used in the analysis of the data collected, similar to Enshassi, Ayyash and Choudhry (2016) study. Those participating in the questionnaire were invited to answer the questions on a five-point Likert scale between "1" for strongly disagreeing and "5" for strongly agreeing, and in accordance with their responses, the RII was measured by employing the equation below:

Relative Importance Index (RII) $= \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$

Where:

'*W*' is the weighting provided to the respective factors by those participating in the questionnaire extending from 1 to 5, $n1$ = the number of those participating who strongly disagree, $n2$ = the number of those participating who disagree, $n3$ = the number of those participating who do not agree or disagree, $n4$ = the number of those participating who agree, $n5$ = the number of those participating who strongly agree.

'*A*' is the greatest weight (5 in this survey) and 'N' is the overall number of responses (Enshassi, Ayyash & Choudhry 2016).

The research data has been organised, responses examined and a synthesis of participants' comments developed.

Chapter 4 - Data Analysis and Findings

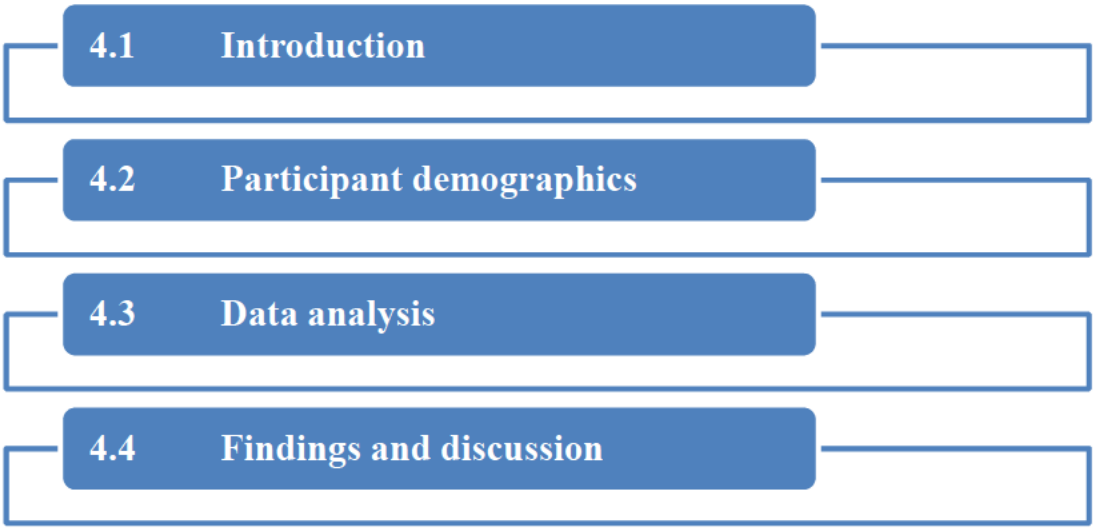


Figure 12: Structure of Chapter 4

4.1 Introduction

This chapter presents the demographic information of 64 industry stakeholders, including engineers, computer aided design (CAD) technicians and BIM managers, after a survey questionnaire was distributed to them. The questionnaire specifically targeted 150 industry stakeholders who are directly involved with the use of BIM on projects to some degree, which were obtained through the researcher's professional contacts within the Australian civil design and construction industry over a two week period. In addition, attempts were made to distribute the questionnaire through the memberships of the Australasian BIM Advisory Board and the Australasian Procurement and Construction Council.

An analysis of the data collected has been undertaken to determine the relative importance of several key areas in relation to BIM adoption practices and standardisation efforts in the civil design and construction industry and the effect they have on project delivery. The results have been categorised, analysed and presented using LimeSurvey software and Microsoft Excel. A discussion of the findings and lessons learned will also be presented.

4.2 Participant demographics

The demographic information collected from participants is divided into five sections, comprising:

(i) Work capacity;
(ii) Primary type of business;
(iii) Public or private sector involvement;
(iv) Level of BIM expertise; and
(v) Value of BIM projects.

Dividing the data into sections endeavours to identify any patterns or potential relationships from participants' replies.

4.2.1 Work capacity

As shown in Table 4, the capacity in which respondents are employed within their organisations was spread mainly between engineers, CAD technicians, BIM managers and project managers, with engineers representing more than half of the sample size. The demographic profile of the respondents demonstrates that they have sufficient knowledge and understanding to reply to the questions on BIM standardisation and its effect on project delivery.

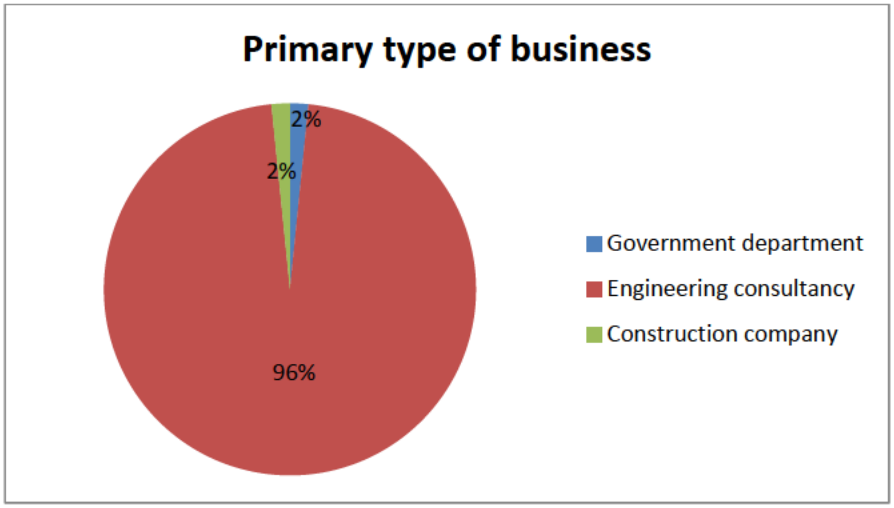
Table 4: Role of Respondents

	In what capacity do you work in the industry?		
	Capacity	**Count**	**Gross Percentage**
1	Engineer	37	57.81%
2	Architect	0	0.00%
3	Designer	1	1.56%
4	CAD Technician	7	10.94%
5	BIM Manager	9	14.06%
6	Project Manager	6	9.38%
7	Estimator	0	0.00%
8	Contractor	0	0.00%
9	Client	1	1.56%
10	Owner/Developer	0	0.00%
11	Other -		
	Design Engineer	1	1.56%
	Pre-contracts Manager	1	1.56%
	No answer	1	1.56%
	Total	**64**	**100%**

4.2.2 Primary type of business

The majority of respondents (96%) are employed in engineering consultancies with construction companies and government departments playing a minor role in this survey. Figure 13 displays the distribution of the primary type of business that respondents are involved with.

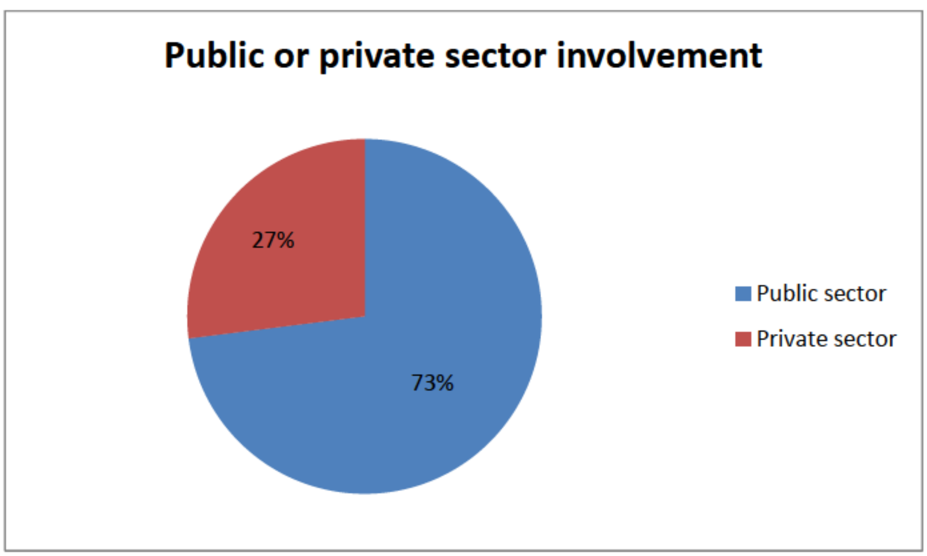
Figure 13: Respondents' primary type of business



4.2.3 Public or private sector involvement

Respondents were invited to indicate their organisation's level of involvement in public or private sector projects. Figure 14 shows that the vast majority of organisations are involved with projects within the public sector.

Figure 14: Organisational level of involvement



It can also be noted that those respondents who work primarily on public sector projects, 63% are engineers, 15% are CAD technicians and 11% are BIM managers, with the remaining minor proportions consisting of project managers, design engineers, pre-contracts managers and clients. In contrast, those respondents who work primarily on private sector projects, 47% are engineers, 24% are BIM managers, 23% project managers and the remaining proportion are designers. Figures 15 and 16 show the proportion of respondents involved in public and private sector projects respectively.

Figure 15: Respondents involved in public sector projects

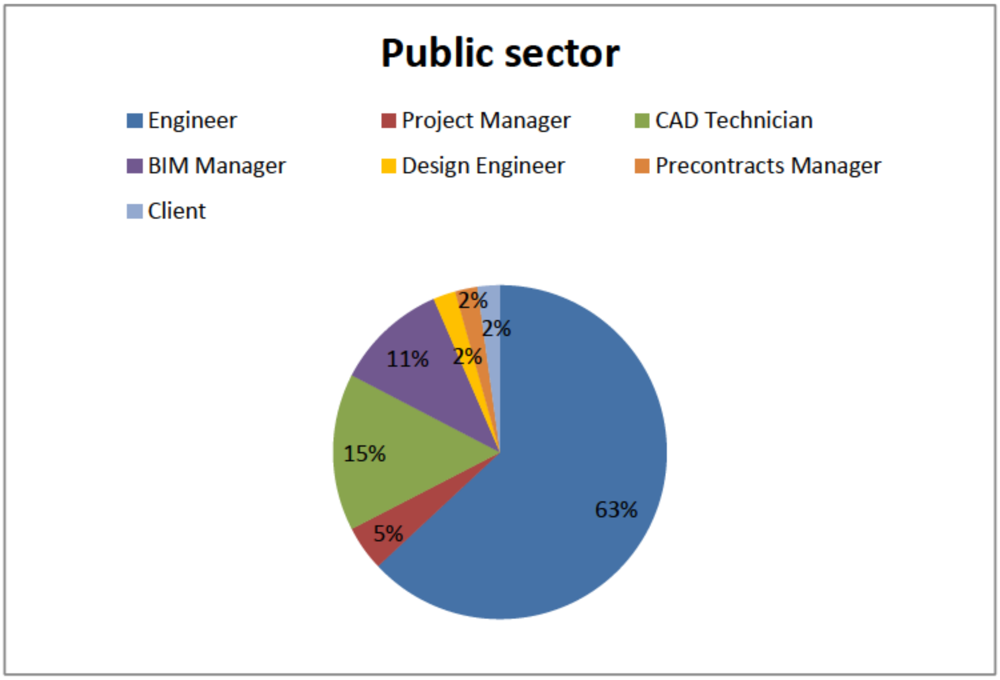
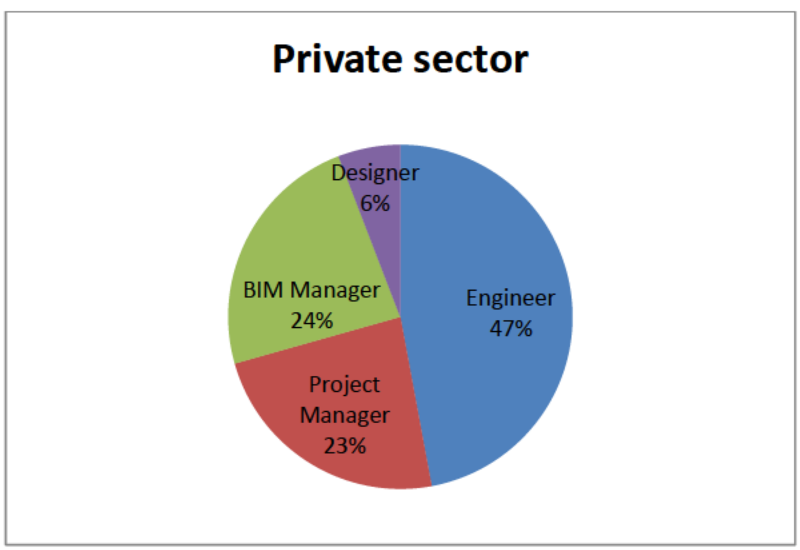


