University of Southern Queensland Faculty of Health, Engineering & Science

Evaluating the impact of new technology on construction project performance, methodologies and productivity

An insight into the forthcoming era of change projected for the construction industry

An analytical proposal submitted by

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Offering a methodological breakdown for:

Future Studies in emerging construction technology

In Completion of University Of Southern Queensland's

Bachelor Of Construction Management (Honours) 2018

Abstract

The increased development of technology in recent years has provided businesses incredibly efficient systems to approach projects. Though studies find that globally, the construction industry lags in the implementations of such technologies in comparisons to other major industries.

In order to present evidence of the viable implementation of emerging technology, a detailed literature review has been undertaken that has established the biggest influence to construction performance, methodology and productivity, are: time, cost and satisfaction; planning, scheduling and documentation processing; and safety, labour efficiently and communication, respectfully. These aspects of construction where crossed referenced with the projected technology set to have the greatest affect on the industry, within the closest timeframe to discover an industry conclusion of Building Information Modelling, Virtual Reality and/or Augmented Reality.

A survey of 22 industry professions consisting 2 females and 22 males, ranging from 21-60 has established that the sampled individuals agreed upon the benefits, though holistically, the industry has a suboptimal knowledge that is decelerating implementation

The report established the impediments causing the lack of integrations, within the Australian market, are primary due to lack of training, financial viability of training, and/or the opinion its not currently required. This data collected shows the general acceptance of change, varies quite significantly between the demographical divisions of positions and age, whereas factors such as construction sectors, and gender effect knowledge and implementation of the technologies at a minimal.

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Certification of Dissertation

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

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

J. Thimios

[redacted]

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A big thankyou you all participants of the surveys within this dissertation which range from work colleagues, industry professionals, peers, local businesses, and many more. Without your help, the statistics and analysis that follow would not have been possible.

Kindest Regards,

Jace Thimios

Bachelor of Construction (Honours) Major Construction Management (BCNH)

University Of Southern Queensland

Table of Contents

List of Figures

List of Tables

Glossary

ACI: Australian Construction Industry

AI: Artificial Intelligence

AR: Augmented Reality

BIM: Building Information Modelling

CCE: Construction Communication Errors

DLP: Defect Liability Period

KPI: Key Progress Indicators

PEOU: Perceived Ease Of Use

PM: Project Manager

PMI: Project Management Institution

PU: Perceived Usefulness

RII: Relative Index of Inequality

SP: Schedule Pressure

TAM: Technology Acceptance Model

VR: Virtual Reality

Chapter One - Introduction

The rapid evolution of technology is a topic of many possibilities. Opinions range dramatically from the dystopian viewpoint depicted in George Orwell's Nineteen Eight-Four, to the limitless idealistic viewpoints of prominent world futurists such as Michio Kaku. However, one thing that is for certain, is that the exponential growth is evident ubiquitously. Current models display evidence that we are doubling the rate of historic innovation each decade (Brynjolfsson, E. and McAfee, A., 2012). Momentarily consider the following facts: throughout the 20th century, progress rates gradually increased. As the century concluded, the rate of growth was such that the entire summation of century's achievements was equivalent to a mere twenty years of progress at the out-dated expansion rate of the year 2000. To validate the fact, consider it took us 14 years to sequence the genome of HIV; SARS took only 31 days (Kurzweil, R 2007). Now consider this with respect to information technology and construction programming.

Recent globalisation has resulted in growth of information technology being particularly rapid. Frequently referenced journals display conclusive evidence that society is doubling in power, measured by capacity, performance and bandwidth in 18-month intervals, commonly acknowledged as Moore's Law (Schaller, R.R., 1997). Mathematically, that factors 1000 years of growth into just 10 years; a million years growth into 20 years. The general population now hold in their pocket a phone with far greater technological capacity than the Apollo 11. The 11-year, universally journalised development of its era (1961-1972), that cost NASA what is estimated in today's value of 150 Billion dollars (The Telegraph, 2009), is now held in the hand of a four-year-old child at a dinner table. This historical reference can be used as a metaphor for modern day construction.

We are currently situated on a bell curve in the midst of historical transformation, a relentless pursuit of progress and success driven by the human ambition. Though, this deranged sense of capitalism is fundamentally unlike any era previously witnesses, as professionals are now relying almost exclusively on emerging information and communication technology to gain a competitive advantage within their selected industry and transpire within a globalised economy.

1.1 - Background

Past technologies have offered professionals a means to remedy business inefficiencies. Future technologies are aiming to improve the already efficient. Within the construction industry, as of 2018, a wide variety of tools and programs such a CAD Revit, Microsoft Outlook, Microsoft Project and Aconex are standard practice in construction management (Dansoh, A., Frimpong, S. and Oteng, D., 2017). The programs allow users to insert greater control over a project, through a large number of strategical, tactical and operational advantages, resulting in an increase in overall productivity, whilst lowering both direct and indirect costs (Love, P.E. and Irani, Z., 2004). However, if technology progresses in accordance with the projected exponential intensification, it is a viable assumption to conclude construction management tools and programs will continue to evolve in the footsteps of Moore's Law and therefore, must be addressed.

The evolution of construction management programs has recently been criticised, as the construction sector, compared to other sectors on an international level, have a well below average adoption rate for integration emerging information technology (Love, et al, 2004). With the Australian construction industry a significant economic driver, producing around 8% of the Gross Domestic Profit (Dansoh, Et Al, 2017), in order to advance on an individual, corporate, and nation level, the famous quote of Albert Einstein, *"The measure of intelligence is the ability to change"* has never been so relevant than the present. To do so, it is important to address the importance, and assess the impact of technologies on construction project performance, methodologies and productivity.

1.2 - Research Problems

Issues in undertaking and implementing the study of the potential effect of emerging technology within the construction sectors have been evaluated under two main constraints.

Table 1 - Research Problems

Research Problems - Evaluating the impact of new technology on construction project performance, methodologies and productivity	
<u>Technical Issues</u>	<u>Educational Issues</u>
• Requirement for programs • Requirement to legislate • Requirement to posses trained staff • Initial financial cost • Integration issues	• Are new processes known within the industry • What to actually teach • How to teach • How it will promote the industry • Why are people sceptical

1.3 - Research Aims and Objectives

The aim of this dissertation is to analyse the current research, trends and predictions that may affect construction management in terms of project performance, methodology and project progress, in a chronological sense of what's predicted to establish itself first in mainstream management. It is important to also consider future developments in order for the technologies to stay relevant once implemented. A large quantity referenced journals and articles will be condensed systematically to conclude what industry professionals could focus time and energy into understanding for personal and company success, before undertaking an industry survey. This survey is largely to discover the industry consensus within Australia to establish implementation impediments, determine how to progress, establish if industry knowledge aligns with the current literature.

In summation the major aims of this dissertation are:

- Understanding what the leading emerging technologies are are
- Predicting when are the emerging technologies expected to be mainstream
- Evaluating how will they enhance the industry
- Establishing if there is a technology knowledge gap in the industry
- Analysing the knowledge gap (if there is one) amongst demographics that indicate the industry requires greater training programs implemented.

1.3.1 - Research Questions

The research questions this dissertation is aimed to establish and resolve the following points throughout yearlong study:

1. What affects project performance
2. What affects project methodology
3. What effects project productivity
4. What are the new technologies expected to have the most impact within the next decade
5. How could these new technologies improve construction management
6. What are the implementation impediments

There are sure to be many more micro questions appear throughout the duration, and with research, the secondary aim is to give an overall summation into:

7. What is predicted to have the greatest impact
8. Why it is predicted to have the greatest impact
9. Are there any negatives with implementing such technologies
10. Does the industry require further training for technology implementation

It is assumed the study could act as a foundation for many future studies, as the topic is currently trending with almost limitless fields to further understand and develop.

1.4 - Scope of works

The work entailed within the research will be compartmentalised into specific sections with consideration into time, which include: planning phase, data collection phase, data analysis phase and reflection phase. The information will be collected using both refereed articles and industry opinions, through the use of a primary data set issued through an online survey.

To do so effectively, a literature review will be performed with the aim to convey the professional determination within the industry of the questions presented in section 1.3.1. As it currently stands, a great number of the research undertaken within the emerging technology in construction management sector has been collected by overseas sources. Studies undertaken to investigate the cultural differences across countries have strong evidence of behaviours variances shown to affect performance (Baranski, E.N., Gardiner, G., Guillaume, E., Aveyard, M., Bastian, B., Bronin, I., Ivanova, C., Cheng, J.T., Kock, F.S.D., Denissen, J.J. and Gallardo-Pujol, D., 2017). The strength of the article, by Baranski Et al, as well as other related cases, presents a strong case for the need in understanding the technical and educations benefits and impediments such technology can provide within Australia.

Once the investigations have been performed, and the foundations of data gathered, a survey will be created to establish the following data, within Australia:

Table 2 - Research Evaluation

Question	Benefit of answer
Does the Australian Industry knowledge align with the current global literature	Ability to establish if we should alter our approach to either implement, or not implement certain technology
Why the knowledge is as established	To evaluate if/how we should approach training, for educational purposes
If the Australian industry deviates with demographic	To understand the current industry and acknowledge if certain field require additional thought

In order to ensure the scope is completed to a standard that is deemed credible for reference, it is important to establish a methodological structure to display the findings.

1.4.1 – Limitations Of Study

The limitations of this study is that there is a level of subjectivity when undergoing literature reviews in terms of how different people may decipher the information. In order to limit this to an adequate degree, a minimum of three journal papers of related to the same topic are to be evaluated. There is also a limitation that the survey may provide swayed information due to lack of sample size if it is unable to be distributed with sufficient time. To mitigate this, the samples will be contacted at the earliest time possible throughout the creation of the dissertation.

The evaluation of the collected data throughout this report will be based both mathematically, though also subjectively using my own interpretation as to the possibilities of occurrence. For the purpose of clarity please consider this fact if relaying data evaluation in future research.

1.5 - Structure of the report

The report will encompass a systematic structure to methodologically breakdown information using previous literature, industrial surveys and data evaluation. Presented below, is the basic structure of the report, for readers to understand the process and aims involved.

Table 3 - Report Structure

Order	Description	Aim Of Specific Section
1	Literature Review	• Answer research questions as per 1.3.1
2	Methodology	• Re Evaluate Goal • Evaluate the best method of data collection • Evaluate the restrictions of data collection • Evaluate the best method to display data collected
3	Data Analysis	• Present the Australian findings for research questions as per section 1.3.1
4	Conclusive Summary	• Statistically and subjectively evaluate and express findings demographical and implementation related findings with consideration and reasoning to: technical specifications, education specifications, current predictions and potential for future studies.

Chapter Two - Literature Review

In order to collate valid evidence of the emerging technology with credible justification, a literature review with the aim of establishing what, from a technological program perspective, will affect performance, methodologies and productivity. This is being undertaken to better define a theoretical framework of influence with a methodological focus to investigate current knowledge gaps.

2.1 – Factors Affecting on Project Performance – Time, Cost, Satisfaction

A Construction performance criterion is generally created to reflect the satisfactory expectation and vested interests of the stakeholders. A traditional system has seen achievement via adherence to the projected specifications such as timelines, quality and cost, current trends seen consideration into communication chains and monitoring to provide future improvements as necessary to successfully achieving a high-level performance evaluation (Barclay, C, Osei-Bryson, KM, 2010). As seen in figure 1, project lifecycle has a direct relationship on project costs and project scope, this in known are the triple constraint of construction management. This gives evidence to assume the project stakeholder would be hoping to have the project completed before the project completion date in order to increase profits. Though upon completing the project, works must still be completed to an adequate standard fit for purpose and as per specifications.

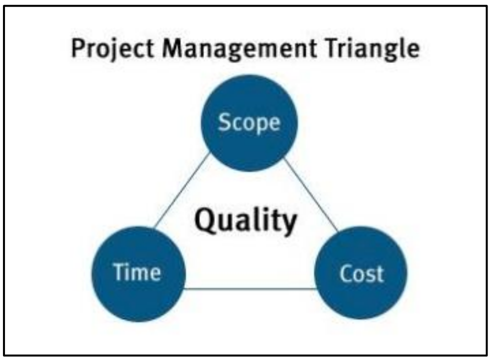

Figure 1 - Project Management Triangle

(Siteready, 2018)

Collecting qualitative data via industry questionnaires concludes factors of project performance that result in dissatisfaction of stakeholders as being: conflict, financial hostility, below average knowledge between professionals involved, ineffective project conceptualisation resulting in varying expectations and aggressive tendering (Jha, KN, Iyer, KC, 2006).

