University of Southern Queensland

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The Efficiencies that Building Information Modelling (BIM) 3D Visualisation can provide the residential sector of the Australian Construction Industry.

Dissertation submitted by

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Abstract

BIM has been touted as advantageous on construction projects not only for large construction but also for new build in the residential sector. Literature evidence suggests that BIM can provide numerous benefits increasing efficiency in the construction industry. One of those advantages is 3D visualisation of a build before commencement which has the potential to revolutionize residential building and save time, cost and added costly rework. The literature was lacking in information from the perspective of the residential builder, and this prompted the need for research to ascertain 3D visualisation of BIM's potential in the residential sector. Results and analysis revealed that although 3D BIM visualisation is highly regarded to provide substantial benefits for residential building it is not used to its full potential, if at all in some cases. Concerns were raised by the sector on a number of issues mainly lack of BIM experience and resources, no client demand, costs to implement BIM and legal issues pertaining to integration between multiple software packages. These issues would need to be addressed before BIM 3D visualisation becomes the standard way of building. Education on the aspects of BIM and contracts drawn by experienced legal counsel to mitigate any legal problems are important considerations to consider in the future. Benefits of BIM 3D visualisation is well known in the residential sector but barriers to adoption need to be addressed before builders would totally embrace BIM in the organisation. Further research would affirm if this trend is similar Australia wide.

Disclaimer Page

I hereby declare that this dissertation is my own original work and has not been submitted before to any institution for assessment purposes.

Further, I have acknowledged all sources used and have cited these in the reference section.

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Matthew Wallis Date

Certification of Thesis

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this thesis are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

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Student No: [redacted]

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Signature of Supervisor/s Date

[Matthew Wallis/ [redacted]

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Abbreviations

AEC Architecture Engineering Construction

ABAB Australasian BIM Advisory Board

ACIB Australian Centre of Industrial Biotechnology

ACIF Australian Construction Industry Forum.

AIB Australian Institute of Building

APCC Australian Procurement and Construction Council

BDS Building Description System

BIM Building Information Modelling.

HIA Housing Industry Association.

IFC International Federation Class

ROI Return on Investment.

USA United States of America.

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Chapter 1 Introduction

1.1 Introduction

According to ACIF (Australian Construction Industry Forum), there has been a strong rebound in Residential Building and growth in engineering construction activity in 2021 even though covid19 and lockdowns have hindered the Australian Economy. To meet this demand, it is essential for the industry to build more efficiently. One approach set to improve the industry is by utilizing BIM, a technology which provides a higher quality build and greater communication. BIM is the acronym for Building Information Modelling.

B “Building”

The entire Architecture Engineering Construction (AEC) Industry is covered by the BIM technology. This includes construction such as residential buildings, public buildings, airports, hospitals, roads, and railways (Infrastructure) and bridges, tunnels and power plants which come under the banner of Engineering. Different software is available for each unique industry.

I “Information”

BIM technology eliminates information chaos and promotes efficiency. Data is obtained speedily and is of a high quality. It can be divided into graphical (e.g. 3D drawings.), non-graphical (information on objects and elements (materials) and documentation such as schedules and cost estimates.

M “Modelling”

The word “management” can be substituted for modelling as all information is contained in this area and it is where all participants in the project are collaborating. If there is no information a model is only a visualisation. (Fugas, 2019)

It is “I” for information which holds the key for its value. Data from conception to completion can be stored, represented in 3D format, shared and actionable. (Lorek, 2021)

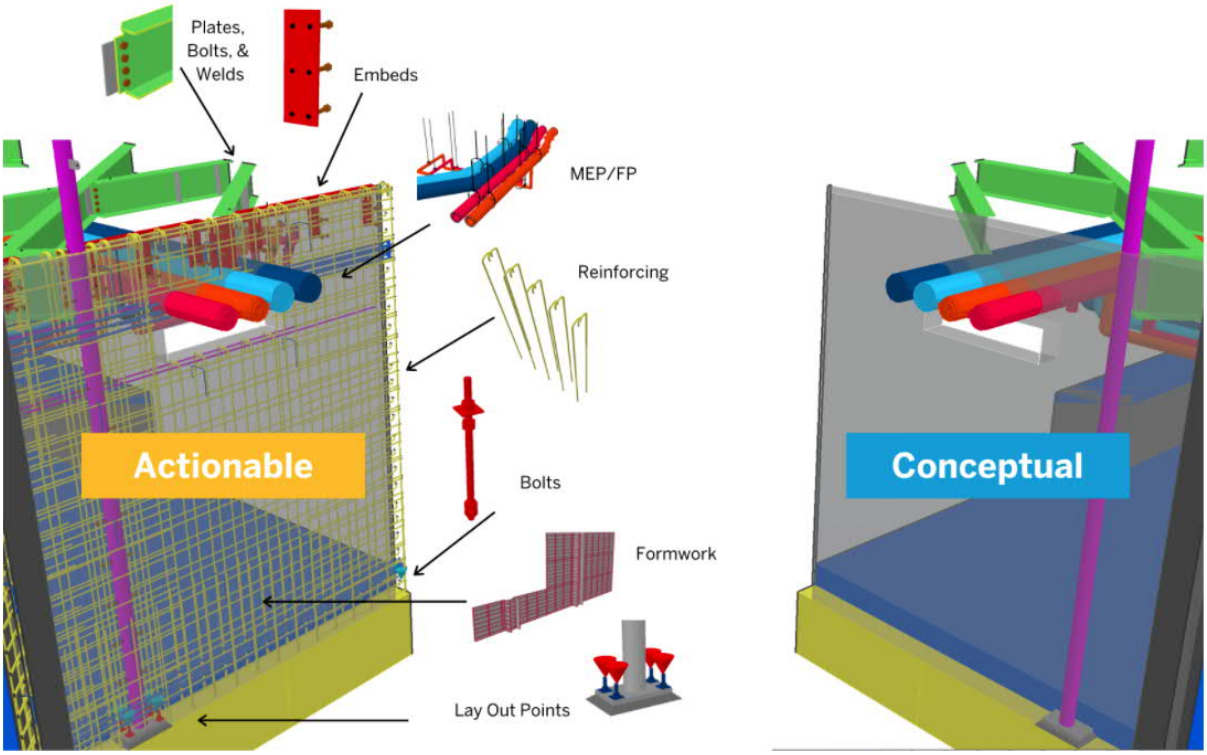


Figure 1.0 Actionable and Conceptual (Lorek, 2021)

The improvements gained can provide for a more efficient build. With the growth in the construction industry and the residential building currently booming this is necessary to meet the demand. The dissertation will investigate how Building Information Modelling's 3D visualisation component can provide for a more efficient build in the residential sector of Australian Construction.

1.2 Status of the Construction Industry

The construction industry generates over $360 billion in revenue producing 9% of the Gross Domestic Product with a projected annual growth of 2.4% over the next five years. (Construction, 2021) The residential construction in Australia statistics show in December 2020 for building activity that the total number of dwelling units commenced rose 18.6%, new private sector housing commencements rose 26.6% to 33,761 dwellings, new private sector in other residential commencements rose 4.1% to 16,049 dwellings and the total value of building work done increased by 0.1% to 29.4billion. Building approvals for the total dwellings rose 21.6% in February 2021, the private housing sector rose 15.1% while private housing dwellings excluding houses rose 45.3% and the value of non-residential building approved rose 27.5%. (Building and Construction, 2021) Since the latest figures show a significant rise in construction in the residential dwellings it is an ideal time to be more efficient by introducing BIM into the residential construction industry.

The standard design and construct in the residential construction industry consists of 2D architectural drawings and 2D engineering drawings for residential buildings of lowset and highset. The co-operation from all groups of ACIF is important that obstacles such as weakness of cooperation, misunderstanding between engineers and architects/drafters, which generate significant issues during the project design and major problems during implementation with the potential of lost time and economic and moral loss. Therefore, to integrate all these fields at the same time and bring them together, BIM will be highly useful as it will highlight the discrepancies missed throughout the project lifecycle and succeed in offering better efficiencies in the project.

The residential construction is separate to the commercial construction industry, but all classed under the one banner. The Australian residential construction industry contributes $95 billion each year for the Australian economy and drives the economic livelihood of millions. (Housing Industry update, 2021) The HIA housing forecasts, state that it has managed the pandemic in 2020 very well. All indications show a very strong 2021 and into the second half of 2022. The residential building workforce industry employ over 1 million across the country. The estimates of employment in the residential building industry includes:

- Builders.
- Construction trade workers.
- Non-construction workers employed by building and trade contacting business.

Estimate of the Residential Building Industry Workforce

	Construction roles	Non-construction roles	Total
New South Wales	248,389	105,978	**354,367**
Victoria	207,481	83,844	**291,325**
Queensland	141,894	58,393	**200,287**
South Australia	36,734	13,956	**50,690**
Western Australia	45,052	19,303	**64,355**
Tasmania	12,629	5,616	**18,245**
Norther Territory	3,400	1,778	**5,178**
Australian Capital Territory	13,193	5,560	**18,753**
Australia	**708,771**	**294,429**	**1,003,200**

Table 1.0 Estimate of Residential Building industry Workforce (The Residential Building Workforce, 2021)

The HIA has stated that we are in a much better position than other economies through the covid pandemic. The signs are positive especially since there was almost 100% increase in December approvals. The graph below shows a strong level through 2021 and into the first half of 2022. (HIA Housing Forecasts, 2021)

[Matthew Wallis/ [redacted]

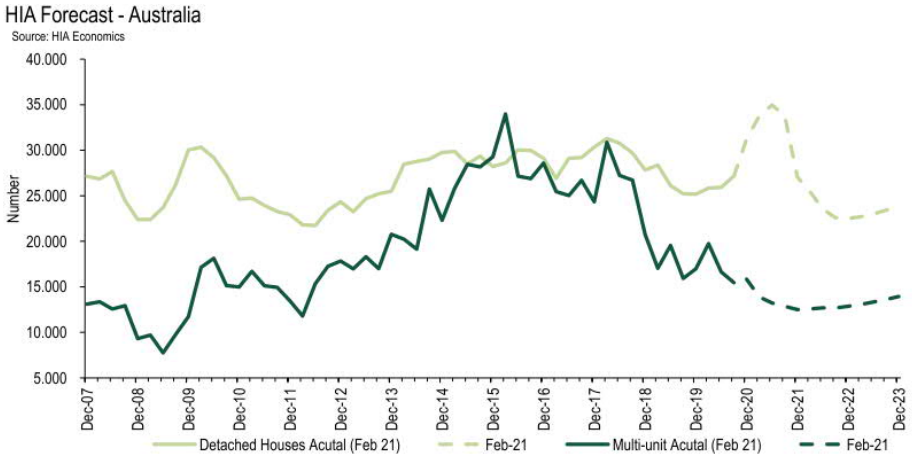


Figure 1.1 HIA Forecast of Dwellings (HIA Housing Forecasts, 2021)

It is a design tool that can be implemented in the residential construction industry to improve efficiency. These efficiencies include time, cost less errors, and providing a visual aspect for better decision making.

1.3 Background & Idea Initiation (The Problem)

The residential construction industry work with 2D drawings and 2D engineering drawings. However, one of the important aspects of BIM focus on 3D visualisation. This shows a precise aspect of the build allowing a better understanding and vision of the proposed work where problems can be exposed. (Extensions architectural) For example, the Cross-River Rail project even though it is a commercial build has been used as a BIM pilot in 2018 for this project. It provides a digital representation of the physical and functional characteristics of a building, piece of physical infrastructure or environment. This is transitioning from paper- based to digital ones and will deliver specific benefits to all phases of the construction. The 3D BIM coordination helps save time, improve design constructability, and project predictability through 3D BIM visualisation. The Queensland Government has mandated the use of BIM beyond 2023 for compulsory government builds. (Building Information Modelling (BIM) | State Development, Infrastructure, Local Government and Planning, 2021).

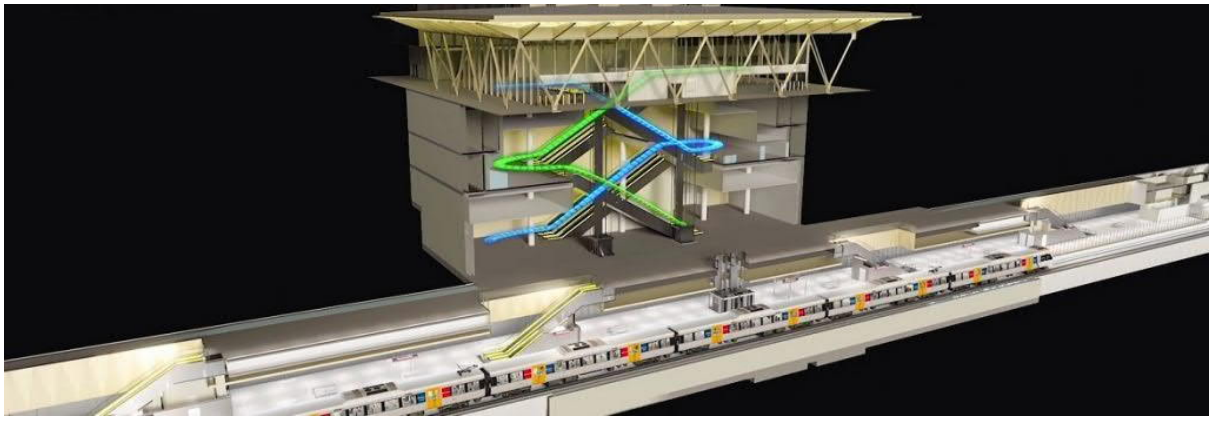


Figure 1.2 Cross River Rail Sector in 3D BIM (Writer, 2021)

It is important during the project lifecycle to provide efficiency that will benefit the project. This is what BIM provides such as speed up of completion time, reducing the number of errors made, and saving costs through the use of prefab materials. (Gelic, Niemann and Wallwork, 2021) The other part is the effectiveness where BIM allows engineers and designers a better visual analysis of a building to promote better decision making. This tool helps provide a better solution for every problem. (Gelic, Niemann and Wallwork, 2021)

The residential sector for the most part use 2D drawings and 2D engineering drawings. Quite often preliminary drawings are in consultation with the client and may not necessarily be drawn by an architect. Then, the engineering construction drawings are produced. Unfortunately, these plans may not always match. Most times the engineering plans are not revised due to extra costs involved. So, the client's interpretation of the build and the proposed build are in conflict. To rectify this situation extra costs and time would occur to bring the two separate plans in alignment. But a BIM programme will allow changes to be implemented because BIM software shows a 3D visualisation technology where discrepancies can be easily seen. This can occur before the start of the build eliminating added time and costs. This aspect of the BIM programme would be beneficial for the residential sector especially the home builders and particularly in a time when the residential sector is booming. This problem has prompted the need for research to establish how extensively BIM is used in residential construction with the view of providing a more efficient build.

1.4 BIM Programs

There are a number of BIM software programs aimed specifically for the residential builder which can be adapted for individual use. Many software companies advertise how 3D

visualisation can enhance the building process including Revit, Autodesk BIM360, Sketchup, Archicad just to name a few.

Figure 1.3 3D Modelling (fugas, 2019)

1.5 Research Questions

Research will investigate if the residential building sector has knowledge of Building Information Modelling and if so to what extent. Also, the questionnaire has been designed to

discover the current understanding in residential building industry with reference to 3D visualisation component. It is also aimed to discover the reasons for the non-use of Building Information Modelling. The questionnaire has been formulated to provide answers on the depth of knowledge of BIM in residential building.

In order to achieve this objective, the following issues will be addressed.

1. Establish the problems faced in the residential construction in Australia focusing on 3D visualisation with potential of saving costs.
2. Undertake an extensive literature review to research the current use of BIM in the residential sector in Australia and the benefits (efficiencies) BIM can provide this sector of the construction industry.
3. Undertake a survey with residential builders to substantiate the findings from the literature review and follow up by telephone.
4. Analyse the Data.
5. List the benefits and outcomes from the data.
6. Provide an associated risk assessment in accumulating the data.
7. Report and discuss the outcomes.

1.6 Research Methodology

The survey/questionnaire (Appendix A) in this research paper will evaluate and analyse the 3D BIM visualisation to find where and if any uses are currently in the residential construction sector and what lies in the future. The survey will identify the efficiencies that can improve the residential construction industry. A review of literature for this research will identify the need for more education for the residential construction industry sector on the use of BIM and in particular the benefits it can provide the business resulting in a more efficient construction build.

1.7 Outcomes/Realisations

The main goal of this survey is to discover and further develop an understanding of the current industry's use of Building Information Modelling. It aims to give a full insight into the current existence of BIM and if it has progressed overtime. This survey report for a construction industry project, aims to provide an analysis and potential advantages and disadvantages, opportunities and barriers of BIM and 3D visualisation that may exist in the residential construction sector. The outcomes of this survey will provide the necessary gap in

the utilisation of 3D visualization of Building Information Modelling in the residential market.

Chapter 2 Literature review

2.1 Introduction

The Australian Construction Industry forum reported in May 2021 that the construction industry is “an engine in Powering Australia’s Recovery.” (Australasian BIM Advisory Board - Australian Construction Industry Forum, 2021) Both State and Commonwealth Governments have initiated infrastructure spending in large scale projects. This coupled with the upsurge in residential building due to government support programs and incredibly low interest rates are the reasons for the strong forecast. The current COVID19 pandemic impacted the construction industry in 2020 but the Governments stimulus measures have greatly uplifted the overall activity in 2021. It is expected that the pandemic lockdowns and border closures will affect some sub sections of the Construction Industry but the growth in residential Building and engineering construction activity are expected to increase employment up to 1.2 million in 2021 and beyond. (Australian Construction Market Report, May 2021, 2021) This favourable forecast for in the Residential Sector suggests that there is a need for efficient builds which would then ensure the industry reaches expectations. One of the drivers for more efficiency in the Residential building is in the use of new technologies. Undoubtably over the years there has been huge changes in the construction industry such as the impact of mechanization where hand shovels, wheelbarrows and working animals have given way to forklifts, tractors and bulldozers but with computer technology, such as BIM all stakeholders involved in a project can see all the aspects of the build through 3D visualisation. All features of the construction can be seen throughout its different phases.(10 Innovations That Have Revolutionized Construction, 2021) This literature review will focus on computer technology and in particular the versatile and collaborative process of the 3D Building Information Modelling concentrating on its utilisation in residential building in Australia.