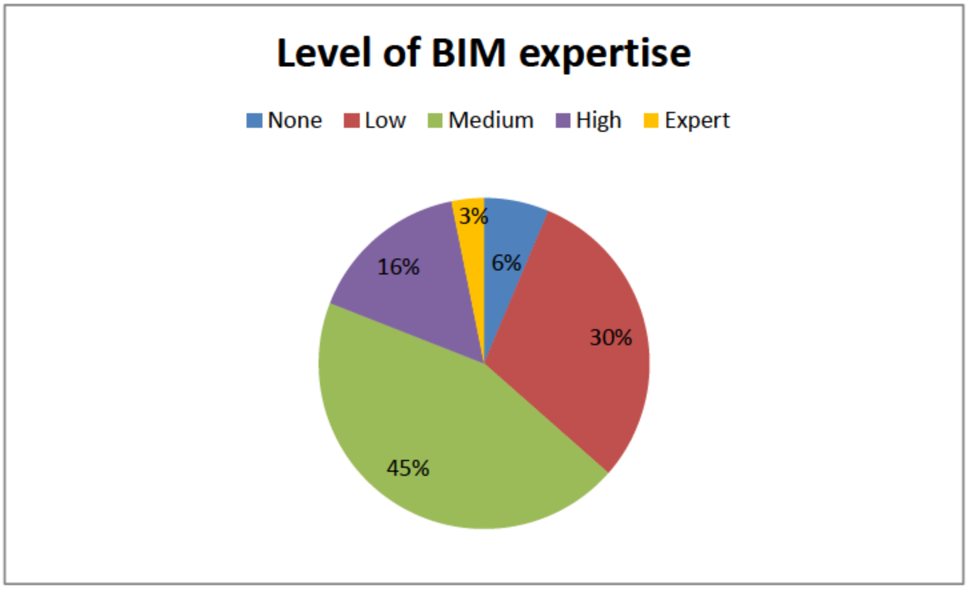
Figure 16: Respondents involved in private sector projects



4.2.4 Level of BIM expertise

Respondents were asked to rate their level of BIM expertise from no experience to expert. The level of expertise among respondents indicates that only 64% are confident in their skills and knowledge in the use of BIM, with 30% less than confident and 6% of respondents having no level of expertise. Figure 17 illustrates the proportion of expertise among respondents.

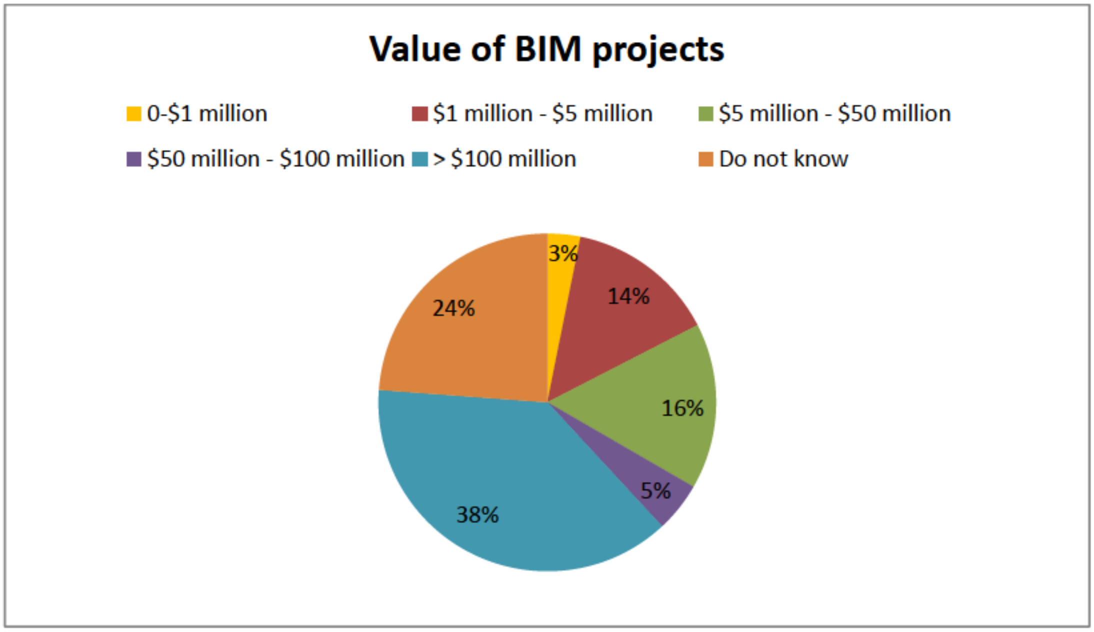
Figure 17: Level of BIM expertise of respondents



4.2.5 Value of BIM projects

Respondents were invited to indicate the value of the majority of BIM projects their organisations had undertaken in the last five years, ranging from less than $1million to more than $100 million. Figure 18 shows that 38% (n=24) of respondents had undertaken BIM projects worth more than $100 million however 24% (n= 15) of respondents were unaware of the value of the projects. As the bulk of respondents were involved with projects worth more than $100 million, this indicates that the majority of respondents (73%) are also primarily involved in public sector projects. It can also be seen that 33% (n=21) of respondents are involved with smaller construction projects worth less than $50 million indicating that they work in small and medium sized organisations.

Figure 18: Value of BIM projects



4.3 Data Analysis

The goal of the analysis is to determine the relative importance of several key areas in relation to BIM adoption practices and standardisation efforts in the civil design and construction industry and the effect they have on project delivery. Calculations were performed to establish the Relative Importance Index (RII) as outlined in previous studies and the subsequent level of agreement using a Likert scale (ranging from 1-5) to particular questions based on participants' responses. The RII method of analysis is a suitable means of prioritising indicators rated on a Likert scale (Rooshdi et al. 2018). Even though there are more sophisticated approaches available, the RII method is often used in construction and it is a useful and quick approach. The analysis reveals the following findings:

- Lack of time on projects to learn BIM and provide the required deliverables is the main barrier for respondents not adopting or using BIM to its full extent;
- Respondents believe that they have not been given sufficient training with the implementation of BIM within their organisations;
- Enhanced collaboration and decision-making process is considered among respondents to be the main benefit that BIM brings to construction projects;
- The Transport for NSW Digital Engineering Framework, the Level of Development Specification 2020 and Uniclass Classification System 2015 are considered to be the top three most important standardisation initiatives among respondents; and
- Respondents consider that it is important for the Australian government to mandate the adoption of BIM in all publicly funded construction projects, regardless of size and cost.

4.3.1 Analysis of Barriers to BIM adoption

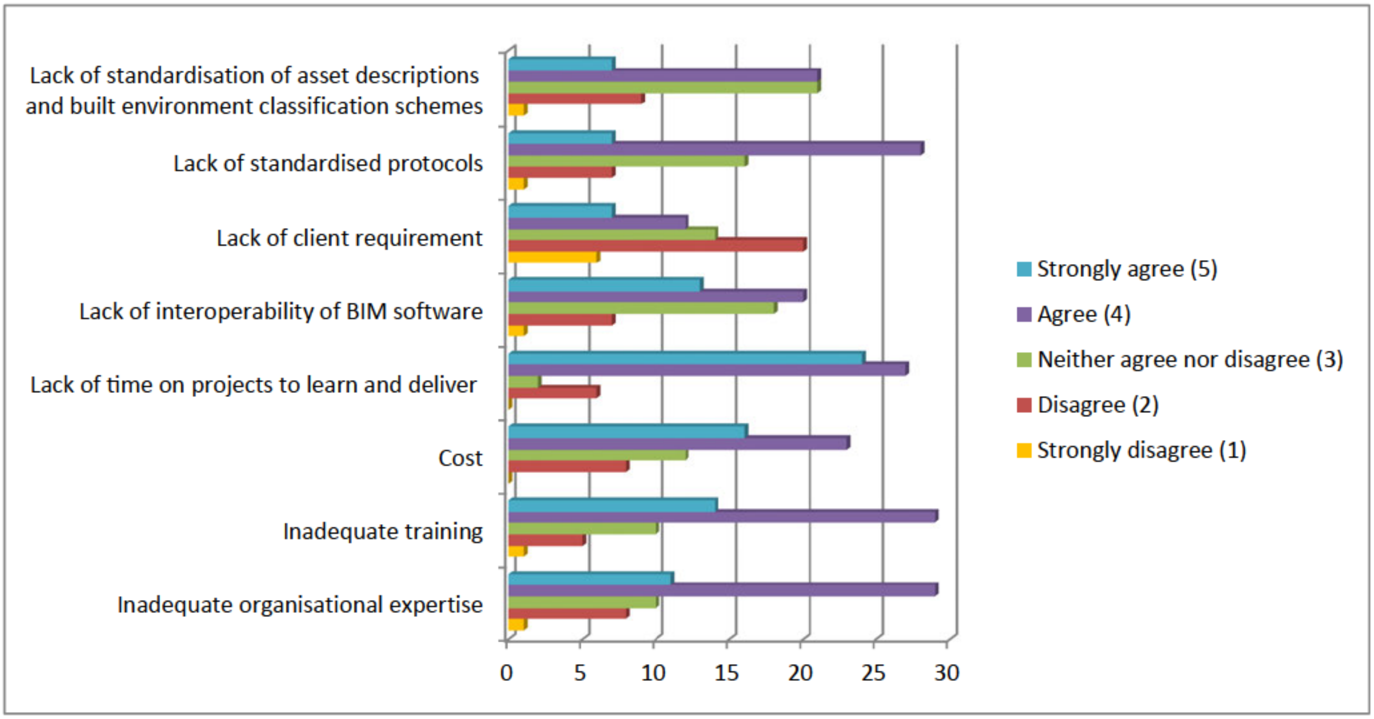
As shown in Table 5 and illustrated in Figure 19 survey participants provided their responses to what they considered were barriers to BIM adoption within the industry, using a Likert scale of a 1-5 level of agreement. It is noted however that 8% (n=5) of respondents did not complete this section of the questionnaire and are therefore not included in the analysis of this section. "*Lack of time on projects to learn and deliver*" with RII = 83% was the ranked the highest in relative importance as to why BIM has not been adopted or being used on projects. "*Inadequate training*" was ranked second with RII = 77% which Czmoch and Pekala (2014) reiterate in their studies that failure to provide knowledge and skills are a key obstacle to the adoption of BIM in organisations. According to Newton and Chelishe (2012) the high cost and lack of expertise within organisations are deterrents for small and medium sized design firms to implement BIM hence respondents have indicated that the relative importance of "*Cost*" (RII = 76%) and "*Inadequate organisational expertise*" (RII = 74%) is high. Unsatisfactory interoperability of BIM software also adds to the financial cost of implementing and using BIM and leads to opportunities being lost that could otherwise produce substantial advantages for the civil design and construction industry. Respondents agreed that the "*Lack of interoperability of BIM software*" with RII = 73% was an obstacle to its adoption.