This is to say that in order to achieve a high level of project performance, management must provide the following services to their stakeholders:

- Cost performance – Completing a project as per originally anticipated budget. Sub factors in ensuring this aspect vary with project managers competencies, support team, and leadership skills (Nepal, M, Park, M Son, B, 2006).

- Time performance - In order to best manage this, the project management team must have an effective level of monitoring, feedback and coordination of labour (Jha, K.N. and Iyer, K.C., 2006)

- Quality performance – Surveys shows a relationship between skilled employees, management and collaboration aid in ensuring quality of works (Hoonakker, P., Carayon, P, Loushine, T. 2010)

2.2 – Factors Affecting on Project Methodology – Costing, Planning, Documentation Control

The methodology used throughout construction projects lifecycles are constantly evolving with the introduction of emerging technology. The methodology itself in regards to emerging technology refers to the systematic approach when undertaking works chronologically, which include: contractual and legal processes, approaches with regards to contracts and risks, planning, in addition the methods of temporary and permanent works with high consideration given towards safety (NZQA, 2018). Studies into the effective planning of projects find evidence of financial reductions of 0.72 % over overall contract price (Faniran, O.O., Proverbs, D.G. and Holt, G.D., 2001). Although this figure may at first seem insignificant, the Australian Bureau Of Statistics released an economic performance review concluding the average operational profit margin on Australian construction companies is 10.1% (Australian Bureau Of Statistics 2013). Thus, making such benefits a 7.13% increase in overall profits due to effective costing of jobs. In order to manage the methodology of construction project effectively to achieve financial gains, many studies have been undertaken.
Findings show that considerations into the following aspects are greatly important in the management of construction methods:

- Estimating – The literature of costing construction jobs is associated with methodology considerations primarily due to the consequential impact of either underquoting, or misinterpretations. This is considered a major aspect that affects the scope throughout the lifecycle (Brook, M., 2016).

- Scheduling – Successfully fast tracking a construction schedule shows evidence of increasing both profit and performance. Though the inverse effect is all but guaranteed if it's preformed incorrectly, resulting in schedule pressure. The SP can be related to defects, clashed, poor quality and increased documentation. (Nepal, M.P., Park, M. and Son, B., 2006).

- Documentation control - The administration of contracts are essentially for the longest length of all construction projects. From preliminary aspects to DLP completion. They are deemed as essential due to the large overhead costs of commissioning, in addition to legislative purposes to minimize risks.

2.3 – Factors Affecting on Productivity - Safety, labour efficiency, miscommunications

Productivity on a construction project is of the upmost importance in order to ensure performance targets are being reach to the relevant standards and satisfaction of all stakeholders. A holistic evaluation of productivity sees the topic focus on input versus output in a sense of work per person rather than work completed, which is referred to as production (Wikforss, Ö. and Löfgren, A., 2007). The consequences of inefficient productivity is evidently related to time loss, profit loss, and issues of quality, safety and environmental management (Loosemore, M., 2014). Relating to this, there is conclusive evidence that a high level of workplace productivity is prevents potential for scope creep and budget overrun, and in related to lean management principles (Forbes, H, Ahmed, M, 2010. Effective production and productivity management tends to related to construction as a machine. This movement, made prominent by Henry Fords lean production methods is being used with notable success in removing unrequired waste related to both material and labour components (Loosemore, M, 2014), and is largely looked due to the positive impacts it can have on environment factors.

The findings of this literature review have demined key factors that affect productivity, that can be related to construction and technology are as follows:

- Safety - Safety is commonly referred to throughout the existing literature and one of the key elements he dictates how construction projects development. Studies show it is the second highest ranked aspect as it related to both building process and sociopsychological factors that increase workplace satisfaction (Aynur Kazaz , Ekrem Manisali & Serdar Ulubeyli (2008), and thus, productivity.

- Labour Efficiency – It's conceptualised that factors effecting labour efficiency compounding from the pre-construction stages of the projects lifecycle. The onsite methodology is linked to an increase in efficiency due to automation and technology such as robotics and machinery (Bock, T., 2015) Furthermore, waste factors associated with efficiency decline show evidence of deriving for miscommunication.

- Miscommunications/Ambiguity – Major issues that cause potential project delay and rework costs are miscommunication and ambiguities. These aspects rank in the top 4 reason for productivity loss in the Journal of Information Technology in Construction and are essential in ensuring schedules are on time, deadline and met to the specified scope, and visions are projected in a way to promote development (Wikforss, Ö. and Löfgren, A, 2007). Studies have identified that incomplete drawings are a key contributor top productivity decline do to clarification drawings and specifications required. Furthermore this is affected as clients are increasingly providing limited time for the design process. As a result, drawings are often incomplete (Makulsawatudom, A, Emsley, M, Akintoye, A, 2001). Evidence shows in order to mitigate the effect on productivity loss; documentation and procedure manuals must be implemented. (Makulsawatudom, A, et al.). Therefore it can be said, consideration into design methods and communicative documentation is highly relevant when assessing the requirement for development.

2.4 – Interactions of Technology with Project Performance, Methodology, and Productivity

In order to analyse and select the most suitable technologies for further evaluation, 50 scholarly articles were perused using the keywords below:

- Construction technology
- Future of construction management
- Emerging construction technology
- Modern construction management
- New construction management methods
- Evolution of construction management

Each time an article was refereed, it was recorded, to determine what technologies were the most currently viable selections. This method was considered quite subjective due to random article selections, so all chosen items were discuss with peers within the industry to further justify their existence on this paper.

Table 4 - Technology most cited in literature

Technology cited as key influences in Future Construction Management		
Technology	**Article lifespans**	**Tally**
Building information Modelling	2000-2018	20
Smart Contracts	2000-2018	4
Artificial Contract Administration	2000-2018	3
Drones & Cameras	2000-2018	12
Virtual & Augmented reality	2000-2018	18
3D Printing and Robotics	2000-2018	10
Construction 'Wearables'	2000-2018	6
Cloud Based Digital Collaboration	2000-2018	8

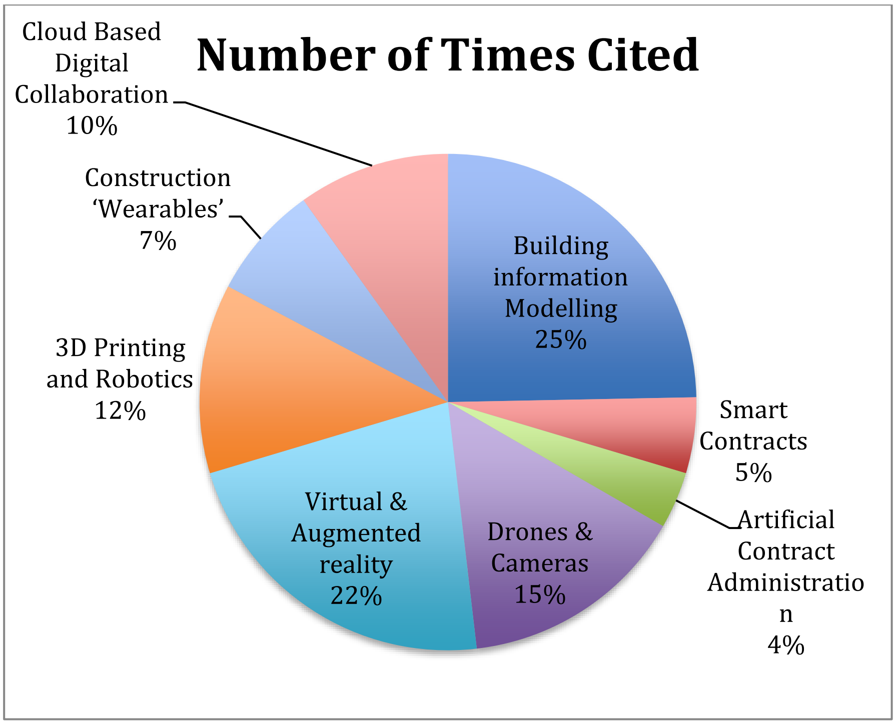

Figure 2 - Breakdown Of Cited Technology

2.5 - Emerging Technologies Used in Construction Project

A wide variety of articles have been analysed for the purpose of creating a statistically analysis into the importance of emerging technology displayed in the tables below.

The prominent technologies cited in the greatest number of articles have been scrutinised using the three main objectives of the report (performance, methodology and productivity). They have been rated using the following matrix to determine impact and ability to implement:

Table 5 - Evaluation Key

0	No impact	10 + years away
1	Low impact	8-10 years away
2	Notable impact	5-7 years away
3	Good impact	3-4 years away
4	Great impact	1-2 years away
5	Extreme impact	Present -very near future

Table 6 - BIM Evaluation

Technology: Building Information Modelling (BIM)						
Description: BIM is a digital representation of physical and functional characteristics of a structure in order to better foresee and manage the overall project. The program consists of 7 dimensions of management that include: 3D plans, scheduling, estimating, sustainability and facility management.						
Citation:	Year written	Performance	Methodology	Productivity	Expected implementation	Overall rating
Zhang, S., Teizer, J., Lee, J.K., Eastman, C.M. and Venugopal, M.	2013	4	5	5	5	19
Azhar, S., Khalfan, M. and Maqsood, T.,	2015	5	5	3	4	16
Hardin, B. and McCool, D., 2015	2015	4	5	4	5	18
Cao, D., Wang, G., Li, H., Skitmore, M., Huang, T.	2015	4	3	3	4	15
Total Ratings		17	18	17	18	68

The relevance and importance of this technology has been calculated as 87.5%.

Upon evaluation the BIM technology shows promising signs of being able to decrease cost and time of projects whilst simultaneously having a positive relationship on safety. The digitalisation of planned works, and collaborative approach shows evidence of increasing accuracy of estimates, decreasing resource clash, and aids in advancing labour productivity, and communication resulting in greater stakeholder satisfaction. It is predicted to revolutionise the processes of construction management on a globalised scale.

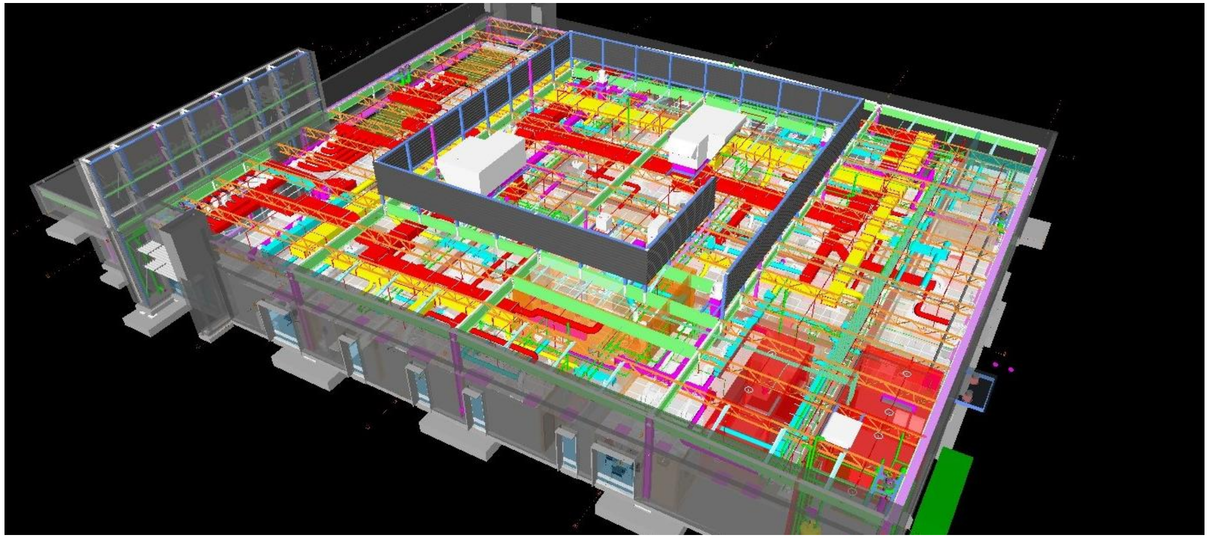

Figure 3 - BIM planning

(BIMpanzee, 2018)

Table 7 - Robotics Evaluation

Technology: 3D Printing and Robotic Constructors						
Description: Futuristic method to fabricate components of structures using CAD plans and datum points mechanically, with minimal human labour						
Citation:	Year written	Performance	Methodology	Productivity	Expected implementation	Overall rating
Tay, Y.W.D., Panda, B., Paul, S.C., Noor Mohamed, N.A., Tan, M.J. and Leong, K.F.	2017	3	2	3	4	12
Engineers Australia	2017	1	3	4	3	11
Kothman, I. Faber, N.	2016	0	2	4	2	8
Totals		4	7	11	9	31

The relevance and importance of this technology has been calculated as 51.6%.