2.2 Overview of Building Information Modelling

2.21 Evolution of BIM

The idea behind Building Information Modelling has existed for long time and is not a new concept. Ideas and technology behind BIM have evolved over time from as far back as

1957 when computer aided design and computer aided machining were developed by Dr Patrick J Hanratty which was called pronto. Computer scientists continued working towards a graphical interface and Ivan Sutherland at MIT Lincoln labs developed “Sketchpad” in 1963. This became the pioneer for human computer interaction. A prototype called Building Description System (BDS) was published in a paper in 1975 by Charles Eastman. This added a database for visual and quantitative analyses and Charles Eastman predicted that drafting would be improved and provide more efficient less costly designs. Two years later Eastman developed graphical language for interactive Design (Glide) which formed the basis of BIM. However, it was not until 1992 that the term BIM became official. Since then, various “BIM” models have been developed such as Jetstream, Revit and Autodesk etc. A BIM model can now operate on a mobile device due to Autodesk’s development of Formit. (Cherkaoui, 2021)

Timeline of Building Information Modelling (BIM) History

1957 – Pronto, first commercial computer-aided machining (CAM) software
1963 – Sketchpad, CAD with graphical user interface
1975 – Building Description System (BDS)
1977 – Graphical language for Interactive Design (GLIDE)
1982 – 2D CAD
1984 – Radar CH
1985 – Vectorworks
1986 – Really Universal Computer-Aided Production System (RUCAPS)
1987 – Archicad
1988 – Pro/ENGINEER
1992 - Building Information Model as official term
1993 – Building Design Advisor
1994 – miniCAD
1995 – International Foundation Class (IFC) file format
1997 – Archicad Teamworks
1999 – Onuma
2000 – Revit
2001 – NavisWorks
2002 – Autodesk buys Revit
2003 – Generative Components
2004 – Revit 6 update
2008 – Parametricist Manifesto
2012 – Formit
2016 – United Kingdom mandates BIM its projects

Table 2.0 (Evolution of BIM and BIM Adoption, 2021)

2.22 Components of BIM?

There is 3D,4D,5D,6D and 7D components of BIM. Description of each will be explained through the project life cycle. Building Information Modelling is an intelligent 3D model-based process that gives a virtual model that is seen in 3D (X, Y, Z). This gives all clients /stakeholders the visualization of the project and enables easier streamlined communication, fantastic collaboration of multiple teams in their area of expertise fields, ability to reduce reworks that are apparent before project commences for construction. 4D is related to planning, scheduling & duration of the projects. Some of the key factors throughout the 4D implementation is that it improves site planning and scheduling optimization, Coordination between architects, contractors and onsite teams, improved preparation of steps through stages of construction, helps avoid costly delays and safety and efficiency due to documentation of an entire plan with specific timelines. 5D is the 5th dimension and is where costs estimation, analysis and budgetary tracking are useful forms in the beginning of the project. This is vital that costs throughout the project activities are analysed using 5D for the cost reporting and budget concerns. The benefits it brings is real time cost visualization with notification changes in costs, automatic count of all components associated within each activity throughout the project, actual spends of the projects between cost and budgeted with excellent reporting. 6D - the 6th dimensional is making the structure self-sustainable and energy efficient. The modelling helps to analyse energy consumption of the building with estimates of energy levels at the initial design stages. This ensures accurate prediction of energy consumption requirements. Some other factors that can benefit are detailed analysis and impact of a decision on economic and operational aspect over the entire lifecycle and better operational management of the building or structure after handover. 7D – the 7th dimensional is all about building managers and owners able to manage the operation and facility where it can track maintenance/operation manuals, warranty information, technical information etc where it can be used in the future. (What are BIM Dimensions - 3D, 4D, 5D, 6D, and 7D BIM Explained | Definition & Benefits, 2021) The Table below give an insight of the BIM services of a project.

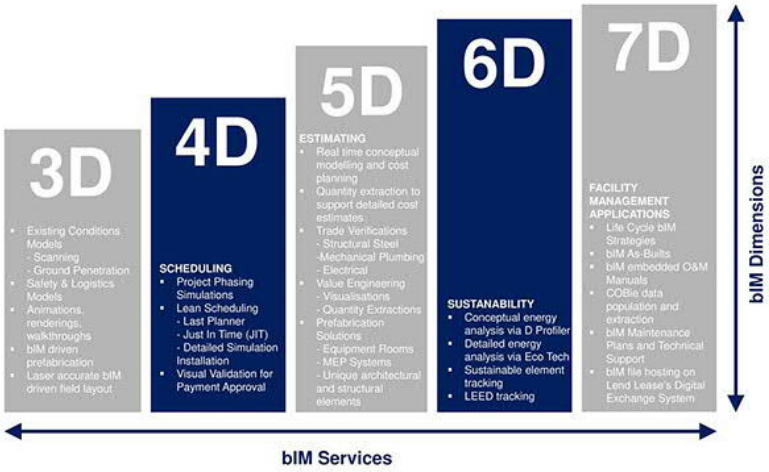


Table 2.0 BIM Services (Blaze, 2021)

The figure below shows how the project will run using BIM.

Figure 2.0 Building Information Modelling (Munro, 2021)

2.23 3D Visualisation

3D Images are shared among the stakeholders involved in a construction project. Pinnacle Infotech, a market leader in architectural and engineering design modelling and coordination solutions using BIM visualisation as:

1. Time saved as 3D BIM visualisation provides a detailed plan with section and elevation representations of building components.

2. As all stakeholders can access 3D visualisation decisions can be made quickly during the pre-construction design phase.

3. 3D visualization application shows an exact replica of the build allowing the stakeholders a realistic view of the project. This also aids those marketing the plans as 3D visualization shows a walkthrough presentation. (Infotech, 2021)

'What does BIM have to do with 3D Visualization?' a blog written in 2014 coins the phrase. "Building it before you build it." This gives an interpretation of 3D modelling and suggests that through computer technology a project is created before workers go to site. (Lytle, 2021)

Most of the literature on 3D BIM visualization reiterated what has already been stated on the topic while an article "3D infrastructure modelling and BIM" added that the 3D model not only allows stakeholders to understand the impact of their decisions on the asset and environment but also their constraints and opportunities. (Cassan, 2021) With these strong advocations for the use of BIM, a research of its implementation worldwide should reveal the importance placed on its use.

2.24 Global Implementation of BIM

Various papers have been written about BIM in a global context. Tianqi Yang and Lihui Lias advocate that BIM technology plays an important role in green building design in China. Through the use of BIM, energy can be conserved, consumption of resources and waste reduced as well as pollution levels thus enhancing work efficiency. BIM's usage in construction is expected to take a significant leap especially as China works towards and promotes the development of green building technology. (Yang and Liao, 2016)

According to Shimonti Pauls 'BIM adoption around the world: how good are we?' the ministry of housing and urban development, Mohurd, suggest that BIM should be considered with management and information technology systems. However, it is Hong Kong that is way ahead keeping up with UK standards. (Paul, 2021)

UK is the leader in BIM adoption and has increased BIM adoption in construction due to the Government Mandate in 2016 imposed on all government funded construction projects. This has filtered down to larger organisations as well as smaller organisations with only a handful of workers where BIM has been adopted. (Paul, 2021)

The use of BIM in the construction industry has also been promoted in Singapore with over 80% of the construction industry using BIM by 2015. Slowly the USA is moving forward in the adoption with some states making the use of BIM Mandatory. However, with US

government support of investments in infrastructure and being one of the largest construction markets in the world it offers opportunities for BIM to become an important tool. (Paul, 2021)

BIM adoption is making inroads in Europe, but it is a rather slow process in Japan and UAE. The Government in Germany is promoting BIM and is expected to make BIM mandatory for public infrastructure construction project by 2020 whist in Denmark the demand for BIM can be attributed to Government requirements, not only large-scale projects are using BIM however smaller projects are moving towards digital platforms. (Paul, 2021)

It is Netherlands which leads the world in BIM adoption. This can be attributed to the fact that large public clients are requesting BIM usage such as Central Government Real Estate Agency and Rykswaterstaat, the Dutch General Directorale for public works and Water management. (Paul, 2021)

Spain is working towards mandates for public construction closely followed by infrastructure projects in 2019. However, progress for BIM adoption is slower in Austria due to lack of expertise on BIM. BIM adoption is increasing in Italy due to Government mandates but interestingly residential buildings without special security requirements will use traditional methods of construction. However, Brazil will mandate BIM in 2021 and adoption rate is very advanced based mostly on cost control. (Paul, 2021)

Michal Juszczyk, Miloslav Vyskala and Krzysztof of Zima discuss research results in prospects for the use of BIM in Poland and the Czech Republic written in 2015. The current overall global BIM adoption was tabled in that publication. (Juszczyk, Výskala and Zima, 2015)

Regions / Countries	Year	Rate of overall BIM adoption
North America (including the USA and Canada)	2012	72%
South Korea	2012	58%
India	2014	22%
The Middle East	2011	25%
Australia	2012	19%
New Zealand	2012	34%
Western Europe (average)	2010	36%
Countries of Western Europe (variations):		
France	2010	38%
Germany	2010	36%
The United Kingdom	2010	35%

Table 2.1 Current overall global BIM options (Juszczyk, Výskala and Zima, 2015)

The National polices and mandates requiring BIM especially for public projects are a key factor in BIM adoption and implementation. In appendix C a summary of Global BIM National polices taken from McGraw – Hill report issues in 2014 shows BIM requirements Worldwide. As far as Poland & Czech Republic is concerned, surveys revealed that BIM adoption is very low in construction projects with only a small number of projects using BIM. No public mandates or polices exist for BIM implementation, it seems it is the national polices or mandates that drive the adoption of BIM as well as a greater understanding of the advantages of BIM usage particularly by the owners in the construction process. (Juszczyk, Výskala and Zima, 2015)

Cameron's Jewels report: Australia a BIM leader but barriers still remain indicated that Australia adoption of BIM is well developed only being surpassed by USA for BIM use of at least 3 years. The key drivers were business benefits, with firms stating that adoption of BIM returned a positive ROI. However, the main reason for non-adoption was demand by owners including a government mandate. (Jewell, 2021) Large projects around the world have been using BIM and this alone reflects the importance of BIM. (Griffey, 2021)

Nationally in Australia there is no government mandate although it has been strongly suggested that BIM becomes compulsory for Government funded infrastructure projects exceeding $50 million in costs by the Australian Governments Standing Committee on Infrastructure. (Griffey, 2021) Queensland is leading the way on the adoption of BIM with the Cross River Rail Project already using BIM and a requirement for Queensland Government Projects over $50 million that BIM be used from the early planning phase by 2023. All major Queensland Government Infrastructure projects will transition to implement

BIM. As of December 2020, there are a number of Government projects using BIM – 22 valued at $50 million or more and 3 under that value. (Building Information Modelling (BIM) | State Development, Infrastructure, Local Government and Planning, 2021) To further develop the implementation of BIM in Australia and New Zealand, an Australian BIM advisory Board has been formulated consisting of BIM experts, influences who are ready to share their knowledge and expertise. This board will address the gap in BIM standards, protocols, systems tools and training in all facets of construction which have been identified by the Australia Procurement and Construction Council (APCC) and the Australian Construction industry Forum (ACIF). The board has no decision-making powers but can make recommendations to the ACIF Board and APCC council. The advisory boards are expected to harmonise the approach of BIM adoption in the Construction Industry, identifying and reducing barriers, identifying the most suitable overseas practices through developing a strategy and framework, to focus on the big issues with what needs to be achieved and how it will be achieved whilst working collaboratively with other bodies. Expectations are to accelerate the Adoption of BIM in Australasia (Australasian BIM Advisory Board - Australian Construction Industry Forum, 2021)

Figure 2.1 Australasian BIM Advisory Board (Australasian BIM Advisory Board- Australian Construction Industry Forum, 2021)

[Matthew Wallis/ [redacted]

2.25 Development of BIM in Australia

The Australian Institute of Building has undertaken to promote the implementation of BIM in the Australian Building and construction Industry. This is expected to be achieved through the distribution of BIM information, development of standards, education, consultation with Government and other industry key officials and software developers. (AIB Policy on Building Information Modelling (BIM), 2021) This strong action indicates the level of importance the AIB places on the acceptance and use of BIM which is believed to provide greater efficiency in the building and construction industry. (AIB Policy on Building Information Modelling (BIM), 2021) It is the belief of the board that eventually will be used by all sectors of the construction industry and that there will be no need to mandate as the significant advantages that BIM can provide will be sufficient justification for its use. (ACIB) The international standard ASISO16739 a data schema and an exchange file format for BIM data has been adopted by Australia with the publishment of ASISO16739:2017. Industry foundation classes (IFC) for data sharing in construction and facility management industries. This means that files can be imported or exported in an IFC (Industry Foundation Classes) format for the most commonly used BIM authorising applications in Australia. This has recognized the value of BIM and its accessibility. (BIM Standards - Australia adopts International Standard for BIM Data Sharing - Standards Australia, 2021)

2.26 Benefits – Efficiency of BIM

Even though barriers exist, the increasing use of BIM in the construction industry worldwide alone indicates the value placed on BIM in construction. (Morrissey, 2021) The number of countries where government mandates are in place for its use further justifies this value. HMC architects list their top 5 BIM benefits as cost and resource savings, greater efficiency and shorter project lifecycles, improved communications and coordination, more opportunities for prefabrication and modular construction and higher quality results. The use of BIM provides a more effective process for costs estimation thus allowing cost savings through the use of more cost-effective materials, buying materials at their lowest price, deciding to prefabricate or build on-site, streamlining construction and reducing costly errors. Return on investment can be enhanced through greater efficiency and shorter project lifecycles. Communications can be improved through the use of a system where all the relevant information is stored in one place and shared with appropriate parties. Decisions can be made to prefabricate or build on site using BIM software and a higher quality structure build can result. (Reyes, 2021) Whilst Cameron Jewell's report Australia's a BIM leader but

barriers still remain states that the top five reported benefits of BIM were less errors, providing an industry image, rework reduction, improving communication and new services offered. (Jewell, 2021)

Projects are delivered with greater speed, accuracy, transparency, and visualisation using BIM. (cubixglobal) A report “Current use of Building Information Modelling within Australian AEC industry” written by Ahmed Alabdulqader, Kriengsak Panuwativanich and Jeung-hwan Doh states the BIM has the capacity in reducing fragmentation, improving efficiency, lowering costs, providing instant visualisation, changes are instant and accurate, improving communication across the whole project, improvement in design and productivity. Benefits from instant visualisation of the projects have provided savings in cost, time, better presentation of the project and production time being reduced with a greater quality of build produced. Another article written by Lee Chad “BIM changing the construction industry – a conference paper also states that using BIM provides a greater level of efficiency, communication and collaboration than the traditional process of construction. According to Nicaholas Chileshe’s conference paper (2012), benefits of BIM have been reported through numerous studies as better information sharing, quality improvement, more efficient use of resources, higher quality building, better design, controlled costs, improved customer service and lifecycle data.

BIM for homebuilders advocated that Building Information Modelling is a system where a project can be managed from start to finish. Home builders who use BIM can expect a reduction in design flaws with the ability to change orders. An increase in productivity, reduction in the over buying of materials and therefore reduced costs and an increase in profit margins are some advantages BIM can offer. (BIM-more than just software) The benefits of BIM for residential are outlined in an article by Construction Dive. Time is saved as a single BIM document stores all the information and can be accessed by those involved in the project and material take-offs are easier. There is an improvement in collaboration through detailed visual information. (Slowey, 2021)

2.27 Barriers to Adoption of BIM

With all that has been written about BIM in particular 3D visualization, its importance, global usage and benefits it can provide there are still barriers to adoption particularly in Australia. These include persistent lack of interoperability, costs of system setup, resistance to change, insufficient knowledge of BIM and culture in the industry.