Table 5: RII and rank for barriers to BIM adoption

Cause	**Level of agreement**					**Importance value**	**Relative Importance Index (%)**	**Rank**
	1	**2**	**3**	**4**	**5**			
Inadequate organisational expertise	1	8	10	29	11	0.7389	74	4
Inadequate training	1	5	10	29	14	0.7694	77	2
Cost	0	8	12	23	16	0.7593	76	3
Lack of time on projects to learn and deliver	0	6	2	27	24	0.8338	83	1
Lack of interoperability of BIM software	1	7	18	20	13	0.7254	73	5
Lack of client requirement	6	20	14	12	7	0.5796	58	8
Lack of standardised protocols	1	7	16	28	7	0.7118	71	6
Lack of standardisation of asset descriptions and built environment classification schemes	1	9	21	21	7	0.6813	68	7

"*Lack of standardised protocols*" (RII = 71%) and "*Lack of standardisation of asset descriptions and built environment classification schemes*" (RII = 68%) were of less importance to respondents. Considering that the bulk of respondents deal primarily with public sector projects, this would indicate that their clients are government organisations which would have standardised protocols and strategies already in place. This would also account for "*Lack of client requirement*" (RII = 58%) being ranked last in the overall rankings.

Figure 19: Barriers to BIM adoption



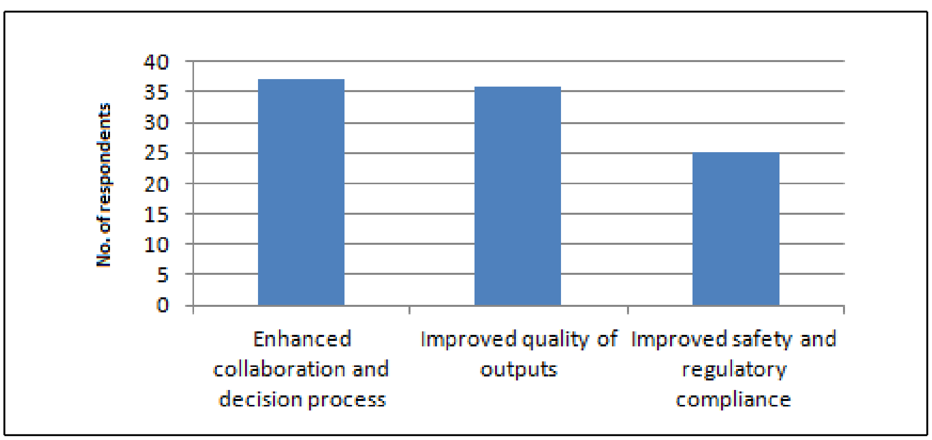
4.3.2 Analysis of Benefits of BIM adoption

Participants were asked to respond to what they considered were benefits from the adoption and use of BIM on projects, using a Likert scale of a 1-5 level of agreement. It is noted however that 20% (n=13) of respondents did not complete this section of the questionnaire and are therefore not included in the analysis of this section. The results in Table 6 show that *"Enhanced collaboration and decision process"* (RII = 77%) and *"Improved quality of outputs" (RII = 73%)* were the most highly ranked benefits in relation to their relative importance. Improved quality of outputs is an extremely important driver for BIM adoption and use. Figure 20 also illustrates the level of agreement among respondents to the three main benefits of BIM adoption, which are also comparable to the findings of Abanda et al. (2018). The least important benefits are the cost efficiencies in the pre-construction phase (RII = 56%) and cost efficiencies generally gained from the adoption of BIM (RII = 49%). The fact that respondents have ranked these benefits last with regard to their relative importance could imply that they are unaware of the actual cost efficiencies produced from the adoption of BIM within their organisations or alternatively, they are not utilising BIM across the entire project timeline and are therefore unable to gauge cost efficiencies.

Table 6: RII and rank for benefits of BIM adoption

Cause	**Level of agreement**					**Importance value**	**Relative Importance Index (%)**	**Rank**
	1	**2**	**3**	**4**	**5**			
Accelerated project delivery in the pre-construction design phase	7	11	16	16	1	0.5725	57	8
Accelerated project delivery in the construction phase	3	7	21	16	4	0.6431	64	5
Improved quality of outputs	3	4	8	28	8	0.7333	73	2
Improved productivity	8	12	16	11	4	0.5647	56	9
Cost efficiencies generally (improved margins / fees / profits)	11	19	12	5	4	0.4901	49	11
Cost efficiencies in the pre-construction phase	6	17	14	10	4	0.5568	56	10
Cost efficiencies in the construction phase	2	4	25	17	3	0.6588	66	4
Enhanced collaboration and decision process	1	4	9	25	12	0.7686	77	1
Easier to work with offshore counterparts	4	8	19	15	5	0.6352	64	6
Improved safety and regulatory compliance	2	6	18	21	4	0.6784	68	3
Reduced a project's carbon footprint	8	4	25	10	4	0.5921	59	7

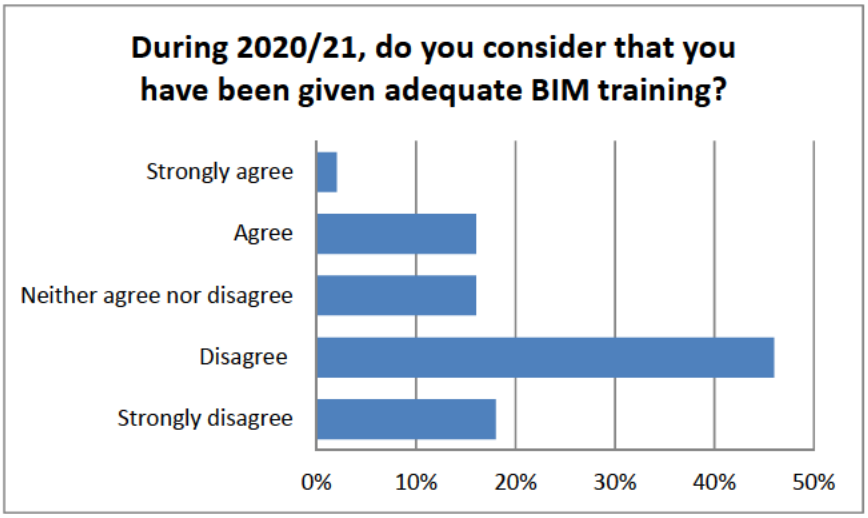
Figure 20: Top three benefits of BIM adoption



4.3.3 Analysis of BIM implementation

As shown in Figure 21, survey participants provided their responses as to whether they thought they had received adequate BIM training during 2020/21 for the purpose of successful delivery of BIM projects. The majority of respondents (64%) noted that they have not been given satisfactory training. This is reiterated in the findings of Newton and Chelishe (2012), Czmoch and Pekala (2014) and Sanchez, Kraatz and Hampson (2014) that successful implementation of BIM requires skilled personnel. This is also highlighted by the high RII score respondents gave for *"Inadequate training"* (77%) as a barrier to BIM adoption.

Figure 21: BIM training amongst participants



Participants were also surveyed as to the number of projects their organisations had been involved in using BIM Maturity Level 2 and Level 3 and also invited to provide any comments. It is assumed however that respondents have achieved at least BIM Maturity Level 1, which uses 2D drafting and 3D CAD models shared in a common data environment (CDE). It is also noted that 22% (n=14) of respondents did not complete this section of the questionnaire and are therefore not included in the analysis of this section. Results show that 29% of respondents stated that their organisation used BIM on more than ten projects during 2020/21 with 6% of respondents not using Level 2 on any projects at all, as illustrated in Figure 22. General comments received from respondents who are not using Level 2 BIM include:

- *No projects have achieved Level 2 BIM - they have only achieved Level 1.5 BIM at best and only a specific single discipline;*

- *My organisation only uses CAD models with no 4D (time) and 5D (cost) related items;* and
- *I am unaware of how many projects my organisation has done to Level 2 BIM.*

Similar results can be seen in Figure 23 from those respondents whose organisations have achieved BIM Maturity Level 3 during 2020/21 with 23% using Level 3 BIM on ten or more projects. It can noted that the same percentage (33%) of organisations using Maturity Level 2 BIM on three to five projects during the year also used Level 3 BIM, a collaborative process centred around a single model comprising the data of an entire project's lifecycle (Martin, Beladjine & Beddiar 2019). General comments received from respondents regarding BIM Maturity Level 3 include:

- *My organisation uses software such as Projectwise, 12d Synergy, BIM360, Navisworks, Autodesk Revit, Autocad Civil 3D which are used to federated the model, however sometimes getting the outputs to feed in is time consuming;*
- *The full integration with Level 3 BIM is still a bit clunky but it's getting there;*
- *No projects are expected to engage with Level 3 BIM for at least the next 2-5 years;* and
- *I am unaware of how many projects my organisation has done to Level 3 BIM.*

Figure 22: Projects using Level 2 BIM during 2020/21

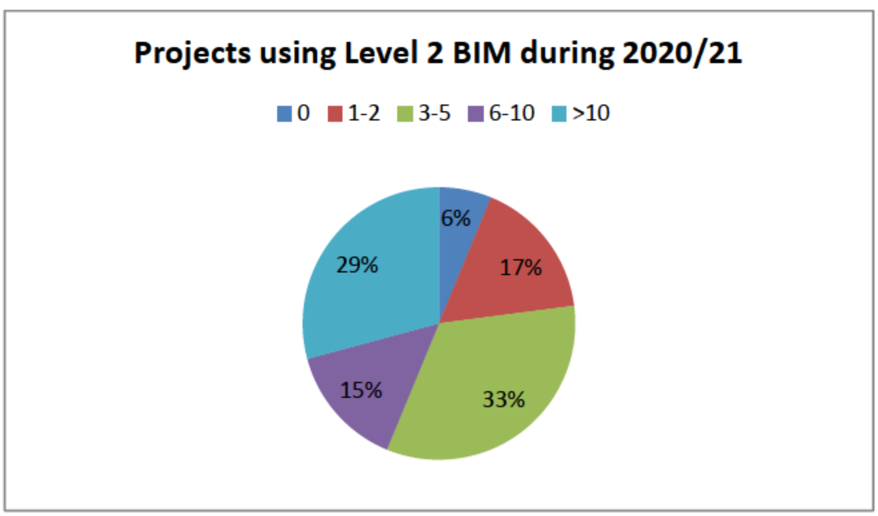
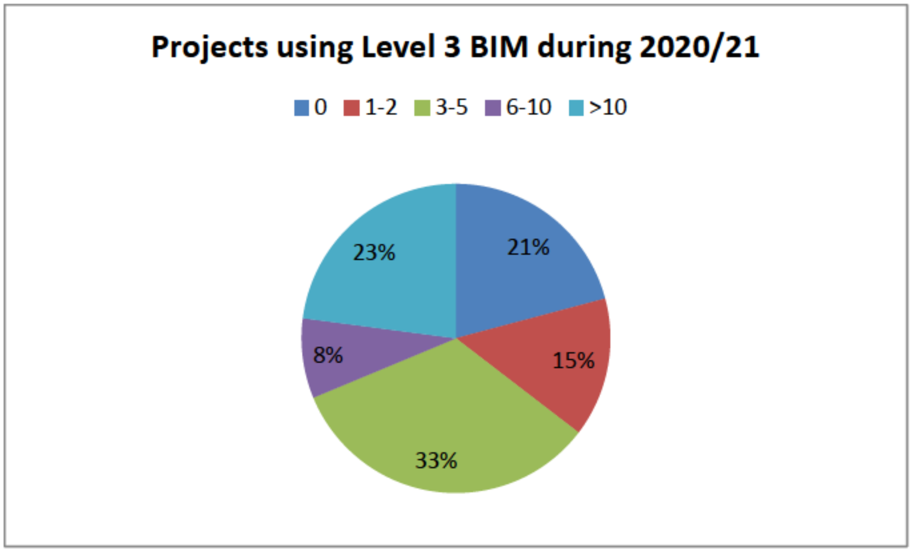


Figure 23: Projects using Level 3 BIM during 2020/21



Achieving a BIM maturity Level 3 relies on the successful implementation of BIM by incorporating information modelling technologies with the organisational procedures and processes for a project (Mohammed 2020). With the implementation of BIM, companies attempt to increase their productivity in project delivery with regard to quality, timelines and cost.