The technology of 3D printer and robotics is still currently developing and shows signs of promise for the future of the construction industry as it provides an increase in productivity, much like prefabricated materials. Though, it has current restrictions in sense of overall performance due to the low demand and high cost associated with the preliminary works. In summation the technology is projected to give contractors and subcontractors a competitive advantage, though offers no real fulfilment to stakeholders, higher management or communication betterment as of present.

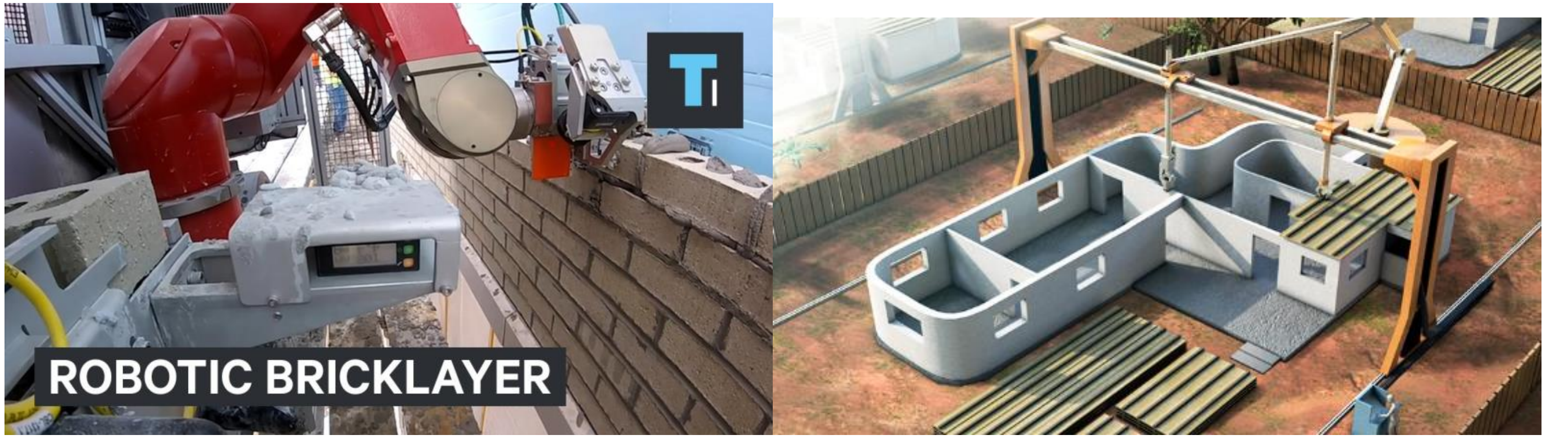

Figure 4 - Robotics In Construction

(Howe, M, 2018)

Table 8 - Photographic Evaluation

Technology: Drones and Cameras						
Description: Drones, knows as UAV's (unmanned aerial vehicles) are increasingly being used for site inspections and defect examination for unsafe zones.						
Citation:	Year written	Performance	Methodology	Productivity	Expected implementation	Overall rating
Snow, C.	2016	4	3	4	4	15
Ashour, R., Taha, T., Mohamed, F., Hableel, E., Kheil, Y.A., Elsalamouny, M., Kadadha, M., Rangan, K	2016	2	3	4	5	14
Zainuddin, A.Z	2015	1	3	3	5	12
Total		7	9	11	14	41

The relevance and importance of this technology has been calculated as 68.3%.

The use of drones in construction is on a path to completely revolution the methodology in which inspections can be performed. In 2015, there were close to 1000 fatalities in the construction industry (Howard, J, 2017) due to high-risk works and inspections. Drones have potential to seriously mitigate the risk involved with inspections of high-risk nature. Though, as a holistic management tool, the general consensus is they lack potential in relation to overall project performance.

Figure 5 – Drone Use In Construction

(Zainuddin, A, 2015)

Table 9 - Virtual/Augmented Reality Evaluation

Technology: Virtual/Augmented Reality						
Description: A technology used to digitally represent physical attributes of a build as per plan, with the devices excelling to provide the service, in real time.						
Citation:	Year written	Performance	Methodology	Productivity	Expected implementation	Overall rating
Carreira, P., Castelo, T., Gomes, C.C., Ferreira, A., Ribeiro, C	2018	4	5	5	4	18
Guo, H., Yu, Y. and Skitmore, M.,	2017	5	4	5	3	17
Wang, X., Truijens, M., Hou, L., Wang, Y. and Zhou, Y.,	2014	5	4	5	3	17
Blinn, N., Robey, M., Shanbari, H. and Issa, R.R.,	2015	5	5	5	4	19
Total		19	18	19	17	71

The relevance and importance of this technology has been calculated as 88.6%

This technology is being used in conjunction with BIM programming in order to expose stakeholders to projected works through digital representation prior to physical works commences. The general consensus of this mechanism is that is will provide for greater control of works, safety and highly improve communication with respect to clients expectations of finish.

Figure 6 – Virtual Reality Projection

(UX Collective, 2018)

Using the data established in tables 6-9, the overall ratings of technology are as follows:

Table 10 - Emerging Technology Overview

Emerging Technology	Overall Rating
Building Information Modelling	87.5%
3D Printing & Robotics	51.6%
Drones & Cameras	68.3%
Virtual & Augmented Reality	88.6%

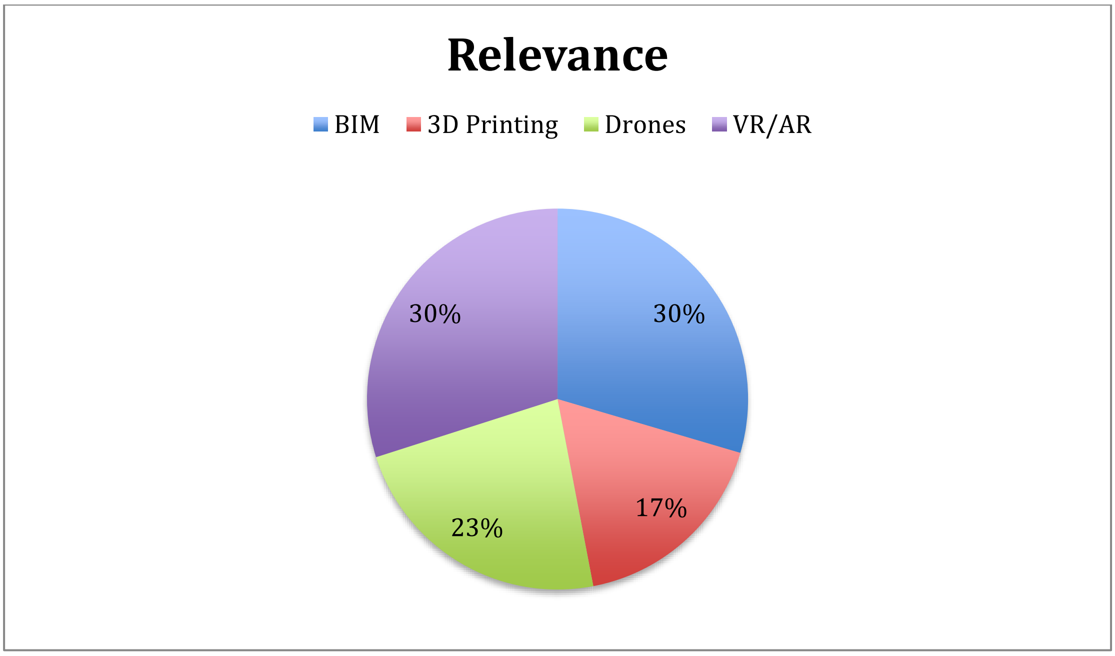

Figure 7 - Relevance Of Emerging Technology

2.5.1 - Technology one – Building Information Modelling

In terms of recent developments, Building Information Modelling (BIM) is proving a new paradigm in the world of construction from both theoretical and pragmatic standpoint. The technology is a 7-dimensional program capable of digitally presenting an accurate virtual model of a structure under construction that is used to advance project planning, project design, construction efficiencies, operational safety and operations after commissioning (Azhar, S., 2011). This encompasses the three-dimension parametric data capable of collaborating aspects of multidisciplinary industries to successfully examine the complexities of special awareness using an individual ‘master plan’ that allows for effective clash detection (Azhar, Et Al, 2015). The fourth dimension of scheduling assists managers, engineers and architects in visualising the methodology under a specific environment by providing visual validation with respect to their idolised plans and timeframe promoting the current lean scheduling and lean construction movements (Dave, B, Koskela, L, Kiviniemi, A, Tzortzopoulos, P,Owen, 2013) by pre-emptively addressing potential issues related to design and construction operations allowing for accuracy on pricing. Quantitative data provided by dimension three and four, in conjunction with supply chain verification allows for real time estimating, fabrication modelling and price verification when preforming take-offs (Forgues, D, Iordanova, I, Valdivesio, F, Staub-French, S, 2012).

Modern trends and social movements have seen a shift in construction to focus on sustainable development and environmentally friendly design with a push towards LEED (leadership in Energy and Environment Design) tracking (Hammond, R, Nawari, N, Walters, B, 2014). Dimension 6 of the BIM technology provides management and designers just with a detail energy analysis and tracking system capable of detecting natural light, heat and loading through x-ray detection pending the buildings orientation with the natural surroundings which can servery impact energy consummation required, and potential for energy consumption generated. Dimension 7 sees the efficient management of the project before, during and after commissioning through the extraction and tracking of project asset data to manage specifications, component status, warranty data and maintenance/operation manuals (BIMpanzee, 2018).

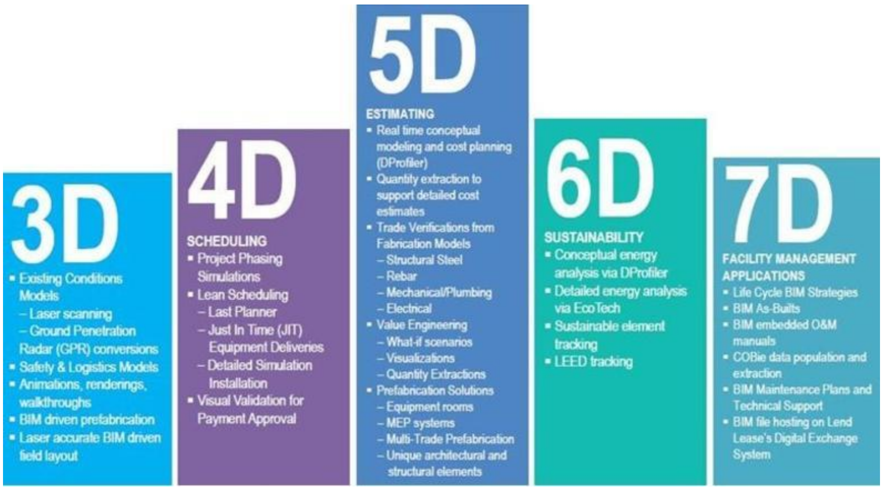

Figure 8 - BIM Dimensions

(BIMpanzee, 2018)

These aspects show evidence in increasing a management’s ability to organise and budget works, establishing greater control in respect to documentations and subcontractor management to minimise construction lifestyle and increase overall profits that has seen a direct relationship in stakeholder satisfaction (Forgues, D, Et al, 2012).