(Morrissey Law) Acceptance of change is a major issue as it can be difficult particularly for the smaller operator to adapt to new technology. Setup costs, limited resources and lack of knowledge would add to lack of interest in implementing BIM. Little demand by clients and no Australian government mandates exasperates the situation. (Morrissey, 2021)

Another barrier to adoption of BIM is the legal issues associated with using BIM. For example, if owners require the use of BIM, their expectations would be required up front so that all parties understand the agreements. Carefully worded contracts should be used to address BIM issues, such as indicating responsibilities for each BIM model, the degree of participation, schedules for BIM deliverables, and permissible uses of the BIM model to prevent the use on the other projects or for unauthorized purposes. Some design firms familiar with BIM technology have developed contract language which may transfer a disproportionate risk to others. Therefore, when contracts are negotiated it may be necessary to consult experienced construction counsel to decipher the contract language which would in turn add more costs. However, as BIM becomes a preferred application in construction the unique risks associated with the technology need to be addressed. (Woolford, 2021)

2.28 Risks Associated with BIM

Minter Ellison's BIM in Australia defines the legal issues, risks and risk mitigation strategy as follows:

Legal Issue	Risk	Risk Mitigation Strategy
Individual Participants Ownership	Ownership uncertainty Risk of Information Infringement and Misuse Disputes	Define rights of owners and participants Technical and contractual restrictions Avoidance of Joint ownership
Licensing	Software licensing Lack of experience	Clearly defined license , scope, purpose, duration, Inclusions and conditions
Privacy	Unauthorised Access to Data Privacy laws breached	Contractual and Legislative Privacy constraints Security protocols - Strict
Data and Asset Ownership	Key Data Lost Access to Data	Storage Information Data Transfer Consideration
Data Security	Unauthorised access to data Data corruption	Protective Data security plan Security risk profile assessment
Information - Reliance	Disputes - Regarding data Loss of Information Reliance on fitness for purpose warranties	Fitness for purpose warranties Information only data Loss of Data exclusion
Insurance	Unauthorised Access Cannot obtain Insurance	Cyber Insurance Contractual division of Insurance

Table 2.2 Legal Issue and Risks

2.3 Conclusion

Whilst the use of BIM is escalating overseas, its use in Australia is mainly limited to large projects. The literature review revealed limited information on residential building and 3D BIM visualization in that sector. This has prompted the need for research to understand firstly if builders are aware of 3D BIM visualization and the extent of its use in the industry. This in turn would highlight the benefits BIM can provide the builder. Research is expected to reveal barriers to adoption of BIM. If a number of responses express their concerns on BIM adoption for residential building it would provide a greater understanding of BIM technology especially 3D BIM visualisation.

Chapter 3 Research Design and Methodology

3.1 Objective Overview

This synopsis will outline the methods used to gain an understanding of this dissertation topic and will provide answers to the proposed survey/questionnaire questions.

The goal of this research project is to determine the extent of BIM adoption in the residential sector in Australia focussing on 3D BIM visualization with the objective of providing more efficient builds in Australian residential construction. It is also expected to evaluate the potential advantages, disadvantages, and barriers that 3D BIM visualisation that currently exist in the residential building sector. This was undertaken via the following. A survey questionnaire was formulated based on the information attained from the literature review. It has the ability to be emailed with the receiver being able to tick the appropriate box and return by email. Yes or No answers are limited to establish a greater perception on BIM's usage in the residential sector. Refer Appendix A for the questionnaire supplied.

Residential Building Firms in Southeast Qld mainly focussing on the Sunshine Coast region builders were contacted by telephone. Those who agreed to complete the survey were forwarded the questionnaire. A total of 40 builders were contacted to complete the survey. Responses were slow. However, 26 respondents were received which is sufficient for ideal sampling. This survey is expected to establish the extent BIM is used in residential building as well, through the wording of the question it is envisaged to understand how this sector perceives the advantages of BIM and its value for their organisation. The survey is also expected to highlight the reasons for not implementing BIM and any concerns residential builders have regarding BIM.

3.2 Methodology Procedure

The outline proposed for the assessment of this research topic is based on a mixed research methodology (Qualitative and Quantitative) and was adopted to further increase the understanding, knowledge, and the use of 3D BIM visualisation in residential construction.

Qualitative research methods are used for collecting their understanding, experiences, and opinions through open-ended responses. (McLeod, 2021) This data was helpful as it gauges what the thoughts are of those surveyed and knowledge of the subject.

Quantitative research is undertaken to empathise objective measures behind the topic. A measure of collecting numerical analysis of data and then analysing the overall issues of the

problem. Quantitative methods such as survey/questionnaire were used in this dissertation to gain knowledge of the use of 3D BIM visualisation currently being used in residential construction for builders.

The proposed format of Survey/Questionnaire consisted of the follow methods:

1. Residential Building Firms in Southeast Qld mainly focussing on Sunshine Coast region builders were contacted by telephone with email responses or interviews.
2. A total of 40 builders were contacted to complete the survey to make this a viable survey.
3. A literature review was completed, and information gathered pertaining to BIM. Due to limited information on BIM for residential builders, this analysis will investigate the actual needs, gaps, and expectations in the residential construction industry.
4. Questions were formulated to receive honest answers about their environment, consciousness, knowledge, and behaviour.
5. Pre-testing to involve a small sample of expert participants
6. Modify and refine questionnaire for feedback.
7. Execute the Questionnaire (Email and phone responses)
8. Data Analysis
9. Results and Discussion

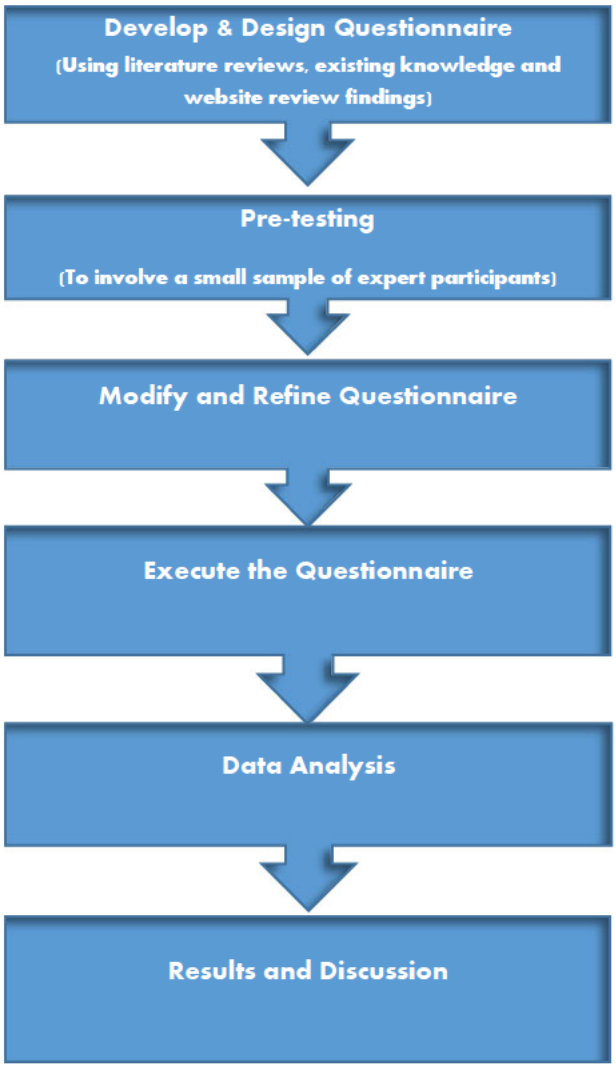


Figure 3.0: Methodology Flowchart

3.3 Data Collection

Data was collected from residential builders whose business ranged from new builds, renovation, small building and residential/commercial. Various personnel from the individual companies completed the survey. These were Director, builder, Estimate and draftsmen, production co-ordinator, estimate/detailer, construction manager, Engineer, Senior contract administrator and permit administrator. Format was mainly electronic via email but some conversations with builders took place.

3.4 Survey/Questionnaire

Information was compiled to investigate whether efficiencies of BIM 3D Visualisation can be advantageous for the residential construction sector. The questionnaire

was conducted in order to view the current perception of BIM in the residential construction industry.

This questionnaire will seek to provide an opinion from professional personnel directly involved in residential building. Key questions sought to gain an understanding of the relevance of the 3D BIM visualisation in residential building are as follows: -

1. Have you ever used Building Information Modelling on any project?

2. Do you think the 3D Modelling of a project using BIM tools will provide substantial benefits before construction?

3. BIM has been touted with many advantages; six advantages were listed to allow participants to indicate the most beneficial to their organisation.

4. Value of BIM if it has been implemented and common barriers not introducing BIM.

5. Benefits BIM 3D visualisation can provide.

Additionally, the questionnaire survey will aid in developing an understanding of current uses of 3D BIM visualisation from industry professionals was gathered. Also, suggestions regarding the topic. A complete survey questionnaire is attached in Appendix A

Chapter 4 Results and Discussion

The following survey questionnaire was forwarded to builders to ascertain where Building Information Modelling 3D visualisation is situated in the residential industry. The survey will show the benefits and barriers that exist currently in the residential construction industry as per responses received.

4.1 Results

1. What is your position in the company?

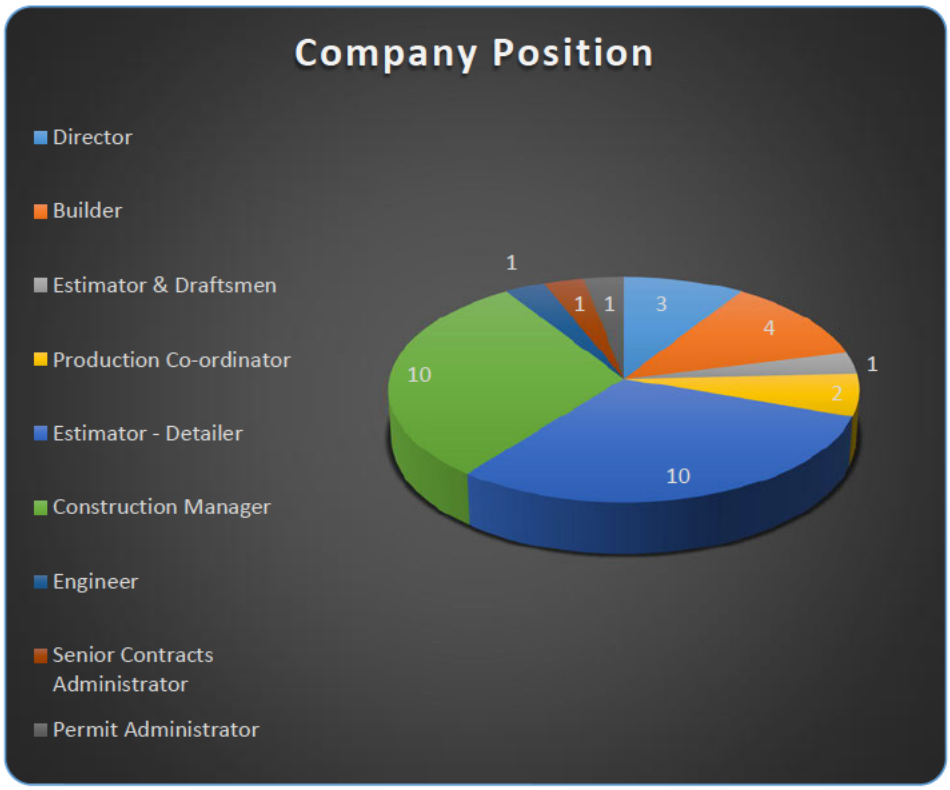


Table 3.0 Company Position

The graph shows numerous different positions in the organisation completed the survey with a builder and estimator/detailer being the most common.

2.What is the main type of construction your company is involved with?

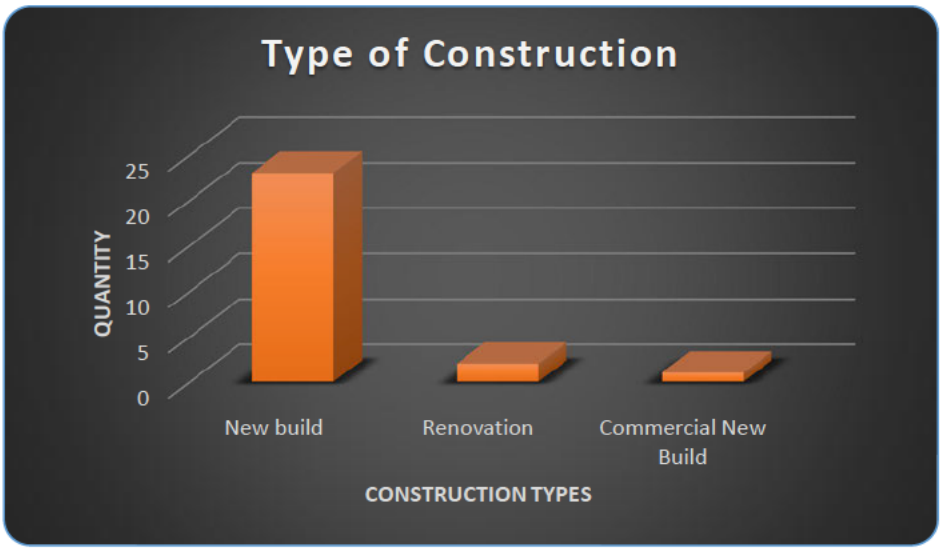


Table 4.1 Type of Construction

The results show that the most common was new build also with a couple builders being involved with both new build and renovation. One respondent has built both commercial and residential constructions.

3. Do you currently use any form of Building Information Modelling on any project before and how complete was the model?

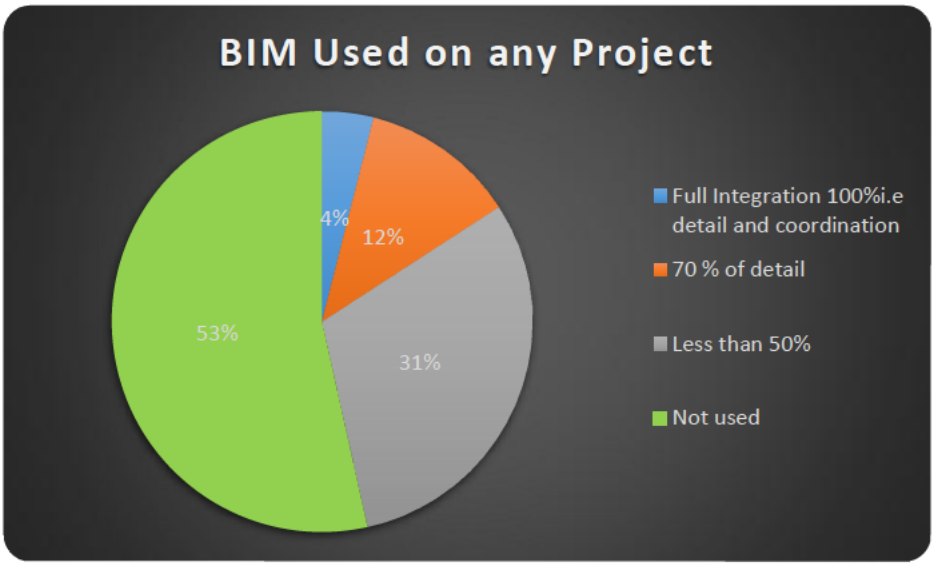


Table 4.2 BIM Used

Of the entire survey, the companies with 53% are not using BIM and 31% of the respondent's state that less than 50% are using some form of a Building Information Modelling. Of the rest 12% use 70% of BIM and 4% use full integration.

[Matthew Wallis/ [redacted]

4. Do you think 3D modelling of a project using BIM tools will provide substantial benefits before construction?

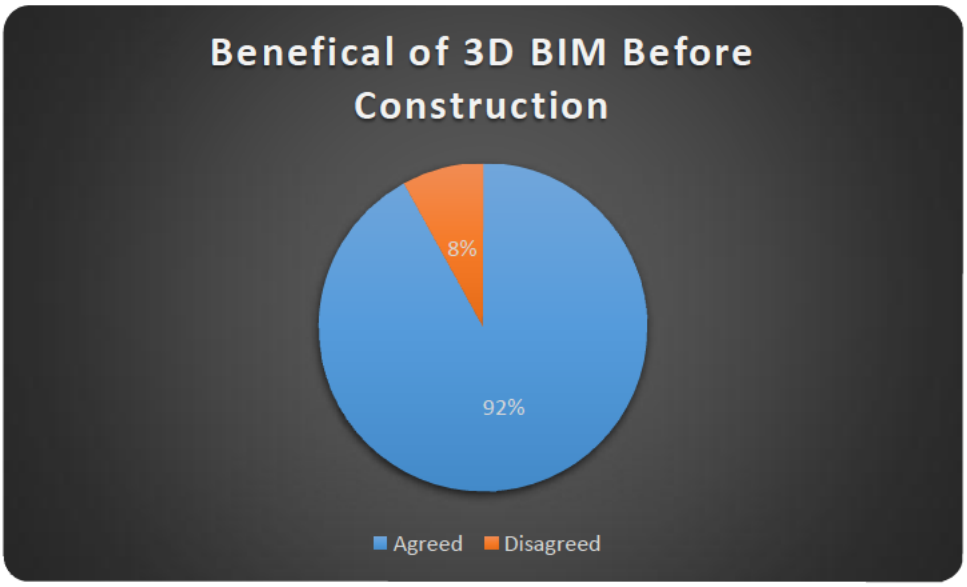


Table 4.3 Benefits of 3D BIM before Construction

92% believed that BIM could provide substantial benefits for their organisation.

5. BIM has been touted as providing many advantages and some are listed below. Please indicate how useful these advantages would be for your business.

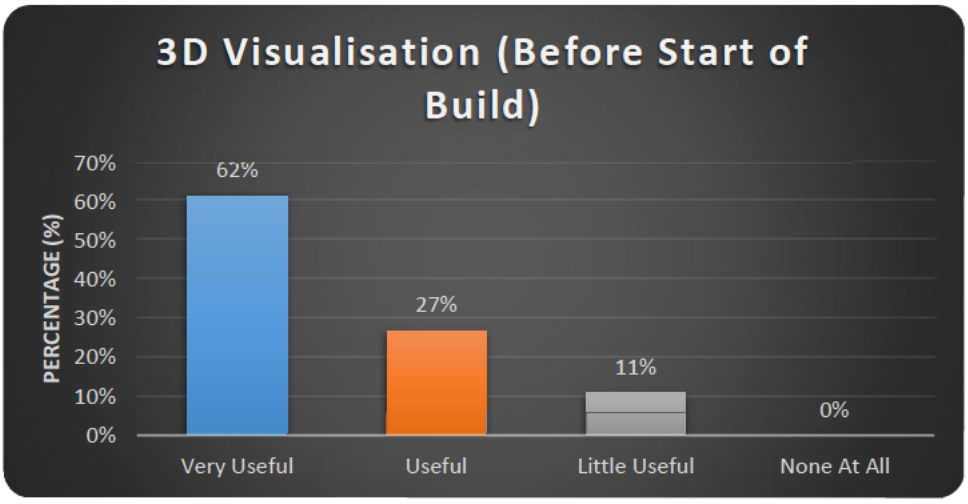


Table 4.4 3D visualisation Before Start of Build

The outcome shows that 62% believed that 3D visualisation of the build provides a very useful marketing tool before start of build.