4.3.4 Analysis of Standardisation efforts

Participants were asked to respond to what they considered were beneficial standardisation initiatives within the Australian construction industry, using a Likert scale of a 1-5 level of agreement. It is noted however that 28% (n=18) of respondents did not complete this section of the questionnaire and are therefore not included in the analysis of this section. The results in Table 7 show that the Transport for NSW (TfNSW) Digital Engineering Framework (RII=77%), Level of Development (LOD) Specification 2020 (RII=74%) and Uniclass Classification System 2015 (RII=71%), were the most highly ranked initiatives in relative importance. These standardisation efforts rank highly as they form the basis and reference points for BIM implementation and use. Following in relative importance are the NATSPEC National BIM Guide and Australian BIM Strategic Framework (RII=67%), and the National Building Information Modelling Initiative (RII= 64%). The Victorian Digital Asset Strategy and the Digital Enablement for Queensland Infrastructure - Principles for BIM Implementation rated last in the overall rankings (RII=60%). These initiatives are not as highly ranked as a large proportion of the participants surveyed are employed in New South Wales and therefore are not familiar with them.

Participants were also invited to rate their level of agreement to certain statements regarding International Standards ISO 19650, in particular AS ISO 19650-1, ISO 19650-2 and ISO 19650-3 as set out in Table 8. The statement *"Improves information management and collaboration on projects*" with RII=73% was decidedly the highest ranked statement with regard to relative importance. This was

Table 7: RII and rank for Australian BIM standardisation initiatives

Standardisation initiative	**Level of agreement**					**Importance value**	**Relative Importance Index (%)**	**Rank**
	1	**2**	**3**	**4**	**5**			
NATSPEC National BIM Guide	0	2	29	12	3	0.6695	67	4
Australian BIM Strategic Framework	0	3	27	14	2	0.6652	67	5
The National Building Information Modelling Initiative (NBI)	2	2	29	12	1	0.6347	64	6
Transport for NSW (TfNSW) Digital Engineering Framework	0	1	14	23	8	0.7652	77	1
Victorian Digital Asset Strategy	0	4	37	5	0	0.5956	60	8
The Digital Enablement for Queensland Infrastructure – Principles for BIM Implementation	1	3	36	6	0	0.6043	60	7
Uniclass Classification System 2015	0	1	23	17	5	0.7130	71	3
Level of Development (LOD) Specification 2020	1	1	16	22	6	0.7347	74	2

closely followed by the statements "AS ISO 19650 complements current practices *within my organisation"* (RII = 68%), *"Leads to better quality output that is delivered more cost effectively"* and *"Has created a unified approach of working across international regions*" both with RII = 65%. Interestingly, only 37% of respondents are actually working to the standards AS ISO 19650 and 39% of respondents are unaware if their organisation is even working to these international standards. In this case, respondents may need to revisit their understanding of the maturity levels of BIM.

Table 8: RII and rank for level of experience with International Standards ISO 19650

Experience with AS ISO 19650-1, ISO 19650-2, ISO 19650-3	**Level of agreement**					**Importance value**	**Relative Importance Index (%)**	**Rank**
	1	**2**	**3**	**4**	**5**			
My organisation is not working to AS ISO 19650	4	13	18	7	4	0.5739	57	5
AS ISO 19650 complements current practices within my organisation	0	3	26	12	5	0.6826	68	2
Improves information management and collaboration on projects	0	2	22	13	9	0.726	73	1
Leads to better quality output that is delivered more cost effectively	2	2	26	15	1	0.6478	65	3
Reduces wasteful activities	3	4	23	15	1	0.6304	63	4
Has created a unified approach of working across international regions	3	1	28	10	4	0.6478	65	3

The push by government is pivotal for the adoption of BIM by the civil design and construction industry. As shown in Table 9, participants were invited to provide their level of agreement to statements regarding the Australian government's BIM policy and programs. It is also noted that 25% (n=16) of respondents did not complete this section of the questionnaire and are therefore not included in the analysis of this section. Results show that the statement *"Due to the high cost involved, the adoption of BIM is primarily limited to large government projects only"* is the most highly ranked statement with RII = 78% in terms of relative importance. This result is consistent with the findings of the 2020 NBS BIM Report where 66% of SMEs believe that their projects are too small to adopt BIM and therefore does not warrant the cost involved of its implementation. Respondents also agree that the statement *"AS IS019650 accreditation programs will ensure consistency of capabilities among stakeholders across projects"* with RII = 68%, which aligns with 64% of respondents stating that they have not been given satisfactory training. However, AS ISO19650 will need to be enforced for this to happen.

Although the federal government dictates that BIM is a key requirement in all major tenders, it is yet to mandate the use of BIM across all of the States. Respondents have agreed that it is important for the Australian government to mandate the adoption of BIM in all publicly funded construction projects (RII = 66%). Of less importance is the introduction of a federal BIM mandate for all public and private construction projects in order to assist small and medium construction firms to win tenders for projects in global markets more equitably and a mandate for the adoption of BIM in all private construction projects, both with RII = 56%. It is interesting to note that half of all respondents agree that BIM adoption should be mandated in publicly funded construction projects but not in private construction projects, with only 27% of respondents being in agreement that a federal mandate for both public and private projects will assist small and medium construction firms win tenders in global markets more equitably (see Figure 24). Mandating therefore appears to be a significant requirement for strong BIM usage.

Figure 24: Federal government BIM mandates

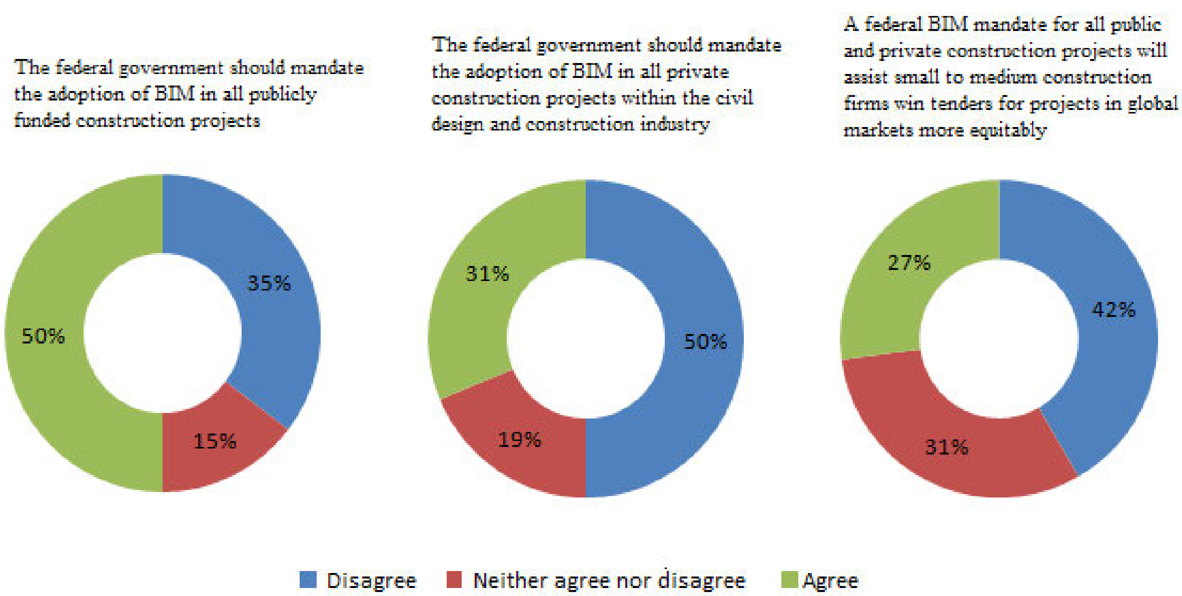


Table 9: RII and rank for level of agreement to government BIM mandates and accreditation

Statement	Level of agreement 1	2	3	4	5	Importance value	Relative Importance Index (%)	Rank
The federal government should mandate the adoption of BIM in all publicly funded construction projects	8	9	7	9	15	0.6583	66	3
The federal government should mandate the adoption of BIM in all private construction projects within the civil design and construction industry	10	14	9	6	9	0.5583	56	5
A federal BIM mandate for all public and private construction projects will assist small and medium construction firms win tenders for projects in global markets more equitably	7	13	15	8	5	0.5625	56	4
Due to the high cost involved, the adoption of BIM is primarily limited to large government projects only	2	5	4	21	16	0.7833	78	1
AS IS0 19650 accreditation programs will ensure consistency of capabilities among stakeholders across projects	3	2	18	21	3	0.6808	68	2

4.4 Findings and discussion

The quantitative research findings provide an overview of the present state of BIM standardisation and its effect on project delivery in the civil design and construction industry, which displays certain confirmations and contradictions with results of comparable studies. The key findings in answer to each of the following survey question are set out in subsequent sections:

1. **Do you consider the following to be obstacles to BIM adoption?**
   - Inadequate organisational expertise
   - Inadequate training
   - Cost
   - Lack of time on projects to learn and deliver
   - Lack of interoperability of BIM software
   - Lack of client requirement
   - Lack of standardised protocols
   - Lack of standardisation of asset descriptions and built environment classification schemes

2. **In your experience, do you consider the following impacts have been beneficial on projects you have worked on since the adoption of BIM?**
   - Accelerated project delivery in the pre-construction design phase
   - Accelerated project delivery in the construction phase
   - Improved quality of outputs
   - Improved productivity
   - Cost efficiencies generally (improved margins / fees / profits)
   - Cost efficiencies in the pre-construction phase
   - Cost efficiencies in the construction phase
   - Enhanced collaboration and decision process
   - Easier to work with offshore counterparts
   - Improved safety and regulatory compliance
   - Reduced a project's carbon footprint
3. **During 2020/21, do you consider that you have been given adequate BIM training?**
4. **How many projects has your organisation been involved in using Level 2 BIM?**
   - None
   - 1-2
   - 3-5
   - 6-10
   - More than 10
   - Comments________________
5. **How many projects has your organisation been involved in using Level 3 BIM?**
   - None
   - 1-2
   - 3-5
   - 6-10
   - More than 10
   - Comments________________
6. **Do you consider the following standardisation initiatives beneficial?**
   - NATSPEC National BIM Guide
   - Australian BIM Strategic Framework
   - The National Building Information Modelling Initiative (NBI)
   - Transport for NSW (TfNSW) Digital Engineering Framework
   - Victorian Digital Asset Strategy

- The Digital Enablement for Queensland Infrastructure – Principles for BIM Implementation
- Uniclass Classification System 2015
- Level of Development (LOD) Specification 2020

7. **Please rate your experience with the introduction of International Standards ISO 19650-1, ISO 19650-2 and ISO 19650-3**
   - My organisation is not working to AS ISO 19650
   - AS ISO 19650 complements current practices within my organisation
   - Improves information management and collaboration on projects
   - Leads to better quality output that is delivered more cost effectively
   - Reduces wasteful activities
   - Has created a unified approach of working across international regions

8. **Do you agree with the following statements?**
   - The federal government should mandate the adoption of BIM in all publicly funded construction projects
   - The federal government should mandate the adoption of BIM in all private construction projects within the civil design and construction industry
   - A federal BIM mandate for all public and private construction projects will assist small and medium construction firms win tenders for projects in global markets more equitably
   - Due to the high cost involved, the adoption of BIM is primarily limited to large government projects only
   - AS IS0 19650 accreditation programs will ensure consistency of capabilities among stakeholders across projects.