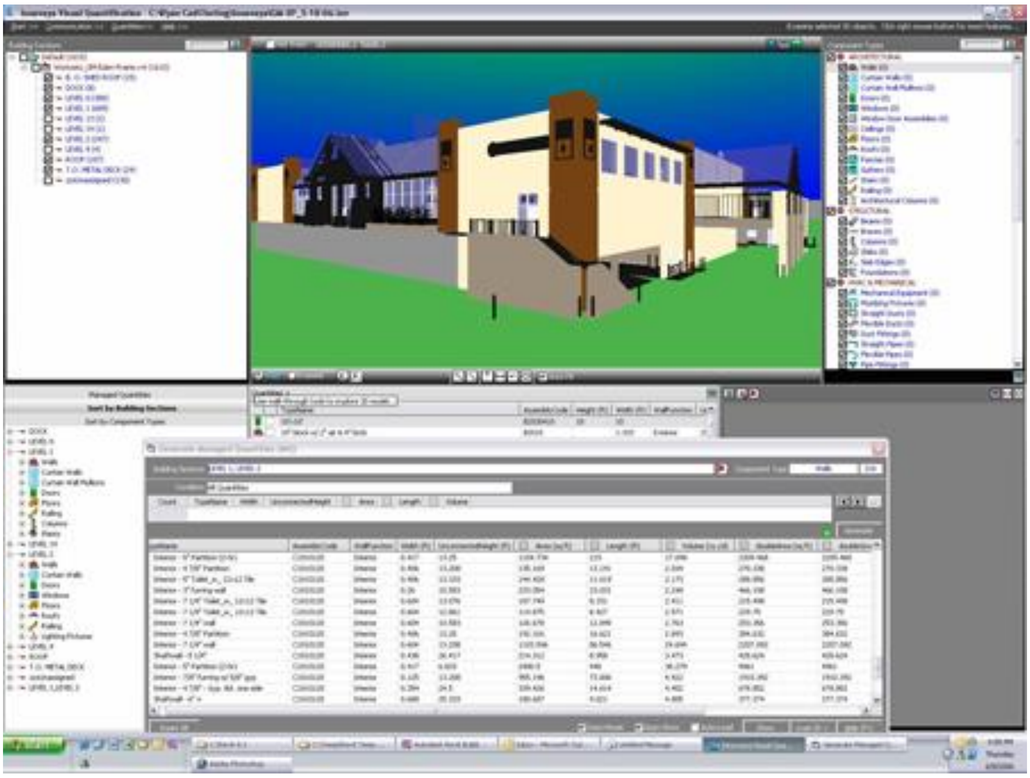

Figure 9 - BIM Estimating

(Rundle, R, 2006)

All stakeholders stand to mutually gain through the implementation of such technology from both a financial management and scheduling viewpoint, specifically with regards to clash detection, which currently makes up for a majority of scope creep in the construction industry (Wang, Et Al 2014). This in sense, would benefit on site productivity, and the consequential performance KPI's would reflect such change.

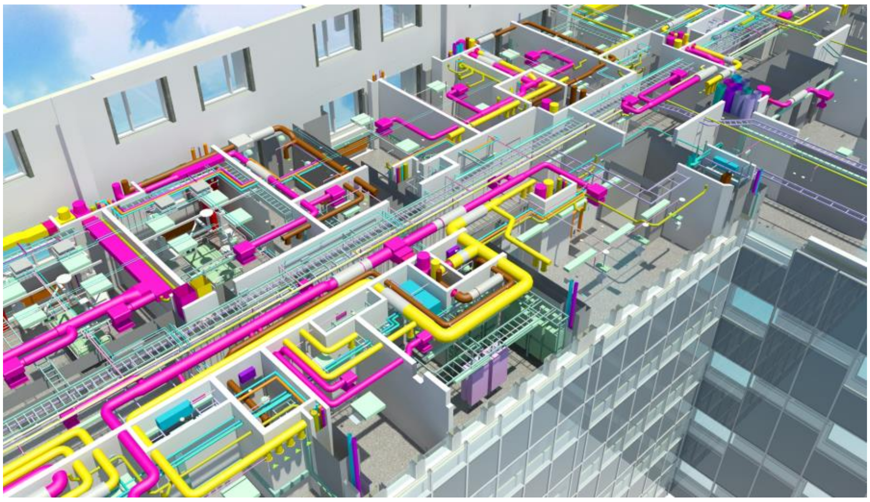

Figure 10 - BIM clash detection

(BIMcrunch, 2014)

There is also theoretical indication that the technology could link to the development of firm growth and overall efficiency (Dave, B Et Al, 2013). Where it is currently lacking is with respect to two key areas being legal, and technical. The legal parameters currently undermining the technology from a legal sense is lack of clarity in ownership (Arensman, D Ozbek, M, 2012) Given the data sharing nature of the technology, proprietary information between industries and companies must be protected, but is subject to copyright issues and ownership rights with apposing legislation (Volk, R, Stengel, J Schultmann, F, 2014). These legal issues are currently a larger issue to manage in comparison to the technological issues that stem from knowledge of program navigation and a required holistic approach towards technological interfaces between parties. To summarise this point the technology cannot be used to its potential unless the project team all collectively use the system.

This sees future studies being undertaken to mitigate the risk of interface issues through advancements in distributed computing and system integration, as well as legislative consideration being undertaken more commonly with the inevitability of globalisation (Arensman, D Ozbek, M, 2012).

2.5.2 - Technology Two - Virtual & Augmented Reality

The advance of virtual reality has a long documented history dating back decades, although recent trends in the exponential development of bandwidth has seen the technology gain the attention of industry professionals with the explosion of glasses and headsets that saturated the market in 2016. The program projects a simulation in order to visualise an environment as if one is there. Further this technology is currently undergoing evolutionary process with the linkage to augmented reality in which the user in able to digitally overlay objects using an interface to visualise objects in real time.

This technology has gained a lot of interest for the positive impact of stakeholder management, as it provides industry professionals a method in which they can accurately explain the specifications of the build, with clients, giving the ability to accurately stipulate expectations. Although, not only are the programs used to accurately display finished construction, but they are also revolutionising safety by simulation and tracking systems. The technology has the capability to simulate on site construction methodology in order to identify potential hazards prior to works in addition to increasing real time communication between managers and subordinates (Park, C.S. and Kim, H.J., 2013). Recent models have been incorporating a programmed inspection module to assist in the mitigation of ongoing defects in order to increase performance indexes with projections showing a steady increase fields in enhancing productivity, safety, and efficiency (Chi, H.L., Kang, S.C. and Wang, X., 2013).

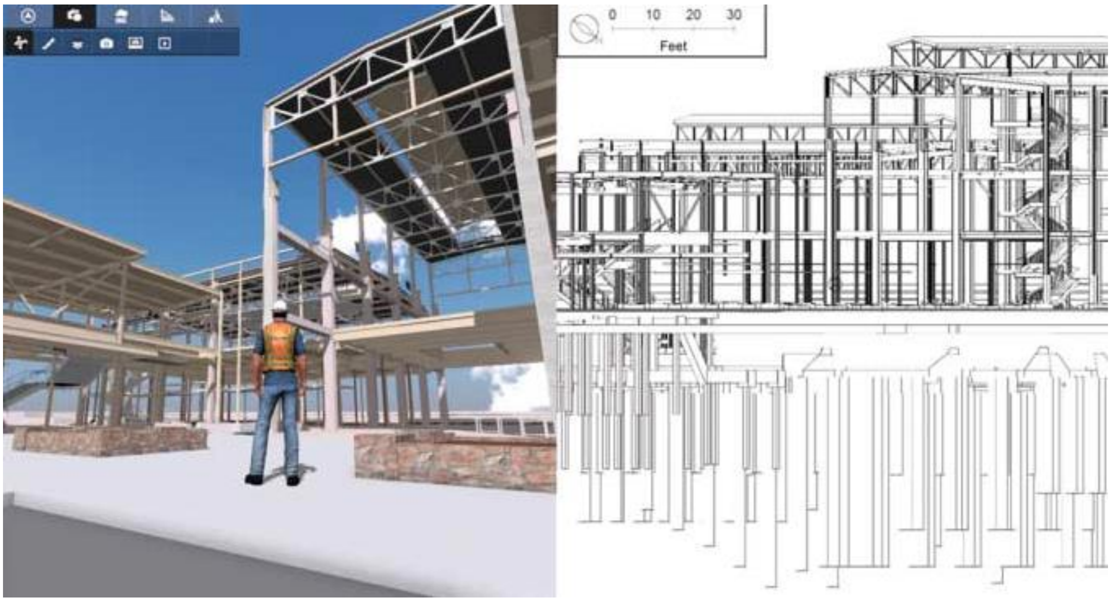

Figure 11 - Projecting works for safety

(Wang, X., Truijens, M., Hou, L., Wang, Y. and Zhou, Y., 2014)

The productivity, aspect encompassing efficiency and safety is proved so effective due the simplistic and visual approach which is seeing BIM data augmented onto real work scenarios to ensure workers of the correct process and product, and additionally used for certification of quality. The overlay of this data shows evidence of improving communication lines with visual specifications, minimising time spent on task due to visual instruction, increasing quality of works, and assists with design estimation, specifically with abstract detail (Wang, X. Et al 2014).

Figure 12 - Integrating VR with BIM

(Grant, C, Thompson, A, 2018)

Augmented reality then differs in that it uses computer generated enhancement to digitally overlay objects in a real time, real world scenario through an external hand-held device. This method is revolutionising construction productivity in that stakeholder that visualise and project scope details prior to the commencement of tasks and is widely being used to establish defects and to established resources unable to be seen, reducing reworks due to human error.

Figure 13 - Augmented Reality Example

(Grant, C, Thompson, A, 2018)

For this reason, the literature evaluations have been further addressed on the following page to assess the technology in terms of performance, methodologies and productivity.

Table 11 - Virtual Reality Summary- Revised

Technology: Virtual Reality						
Description: A technology used to digitally represent physical attributes of a build as per plan, it can be further used for simulation and project planning						
Citation:	Year written	Performance	Methodology	Productivity	Expected implementation	Overall rating
Carreira, P., Castelo, T., Gomes, C.C., Ferreira, A., Ribeiro, C	2018	4	4	5	4	19
Guo, H., Yu, Y. and Skitmore, M.,	2017	5	4.5	4	4	17.5
Total		9	8.5	9	4	30.5

Table 12 - Augmented Reality Summary - Revised

Technology: Augmented Reality						
Description: A technology that used a handset to digitally overlay objects in real time to foresee, or envision items in a real-world scenario						
Citation:	Year written	Performance	Methodology	Productivity	Expected implementation	Overall rating
Jiao, Y., Zhang, S., Li, Y., Wang, Y, Yang, B	2013	4	5	4	3	18
Abdullah, F., Kassim, M.H.B. Sanusi, A.N.Z	2017	4	4.5	4	3	17
Total		8	9.5	8	3	28.5

2.6 - Gaps in literature Review

Analysing the data above in relation to the hypothesis of this report, it's evident the academic gaps in the literature with respect to emerging technology in construction management, are largely due to the lack of data collection from Australian sources. Furthermore, although there is a general understanding of what the impediments of implementing the technologies are, though currently no consideration into demographical variances, or proposed corrections for educational or training purposes. It seems, at this stage of investigation, that the general consensus within the industry, is that a majority believe BIM, VR, and AR will be an essential aspect of their profession, though at this stage, are not willing to consider further training. This mentality is evidentially consistent through both business and tertiary training.

Further gaps in the literature are that it almost exclusively considers just building works, with very little information into the development of civil construction work technology. It is assumed this is due to the much larger areas covered and inability to have configurable plans to base the foundation of works.

Chapter Three - Methodology

The purpose of this research is to analyse how to use of building information modelling (BIM) technology used in conjunction with virtual and augmented reality (VR/AR), can assist professionals in achieving a higher level of project performance, methodologies and productivity, through collaborative tactics, and technological integration.

Through evaluation of the literature review, the aim is to establish if and (if so, why) there is a correlation between knowledge of emerging technology and acceptance of emerging technology amongst varying demographics, in attempt to propose the best method forward, for both businesses and educational entities.

The research will be completed in two parts; Part one will refer to the independent research required for a thorough understanding of the upcoming era of technological implementation. This information, as documented in chapter two of this report, determines technology, performance, methodology and productivity, in order to evaluate the industry. The following information is to be assessed:

Table 13 - Literature Review Findings

Current Literature Review To Analyse Emerging Technology Understanding			
BIM VR AR	Performance	Methodology	Productivity
	Time	Planning	Safety
	Cost	Costing	Labour Efficiencies
	Satisfaction	Document Control	Communication

Part two will be attempting to breakdown the current impediments associated with the movement. In order to increase company performance, a categorical evaluation will be performed to acknowledge where the industry should focus the attention on in terms of employment training and program exposure.