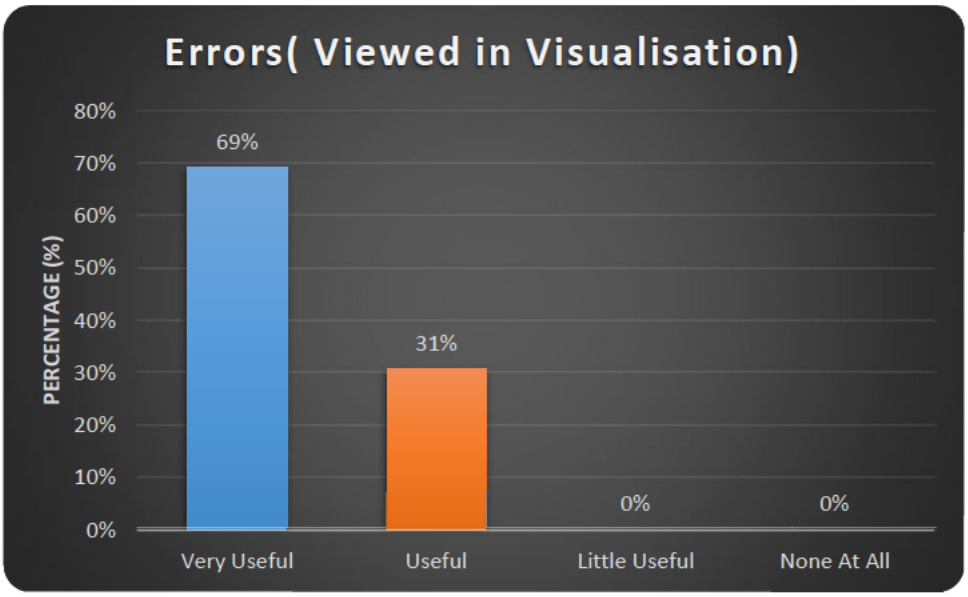


Table 4.5 Instant Errors seen in BIM Tool

The outcome states that 69% of respondents show that errors can be seen instantly through the visualisation tool.

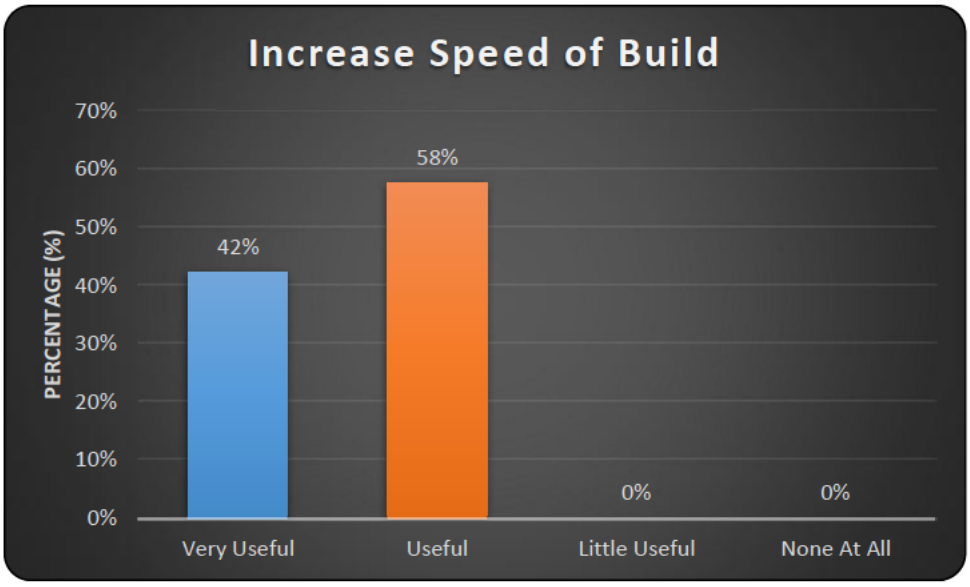


Table 4.6 Increase Speed of Build

The result show 42% very useful and 58% useful where this will increase of speed of the build without significant delays.

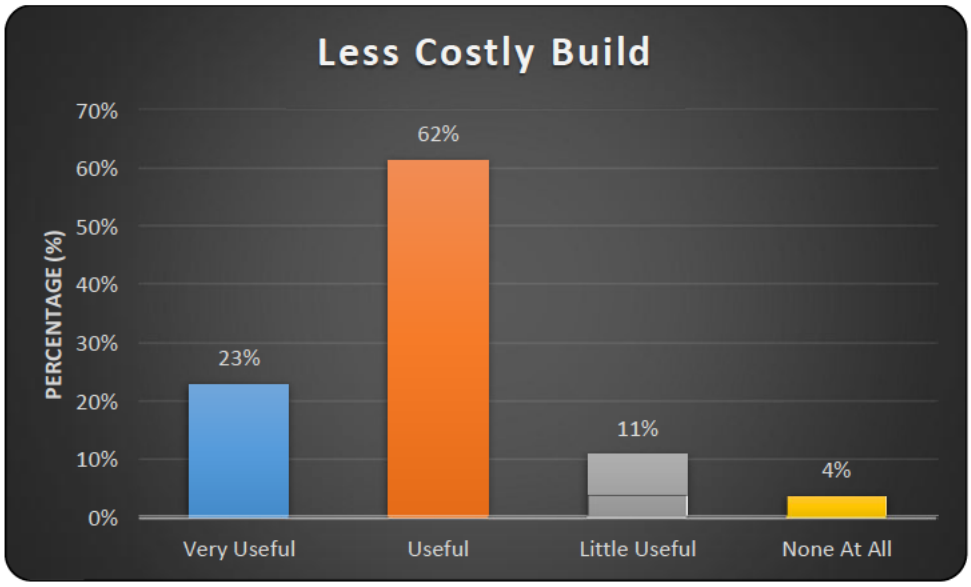


Table 4.7 Less costly build

The respondents on less costly build were staggered in responses with 62% stated it would be useful, 23% very useful and 15% found little use or none at all.

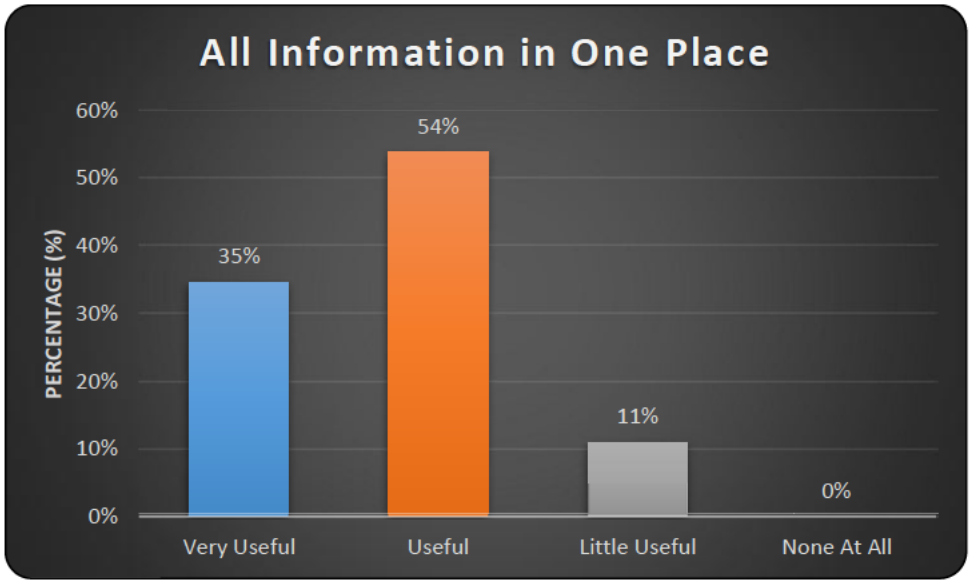


Table 4.8 All Information in One place

89% of the respondents thought having all information in one place to be very useful/useful. Only 11% believed that it is of little or no use.

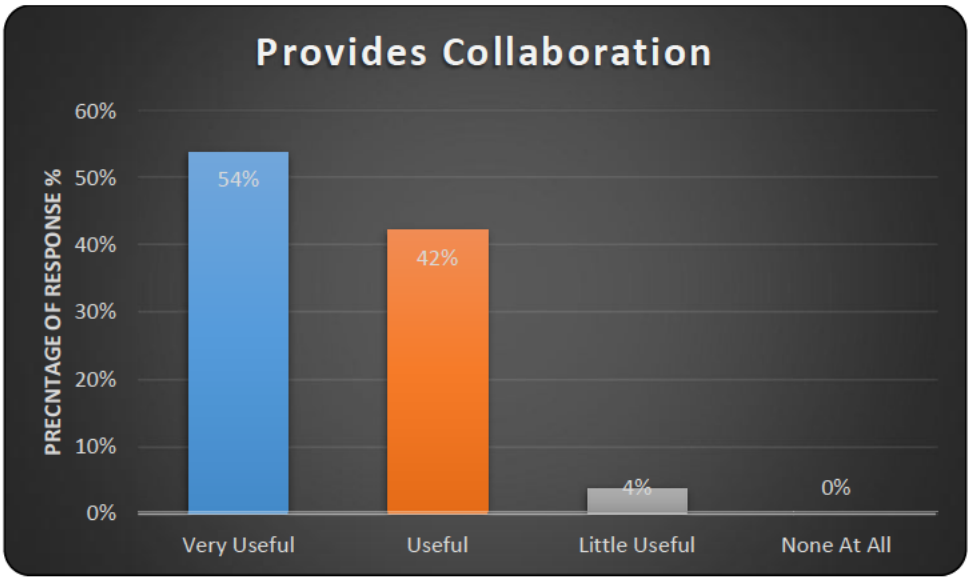


Table 4.9 Provides Collaboration

Providing collaboration on the project was highly regarded with 96% finding this to be a significant advantage.

6. What impact if used would BIM have on your organisation. (Not taking cost of implementation into account)

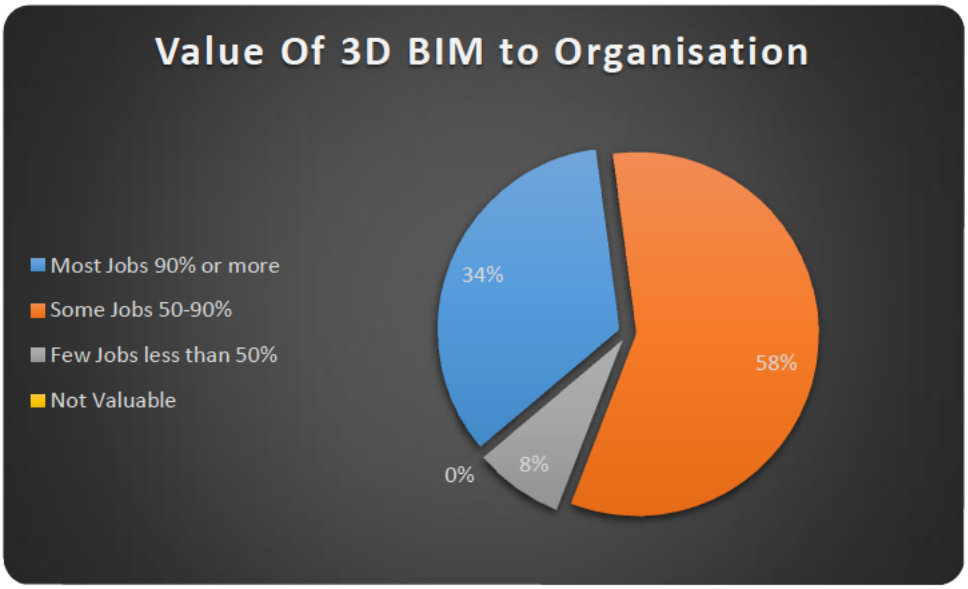


Table 5.0 Value of BIM in Organisation

The pie graph shows the value that 3D BIM tool can be for the retail sector if it was implemented in the organisation. Most agreed that BIM 3D would be of great value to their organisation.

7. The most common reasons for not introducing BIM in an organisation are listed below: - Considering your typical project rank from 1-5 what is stopping BIM being adopted for every project where 1 is the greatest reason and 5 being the lowest reasons)

1	15%	8%	23%	53%	0%
2	35%	27%	15%	27%	4%
3	35%	31%	19%	12%	0%
4	15%	27%	42%	8%	4%
5	0%	8%	0%	0%	92%
Ranking 1 - Greatest Reason 5- Lowest Reason	**No Client Demands**	**Cost to Implement BIM**	**Projects are too small**	**Lack of BIM experience and resources**	**BIM is not relevant to work**

Table 5.1 Reasons Not introducing BIM

Reasons for not adopting BIM can be numerous. However, 5 of the main barriers to adoption were questioned including no client demands, cost to implement BIM, Builds are too small, lack of training expertise and resources as well as irrelevance to the builder's work. The outcome shows no client demands as a reasonable reason. Cost to implementation and projects too small were not considered significant reasons for not introducing BIM. Lack of experience as the greatest reason and BIM is not relevant to work as the lowest reason.

8. The four benefits of 3D visualisation tools in BIM are listed below. Please rank in order of what you think the most important to least important benefits. (1- most important and 4 – least important.)

1	46%	12%	19%	35%
2	15%	42%	12%	30%
3	27%	42%	12%	12%
4	12%	4%	57%	23%
Ranking 1 - Most important 4 - Least Important	**3D Visualisation of the entire project**	**Streamlined communication and sharing of design expectations**	**Collaboration between Teams**	**Complete transparency from beginning reducing rework**

Table 5.2 Four Benefits of 3D Visualisation tool in BIM

This study has paid attention to the 3D BIM visualization tool of BIM. In order to acquire an understanding of residential builder's knowledge of the 3D function, builders were asked to rank the following in order of importance – 3D visualization of the entire project, streamlined communication and sharing of design expectations, collaborations between teams and complete transparency from the beginning reducing rework. The feedback declared that 3D visualisation of the entire project and reducing rework as the most important benefits. The streamline of communication in design appears to be reasonably important but not the most, but collaboration between teams was least important.

9. Do you believe BIM would be advantageous for the design teams? Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

1	62%	19%	8%	23%
2	19%	15%	28%	35%
3	19%	54%	16%	4%
4	0%	12%	48%	38%
Ranking 1 - Most important 4 - Least Important	**3D Visualisation of the entire project**	**Streamlined communication and sharing of design expectations**	**Collaboration between Teams**	**Complete transparency from beginning reducing rework**

Table 5.3 BIM Advantageous for Design Teams

A similar question was asked but only giving reference to the design teams. This will be used to establish if some designers are using BIM as it is thought that this is the area which may be able to take full advantage of 3D BIM visualization tool. 62% declared that 3D visualisation of the entire project would be beneficial for the design teams.

10. What concerns do you have with using BIM in the future?

Comments made by some the responses in regards to the concerns for the future of BIM are listed below: -

- Nothing, perhaps price, but otherwise it makes sense that as technology gets better the benefits will broaden.
- No concerns

[Matthew Wallis/ [redacted]

- Integration between multiple software packages and over reliance on one product. Process changes and upskilling of staff
- The initial learning curve of staff. It may be difficult to convince older builders that it is beneficial to put more resources into documentation stage rather than just dealing with issues on site later.
- User friendliness, computers keeping up.
- If I wasn't using it on a daily basis, I would be concerned that my skill levels would drop, and I may need retraining on the use of the BIM software. The collaboration with older stakeholders that may not be open to BIM may make the comparing of 2D and 3D modelling challenging.
- A universal standard use of components to be used for design so that external software's can read the components for estimating and take-off.
- Can delay design team from completing their aspect of work if BIM design is not complete or available. D&C projects rely on design being developed during construction. Full BIM modelling with all design components incorporated is time consuming and would delay some specialist design aspects like structure, hydraulics, electrical mechanical.

The concerns regarding the use of BIM in the future ranged from no concerns to some serious thoughts on its implementation in the building sector. Skill level in the use of software packages and training of staff seemed to concern a few of the respondents. Knowledge of BIM and resistance to change presented a challenge. For integration between multiple software packages, it may be necessary to seek advice as this alludes to rights and responsibilities regarding the software packages and data stored. Legal issues pertaining to stored data and its use would need to be addressed and probably by experienced legal contractual counsel. Education and information on BIM especially 3D visualisation may alleviate concerns in this area. One response in the commercial sector thought that all design components incorporated in BIM modelling to be time consuming. All of those completed the survey have provided some useful information on the status in the industry.

4.2 Discussion

The survey revealed that 92% of the companies believed that 3D BIM can provide substantial benefits before construction and many thought 3D BIM is a very useful tool. Even so, more than half surveyed do not use BIM in the residential sector. With no National

mandate in Australia except for Queensland's mandate for government projects over $50 million to use BIM by 2023, initially it would be left to client demand for BIM to be used on projects, but many gave this as a reason for not implementing BIM i.e., no client demand. Other barriers to adoption included costs to implement BIM, projects are too small, lack of experience, lack of resources and time to train personnel and BIM is not relevant to the business. Some concerns were raised regarding the integration between software packages and reliance on one product. This alludes to legal issues and rights and responsibilities regarding the use of the software. Experienced contractual counsel would need to be sort to ensure the rights and responsibilities of those using the BIM programme are carefully stipulated. Data implemented in the BIM program should be protected of course, this would also add an extra cost before implementation as far as the residential sector is concerned. Implementation of BIM in the residential sector seems far in the distance with not even a National Mandate at present. For companies who regard BIM implementation as a way of the future government incentives and the benefits for using BIM in their organisations may hasten the implementation of BIM. But this is not predicted in the foreseeable future. Education would ensure that future generations are aware of BIM's potential. Present workers could be guided by information available through Australasian BIM Advisory Board.