In hindsight, additional open-ended questions with an option for further comments could have been useful to clarify some of the responses and gain a more valuable insight into each topic.

4.4.1 Barriers to BIM adoption and use

Considering the majority of industry stakeholders are in agreement on the relative importance of BIM, its adoption and use is still frequently restricted. The key findings have overwhelmingly shown that the main barrier to the adoption and use of BIM on projects is the insufficient amount of time allowed on projects to learn the complexities of BIM as well as providing successful and timely project delivery. This is not surprising as the restrictions of project deadlines, cost, quality and additional constraints imposed on industry practitioners prevents them from becoming familiar with BIM and its related applications sufficiently to provide a successful project delivery. This ties in with inadequate training and inadequate organisational expertise as the main barriers, which is supported by previous studies (NBS 2019, Czmoch & Pekala 2014), Newton & Chelishe 2012). The survey findings show that 64 percent of respondents who work on civil infrastructure projects are confident in their skills and knowledge of BIM, including three percent considered expert, however a large proportion still remains less than confident or has no level of expertise whatsoever. Liu et al. (2015) advocate that there is an affinity between the failure to provide training and education on BIM and the inadequate number of qualified practitioners needed to implement and utilise BIM efficiently, finding that BIM training and education is crucial in avoiding additional obstacles to the implementation of BIM.

Not surprising is the fact that cost is revealed as one of the key constraints to BIM adoption and use. Previous studies by Newton and Chelishe (2012) noted that due to the high costs involved with implementation, including the software and hardware, the application of BIM would be limited to large projects and would also hinder its use in small and medium sized design firms. In the 2019 NBS ANZ BIM Report and the 2020 NBS BIM Report, only 37 percent and 46 percent respectively of survey participants considered that cost was a barrier. These study results are not consistent with the findings of this research where over 66 percent of respondents considered that cost was an issue. This may be due to the fact that overall project costs do not allow for the extra time required to train staff in using BIM so that they can deliver the projects, as specified by the client, and organisations are not willing to bear the expense of training staff. The challenge for design and construction firms is to retrain and re-educate their staff and employ the skilled labour needed to design and deliver projects in this new way.

Lack of interoperability of BIM software has also been highlighted in the survey as a barrier to BIM implementation and use. Collaborative difficulties arise when different project stakeholders are either not utilising BIM or use BIM software tools that are not compatible, resulting in interoperability issues. This is a significant issue, particularly when moving to the higher dimensions of BIM, for example 6D (integration of sustainability into the BIM model) and 7D (operational costs and facility management integrated into the BIM model). The attainment of very advanced software interoperability is partnered with excessive project costs, including time and money needed for construction. It is acknowledged in literature that it is an absolute necessity for BIM application programs and data formats to be compatible and integrated into the lifecycle of a project in order to avoid productivity losses.

Findings reveal that more respondents consider that insufficient client demand is not an obstacle to BIM adoption. This reflects the large number of respondents who are working on government infrastructure projects where the client would be a government organisation and key project requirements include a certain level of BIM engagement. This would also account for the lowest RII scores given to lack of standardised protocols and the lack of standardisation of asset descriptions and built environment classification schemes. Government organisations would already have standardised protocols and strategies in place for the delivery of civil infrastructure projects.

4.4.2 Benefits of BIM adoption and use

A completely integrated and working BIM model can be applied to several applications across the whole lifecycle of a project. Previous studies (Abanda et al. 2018, EUBTG 2016) have identified that a more successful and faster project delivery results from better design quality and greater collaboration between project stakeholders and an increase in productivity. The EUBTG 2016 study further implies that the greatest advantage to the government sector is strictly economical, including higher rates of productivity and competition in the global marketplace. The survey findings validate these studies regarding the top two benefits identified, enhanced collaboration and decision process, and the improved quality of outputs. As expected, these findings also corroborate the fact that respondents consider that the enhanced collaboration and decision-making process from BIM adoption and use also facilitates working relationships with offshore counterparts.

Interestingly, cost efficiencies generally are of least importance among respondents as a benefit of using BIM, however 39 percent of respondents agree that accelerated project delivery will create cost efficiencies in the construction phase rather than the pre-construction phase. Contrary to studies reviewed (Abanda et al. 2018, EUBTG 2016, Newton & Chelishe 2012) improved productivity from the adoption of BIM is considered to be an issue among more than one-third of respondents. This would suggest that any benefits gained from the adoption and use of BIM is not being seen in the pre-construction stage of projects nor are there major cost efficiencies in this stage. This may be due to the fact that respondents are mostly involved in the design phase of construction projects and often struggle with the interoperability and the integrating of BIM application programs and data formats. Additionally, the strict deadlines for deliverables on projects often do not allow practitioners enough time to learn the intricacies of BIM.

Other benefits to the adoption and use of BIM include the improved safety and regulatory compliance throughout multiple phases of a project's lifecycle (with the integration of 8D BIM), of which 49 percent of respondents agree. The utilisation of BIM assists with early detection of hazards on site facilitating the removal or mitigation of potential risks prior to any construction work commencing. Visual risk and safety assessments are able to be conducted automatically, rather than conducted on site, and pursuant to the regulatory framework and compliance requirements. The use of automation and digital engineering considerably reduces the amount of work required to generate design data, evaluate design compliance and safety risks (GHD 2018). The enhanced collaboration and communication that is created by engaging BIM ultimately leads to a safer construction site. Previous studies (EUBTG 2020) advocate that less site waste and resource efficiency is one of the major environmental benefits as a result of adopting and using BIM on projects. This is however contradictory to the majority of survey respondents who neither agreed nor disagreed that BIM adoption actually reduces a project's carbon footprint. These survey findings are therefore inconclusive.

4.3.3 BIM implementation

Survey findings reveal that civil design and construction stakeholders acknowledge the advantages of using BIM on their infrastructure projects, however not all industry practitioners are using it for all projects. Implementing and using BIM, alongside digital engineering, necessitates a change to the manner in which practitioners and organisations operate. It is evident from previous studies and current research efforts that industry practitioners often have issues in implementing BIM to their own and clients' advantage, utilising the terminology correctly and comprehending the various interpretations of all the dimensions of BIM. More than half of respondents highlighted that they have not been given adequate training to cope with the complexities of BIM, in particular training to achieve BIM Maturity Levels 2 and 3 on projects. It is implied that respondents are working at a minimum to BIM Maturity Level 1 as they were specifically targeted in the questionnaire for their professional capacity on BIM projects. Results have also shown that slightly more than one-third of respondents have very little or no expertise in using BIM on designated BIM projects. These findings are consistent with the 2019 ANZ BIM Report where lack of training is reported as a major obstacle to implementation.

The findings regarding BIM Maturity Levels 2 and 3 are expected. The vast majority of respondents (94 percent) have achieved Level 2 BIM and have incorporated it into their projects, with 79 percent having achieved Level 3. Although 94 percent seems quite a high proportion of respondents having achieved BIM Maturity Level 2, these findings are a reflection of the large number of respondents who are working on government infrastructure projects where BIM Maturity Level 2 is a key requirement. Those respondents who have engaged with Level 3 BIM note that full integration is somewhat cumbersome and time consuming, bringing the issue of interoperability of BIM software into play which often leads to lost productivity on projects. It is therefore apparent from the findings that any transition from BIM Maturity Level 2 to Level 3, or even Level 1 to Level 2 BIM, skills training is a priority for practitioners, from government institutions to engineering consultancies and contractors. BIM Maturity Level 2 is concerned with processes and procedures, whereas Level 3 BIM demands major changes with the method of communication used in the workplace. The attainment of Level 3 BIM within the construction industry necessitates a larger degree of collaboration. It also requires the implementation of international standards that govern BIM methods and practices such as the AS ISO 19650 suite of documents.

The implementation of BIM is influenced by the size of an organisation, with large organisations paving the way. This is due to larger organisations having greater ability and financial means to implement BIM compared with smaller organisations, as well as frequently being awarded the major and more difficult projects (Dainty et al. 2017). Hosseini et al (2016) agree that BIM adoption and use is responsive to the size of organisations and consequently its implementation is guided by larger organisations, even though small and medium sized organisations throughout the supply chain have limited knowledge and expertise of BIM. Results from this survey questionnaire show that 17 percent of respondents are employed in small and medium engineering consultancies although only a very small proportion purport to have extremely limited BIM expertise, which ultimately contradicts the study by Hosseini et al. (2016). Even if a larger percentage of industry stakeholders had responded to the questionnaire, the distribution of the results would be similar as all stakeholders surveyed are involved with the use of BIM on projects to some degree.

4.4.4 Standardisation efforts

Governments are key players in the standardisation of BIM, whether at national level or internationally. The Australian government dictates that BIM is to be used in all major public construction projects however it is not mandated across all states and is not mandated for smaller infrastructure projects. Despite the successful implementation of BIM throughout the private sector it is not a key requirement on all civil construction projects. Key quantitative findings have shown that there is a lack of uniform adoption of certain standards within the industry, noting that more than half of respondents agree that inadequate standardised procedures, asset definitions and systems of classification create obstacles to the adoption and use of BIM. This frequently results in an inefficient workflow and much more effort needed to consolidate and deliver projects. Previous studies (Lea et al. 2015, NBS 2019) support these findings in emphasising the necessity for consistency in terminology and industry standards. Interestingly, only one-third of respondents are actually working to the standards AS ISO 19650, a similar number of respondents are unaware if their organisation is even working to these standards, with one-fifth of respondents not even working to AS ISO 19650 on their designated BIM projects. Results reveal that those organisations complying with AS ISO 19650 found that these standards complement their current practices and has improved information management and collaboration on projects.

The Australian government's policies and standardisation efforts, both state and federal, in conjunction with industry initiatives, are crucial to the successful delivery of BIM. Several studies have identified that clients do not necessarily require the utilisation of BIM on projects, however this is primarily due to the small size of projects or a client's limited understanding of the benefits BIM brings to a project, particularly at the construction and operational phases. Survey findings reveal that 33 percent of respondents are engaged in BIM projects worth less than $50 million.

A large proportion of respondents however are engaged in New South Wales' public sector projects worth in excess of $100 million where BIM is definitely a client requirement and have indicated that they primarily refer to the Transport for NSW (TfNSW) Digital Engineering Framework, Level of Development (LOD) Specification 2020 and Uniclass Classification System 2015 as reference points in order to comply with and deliver a civil infrastructure project. Nevertheless, the national initiatives, NATSPEC National BIM Guide, Australian BIM Strategic Framework and the National Building Information Modelling Initiative were of limited importance to the vast majority of respondents. These initiatives are intended to lay the foundation for governments to create a uniform approach towards BIM in large civil construction throughout Australia, therefore a question to be answered is why are these national initiatives of no interest to the majority of survey respondents? One possible reason is that professional practitioners in the civil design and construction industry are not aware of these national BIM initiatives.

Previous studies (Poljanšek 2017, Schafermeyer & Rosenkranz 2011) have examined the effect of a wide array of national BIM policies and standardisation efforts around the world. Due to numerous BIM policy processes being concealed within organisations' in-house BIM handbooks, there is a high possibility that the construction industry develops an ad-hoc approach towards terminology, policies and standards, including the AS ISO 19650 suite of documents, rather than a consistent and unified approach. Survey findings indicate that the Australian construction industry is struggling with enforcing these standards among various organisations, both large and small, which demonstrates the problem of developing standards for providing information that the industry as a whole can actually work with. Fifty-nine percent of respondents consider that the lack of standardised procedures are a major disadvantage in the adoption and use of BIM.