In order to establish a methodological process to conclude the hypothesis, the research paradigm has been stipulated below for viewing.

3.1 - Research Paradigm

The evaluation of technological implementation, possess a threat to a credible dissertation, due to the subjective nature of both article information, and individual ideation of programs between industry professionals. If a survey exclusively relied upon to decipher information, this subjectiveness of interpretation will assumedly be enhanced due to a knowledge deviation between interviewees. Whilst on the contrary, many refereed articles could be criticised for conforming to a confirmation bias or be deemed subject to an availably heuristic within the numerous fields of academic research. Acknowledging this issue, essentially creates both a type one, and type two analytical issue for data processing (Kahneman, Daniel, 1934-(2011), therefore, the decision has been made to integrate the two, to find a medium, whilst further preforming a statistical analysis of congruence by using a large sample of the literature (number of citing', references, author creditability and year created) in order to mitigate to risk of creating misleading findings.

3.1.1 – Literature review

Using a literature review is considered as an efficient means of increasing the knowledge and understanding the knowledge gaps. It is beneficial to this study as it provides the current (within the last decade) industry consensus on what affects performance, methodology and productivity, in addition to what the expected technology projected to influence the industry is. Although, the negative aspects are that there in limited information formed in Australia, and currently, little information on both civil and residential construction. Out-dated information will be mitigated through the use on articles from 2008 onwards. The information found will then be used as the foundations for the report.

Conducting a survey to gather information of specifications was briefly considered as a method of data collective, though it was considered flawed due to the fact a majority of the interviewees would not be considered as eminent' within the field which could lead to misguided questions being posed.

3.1.2 – Methods and Reasoning

In creating the paper, there was the consideration into whether to use two main methods of research; Deductive and Inductive. Due to the nature of the thesis and two-part approach, the overall method to be used is mixed.

Part one consists of the literature review, which is considered deductive as it analyses the current information to understand if ideas conform to the data. The benefits of this will establish the Australian Industry although trailing behind in terms on implementation still conforms, at least on a theoretical level, to a similar ideology. The survey itself is also considered deductive as I wish to establish if the general belief in Australia is as researched internationally. Though, being generally deductive, the analysis of the data and recommendation will be assessed with indicative reasoning. This will be beneficial as the data can be used to determine a demographic difference and establish if training should be focused more towards certain groups, or if a certain demographic is more partial to enjoy partaking is different technology related tasks that could result in preforming, methodology and productivity increases.

The downside to this is that the recommendations and method to increase implementation have credible foundations though the evaluation is subject to interpretation that is based off personal hypotheses. In order to formulate the data in a structure manner to reduce the quantity of information left to subjective thought, the set out of the survey will be of great importance.

When pre-emptively mind mapping theories that could affect the questionaries. I have had to determine the approach to best collect data, though considerations into time restraints are also important given the scope of the dissertation. This poses the question of whether to incorporate and quantitative, qualitative or mixed system to amass the information.

The surveying approach has dictated a qualitative approach due to the observations collected by industry professional. Quantitative research has been considered, though it could not be possible until information is gathered and themes or trends are established. Therefore, the data collection will be imperative for the thesis. It is important to establish an ideal sample size to stipulate how many forms must be distributed in order to have a substantial amount to data for future evaluation. To do this, the following generic rule has been followed:

$$(Number\ of\ responses\ desired \div Expected\ response\ rate\ \%) \times 100$$

Ideally, this study aims to collect 50 responses, given the network used is integrated with a pre-existing system (current employer), it is expected to have a 50% return rate, meaning 100 forms will have to be distributed using an online link to Google Forms. In order to be considered for the survey, the samples must conform to the following criteria.

Table 14 - Data Collection Method

Question	Answer	Reasoning
Who will be considered to be a participant of the survey	Participants must be over the age of 20 and currently be working within the industry in a position that related to management, costing, planning, designing or client communication	Applicants under the age of 20 have been evaluated to have a lack of industry experience
Why are the participants being considered?	They have been chosen as the directly related to the hypotheses and can assist is establishing the general consensus of the industry	This is required the to deductive evaluation that related to the literature review of 2.0
How will participants be contacted?	They will be contacted digitally via email	This is considered as the most practical form of delivery for all parties
How long will the survey take the participants?	The survey will aim to be 5-10 minutes, although optional videos will be included to help refresh the top which will be an additional 10 minutes	I aim to keep it short, in order to increase the probably of surveys coming completed
How will participants give consent?	The information sheet will contain a consent statement in that proceeding will result in implied consent	This is required due to the ethics approval process required for tertiary compliance
How will participants respond	The survey is in online format, and they can simply press completed when ready	This again, is determines as the most practical solution.

This data is being collected in accordance with the CSIRO Research Information Management System.

ID number: H18REA226

Status: Approved

A number of different surveys could be implemented in order to gather the information for analysis. For the purpose of this paper, a ranked fully structured approach was used. This has the strength on simplifying analysis and providing greater mathematical accuracy, as the answers are objective and capable of marginalisation. Though with this, come negative aspects of not being truly privy to any deeper opinions of the samples, which is a benefit of other styles such as short response. This, is likely an interesting topic to evaluate in greater depth, though is measured to not adhere as closely with the project scope, as the completely structured questionnaire to receive results able to be mathematically derived without subjectivity.

Questions will be intended to collect data on demographic, knowledge in relation to the top three performance, productivity and methodology indicators as seen an section 2, with a secondary aim to collect opinion based information on why they believe they may be lacking in implementation. There will be no comment box option due to time restraints and subjective nature of interpretation.

Table 15 - Demographic Targeted

Part one - Demographic	
Question	Answer
What sector of construction do you work in?	Residential/Commercial
Age	21-30.31-40.41-50.51-60. 61-70
Gender	Male/Female
Experience in industry?	1-5.6-10.11-15.15-20.21-30.31-40. 41+
Position in company	Manager, Director, Contract Administer, Architect, Draftsmen, Engineer, Builder
Education	Year 10, High school, TAFE diploma, under grad, PHD
Primary location of business	OLD NSW SA WA NT ACT VIC

3.2 - Research Method Summary

This research will be formulated using the literature analysed throughout the review of part 2 to establish the validly of information that is required to be gathered via the online questionnaire. The survey approach has been embraced in order to understand the deviation (if any) in demographical adoption and general understanding within the Australian Industry, and cross analyse the data with current literature conveyed in order to accelerate the technology movement. A survey for construction professionals representing multiple sectors on the Australian field was conducted. The scope required heterogeneity of respondents to be prioritised highly within the structured criteria, to currently capture data.

Please see Appendix 1 for the dispersed survey that aims to compartmentalise answered into the three categories:

- Demographic
- General Understanding
- Impediments

The survey has been created using Google forms, primarily due to the ability to directly export data to excel, which possess a higher level of analytical tools. Survey Monkey was highly recommended, though, the basic package of the system did not allow for a direct export without expense.

3.2.1 –Research Risks

Given the subjective nature of the literature review, and use of a survey, the following aspects will need to be considered and critiqued during the conclusive summary.

Table 16 - Research Risks

Risk Description	Outcome	Mitigation
Online articles containing misguided information	Incorrect information in report	Ensure all unreferenced articles/videos are used for base research only and look further into topic with credible referenced pieces
Industry networking/ surveying time restraints	Insufficient time could result in reduces sample size	Create survey as soon as possible and send research out to network
Insufficient sample size	Increase margin of error	Expand network. Create survey as soon as possible and send research out to network
Subjective recommendations	Data would need to be tested using a different hypothesis	Encourage works

3.3 - Data Analysis Method

The data will be collected digitally and exported as an excel document to allow for further evaluation of statistics. To evaluate the data that will be extracted, it's important to recognise the information sourced via the literature review founded in part 2 of the questionnaire, in order to cross-examine if the industry have a collective understanding of the technology:

Table 17 - Technology Benefit Rating Out of 5

Description/Technology	BIM	VR	AR
Performance	4.5	4.25	4
Methodology	4.75	4.5	4.25
Productivity	4.5	4.25	4.25

The demographical breakdown of data that will need to be analysed in order to establish if/ why the statistics vary between different demographic and sectors of construction, and if/why the implementation is considered slow in order to give validation to the report hypothesis. In order to effectively display the findings, the following statistical analysis will be preformed

Table 18 - Method Of Statistics

Testing	Benefits	Disadvantaged	Why
Demographical means	Gives an overall breakdown that's simple to decipher	Very generic breakdown method	It is required to establish for the hypothesis evolution
Standard deviation	Shows the extent of demographical variance	Sample size of certain demographic could alter data	Will assist in analysing subjective data

3.4 - Validation

In order to validate the findings of this report, the statistical evaluation is required to be mathematically credible. This is in relation to both the demographical percentile in accordance with the Australian Bureau of Statistic information, and mathematical evaluation for graphing purposes. In this is the case it is advised that a future case study would be of great benefit to increase statistics to mathematically derive a cost benefit analysing of projects using a greater level of statistics the industry in the implementation of training requirements. Regression validation has not been used throughout this research due to time restraints and is highly proposed for future researchers to build upon.

Chapter Four – Data analysis

The data collected throughout the process of this dissertation has been kindly supplied by 22 interviewees in completed the formed presented in appendix 1. The demographic of sample has varied in terms of age, construction sector, experience, role, gender and education as seen below in figure 13, and further detailed by 4.1.1-4.1.6. It has been established the demographic variance is credible due to its close adhering with the *Australian and New Zealand Standard Industrial Classification (ANZSIC), 2006 (Revision 2.0).* This is justification for providing a valid level of statistical analysing throughout the evaluation.

4.1 – Demographical Overview

Out of 22 interviewees that partook in the questionnaire the demographics varied in the following means:

Demographical Breakdown of Participants - Emerging Technologies

Age (Yrs)	20-30	10	45.45%
	31-40	6	27.27%
	41-50	3	13.64%
	51-60	3	13.64%
	Total	22	100.00%
Experience (Yrs)	1-5	8	36.36%
	6-10	3	13.64%
	11-15	6	27.27%
	16-20	2	9.09%
	21-30	3	13.64%
	Total	22	100.00%
Sector	Commercial	12	57.14%
	Residential	8	38.10%
	Civil	1	4.76%
	Total	21	100.00%
Position	Engineer	6	27.27%
	Contract Admin	2	9.09%
	Construction Manager	9	40.91%
	Construction Director	1	4.55%
	Architect	4	18.18%
	Total	22	100.00%
Education	TAFE diploma	2	9.09%
	University degree	19	86.36%
	Post-graduate degree (masters, PhD etc)	1	4.55%
	Total	22	100.00%
Gender	Male	20	90.91%
	Female	2	9.09%
	Total	22	100.00%