The survey did highlight that 3D Visualisation is an important tool for the residential sector, but the barriers to adoption would need to be addressed to ensure that the implementation of 3D BIM has a chance of success. These issues which were uncovered include lack of experience, lack of computer software packages, legal issues regarding rights and responsibilities of information, time, and cost restraints. Education and information on BIM processes as well as expert legal advice would assist in the development of BIM 3D visualisation in the residential sector. The fact that strong action has been taken by the Australian Institute of Building in the adoption of BIM through the development of standards, education, BIM information leaflets, consulting with government and software developers in order to uphold beliefs that BIM is advantageous for all sectors of the construction industry. As more clients request the use of BIM then BIM will began to be utilised more widely in construction including residential building. Further research in other states would need to be undertaken to ascertain if residential sector Australia wide follows the trend established by Queensland Residential Sector.

Chapter 5 Conclusions

BIM is gaining popularity in construction projects worldwide. Many large projects are using the system due mainly to government mandates. The Cross River Rail Project presently underway in Queensland is using this concept. But this can also be an important tool for the residential sector especially the 3D visualisation components as errors can be easily seen before construction saving time, costs, and rework. It was this idea that prompted the need for this paper. The comprehensive literature review revealed there was a gap in the literature material from the perspective of the residential builder. Little information on the use of BIM in residential building which prompted the need to conduct a research of residential personnel directly involved in the building industry. A comprehensive survey was undertaken of a sector of residential builders in Queensland. This discovered some surprising results. Whilst nearly all of the participants agreed 3D BIM visualisation would provide substantial benefits before construction more than half haven't heard of BIM or never use it. Education is the key in promoting BIM and the Australian BIM Advisory Board has undertaken this role.

It seems it is the barriers to adoption that is preventing BIM's implementation. Lack of BIM experience and resources was the greatest reason for this. Other concerns were raised including integration between multiple software packages over reliance on one product, changes which would occur and training staff. Legal issues which would result with integration between multiple software packages would need to be addressed through consultation with experienced contractual counsel. Education in BIM processes would be necessary to address lack of BIM experience. These would incur extra cost burden. So, it can be easily seen why BIM is not at the forefront of smaller organisations especially in the residential sector. Yes, the benefits BIM can provide the residential sector are well known but it is the barriers that need to be addressed if BIM 3D visualisation is to become widely used in residential building. More research would be necessary focussing on the barriers and also more research throughout Australia to discover if the trend discovered in Queensland continues Australia wide.

Chapter 6 Risk Assessment

The risks associated with this project are listed as well as methods in place to minimise or mitigate the risk.

Risks	Degree of Risk	Minimisation
Unable to obtain sufficient replies from Questionnaire	Medium	Plan in place to contact other smaller firms
Not sufficient information divulged in telephone interview	Medium	Plan to verbally contact other firms
Loss of information received	Medium	Backup Information
Loss of recorder information via telephone conversations	High	Immediate input information in computer and back up this information
Computer down time	Low	Record manually for later input.

Table 6 Risk Assessment

The personal health risks for researching this project have been listed in the table 2 that can be seen below.

Risks	Degree of Risk	Minimisation
Incorrect Posture	Medium	Make sure suitable ergonomic chair is available and frequent breaks.
Eye strain	Medium	Use computer in correct lighting. Do not stare at the computer to long and frequent breaks.
Repetitive Injury Syndrome	Medium	Frequents breaks throughout the project lifecycle
Avoid long spells at computer	Medium	Every 45 minutes have a break.

Table 6.1 Personal Risk

Appendices

Appendix A

APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Choose an item.

   Others Please specify: -

2. What is the main type of Construction your company is involved with?

   Choose an item.

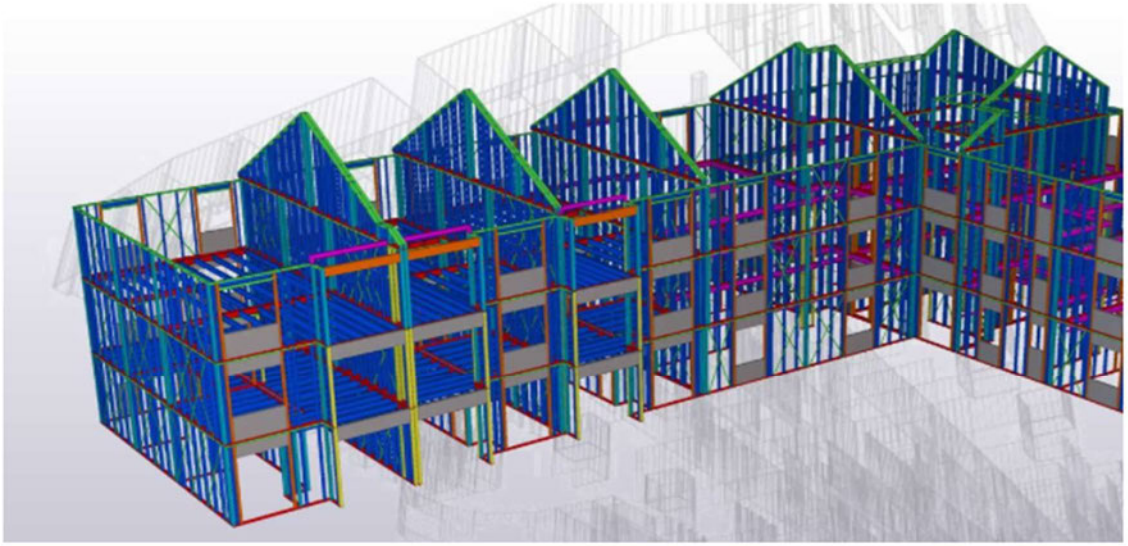
3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

   ☐ Full Integration 100% i.e detail and cordination ☐ 70% of detail

   ☐ Less than 50% ☐ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☐ Yes ☐ No



Definition of Building Information Modelling: - (BIM) is the holistic process of creating and managing information for a built asset. Based on an intelligent model and enabled by a cloud platform, BIM integrates structured, multi-disciplinary data to produce a digital representation of an asset across its lifecycle, from planning and design to construction and operations.

5. BIM has been touted as providing many advantages and some are listed below. Please indicate how useful these advantages would be for your business.

Advantage	Very Useful	Useful	Little Useful	None at all
1. 3D visualisation of the build provides a marketing tool before start of build.	☐	☐	☐	☐
2. Errors can be seen instantly though visualisation tool	☐	☐	☐	☐
3. Can increase the speed of the build	☐	☐	☐	☐
4. Less costly build	☐	☐	☐	☐
5. All information in one place	☐	☐	☐	☐
6. Provides collaboration	☐	☐	☐	☐

6. If you implement BIM in your organisation to what extent would it be of value? (Not taking cost of implementation into account)

☐ Most Jobs 90% or more ☐ Some Jobs 50-90%

☐ Few Jobs less than 50% ☐ Not valuable

7. The most common reasons for not introducing BIM in an organisation are listed below: - Considering your typical project rank from 1-5 what is stopping BIM being adopted for every project where 1 is the greatest reason and 5 being the lowest reasons)

Choose an item. No client demands

Choose an item. Cost to implement BIM

Choose an item. Projects are too small

Choose an item. Lack of BIM experience and lack of resources (time or people) to be trained

Choose an item. BIM is not relevant to work

8. The four benefits of 3D visualisation tools in BIM are listed below. Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

Choose an item. 3D Visualisation of the entire project

Choose an item. Streamlined communication and sharing of design expectations

Choose an item. Collaboration between Teams

Choose an item. Complete transparency from beginning reducing rework

9. Do you believe BIM would be advantageous for the design teams? Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

Choose an item. 3D Visualisation of the entire project

Choose an item. Streamlined communication and sharing of design expectations

Choose an item. Collaboration between Teams

Choose an item. Complete transparency from beginning reducing rework

(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

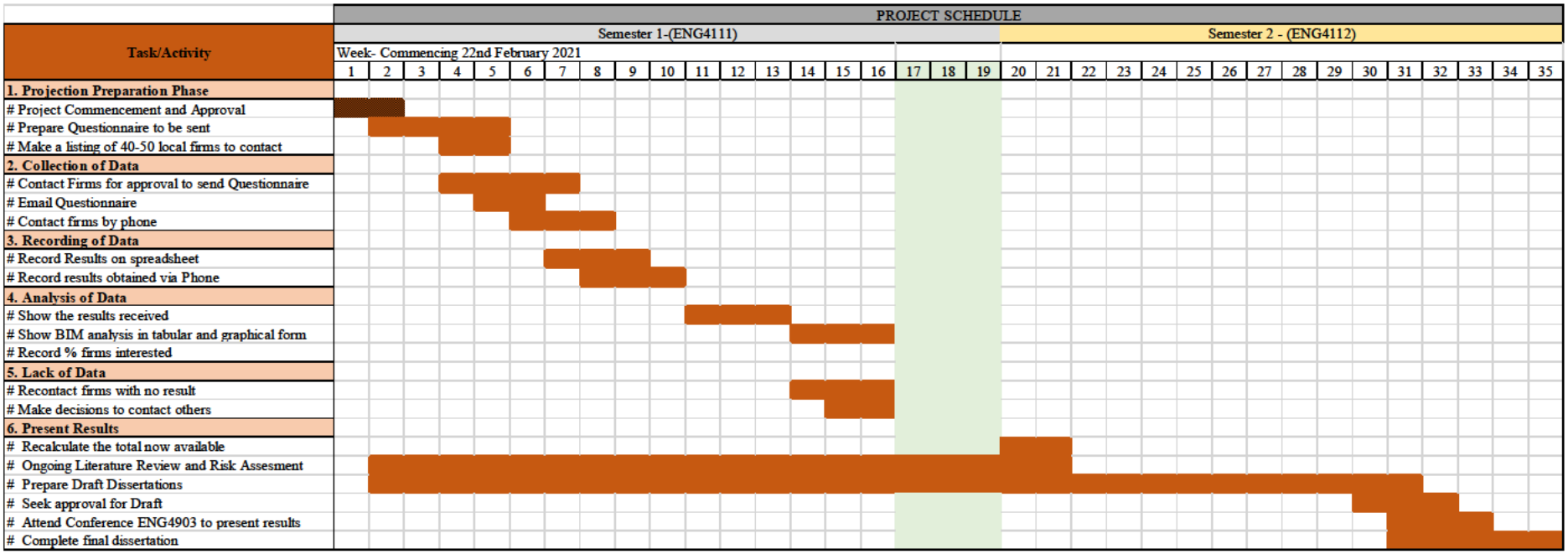
Thank you for your time!

It is hoped that research like this will enable researchers and industry to create tools and resources to make construction more efficient.

[Matthew Wallis/ [redacted]

Appendix B

PROJECT PLAN



Appendix C

ENG4111/4112 Research Project

Project Specification

For: Matthew Wallis

Title: The Efficiencies and Effectiveness that Building Information Modelling can deliver for Residential Construction in Australia.

Major: Bachelor of Construction (Honours)

Supervisor: Dr Amirhossein Heravi

Enrolment: ENG4111-EXT S1,2021.

ENG4112-EXT S2,2021.

Project Aim: To investigate the efficiencies and effectiveness of Building Information Modelling and the improvement Building Information Modelling can provide to the residential construction in Australia.

Programme: Version 1, 5th March 2021.

1. Research Information regarding the efficiencies and effectiveness of Building Information Modelling in residential construction.
2. Analyse all the data.
3. Establish efficiencies and effectiveness Building Information Modelling can offer the residential sector.
4. Discover the extent of the usage of Building Information Modelling in construction overseas.
5. Relate this information to the Australian Residential sector.
6. Establish the gap in the literature review and justify the need for a study on topic.

7. Collect data via surveys and telephone conversation.
8. Analyse the data and establish the benefit of the study.
9. Undertake an extensive risk assessment.
10. Overall findings of the project.

Appendix D

Summary of BIM National Policies

Country	Name of Mandate / Policy	BIM data required	Projects requiring BIM
USA	National 3D-4D-BIM Program	Architecture and design	All national public projects (from 2007 onwards)
South Korea	BIM Guide Version 1.2	Architecture and property data	All public buildings costing over $27.6M (from 2010 onwards)
Singapore	BIM Road map and e-submission requirements	Architecture and engineering data	All new buildings over 20,000 sq. m. (from 2012 onwards)
Denmark	Executive Order No. 118	Project lifecycle (architecture through O&M)	5M kroner and higher for national projects 20M kroner and higher for regional and municipal projects (from 2007 onwards)
Norway	Statsbygg BIM Manual 1.2.1	Architecture and handover data	All national public projects (from 2005 onwards)
Finland	Common BIM Requirement 2012	Project lifecycle (architecture through O&M)	All national public projects (from 2007 onwards)
United Kingdom	Government Construction Strategy	Project lifecycle (architecture through O&M, defined in the U.K. as Level 2)	All national public projects (from 2011 onwards)

APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Builder

   Others Please specify: -

2. What is the main type of Construction your company is involved with?

   New Build

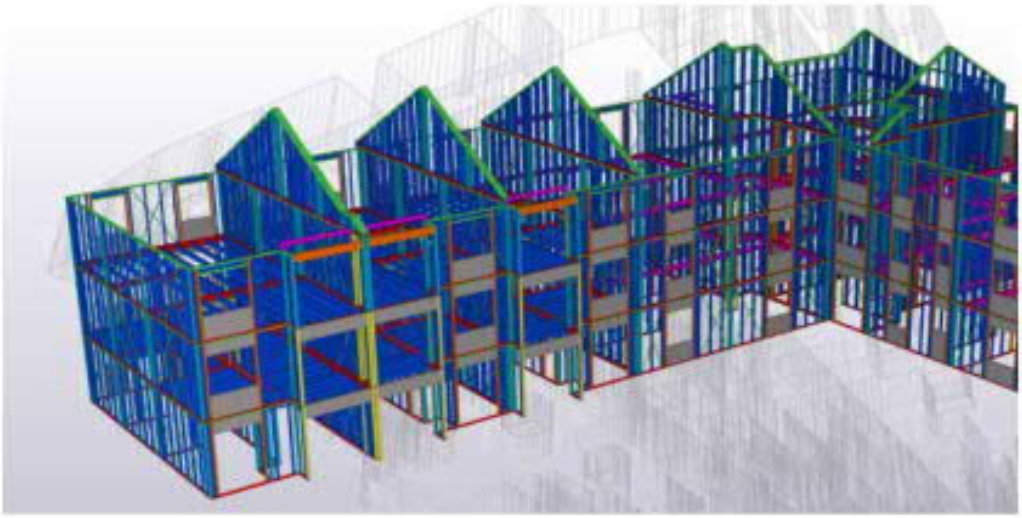
3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

   ☐ Full Integration 100% i.e detail and cordination ☐ 70% of detail

   ☐ Less than 50% ☑ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☑ Yes ☐ No



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5. BIM has been touted as providing many advantages and some are listed below. Please indicate how useful these advantages would be for your business.

Advantage	Very Useful	Useful	Little Useful	None at all
1. 3D visualisation of the build provides a marketing tool before start of build.	☒	☐	☐	☐
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3. Can increase the speed of the build	☒	☐	☐	☐
4. Less costly build	☒	☐	☐	☐
5. All information in one place	☒	☐	☐	☐
6. Provides collaboration	☒	☐	☐	☐

6. If you implement BIM in your organisation to what extent would it be of value? (Not taking cost of implementation into account)

☑ Most Jobs 90% or more ☐ Some Jobs 50-90%

☐ Few Jobs less than 50% ☐ Not valuable

7. The most common reasons for not introducing BIM in an organisation are listed below: - Considering your typical project rank from 1-5 what is stopping BIM being adopted for every project where 1 is the greatest reason and 5 being the lowest reasons)

1 No client demands

3 Cost to implement BIM

4 Projects are too small

2 Lack of BIM experience and lack of resources (time or people) to be trained

5 BIM is not relevant to work

8. The four benefits of 3D visualisation tools in BIM are listed below. Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

3 3D Visualisation of the entire project

2 Streamlined communication and sharing of design expectations

4 Collaboration between Teams

1 Complete transparency from beginning reducing rework

9. Do you believe BIM would be advantageous for the design teams? Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

3 3D Visualisation of the entire project

2 Streamlined communication and sharing of design expectations

4 Collaboration between Teams

1 Complete transparency from beginning reducing rework

(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

- The initial learning curve for staff
- It may be difficult to convince older builders that it is beneficial to put more resources into the documentation stage rather than just dealing with issues on site later.

Thank you for your time!

It is hoped that research like this will enable researchers and industry to create tools and resources to make construction more efficient.

APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Choose an item. Construction Manager

   Others Please specify: -

2. What is the main type of Construction your company is involved with?

   Choose an item. Residential

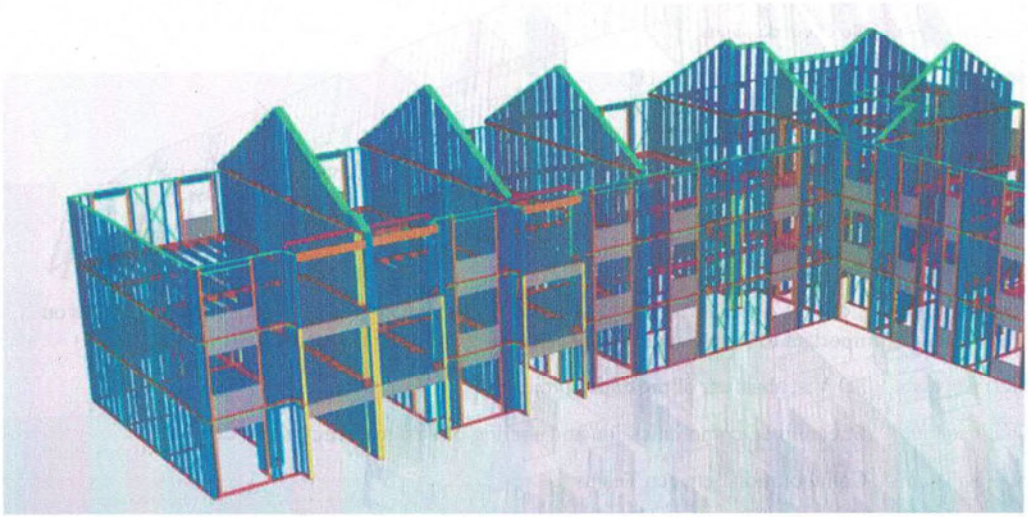
3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

   ☐ Full Integration 100% i.e detail and cordination ☒ 70% of detail

   ☐ Less than 50% ☐ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☒ Yes ☐ No



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5. All information in one place	☒	☐	☐	☐
6. Provides collaboration	☐	☒	☐	☐

6. If you implement BIM in your organisation to what extent would it be of value? (Not taking cost of implementation into account)

☒ Most Jobs 90% or more ☐ Some Jobs 50-90%

☐ Few Jobs less than 50% ☐ Not valuable

7. The most common reasons for not introducing BIM in an organisation are listed below: - Considering your typical project rank from 1-5 what is stopping BIM being adopted for every project where 1 is the greatest reason and 5 being the lowest reasons)

Choose an item. No client demands 3

Choose an item. Cost to implement BIM 5

Choose an item. Projects are too small 1

Choose an item. Lack of BIM experience and lack of resources (time or people) to be trained 4

Choose an item. BIM is not relevant to work 2

8. The four benefits of 3D visualisation tools in BIM are listed below. Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

Choose an item. 3D Visualisation of the entire project 2

Choose an item. Streamlined communication and sharing of design expectations 3

Choose an item. Collaboration between Teams 4

Choose an item. Complete transparency from beginning reducing rework 1

9. Do you believe BIM would be advantageous for the design teams? Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

Choose an item. 3D Visualisation of the entire project (1)

Choose an item. Streamlined communication and sharing of design expectations (3)

Choose an item. Collaboration between Teams (4)

Choose an item. Complete transparency from beginning reducing rework (2)

(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

User friendliness.
Computers keeping up.

Thank you for your time!

It is hoped that research like this will enable researchers and industry to create tools and resources to make construction more efficient.

APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Builder

   Others Please specify: -

2. What is the main type of Construction your company is involved with?

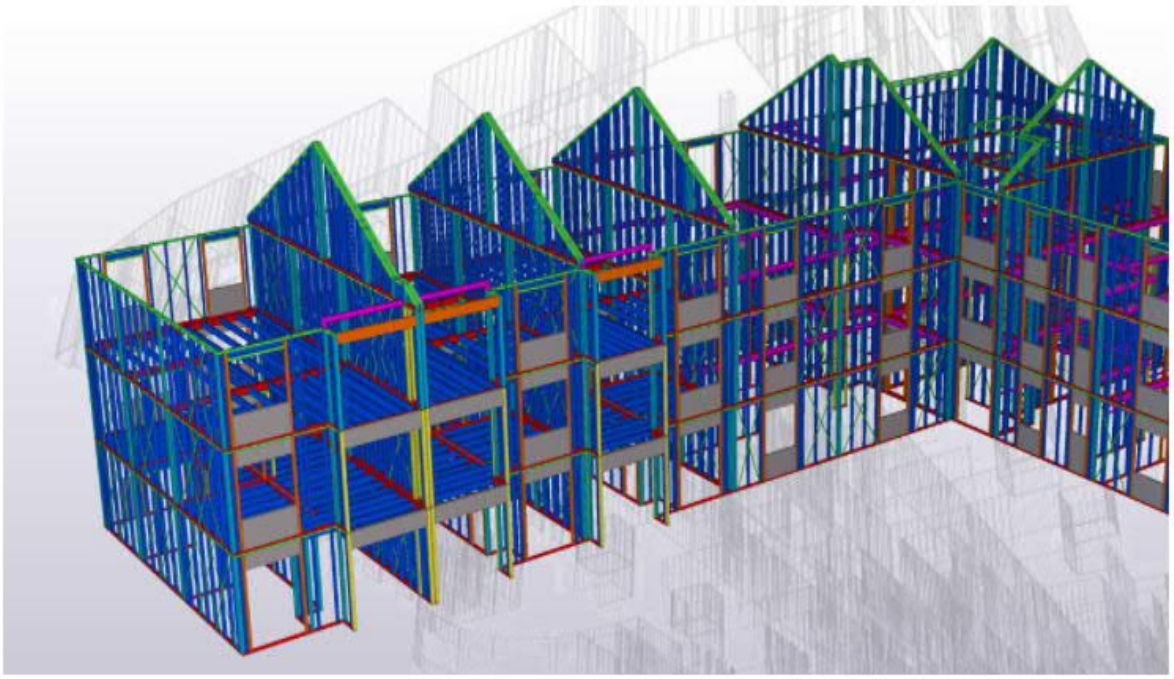
   New Build

3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

   ☐ Full Integration 100% i.e detail and cordination
   ☐ 70% of detail
   ☐ Less than 50%
   ☑ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☑ Yes ☐ No



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4. Less costly build	☐	☐	☒	☐
5. All information in one place	☒	☐	☐	☐

[Matthew Wallis/ [redacted]

6. Provides collaboration	☒	☐	☐	☐

6. If you implement BIM in your organisation to what extent would it be of value? (Not taking cost of implementation into account)

☑ Most Jobs 90% or more ☐ Some Jobs 50-90%

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5 No client demands

2 Cost to implement BIM

5 Projects are too small

3 Lack of BIM experience and lack of resources (time or people) to be trained

5 BIM is not relevant to work

8. The four benefits of 3D visualisation tools in BIM are listed below. Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

1 3D Visualisation of the entire project

3 Streamlined communication and sharing of design expectations

3 Collaboration between Teams

2 Complete transparency from beginning reducing rework

9. Do you believe BIM would be advantageous for the design teams? Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

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2 Streamlined communication and sharing of design expectations

3 Collaboration between Teams

1 Complete transparency from beginning reducing rework

(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

A universal standard use of components to be used for design so that external software's can read the components for estimating and take-off.

Thank you for your time!

It is hoped that research like this will enable researchers and industry to create tools and resources to make construction more efficient.

APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Choose an item.

   Others Please specify: - Director

2. What is the main type of Construction your company is involved with?

   Choose an item.

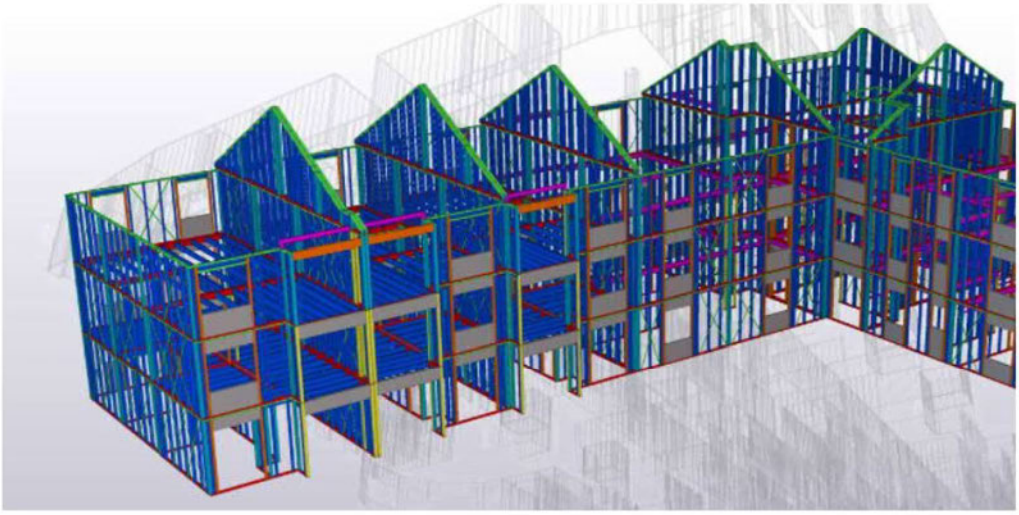
3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

   ☐ Full Integration 100% i.e detail and cordination ☐ 70% of detail

   ☐ Less than 50% √ ☐ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☐ Yes √ ☐ No



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6. If you implement BIM in your organisation to what extent would it be of value? (Not taking cost of implementation into account)

☐ Most Jobs 90% or more √☐ Some Jobs 50-90%

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Choose an item. No client demands

Choose an item. Cost to implement BIM

Projects are too small

Choose an item. Lack of BIM experience and lack of resources (time or people) to be trained

Choose an item. BIM is not relevant to work

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1 Collaboration between Teams

2 Complete transparency from beginning reducing rework

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4 Complete transparency from beginning reducing rework

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10. What concerns do you have with using BIM in the future?

Thank you for your time!

It is hoped that research like this will enable researchers and industry to create tools and resources to make construction more efficient.

APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Choose an item.

   Others Please specify: - Production Co-ordinator

2. What is the main type of Construction your company is involved with?

   New Build

3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

   ☐ Full Integration 100% i.e detail and cordination

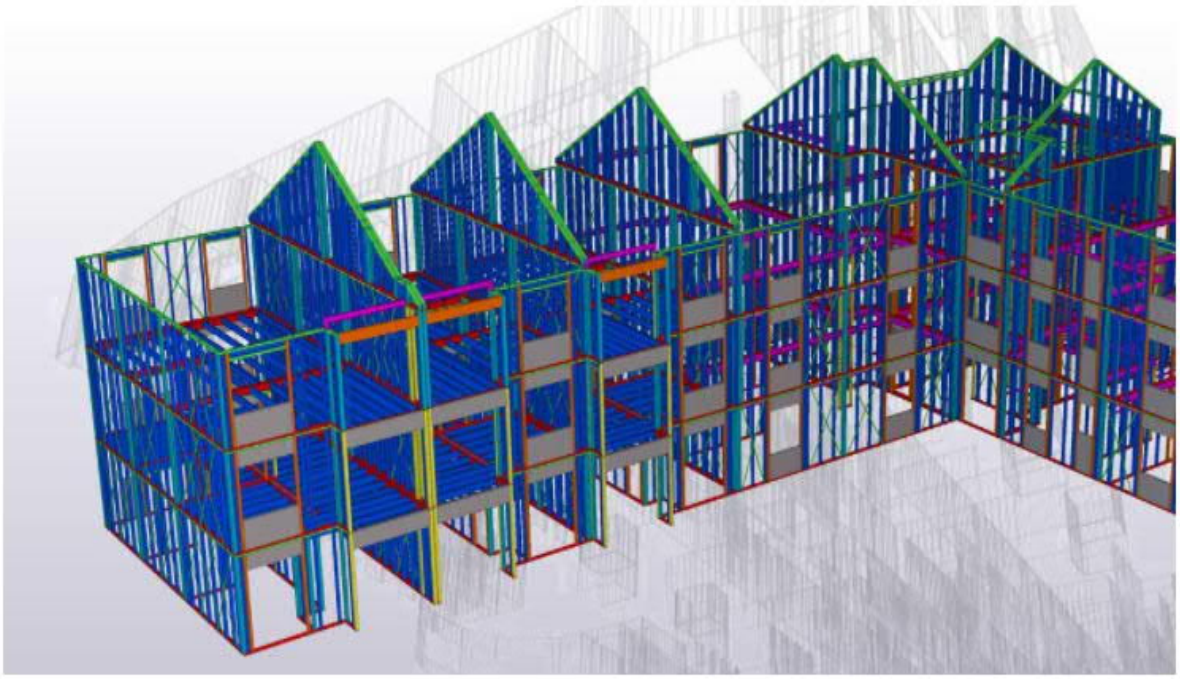
   ☐ 70% of detail

   ☐ Less than 50%

   ☑ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☑ Yes ☐ No



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(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

No concerns

Thank you for your time!

It is hoped that research like this will enable researchers and industry to create tools and resources to make construction more efficient.

APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Choose an item.

   Others Please specify: - Permit Administrator

2. What is the main type of Construction your company is involved with?

   New Build

3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

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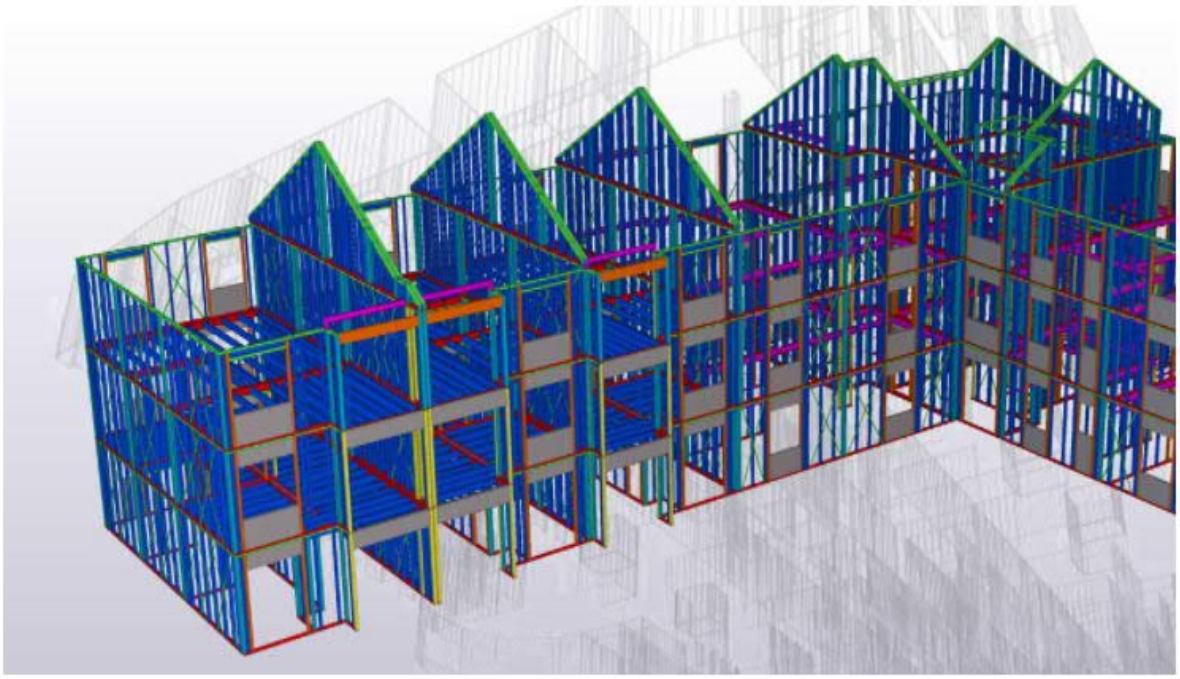
   ☐ Less than 50% ☑ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☑ Yes ☐ No



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Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Estimator / Detailer

   Others Please specify: - ☐

2. What is the main type of Construction your company is involved with?

   New Build

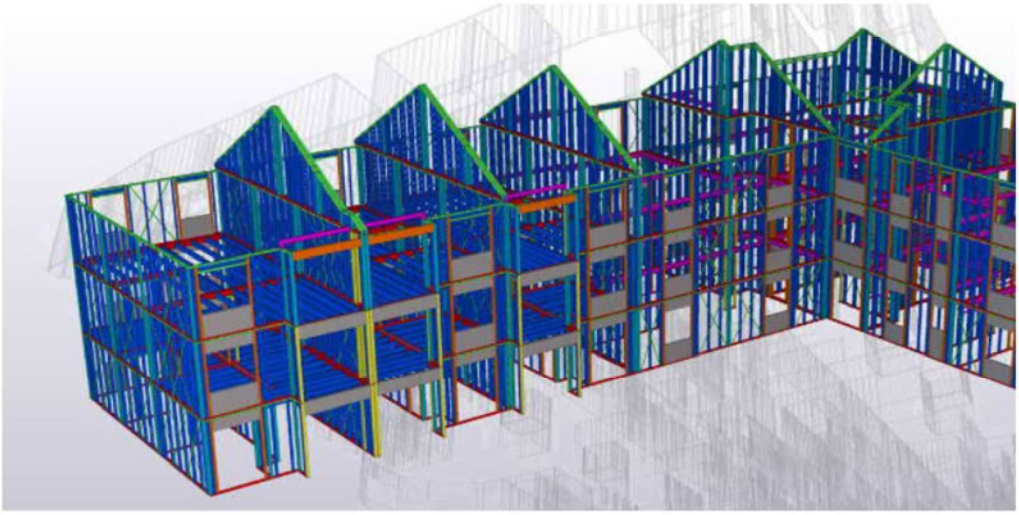
3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

   ☐ Full Integration 100% i.e detail and cordination ☐ 70% of detail

   ☑ Less than 50% ☐ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☑ Yes ☐ No



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(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

Nothing, perhaps price, but otherwise it makes sense that as technology gets better the benefits will broaden.

Thank you for your time!