In relation to the Australian government's BIM requirement on major public construction projects, survey findings show that more than half of all respondents agree that the government should mandate the adoption of BIM in all publicly funded construction projects in the civil design and construction industry, with all BIM managers agreeing that it should be mandated in both publicly and privately funded projects. More than half of engineers surveyed agree that mandates should be imposed on publicly funded projects however only one-third agree to mandating

BIM on privately funded projects. Even though the federal government's main aim is a consistent approach to BIM for major infrastructure projects, it is acknowledged that it is essential for all state governments to keep working within their policy frameworks to satisfy the particular needs and demands of industry practitioners. Dainty et al. (2017) suggested that BIM mandates may strengthen the digital divide in the construction industry as small and medium sized organisations do not have equal opportunities when it comes to the implementation of BIM in comparison with larger organisations. Findings from this survey are therefore not conclusive that a federal BIM mandate should be imposed on privately funded infrastructure projects. It does however suggest that the Australian government should offer some form of inducement to the small and medium sized organisations, with care being exercised so as to not isolate them in the industry's current fragmented state. Consequently, small and medium sized organisations need to be consulted regarding BIM strategies so as not to broaden the digital divide.

Chapter 5 - Conclusion

Figure 25: Structure of Chapter 5

5.1 Achievements

This research project was concluded by following the quantitative methodology approach outlined in Chapter 3. The aims and objectives defined in Chapter 1 have been fulfilled even though there were some limitations encountered with the research. The questionnaire targeted 150 Australian civil design and construction industry professionals over a two week period which produced an excellent response rate of 43 percent in a short period of time. Online surveys often have a targeted response rate of less than 20 percent and it is not unusual for online surveys to even have a response rate of below 10 percent (Mol 2017). The responses to the questionnaire generated some worthwhile results and valuable insight into BIM standardisation and adoption practices in the industry. Conclusions drawn from the responses include:

- there is insufficient amount of time allocated on construction projects for practitioners to learn the complexities of BIM while also providing a successful and timely project delivery;
- accelerated project delivery will create cost efficiencies in the construction phase rather than the pre-construction phase;
- inadequate BIM training is of concern to industry practitioners, in particular training to achieve BIM Maturity Level 2 and then the transition to Level 3 BIM on projects. Greater understanding is therefore required in order to train and educate industry practitioners to satisfy state and national BIM demands;
- there is a lack of uniform adoption of certain standards within the industry, noting that more than half of respondents agree that inadequate standardised procedures, asset definitions and systems of classification create obstacles to the adoption and use of BIM; and

- the federal government should have a blanket mandate for the adoption of BIM in all publicly funded civil infrastructure projects, regardless of size and value, however a federal BIM mandate on privately funded projects was not conclusive.

5.2 Limitations

Limitations in quantitative research are constraints that cannot realistically be discarded and which may impact the design of the survey and its outcomes. The limitations listed below are fundamental to meet the goals of this research:

1. the quantitative methodology of the research is confined to the number and demographic type of industry stakeholders who replied to the survey questionnaire.
2. the survey is confined to the quantity and quality of the information that the respondents' supplied. In retrospect, a few qualitative questions at the end of the survey would have been useful for participants to reflect on and further explore the topics in question; and
3. the survey is limited by researcher bias.

It is difficult to entirely remove limitations in a research project. In effect, limitations can identify the extent of a research project and often can influence the conclusions that are derived. There are a number of limitations in this research including time constraints, sampling size and the unwillingness of stakeholders to participate in the survey.

The time allowed to undertake this research project has been confined to semester 1 and 2 of the 2021 academic year with completion during this period. Survey response rates are frequently low and receiving an acceptable response rate can be relatively difficult. This is particularly a challenge where prospective participants are chosen randomly and where there is no direct connection with the prospective participants (Denscombe 2014). It is easy to overlook a request to complete a survey that arrives online. Therefore, the final sampling size of industry professionals with relevant knowledge and experience using BIM may not be large enough to draw concrete conclusions. This was apparent when assistance was sought from the Australasian BIM Advisory Board and the Australasian Procurement and Construction Council in order to obtain a wider and more representative coverage of industry stakeholders to give further credibility to the survey findings. The researcher however was advised that these organisations do not engage in surveys and therefore were unable to assist. Despite the lack of assistance from these member organisations, the 43 percent response rate from this survey exceeded the 20 percent targeted response rate of online surveys indicated in previous research. However, the vast majority of respondents are employed in engineering consultancies with construction companies playing a minor role in this survey, For a more thorough analysis, it would have been beneficial if the construction companies were better represented. Validation of the final results would also have been useful however the time allowed in ENG4111/ENG4112 research project makes it difficult.

5.3 Summary

The impact that BIM standardisation and adoption practices has on project delivery in the Australian civil design and construction industry has been investigated and conclusions drawn. The following points have been highlighted as of great importance to industry professionals:

- The restrictions of project deadlines, cost, quality and additional constraints imposed on industry professionals prevent them from becoming familiar with BIM and its related applications sufficiently to provide a successful project delivery. Training and education is therefore essential for the purpose of achieving the successful adoption and use of BIM and to respond to the demand of a growing industry, in the face of inconsistency. Training must not just concentrate on BIM technology, it must also concentrate on the enforcement of standards, and a general strategy concerning data management and project delivery. An awareness campaign of national BIM initiatives would be beneficial to all industry professionals.

- Any advantages gained from the adoption and use of BIM is not being seen in the design phase of construction projects as industry professionals are struggling with the interoperability and the integrating of BIM application programs and data formats. The design phase is important otherwise its implementation will be hindered. Too many collaborative difficulties are arising in the workplace where different project stakeholders are either not utilising BIM or use BIM software tools that are not compatible, resulting in interoperability issues. It is therefore a necessity for BIM application programs and data formats to be compatible and integrated into the lifecycle of a project in order to avoid future productivity losses.

- Private organisations, especially small and medium sized ones, must assume the responsibility of achieving at least BIM Maturity Level 2 in order to reach the new international standards for BIM and improve their prospects of winning tenders for projects, especially government infrastructure projects. This will put them on more of an even playing field with larger organisations and will also assist their prospects nationally and globally. Although BIM Maturity Level 3 is still in its early development stages and not a key requirement on most construction projects, it demands major changes with the method of communication used in the workplace. The attainment of BIM Maturity Level 3 within the construction industry necessitates a larger degree of collaboration and requires the implementation of international standards that govern BIM methods and practices, such as the AS ISO 19650 suite of documents. The federal government claims that processes will be standardised by the use of BIM on projects and the method that information is delivered to the client. However, as all design and construction firms have different structures, varying degrees of understanding, and operate individually, achieving BIM Maturity Level 3, let alone Maturity Level 2, will not occur.

This research project has added to the area of study however further work may be required in the areas of government mandates on privately funded infrastructure projects and cost efficiencies in the pre-construction phase as a percentage of the whole lifecycle of a project.

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Appendices

Appendix A - Project Specification

ENG4111/4112 Research Project

Project Specification

For: Ryan Thrower

Title: BIM standardisation and its effect on project delivery in the Australian civil design and construction industry

Major: Civil Engineering

Supervisor: Associate Professor David Thorpe

Confidentiality: Measures to be taken to ensure that those participating in the research project maintain anonymity, data to be kept confidential, those participating realise the nature of the research and their contribution, and those participating voluntarily approve to taking part.

Enrolment: ENG4111 - ONL S1, 2021
ENG4112 - ONL S2, 2021

Project Aim: The goal of this research is to deliver fundamental data on what is needed to successfully operate and deliver a BIM project over its entire lifecycle, the barriers to adoption of BIM and current standardisation efforts from both an organisational and national level in the Australian civil design and construction industry. Additionally, with the release of the new International Standards for BIM, this research may also form a basis of encouragement for the Australian government to mandate the adoption of BIM in all major public and private construction projects nationally as a first step, followed by a mandate for the whole civil design and construction industry.

Programme: Version 1, 17 February 2021

1. Conduct a detailed literature review of international and Australian BIM standards and policy initiatives, background to BIM adoption practices, barriers to its adoption and the impact BIM has on project deliverables.

2. Develop methodology to address the project aim and design an online industry questionnaire to gather data from a cross-section of relevant industry stakeholders to measure a respondent's opinions on current standardisation efforts from both an organisational and national level, as well as their BIM practices, its impact on project delivery and any obstacles that need to be overcome in order to adopt BIM over the entire lifecycle of a project.

3. Prepare Participant Information for USQ Research Project Questionnaire to explain the nature of the research with an assurance of confidentiality and distribute to prospective industry participants via email and await responses.

4. Distribute the online industry questionnaire to respondents of participation questionnaire, gather and organise research data for analysis.

5. Analyse the research data using the Relative Importance Index (RII) method, synthesise the participants' comments and prepare a report of the results.

6. Research appropriate case studies of completed civil infrastructure projects that have implemented BIM throughout the lifecycle of the project and identify the positive and negative effects that BIM standardisation and adoption practices have on project delivery.

If time and resources permit:

7. Make recommendations of what is required in the industry in order for private organisations to reach the new international standards for BIM and what will assist the global prospects for small and medium construction firms to win tenders for projects in new markets more equitably.

Appendix B - USQ Human Research Ethics Approval

USQ

Ryan Thrower <u1051420@umail.usq.edu.au>

[RIMS] USQ HRE Application - H21REA119 - Expedited review outcome -Approved

1 message

human.Ethics@usq.edu.au <human.Ethics@usq.edu.au> Mon, Jul 12, 2021 at 9:28 **AM**

To: [redacted]

Cc: David.Thorpe@usq .edu.au

Dear Ryan

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: H21REA119
Project title: BIM standardisation and its effect on project delivery in the Australian civil design and construction industry
Approval date: 12/07/2021
Expiry date: 12/07/2022
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

This email (including any attached files) is confidential and is

Appendix C - Research Project Risk Assessment

Phase	Risk	Risk Mitigation	Risk Level
Phase 1: Projection Preparation	Resources are difficult to obtain in order to start project	Start resource acquisition immediately research project is approved. If resources cannot be obtained use alternate resources from other available options.	B5: Low
Phase 2: Research design	Approval to send out online questionnaire not given by USQ Human Research Ethics Committee	Start discussions with USQ supervisor and Human Research Ethics Committee supervisors to guarantee approval is received before commencing survey.	B4: Low
	Australasian BIM Advisory Board denies request assist with sending out the industry questionnaire to their membership base	Enquire with other industry bodies to ascertain if they can assist with sending out the questionnaire to their membership base.	C3: Medium
Phase 4: Data Analysis	Response rate from participation questionnaire is inadequate	Ensure that the questionnaire is distributed on a large scale to industry professionals and if necessary, make direct contact via telephone to follow up	D3: Medium
	Data interpretation and analysis takes longer than anticipated	Ensure sufficient time has been set aside for data interpretation and analysis. Start data analysis early	A2: Low
Phase 4/5: Data Analysis/ Dissertation	Poor posture and eye fatigue from continual computer use.	Take breaks often, ensure that the study environment is set up ergonomically and ensure there is plenty of light to work in.	B3: Medium
Phase 5	Insufficient time available to adequately write up or present results	Start writing draft dissertation at the beginning of the project before results are obtained. Regularly commit time to writing dissertation. Seek review of draft dissertation.	B4: Low
	Loss of research, data and draft research papers	Regularly back up all research, data and draft research papers throughout the academic year using an external hard drive and cloud based storage.	E3: High