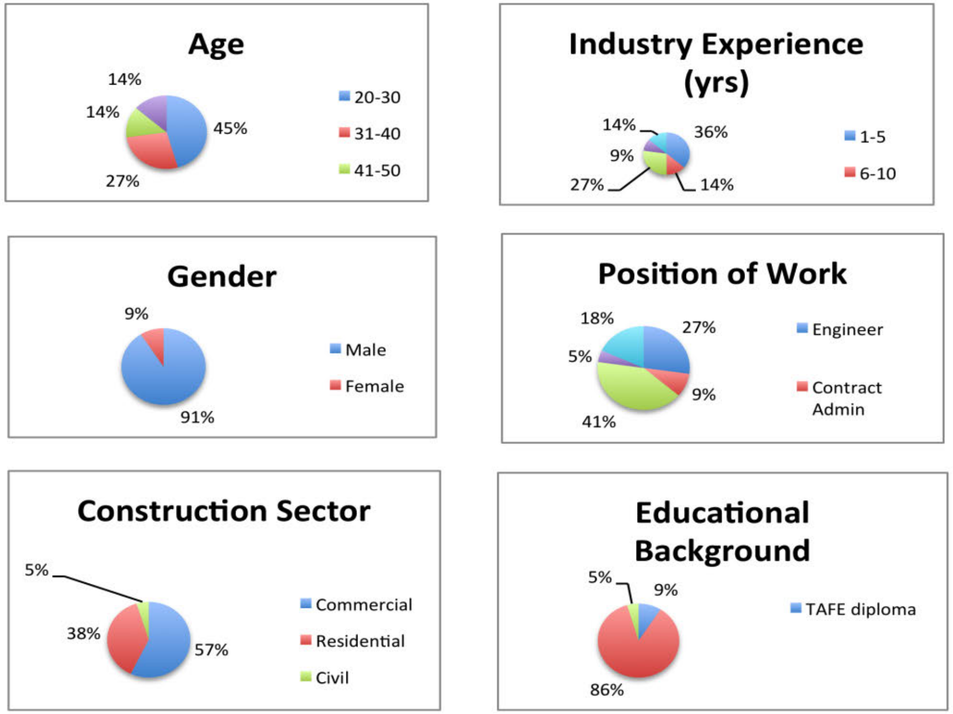

Figure 14 - Demographic Breakdown

4.1.1 – Gender

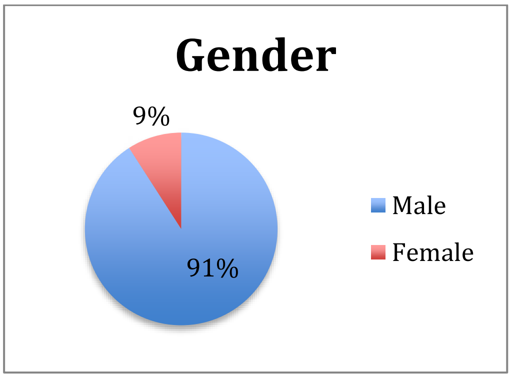

Figure 15 - Survey Participants - Gender

4.1.2 – Age

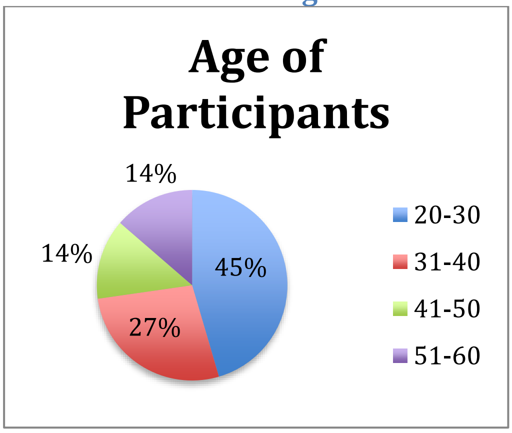

Figure 16 - Survey Participants - Age

4.1.3 – Sector

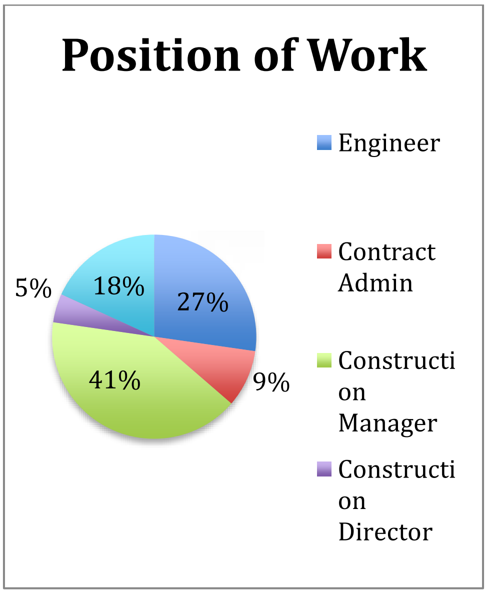

Figure 17 - Survey Participants - Position

4.1.4 – Position

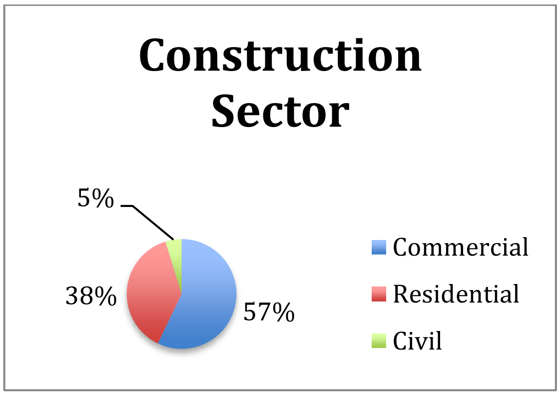

Figure 18 - Survey Participants - Sector

4.1.5 – Experience

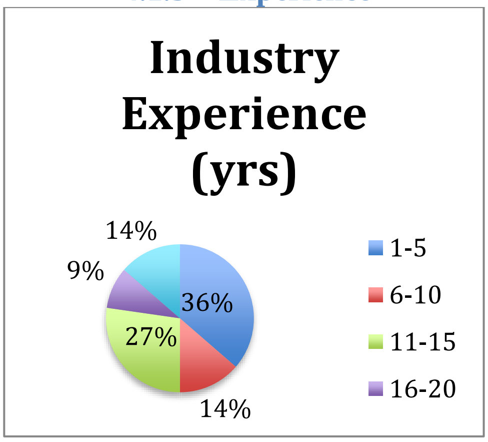

Figure 19 - Survey Participants – Experience

4.1.6 – Education

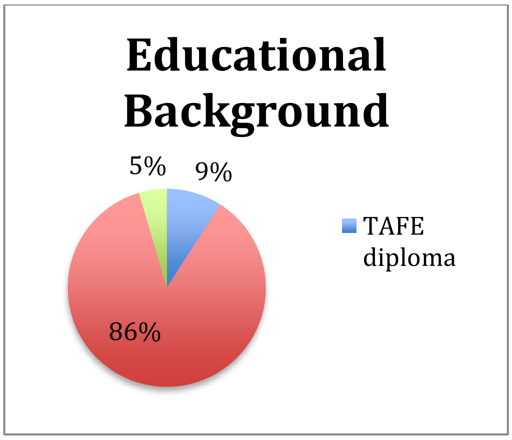

Figure 20 - Survey Participants - Education

4.2 – General Knowledge Evaluation

Statistically evaluating the differing demographical knowledge of 2, against the current scientific literature of section 2, with respect emerging technology projected to influence industry methods, the following data has been established:

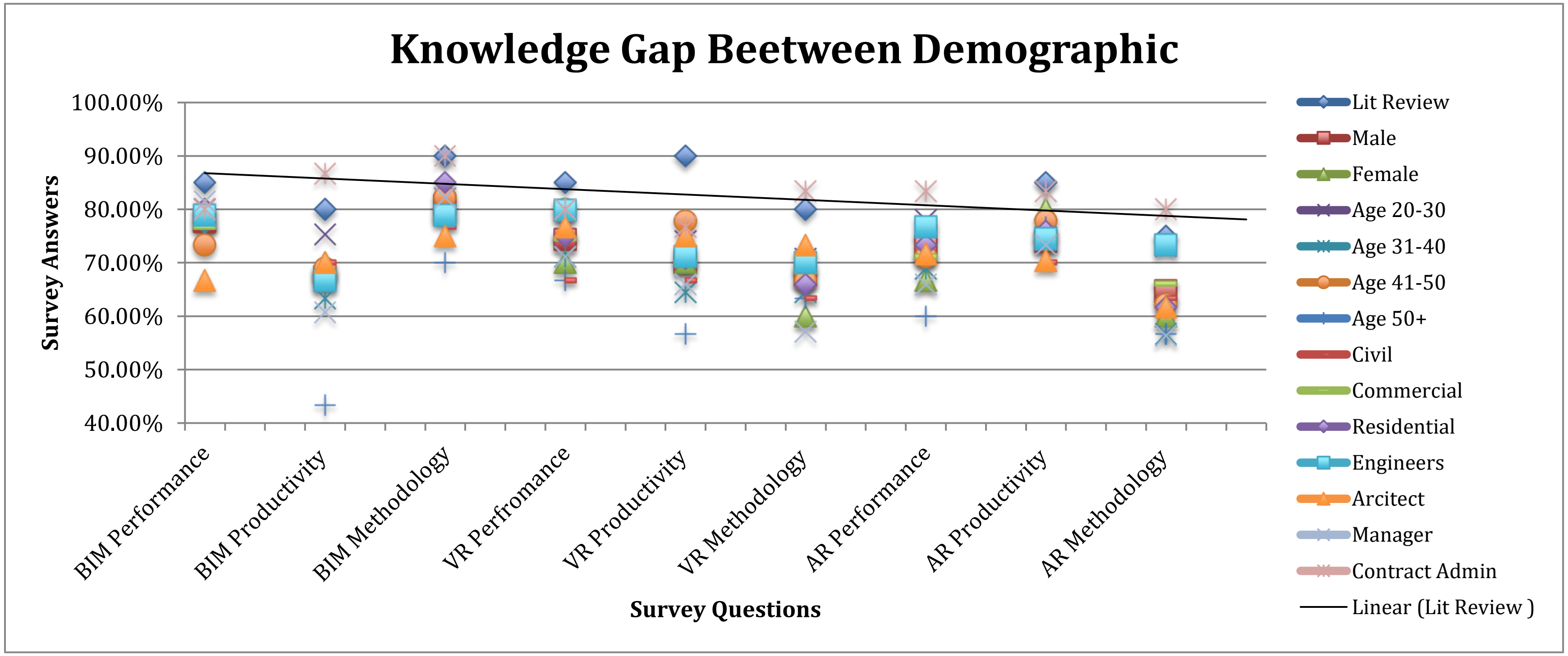

Figure 21 - Demographic Knowledge Gap

4.2.1 – Gender

The findings derived from the questionnaire show of very minimal knowledge gaps between genders within the industry. A small deviation appears to be establishing that would display evidence of females possessing a higher level of understanding with respect to using VR for planning and internal management purposes.

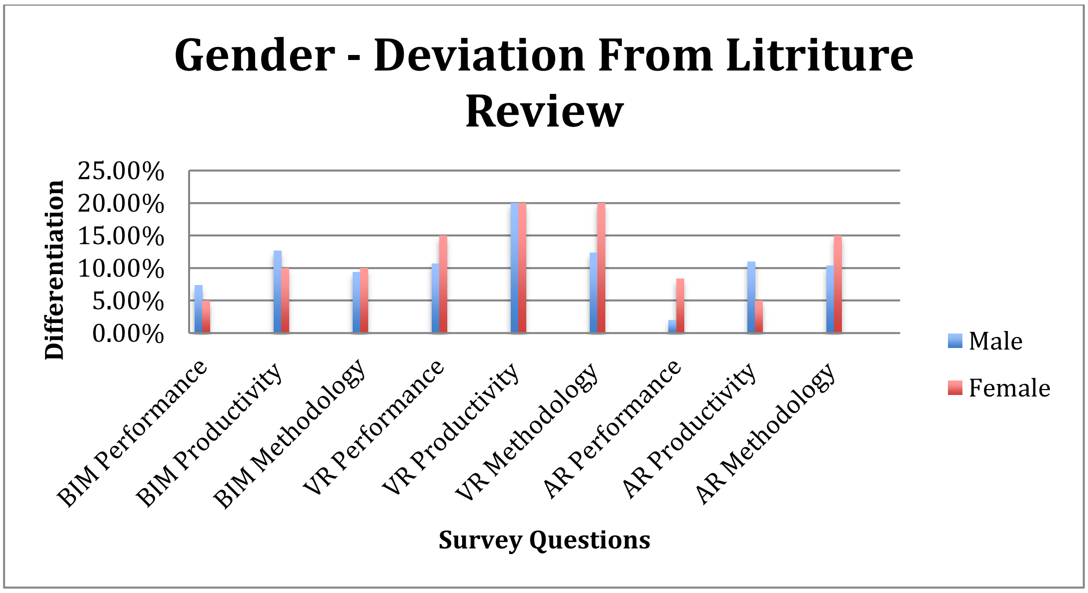

Figure 22 - Knowledge Gap - Gender

In order to establish conclusive evidence of this, a larger sample size between male and females within an identical category is required. Consequently, due to sample size (9% female of 22 participants), the findings within the report can show no conclusive evidence of technological knowledge inconsistencies between genders. Therefore, from this study, gender would not need to be considered when strategizing implementation methods to enhance performance, methodology or productivity.