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APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Architect / Draftsman

   Others Please specify: - ☐

2. What is the main type of Construction your company is involved with?

   New Build

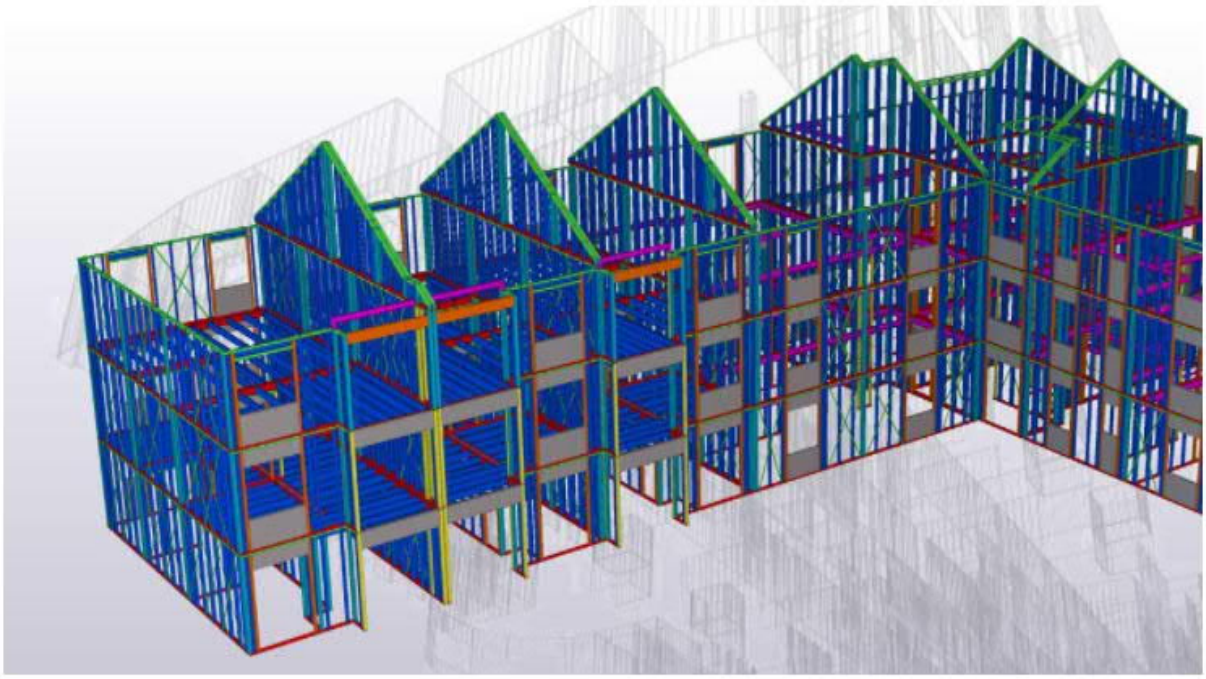
3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

   ☑ Full Integration 100% i.e detail and cordination ☐ 70% of detail

   ☐ Less than 50% ☐ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☑ Yes ☐ No



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2 Cost to implement BIM

4 Projects are too small

3 Lack of BIM experience and lack of resources (time or people) to be trained

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8. The four benefits of 3D visualisation tools in BIM are listed below. Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

1 3D Visualisation of the entire project

2 Streamlined communication and sharing of design expectations

4 Collaboration between Teams

3 Complete transparency from beginning reducing rework

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(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

The best BIM programs typically require significant setup and behind the scenes setup from templated construction items and other items used as per the BIM user / companies needs. These can be something that is overlooked (time and money spent on this setup), and thus this could be something that limits the usage within some companies due to this cost (time and money).

Thank you for your time!

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APPENDIX A – Survey Questions

Matthew Wallis Student Research

Project Survey Questions

University of Southern Queensland

Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

Survey Questions:

1. What is your position in the company?

   Choose an item.

   Others Please specify: - Senior Contracts Administrator

2. What is the main type of Construction your company is involved with?

   Choose an item. Commercial Construction - Schools, Age care, Wharehouses, Defence, Police & Ambulance stations

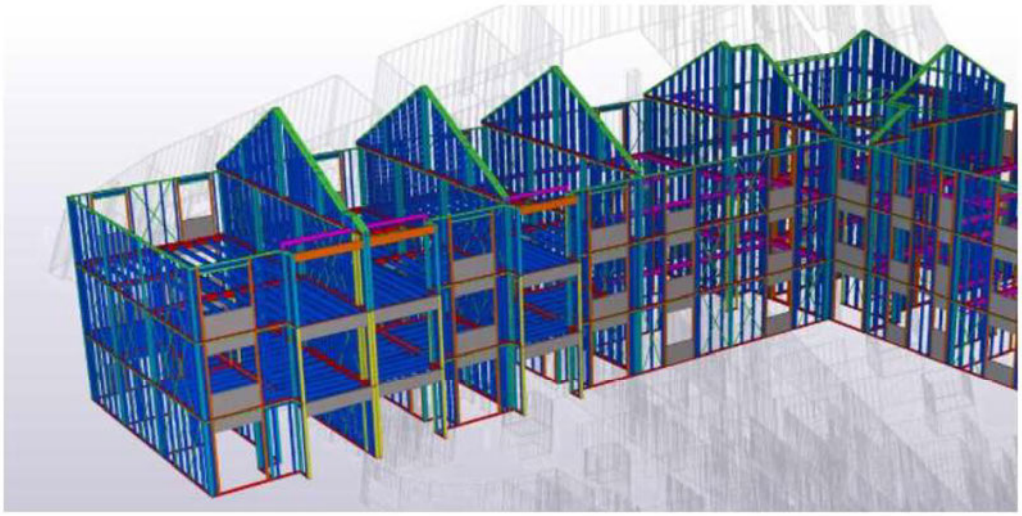
3. Have you ever used Building Information Modelling on any project? If so, how complete was the model? Yes

   ☐ Full Integration 100% i.e detail and cordination ☒ 70% of detail

   ☐ Less than 50% ☐ Not used

4. Do you think the 3D modelling of a project using BIM tools will provide substantial benefits before construction?

   ☒ Yes ☐ No



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5. BIM has been touted as providing many advantages and some are listed below. Please indicate how useful these advantages would be for your business.

Advantage	Very Useful	Useful	Little Useful	None at all
1. 3D visualisation of the build provides a marketing tool before start of build.	☐	☒	☐	☐
2. Errors can be seen instantly though visualisation tool	☒	☐	☐	☐
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6. Provides collaboration	☒	☐	☐	☐

6. If you implement BIM in your organisation to what extent would it be of value? (Not taking cost of implementation into account)

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Choose an item. No client demands -3

Choose an item. Cost to implement BIM -2

Choose an item. Projects are too small -4

Choose an item. Lack of BIM experience and lack of resources (time or people) to be trained -1

Choose an item. BIM is not relevant to work -5

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Choose an item. 3D Visualisation of the entire project -3

Choose an item. Streamlined communication and sharing of design expectations -2

Choose an item. Collaboration between Teams -1

Choose an item. Complete transparency from beginning reducing rework -4

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(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

Can delay design team from completing their aspect of work if BIM design is not complete/ available.
D&C projects rely on design being developed during construction.
Full BIM modelling with all design components incorporated is time consuming and would delay some specialist design aspects like structure, hydraulics, electrical, mechanical.

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2. What is the main type of Construction your company is involved with?

   New Build

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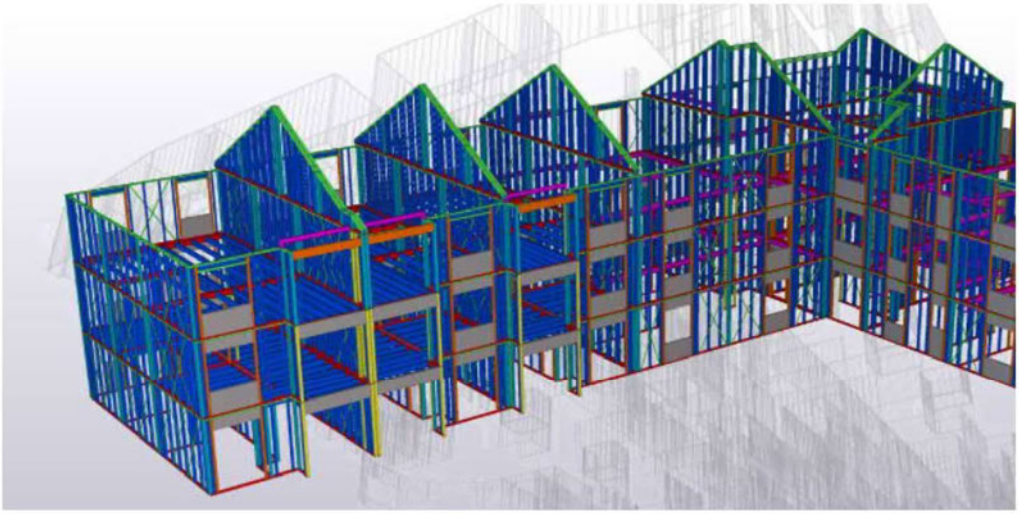

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10. What concerns do you have with using BIM in the future?

Integration between multiple software packages and over reliance on one product.

Process changes and upskilling of staff

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Efficiencies that BIM 3D Visualisation can deliver to new homes in the residential construction.

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   Estimator / Detailer

   Others Please specify: - ☐

2. What is the main type of Construction your company is involved with?

   New Build

3. Have you ever used Building Information Modelling on any project? If so, how complete was the model?

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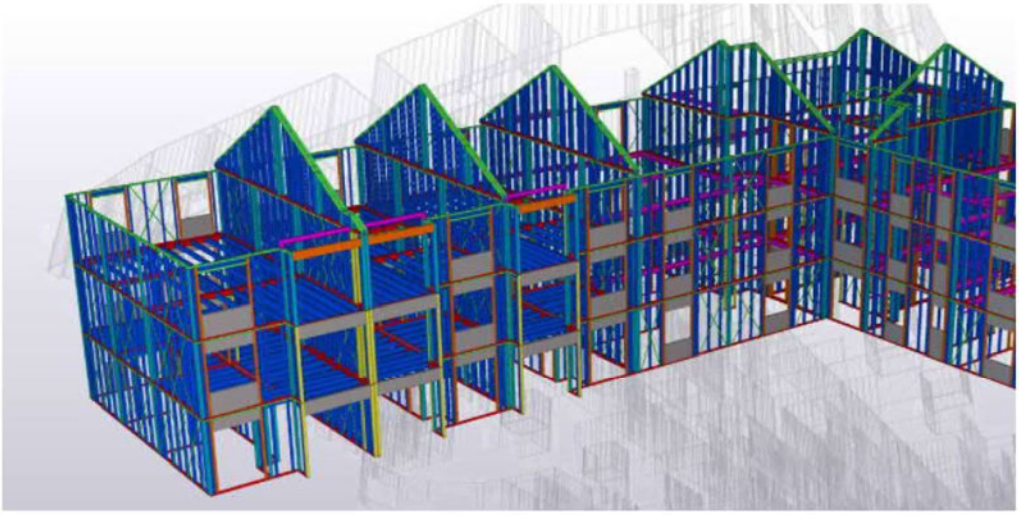
   ☑ Yes ☐ No



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Project Survey Questions

University of Southern Queensland

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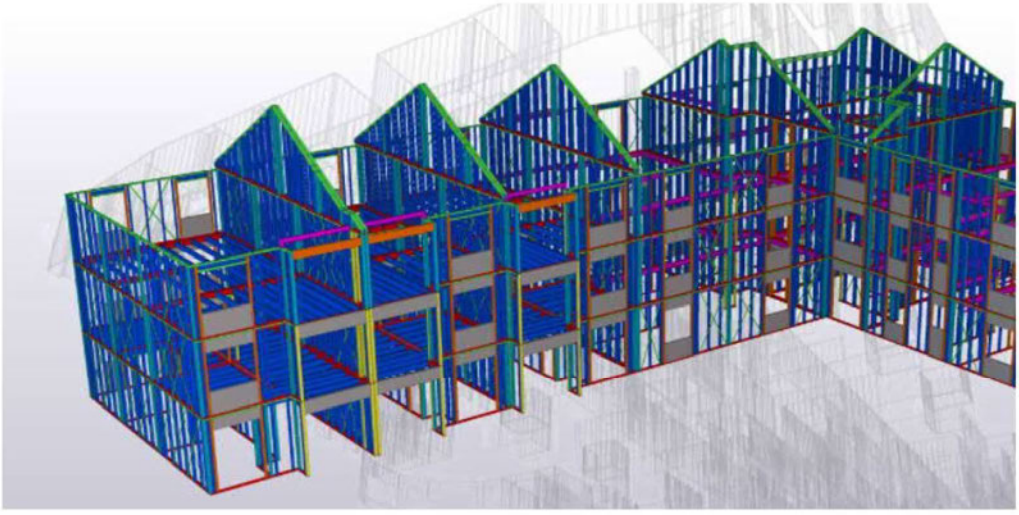

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University of Southern Queensland

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   Others Please specify: - ☐

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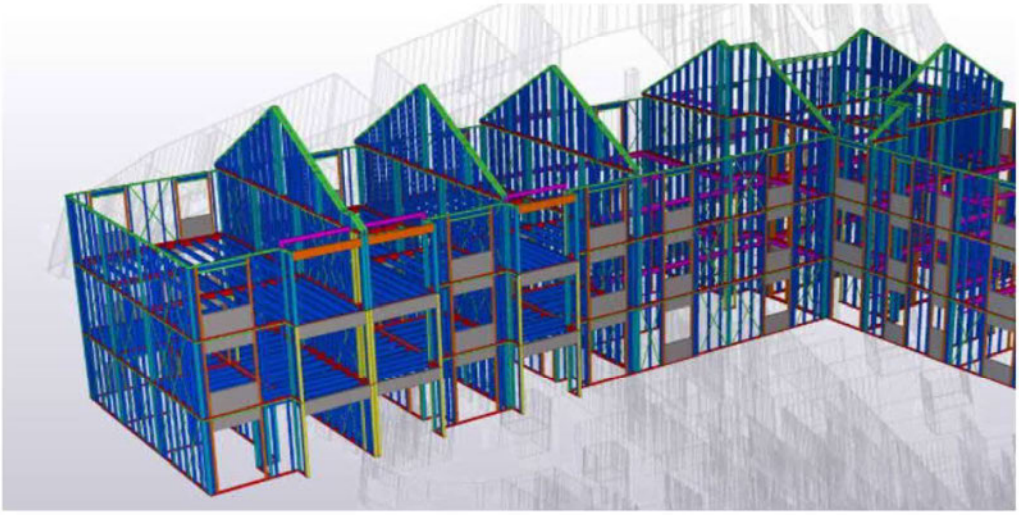

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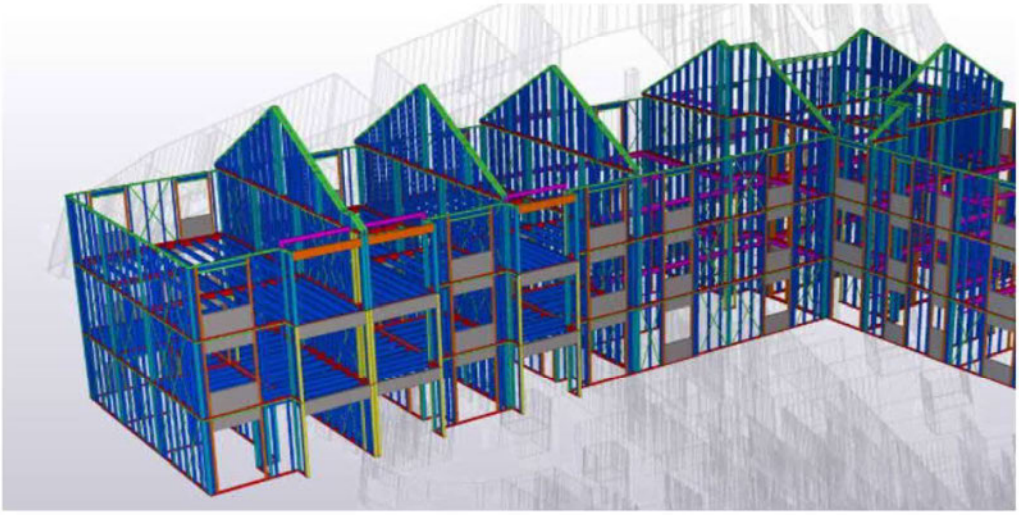

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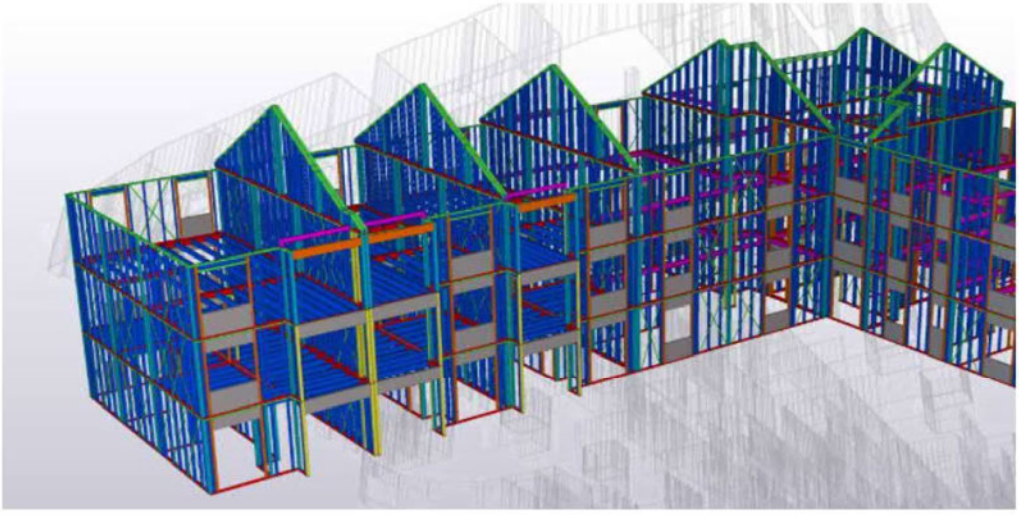