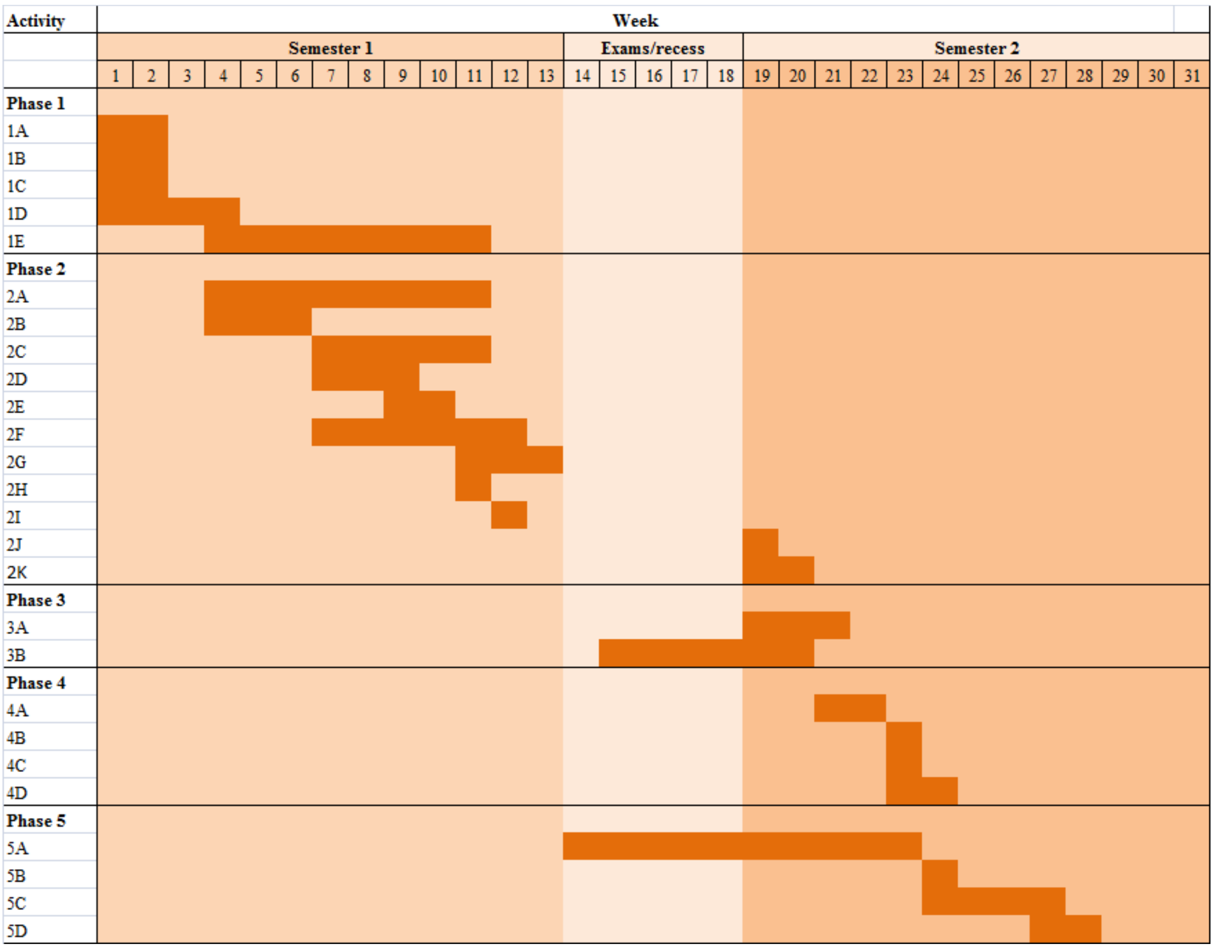
Legend:

Likelihood	Consequence				
	A. Insignificant	B. Minor	C. Moderate	D. Significant	E. Critical
1. Almost certain	Medium	Medium	High	Extreme	Extreme
2. Likely	Low	Medium	High	High	Extreme
3. Possible	Low	Medium	Medium	Medium	High
4. Unlikely	Low	Low	Medium	Medium	High
5. Rare	Low	Low	Low	Low	Medium

Appendix D - Project Plan 2021 v3

To guarantee that the research project goals can be met within the allocated time limit and to ensure that all tasks and benchmarks can be tracked and checked, a weekly plan of the project timetable has been created as shown in Table 1 and specific key project task list in Table 2.

Table 1   2021 Weekly Project Schedule v3



The research is proposed to be conducted over five phases:

Phase 1: Project preparation - obtaining approvals from relevant authorities and resource acquisition;

Phase 2: Research design - detailed literature review, development of methodology, design and formatting of online industry questionnaire and preparation and distribution of participation approvals;

Phase 3: Data collection - distribution of online industry questionnaire and conduct case study research;

Phase 4: Data analysis - collect, analyse and synthesise results; and

Phase 5: Dissertation - prepare dissertation and presentation of results.

Table 2 Key project task list v2

Phase 1	**Project preparation**
1A	Project commencement approval
1B	Draft project specification, including project plan and key resources, and submit to USQ Research Supervisor for review and comment
1C	Resource acquisition – Procure all resources required to undertake project, for example, survey software
1D	Submission of Project Specification due 17 March 2021
1E	Commence human research ethics application
Phase 2	**Research design**
2A	Commence detailed literature review
2B	Develop methodology to address project aim
2C	Design online industry questionnaire
2D	Prepare Participant Information for USQ Research Project Questionnaire to explain the nature of the research with an assurance of confidentiality
2E	Prepare a Consent Form to participate in the questionnaire
2F	Draft Progress Report, including risk assessment, and submit to USQ Research Supervisor for review and comment
2G	Obtain endorsement from USQ Research Supervisor to submit a human research ethics application.
2H	Submission of Progress Report due by 27 May 2021
2I	Submission of human research ethics application to Human Research Ethics Committee for official approval to conduct survey.
2J	Contact the Australasian BIM Advisory Board to request their assistance with sending out the industry questionnaire to their membership base
2K	Distribute Participant Information and questionnaire for USQ Research Project to prospective industry participants via email and await responses
Phase 3	**Data collection**
3A	Collect responses to online industry questionnaire
3B	Research case studies of completed civil infrastructure projects that have implemented BIM throughout the lifecycle of the project
Phase 4	**Data Analysis**
4A	Gather and organise research data for analysis
4B	Using the Relative Importance Index (RII) method, analyse the results
4C	Synthesise results
4D	Prepare a report of the results
Phase 5	**Dissertation**
5A	Prepare draft dissertation and submit to the USQ supervisor for review and comment by 8 September 2021
5B	Present results at USQ Residential School for ENG4903 (Professional Practice 2) mid-late September
5C	Following feedback from the USQ supervisor, prepare final dissertation and submit for marking
5D	Prepare a Human Research Ethics Milestone Report and submit

Appendix E - Participant Information Sheet

University of Southern Queensland

Participant Information Sheet

USQ HREC Approval number: H21REA119

Project Title

BIM standardisation and its effect on project delivery in the civil design and construction industry

Research team contact details

Principal Investigator Details

Mr Ryan Thrower
Email: [redacted]
Telephone: +61 430197597
Mobile: +61 430 197 597

Supervisor Details

Associate Prof David Thorpe
Email: David.Thorpe@usq.edu.au
Telephone: +61 7 3470 4532
Mobile: +61 422 457 749

Description

This project is being undertaken as part of an Honours year in a Bachelor of Engineering degree majoring in Civil Engineering (BENH Civil Engineering) through the University of Southern Queensland.

Up-to-date uniform standards and policies are crucial to facilitate BIM, however it is necessary for these to be taught and accepted by industry professionals so that they can apply them correctly and routinely. The goal of this research is to establish an understanding of BIM adoption practices, the barriers to its adoption and the impact BIM has on project deliverables throughout the civil design and construction industry in Australia, with a specific focus on international and national BIM standardisation. BIM standardisation on a national level is something that the Australian government needs to address to ensure the successful delivery of projects industry wide.

The research team requests your assistance because there is very little guidance available in the adoption and use of BIM in the delivery of infrastructure projects within the industry, including the difficulties arising from inconsistencies in the new terminology and standards. There is no particular international guideline for the work that needs to be acquired and executed on a project for it to be deemed a BIM project. This inconsistency creates chaos and discrepancies within the industry, producing obstacles for the favourable implementation of BIM. Your responses to the research questions will lead to a better understanding of what is required in the industry in order to reach international standards, which will in turn assist the global prospects for small and medium construction firms to win tenders for projects in new markets more equitably.

Participation

Your participation will involve participation in an online questionnaire that will take approximately five minutes of your time.

Questions will include but not limited to:

- During 2020/21, do you consider that:
  Likert scale (agreement x 5)
  - you have been given adequate BIM training;
  - BIM is being implemented/used on projects your company is currently working on;
  - 2D digital drawings are being produced from live 3D models;
  - clients are requesting BIM be used on all projects;
  - models are being shared across disciplines within projects;

- Do you consider the following to be obstacles to BIM adoption?

Likert scale (agreement x 5)
- Inadequate organisational expertise;
- Inadequate training;
- Cost;
- Lack of time on projects to learn and deliver;
- Lack of interoperability of BIM software;
- Lack of client requirement;
- Lack of standardised protocols.

• In the adoption of BIM, do you consider the following to be beneficial:
Likert scale (agreement x 5)
- Cost efficiencies;
- Accelerated project delivery;
- Improved quality of outputs;
- Improved productivity;
- Enhanced collaboration and decision process;
- Easier to work with offshore counterparts.

Your participation in this project is entirely voluntary. If you do not wish to take part, you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. You may also request that any data collected about you or your company be withdrawn and confidentially destroyed. If you do wish to withdraw from this project or withdraw data collected, please contact the Research Team (contact details at the top of this form).

Your decision whether you take part, do not take part, or to take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland.

Expected benefits

It is expected that this project will not directly benefit you however it may benefit your company and other industry stakeholders in the civil design and construction industry in identifying the positive and negative effects that BIM standardisation and adoption practices has on project delivery.

The ability to collaborate without difficulty is an important benefit of BIM however inadequate generally-acknowledged standards for BIM content frequently hinders the collaboration process and results in an ineffective workflow and a great deal of additional effort to deliver projects. This research is expected to deliver fundamental data on what is needed to successfully operate and deliver a BIM project over its entire lifecycle, the barriers to adoption of BIM and current standardisation efforts from both an organisational and national level. It is expected to show the effects of poor implementation of BIM on project delivery versus the effects of successful implementation. This will assist industry stakeholders to adopt and use BIM throughout the entire lifecycle of a project.

Additionally, with the release of the new International Standards for BIM, this research may also form a basis of encouragement for the Australian government to mandate the adoption of BIM in all major public and private construction projects nationally as a first step, followed by a mandate for the whole design and construction industry.

Risks

In participating in the questionnaire there are minimal risks, such as the perceived possibility of disclosure of confidential information; the survey design may be flawed and the results could be prejudiced and unquantifiable; or the collection of online information cannot be guaranteed as completely secure due to the possible risk of hacking or malicious activity.

Measures will therefore be taken to ensure you or your company maintain anonymity with only identifiable information to be collected that is specifically in relation to the research project; data will be kept confidential; the survey sample size will be indicative of the target demographic; IP addresses will be deleted from the datasets before saving the data files to a computer hard drive or any cloud based software and the data collected from the online survey will be as secure as possible with updated antivirus software.

Privacy and confidentiality

All comments and responses will be treated confidentially unless required by law.

In accordance with 2.5.2 of the "Australian Code for the Responsible Conduct of Research", all research data will be made available for future research purposes for similar projects unless this is prevented by ethical, privacy or confidentiality matters. Any data collected as a part of this project will be stored securely as per University of Southern Queensland's Research Data Management policy and shared as non-identifiable information via open access. A summary of the research findings will be communicated to you prior to the research outputs being disseminated in late 2021, of which a copy will be forwarded to you for your information.

Consent to participate

The return of the completed questionnaire is accepted as an indication of your consent to participate in this research. Please click on the policy link below to consent to the survey before proceeding!

Questions

Please refer to the Research team contact details at the top of the form to have any questions answered or to request further information about this project.

Concerns or complaints

If you have any concerns or complaints about the ethical conduct of the project, you may contact the University of Southern Queensland, Manager of Research Integrity and Ethics on +61 7 4631 1839 or email researchintegrity@usq.edu.au. The Manager of Research Integrity and Ethics is not connected with the research project and can address your concern in an unbiased manner.