4.2.2 – Age

The leading predictor for disparity of technological knowledge is age (Poster, M, 2018). In the case of this study, compliance to the findings of Poster, is so much so that if you were, in the construction industry, to randomly select an individual ranging between 20-30 and an individual ranging from the 50+ category and assume the younger member would be more proficient in understanding the emerging technology, you would almost 70% of the time.

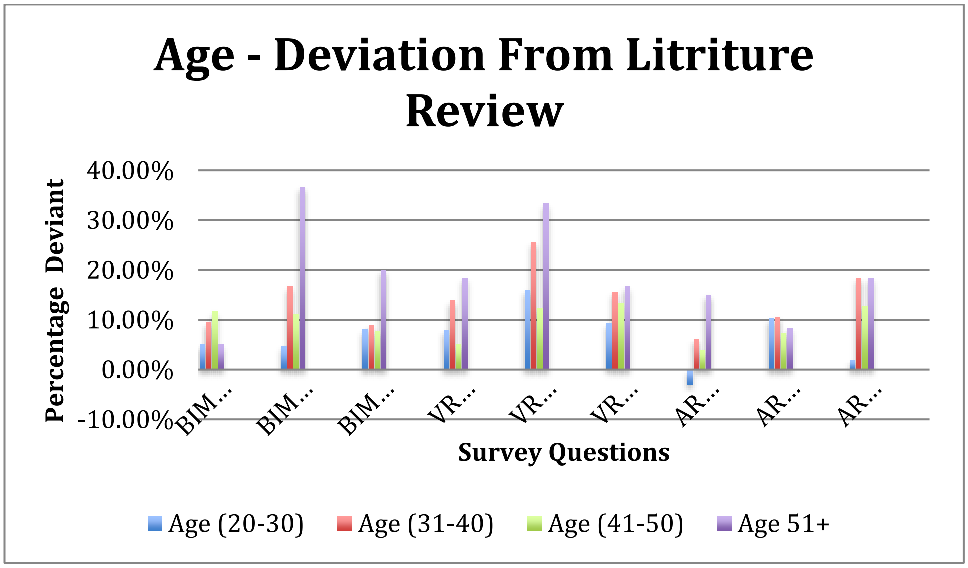

Figure 23 - Knowledge Gap - Age

The graphs depicted in figure 22 show a clear indication that age is a leading factor in the knowledge gap. The findings of VR performance and Productivity, has been partially swayed due to the large number or architects within the 41-50 demographic that took place in the survey. Furthermore, it is currently assumed that the age differentiation data depicted, is presumably not exclusively due to age, but due the more recent studies the individuals have partaken, showing evidence of training programs being beneficial to industry implementation. Though more importantly, gives suggestion that the knowledge gap should be addressed.

4.2.3 – Sector

Construction sectors have been found to have a reasonable identical understanding of the emerging technology when cross-examined holistically. It is in fact the closest element shared between demographics and understanding knowledge, specifically when analysing building works versus civil works. This finding suggests that implementation is not due to a lack of industry information, and an equal level of understanding is synonymous throughout the different branch of construction, with minor discrepancies seen below in figure 23.

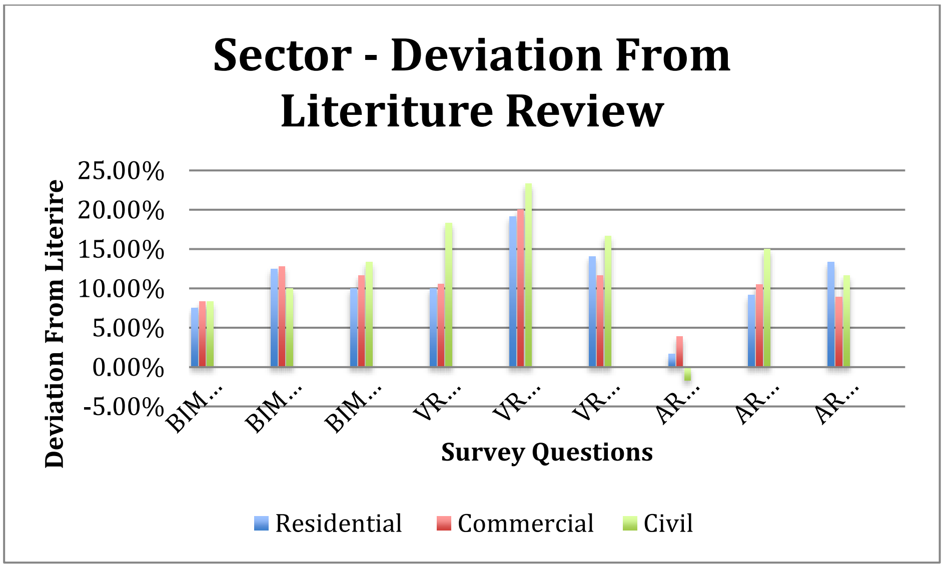

Figure 24 - Knowledge Gap - Sector

As you can see in the table above, and in further detailed through appendix 2. The civil sector of construction has a slightly higher level of understanding when it comes to technology. This finding is assumed to be primarily due to the higher active used established using Appendix 1. Although the basic level of understanding is higher, literature reviews suggest this is due to civil projects requiring far less detail calibration in order to have the technology function at a basic level. As integration of systems evolve, it is the current believe that the slight knowledge gap between sectors reach equilibrium.

4.2.4 – Position

The notable deviation of knowledge scores across professions accumulated throughout the report was an interesting finding. The results in figure 24, display construction related professions (management and administration) to have a much higher knowledge to the design sections (Engineering and architect) when evaluating BIM. On the contrary, the design counterpart of engineers has a much higher understanding of VR and AR emerging technologies. Although this is justifiable on the basis of positional related tasks, the fundamental ideation of this expresses contradictions of the current literature amongst positions. Thus, resulting in the lack of true understanding of the extent of which the technology could act as an asset.

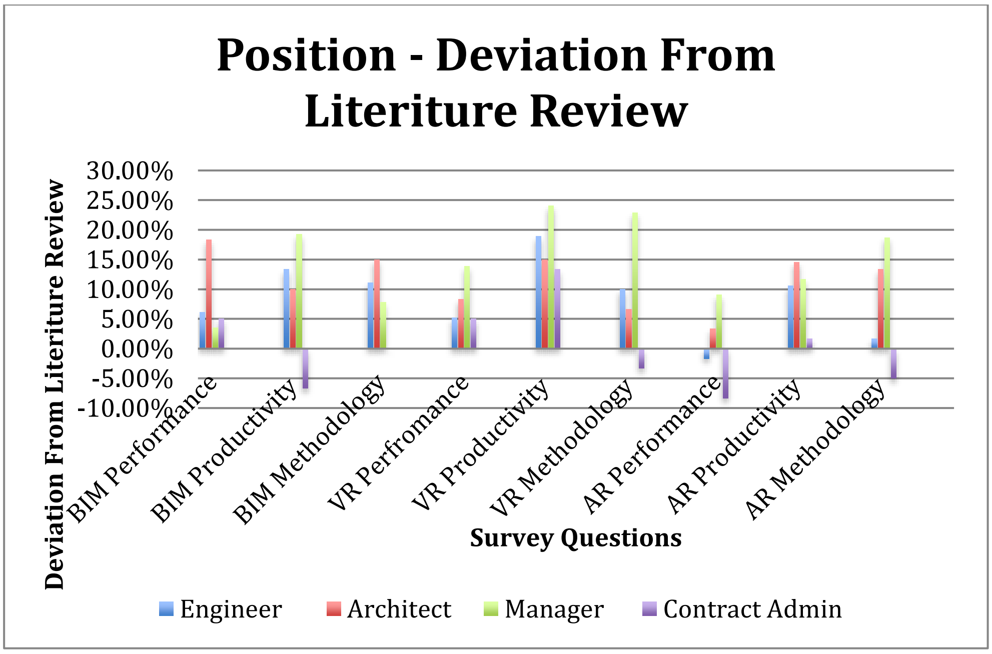

Figure 25 - Knowledge Gap - Sector

The findings of Appendix 2, show that there are notable gaps is knowledge between professions' in the construction industry. Although this is one of the larger facers of deviation, it is expected to have a lower level of influence on construction project performance due to individual professions needing to excel in there given area.

Although, It is important to acknowledge that VR productively is as large factor that contributes greatly to knowledge gaps between all positions, when ironically, it is an aspect in which all professions could benefits from implementation in their own area. This, it has been established that implementation specific to virtual reality is highly import to benefit industry efficiency.

4.2.5 – Education

Educational accreditation has been deemed insignificant for analysis, due to only 2 of 22 samples (both from dissimilar categories (as seen in appendix 2) having not being categorise with a bachelor degree.

4.2.6 – Experience

Experience is loosely related to age factors that contribute to understanding emerging technologies projected to influence project success, and similarities of the two can be viewed throughout appendix 2.

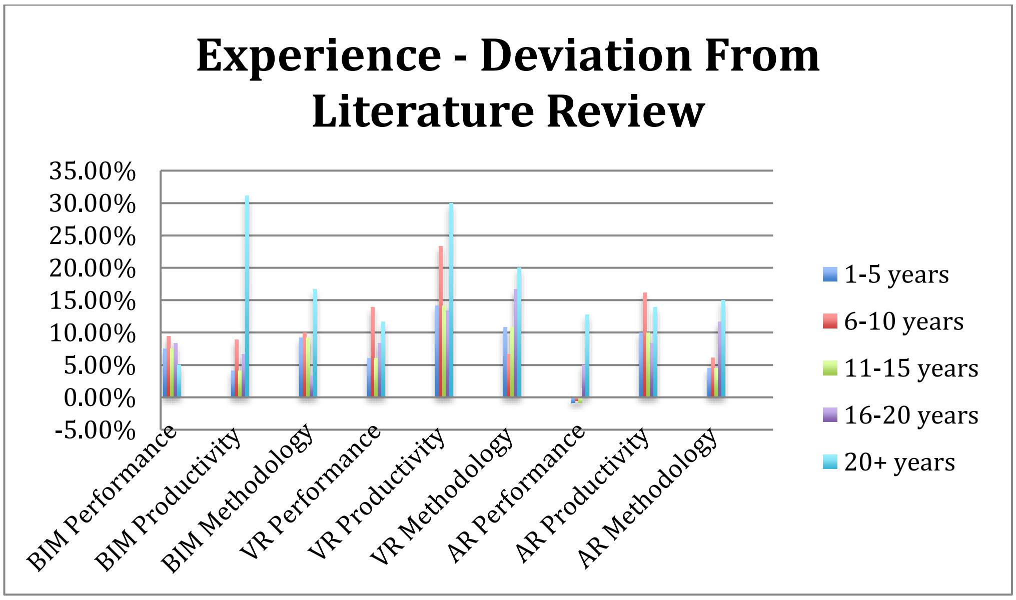

Figure 26 - Knowledge Gap – Experience

Accepting that the perceived understanding amid the surveyed participants sees a large knowledge gap related to those with the greater experience establishes a concern for industry development. The general consensus is that with experience, comes expertise; this expertise leads to acting in a position that influences culture, strategy and performance (Kahneman, Daniel, 1934-2011). This issue, if not addressed and the potential to cause further delays in the implementation of this new technology and is assumed to be a major factor to be proposed when evaluating the current implementation impediments.

4.3 – Implementation Impediments

The current impediments established throughout this report have been acquired through both the current literature, and industry evaluation. The overview below displays that generally, the impediments of the samples seem to align with that of the literature founded on a global level.