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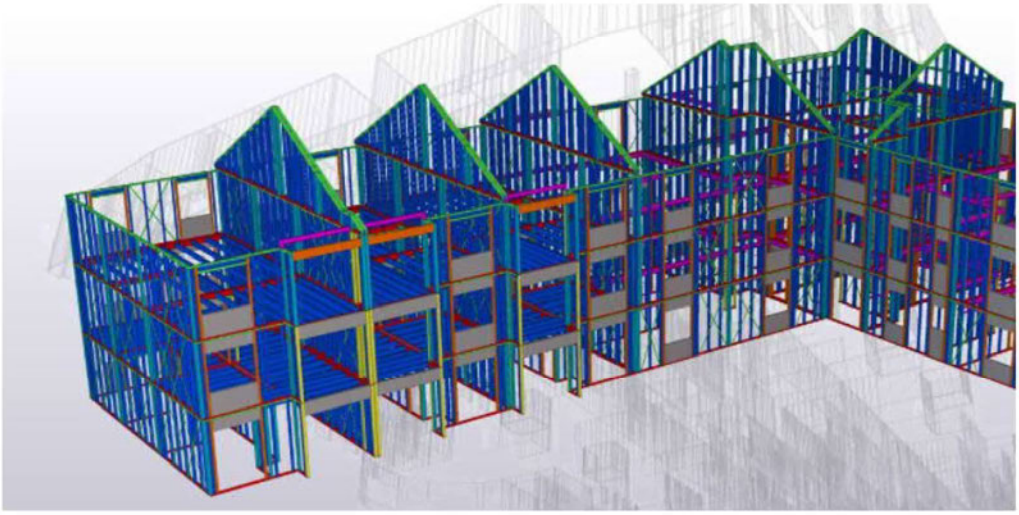

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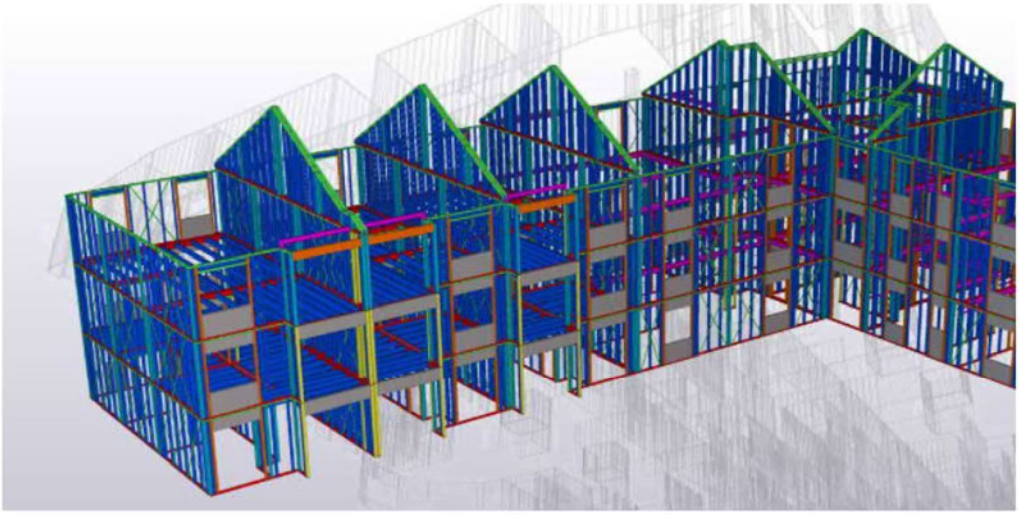

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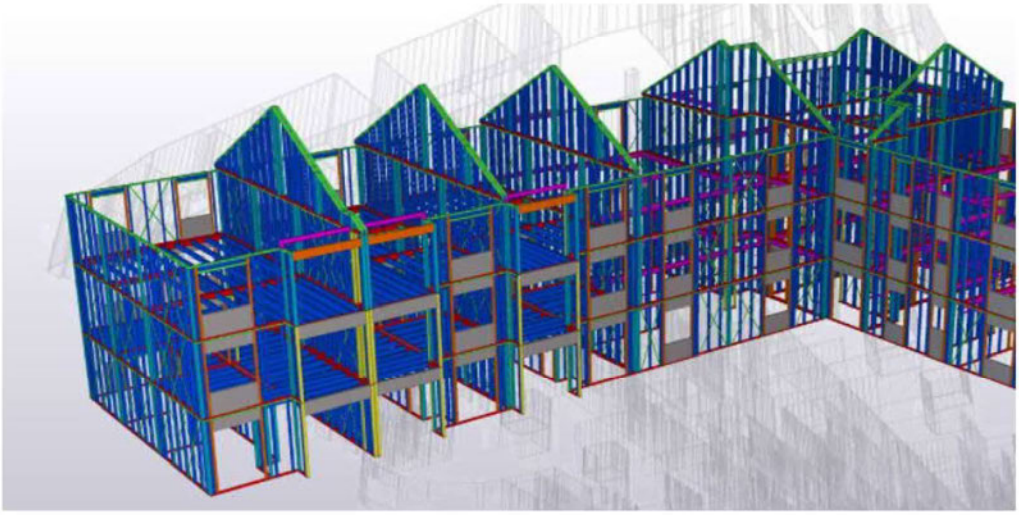

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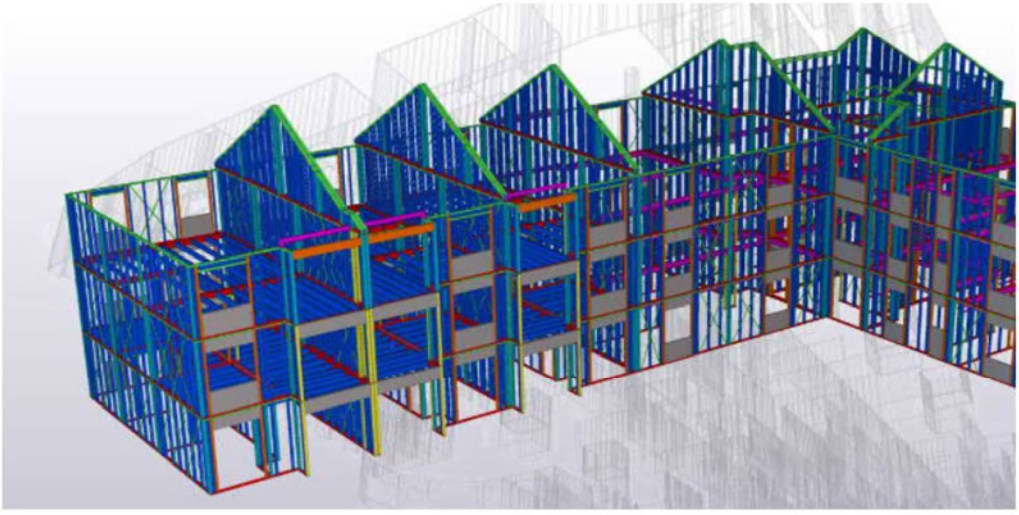

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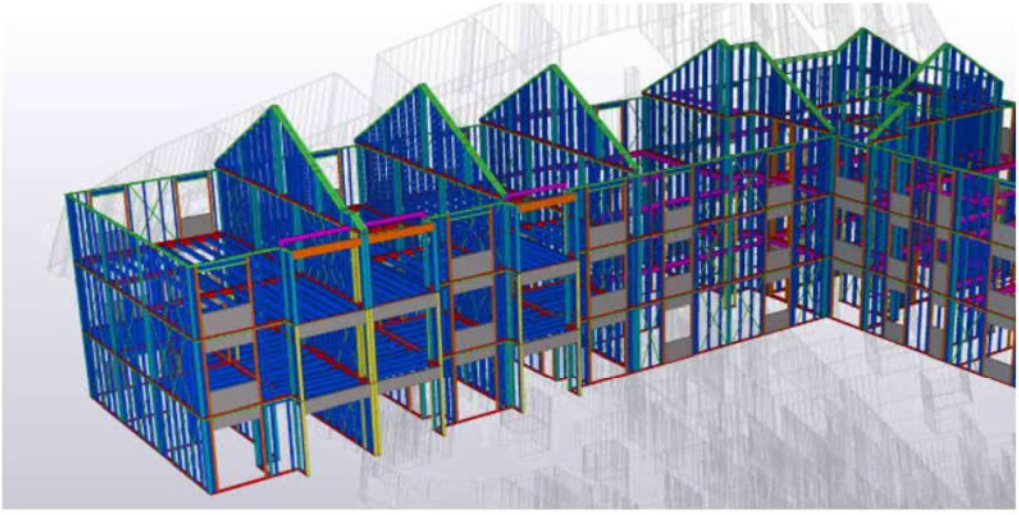

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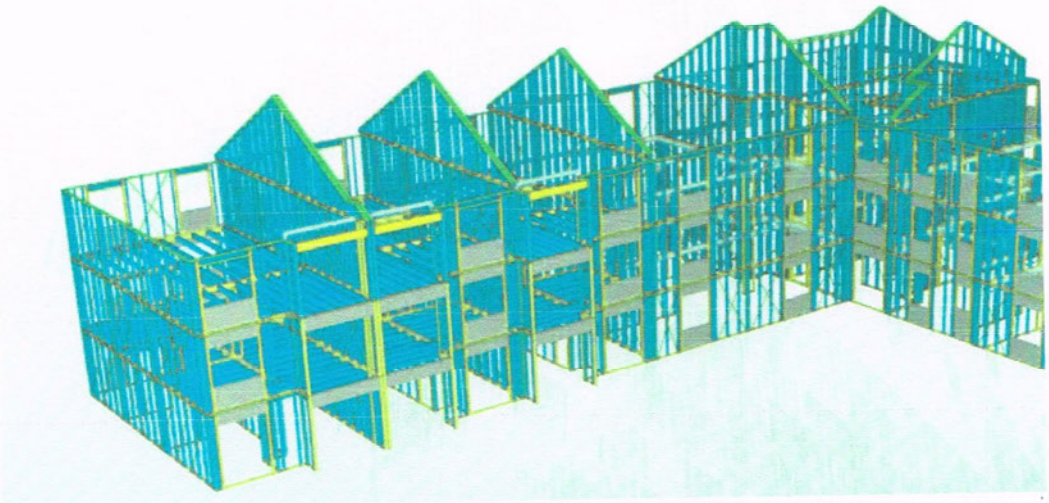

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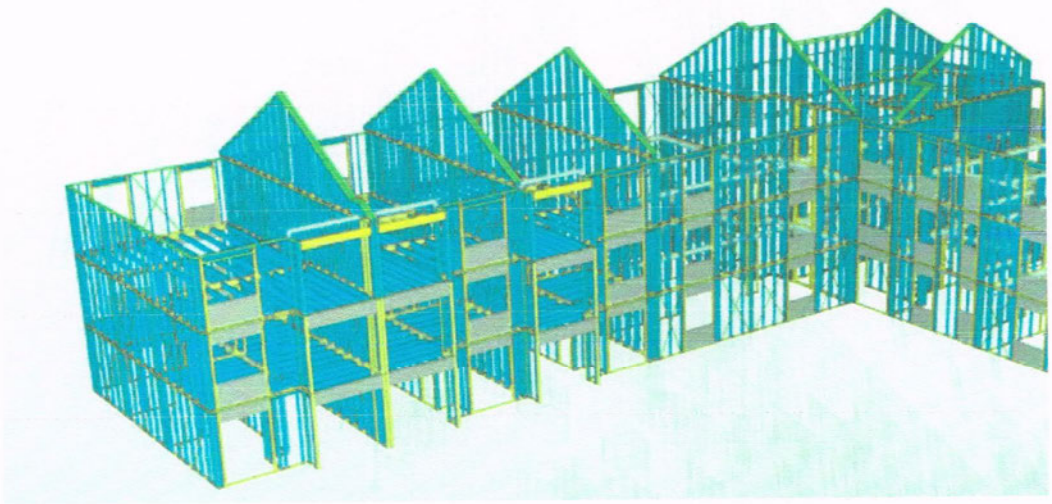

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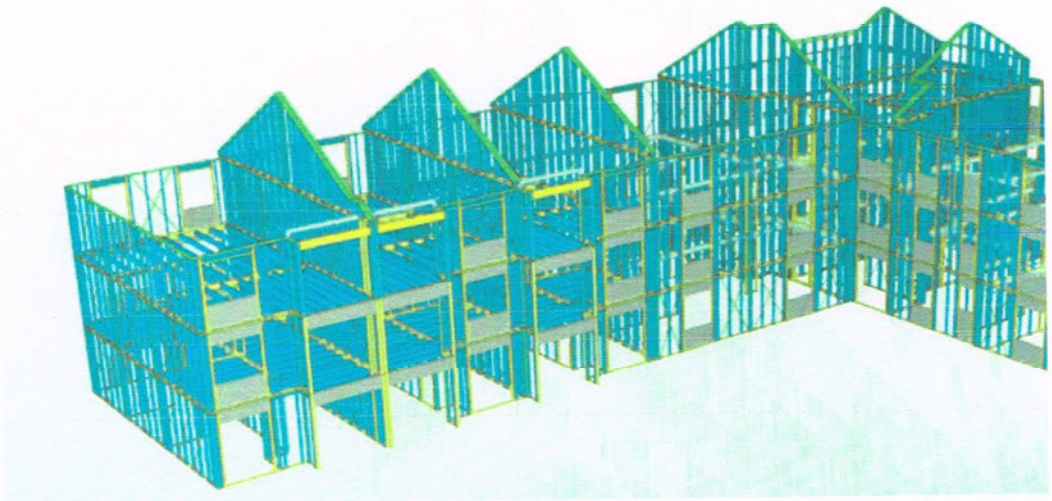

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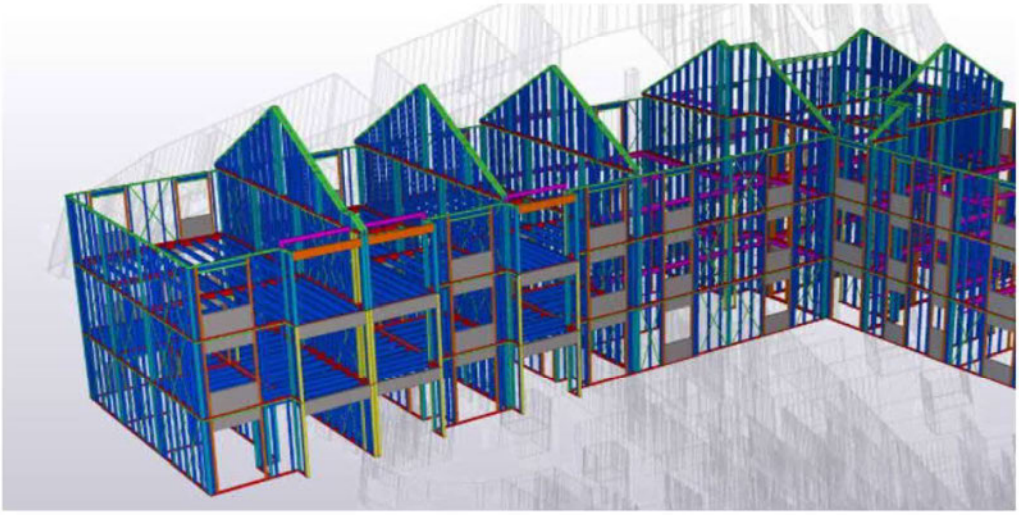
   ☑ Yes ☐ No



Definition of Building Information Modelling: - (BIM) is the holistic process of creating and managing information for a built asset. Based on an intelligent model and enabled by a cloud platform, BIM integrates structured, multi-disciplinary data to produce a digital representation of an asset across its lifecycle, from planning and design to construction and operations.

5. BIM has been touted as providing many advantages and some are listed below. Please indicate how useful these advantages would be for your business.

Advantage	Very Useful	Useful	Little Useful	None at all
1. 3D visualisation of the build provides a marketing tool before start of build.	☒	☐	☐	☐
2. Errors can be seen instantly though visualisation tool	☒	☐	☐	☐
3. Can increase the speed of the build	☐	☒	☐	☐
4. Less costly build	☐	☒	☐	☐
5. All information in one place	☐	☒	☐	☐
6. Provides collaboration	☒	☐	☐	☐

6. If you implement BIM in your organisation to what extent would it be of value? (Not taking cost of implementation into account)

☐ Most Jobs 90% or more ☑ Some Jobs 50-90%

☐ Few Jobs less than 50% ☐ Not valuable

7. The most common reasons for not introducing BIM in an organisation are listed below: - Considering your typical project rank from 1-5 what is stopping BIM being adopted for every project where 1 is the greatest reason and 5 being the lowest reasons)

2 No client demands

3 Cost to implement BIM

4 Projects are too small

1 Lack of BIM experience and lack of resources (time or people) to be trained

5 BIM is not relevant to work

8. The four benefits of 3D visualisation tools in BIM are listed below. Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

1 3D Visualisation of the entire project

3 Streamlined communication and sharing of design expectations

4 Collaboration between Teams

2 Complete transparency from beginning reducing rework

9. Do you believe BIM would be advantageous for the design teams? Please rank in order of what you think the most important to least important benefits (1- most important and 4 least important)

1 3D Visualisation of the entire project

3 Streamlined communication and sharing of design expectations

4 Collaboration between Teams

2 Complete transparency from beginning reducing rework

(Please rank in order of most important to least important (1-most important and 4 least important)).

10. What concerns do you have with using BIM in the future?

Thank you for your time!

It is hoped that research like this will enable researchers and industry to create tools and resources to make construction more efficient.

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