Thank you for taking the time to help with this research project. Please keep this document for your information.

Appendix F - Participant Survey Invitation Email

Online Survey Email Invitation

Subject: Invitation to participate in a BIM survey

Dear {first name},

My name is Ryan Thrower and I would like to invite you to participate in a research study that I am conducting as part of my Honours year in a Bachelor of Engineering degree majoring in Civil Engineering at the University of Southern Queensland. My study is titled "BIM standardisation and its effect on project delivery in the Australian civil design and construction industry".

The purpose of this research is to establish what is needed to successfully operate and deliver a BIM project over its entire lifecycle, the barriers to adoption of BIM and current standardisation efforts from both an organisational and national level. In addition, it will lead to a better understanding of what is required in the industry in order to reach international standards.

Your participation will involve completing an online questionnaire that will take approximately 5-10 minutes of your time. Participation is voluntary and you may choose to discontinue participation at any time. The study is completely anonymous and confidential. Completion and return of the questionnaire will indicate your willingness to participate in this study. If you require additional information or have questions, please do not hesitate to contact me.

To begin the study, click here to access the survey.

Thank you for your time and participation.

Kind Regards

Ryan Thrower
Research Student
University of Southern Queensland
E: u1051420@umail.usq.edu.au

Appendix G - Industry Association Survey Invitation Email

Online Survey Email Invitation
(to industry associations)

TO: Australasian BIM Advisory Board

Subject: Invitation to participate in a BIM survey

Dear Sir/Madam,

My name is Ryan Thrower and I would like to invite your members to participate in a research study that I am conducting as part of my Honours year in a Bachelor of Engineering degree majoring in Civil Engineering at the University of Southern Queensland. My study is titled "BIM standardisation and its effect on project delivery in the Australian civil design and construction industry".

The purpose of this research is to establish what is needed to successfully operate and deliver a BIM project over its entire lifecycle, the barriers to adoption of BIM and current standardisation efforts from both an organisational and national level. In addition, it will lead to a better understanding of what is required in the industry in order to reach international standards.

Your members' participation will involve completing an online questionnaire that will take approximately 5-10 minutes of their time. Participation is voluntary and they may choose to discontinue participation at any time. The study is completely anonymous and confidential. To access the information sheet and survey, please click here.

Feedback from within the construction industry is essential and therefore I would appreciate if you would forward the survey to your membership base on my behalf.

If you require additional information or have questions, please do not hesitate to contact me.

Thank you for your consideration.

Kind Regards

Ryan Thrower
Research Student
University of Southern Queensland
E: u1051420@umail.usq.edu.au

BIM standardisation and its effect on project delivery in the Australian civil design and construction industry

Demographics

Q1. In what capacity do you work in the industry?

Choose one of the following answers:

- o Engineer
- o Architect
- o Designer
- o CAD Technician
- o BIM Manager
- o Project Manager
- o Estimator
- o Contractor
- o Client
- o Owner/Developer
- o Other _______________

Q2. Please rate your level of expertise in the use of BIM

Choose one of the following answers:

- o None
- o Low
- o Medium
- o High
- o Expert
- o Other _______________

Q3. Is your organisation primarily involved in public or private sector projects?

Choose one of the following answers:

- o Public sector
- o Private sector

Q4.	What is your organisation's primary type of business?

Choose one of the following answers:

- o Government department
- o Engineering consultancy
- o Construction company
- o Supplier
- o Industry Association
- o Other _______________

Q5.	Please indicate the value of the majority of BIM projects your organisation has undertaken in the last five years

Choose one of the following answers:

- o 0 - $1 million
- o $1 million - $5 million
- o $5 million - $50 million
- o $50 million - $100 million
- o More than $100 million
- o Do not know

Obstacles to BIM adoption

Q.6	Do you consider the following to be obstacles to BIM adoption?

Likert scale (agreement x 5)

- o Inadequate organisational expertise
- o Inadequate training
- o Cost
- o Lack of time on projects to learn and deliver
- o Lack of interoperability of BIM software
- o Lack of client requirement
- o Lack of standardised protocols
- o Lack of standardisation of asset descriptions and built environment classification schemes

Benefits of BIM adoption

Q.7	In your experience, do you consider the following impacts have been beneficial on projects you have worked on since the adoption of BIM?

Likert scale (agreement x 5)

- o Accelerated project delivery in the pre-construction design phase
- o Accelerated project delivery in the construction phase
- o Improved quality of outputs

- Improved productivity
- Cost efficiencies generally (improved margins / fees / profits)
- Cost efficiencies in the pre-construction phase
- Cost efficiencies in the construction phase
- Enhanced collaboration and decision process
- Easier to work with offshore counterparts
- Improved safety and regulatory compliance
- Reduced a project's carbon footprint

BIM Implementation

Q.8 During 2020/21, do you consider that:

Likert scale (agreement x 5)

- You have been given adequate BIM training?

Q.9 How many projects has your organisation been involved in using Level 2 BIM?

(Level 2 BIM - full collaboration and partial interoperability through the use of distinct CAD models; links with 4D and 5D information models)

Choose one of the following answers:

- None
- 1-2
- 3-5
- 6-10
- More than 10
- Comments________________

Q.10 How many projects has your organisation been involved in using Level 3 BIM?

(Level 3 BIM - fully integrated and collaborative process in a cloud based environment. All disciplines feed into one single model)

Choose one of the following answers:

- None
- 1-2
- 3-5
- 6-10
- More than 10
- Comments________________

Standardisation efforts

Q.11 Do you consider the following standardisation initiatives beneficial?

Likert scale (agreement x 5)

- NATSPEC National BIM Guide
- Australian BIM Strategic Framework
- The National Building Information Modelling Initiative (NBI)
- Transport for NSW (TfNSW) Digital Engineering Framework
- Victorian Digital Asset Strategy
- The Digital Enablement for Queensland Infrastructure – Principles for BIM Implementation
- Uniclass Classification System 2015
- Level of Development (LOD) Specification 2020

Q.12 Please rate your experience with the introduction of International Standards ISO 19650-1, ISO 19650-2 and ISO 19650-3

Likert scale (agreement x 5)

- My organisation is not working to AS ISO 19650
- AS ISO 19650 complements current practices within my organisation
- Improves information management and collaboration on projects
- Leads to better quality output that is delivered more cost effectively
- Reduces wasteful activities
- Has created a unified approach of working across international regions

Q.13 Do you agree with the following statements?

Likert scale (agreement x 5)

- The federal government should mandate the adoption of BIM in all publicly funded construction projects
- The federal government should mandate the adoption of BIM in all private construction projects within the civil design and construction industry
- A federal BIM mandate for all public and private construction projects will assist small and medium construction firms win tenders for projects in global markets more equitably
- Due to the high cost involved, the adoption of BIM is primarily limited to large government projects only
- AS IS0 19650 accreditation programs will ensure consistency of capabilities among stakeholders across projects

Appendix I - Project Proposal

OWN PROPOSAL - Ryan Thrower

BIM standardisation and its effect on project delivery in the Australian civil design and construction industry

Background

Within the civil design and construction industry, there is little guidance available in the adoption and use of Building Information Modelling (BIM) in the delivery of infrastructure projects, including the difficulties arising from inconsistencies in the new terminology and standards. In order for BIM to be implemented completely throughout the Australian civil design and construction industry there needs to be a consolidated uniform approach, incorporating up-to-date standards and strategies in line with international standards, training and a standardised strategy towards information management and project delivery.

Idea Development

From the student's personal experience, there is very little guidance available in the adoption and use of BIM in the delivery of infrastructure projects within the industry, including the difficulties arising from inconsistencies in the new terminology and standards. There is no particular international guideline for the work that needs to be acquired and executed on a project for it to be deemed a BIM project. This inconsistency creates chaos and discrepancies within the industry, producing obstacles for the favourable implementation of BIM.

Objectives

Up-to-date uniform standards and policies are crucial to facilitate BIM, however it is necessary for these to be taught and accepted by industry professionals so that they can apply them correctly and routinely. The goal of this research is to establish an understanding of BIM adoption practices, the barriers to its adoption and the impact BIM has on project deliverables throughout the civil design and construction industry in Australia, with a specific focus on international and national BIM standardisation. BIM standardisation on a national level is something that the Australian government needs to address to ensure the successful delivery of projects industry wide.

Methodology

To fulfil the aims of this project a quantitative approach will be employed. Research data will be collected through an extensive literature review of international and Australian BIM standards and policy initiatives, a relevant industry case study will be examined and a questionnaire will be designed to gather data from a cross-section of relevant industry stakeholders, such as clients, contractors and consultants, for analysis. Each participant in the questionnaire will be employed in a significant role within their firm and will have a thorough knowledge of BIM procedures within their firm and in the civil design and construction industry generally. To obtain an adequate sample size for the questionnaire, assistance will be sought from member organisations and alliances of key industry leaders from both government and private sectors in Australia and New Zealand, such as the Australasian BIM Advisory Board.

Expected outcomes

The research project will aim to deliver fundamental data on what is needed to successfully operate and deliver a BIM project over its entire lifecycle, the barriers to adoption of BIM and current standardisation efforts from both an organisational and national level. It is expected to show the effects of poor implementation of BIM on project delivery versus the effects of successful implementation. This will assist industry stakeholders in the civil design and construction industry to adopt and use BIM throughout the entire lifecycle of a project. Additionally, with the release of the new International Standards for BIM, this research may also form a basis of encouragement for the Australian government to mandate the adoption of BIM in all major public and private construction projects nationally as a first step, followed by a mandate for the whole design and construction industry.

Appendix J - Key Resources

Key Project Resources

Time:

Various resources will be required to guarantee this research project accomplishes its objectives. The main resource will be the significant amount of time invested into the project. The survey strategies chosen for this research project, comprising questionnaires and case studies, will necessitate meeting strict deadlines and to conclude the research within a given amount of time. Nonetheless, as the strategies are somewhat predictable with regard to their timeframe they are able to accommodate quite strict timetabling.

Survey Software:

Online survey software programs will be required to produce, distribute and analyse results gathered from the research data, for example Survey Monkey or Mailchimp. Online surveys allow a quick and cost-effective method of sampling a cross-section of participants with the data being delivered in a format that is prepared for examination and evaluation. They also minimise the turnaround time between disseminating the survey and receiving replies.

The questionnaire will be designed to measure a respondent's opinions on current standardisation efforts from both an organisational and national level, as well as their BIM practices, its impact on project delivery and any obstacles that need to be overcome in order to adopt BIM over the entire lifecycle of a project. The Relative Importance Index (RII) method will be used in the analysis of the data collected. Those participating in the questionnaire will be asked to respond to the questions on a five-point Likert scale between "1" for strongly disagreeing and "5" for strongly agreeing, and in accordance with their responses, the RII will be measured by employing the equation below:

$$\text{Relative Importance Index} = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Where:

'W' is the weighting provided to the respective factors by those participating in the questionnaire extending from 1 to 5, n1 = the number of those participating who strongly disagree, n2 = the number of those participating who disagree, n3 = the number of those participating who do not agree or disagree, n4 = the number of those participating who agree, n5 = the number of those participating who strongly agree.

'A' is the greatest weight (5 in this survey) and 'N' is the overall number of responses.

Survey Participants:

The survey sample for this research project will come from a cross-section of civil design and construction industry professionals, with the assistance of the Australasian BIM Advisory Board membership, with prior knowledge of BIM procedures however authorisation to contact industry professionals, register locations or inspect documentation will be necessary prior to disseminating the questionnaire. This will give a wider and more representative coverage in order to give credibility to the findings. Measures will need to be taken to ensure that those participating in the research project maintain anonymity, data will be kept confidential, those participating realise the nature of the research and their contribution, and those participating voluntarily approve to taking part. If the strict deadlines are adhered to and the ethical concerns are taken into account, the proposed survey strategies will be an effective sampling method.