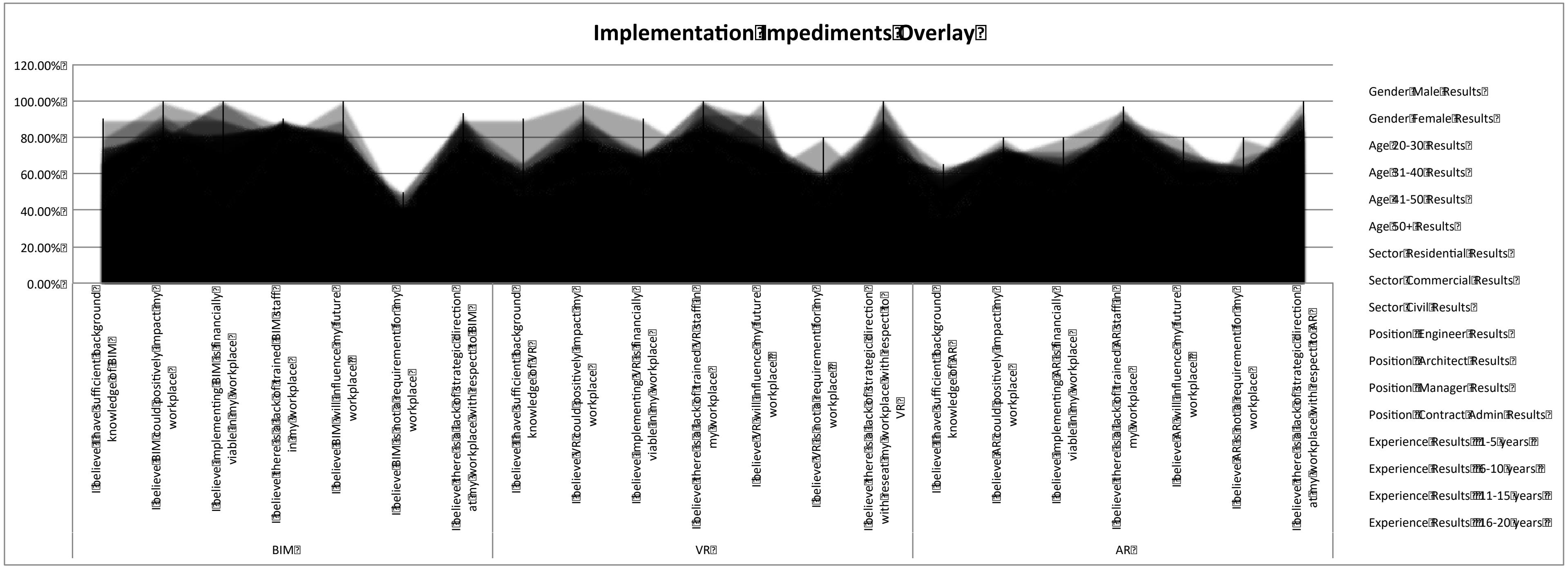

Figure 27 - Implementation Impediment Overview

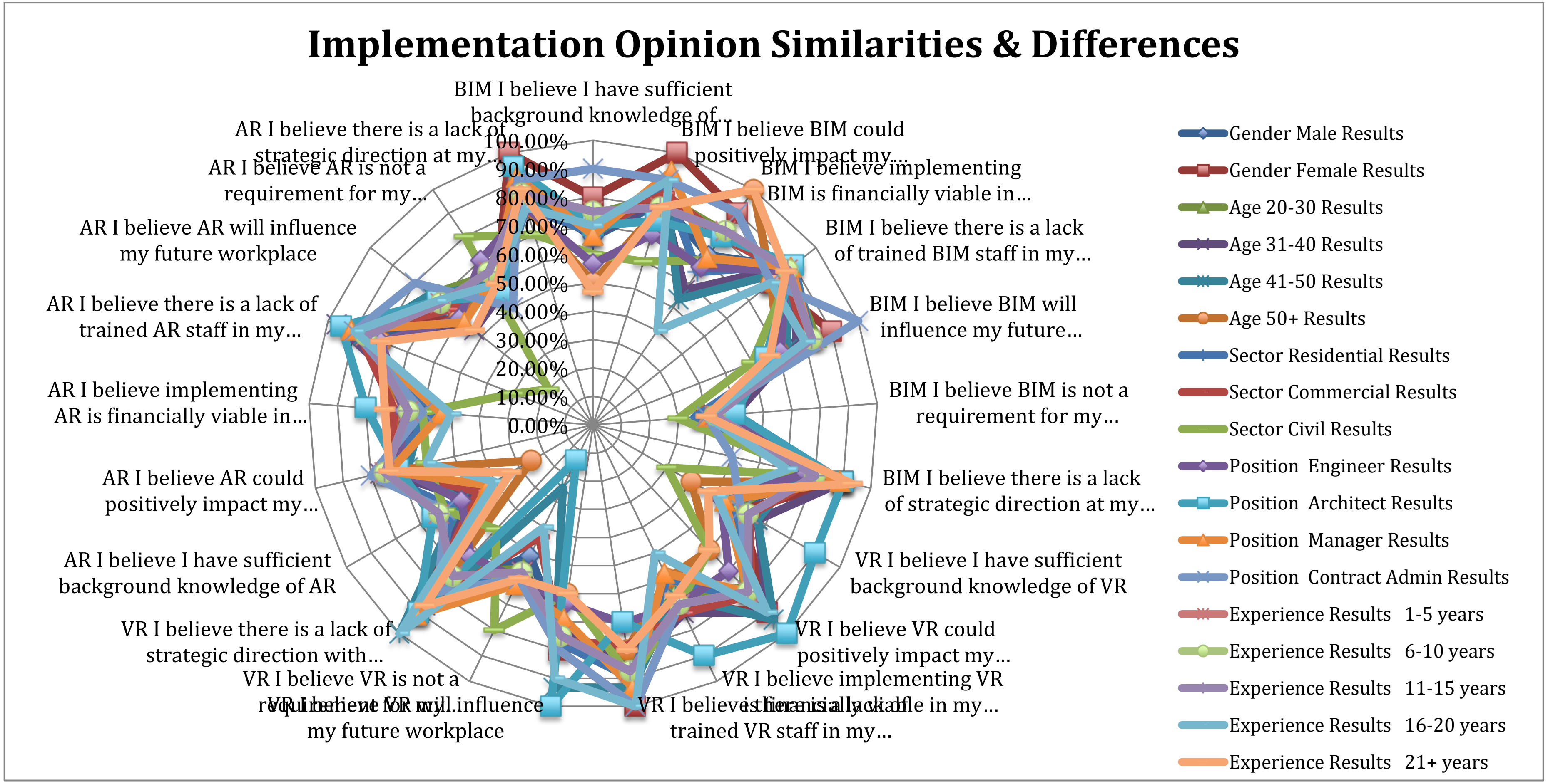

Figure 28 - Implementation Opinion Deviate

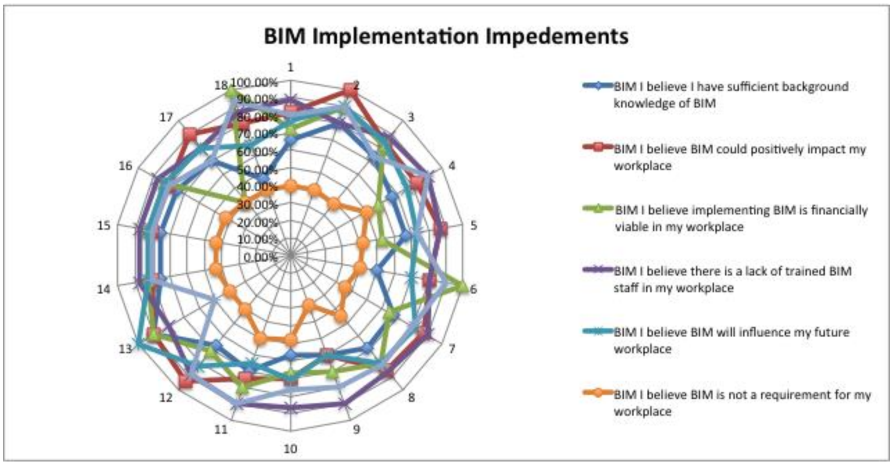

Figure 29 - BIM Impediment Opinions

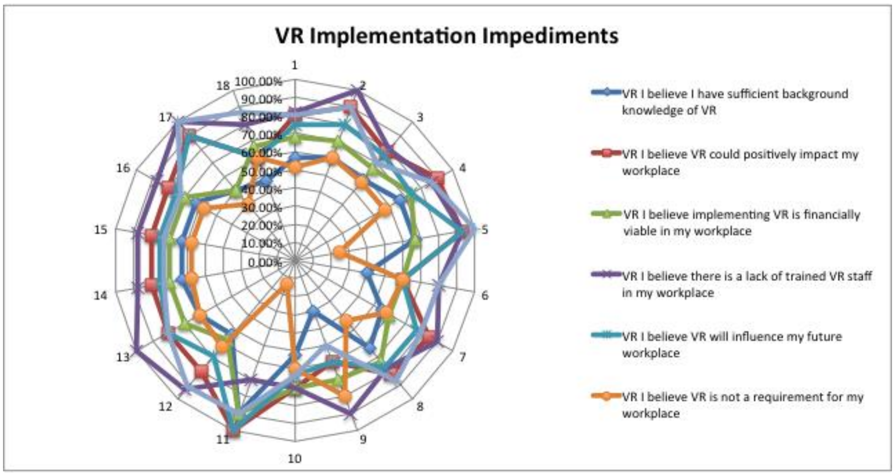

Figure 30 - VR Impediment Opinions

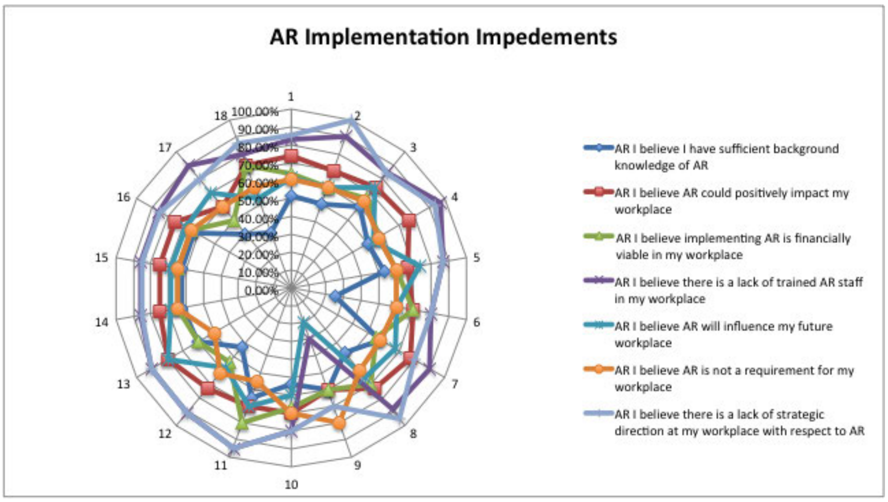

Figure 31 - AR Impediment Opinions

The radar charts in Figure 28-31 provide a graphical method of expressing the multivariate data, of 27 possible implementation impediment variables in an idiosyncratic manner. The formation of a relatively distinct pattern conveys a similar crowd consensus to reason the suboptimal implementation of the current industry. Further analysis of Appendix 2 establishes the following information.

Within the residential sector of construction the data represents that the industry professionals have a high level of enthusiasm in that they believe implementing the technology could be highly beneficial. They also believe that the strategic management of their teams would have a desire and are pushing towards adopting such processes. The impediment is that the benefits enabled through the use of BIM, VR, and AR, are considered to be ‘not financially viable’ for the market and is the primary reason why implementation of construction technology is not being adopted for residential business undertakings.

On the contrary, commercial construction employers have a medium level of desire to implement BIM, VR and AR. The commercial sector, like the residential sector, acknowledge the benefits at a satisfactory level, though differ in management perception. Employees within the commercial sector believe that the lack of implementation of such technologies is due to strategic management methods. In order to rectify these issues, training issues will be referred to later in this report. In reference to section 4.2.6, experience plays a large role in noncompliance of samples. It is a reasonable assumption that the lack of strategic management, and lack of knowledge from industry professional with experience/ (due to age) acting in leadership roles that such influence decision are related, and thus could be a defining reason as to why implementation of commercial construction is currently lagging in comparison to other industries.

It if further addressed that these knowledge gap issues will cause potential execution issues for the industry until addressed. Therefore, using the literature throughout section 2 of this dissertation in conjunction with appendix 2, it is important to establish the knowledge gaps for future studies in order to rectify issues to best benefit the industry.

4.3.1 – Knowledge Gap Issue

When analysing appendix 2, the emphasised knowledge gap that requires immediate attention is the comprehension of VR in construction projects. Currently, VR is widely recognised due to the headset bubble of 2016. This gives users, and industry personnel and false sense of what the technology has to offer the industry. The general consensus of the industry survey saw a majority of the samples being under the impression VR was used exclusively for client satisfaction and architectural uses you project and visualise projects. Table 11 established VR offer the greatest ability to users using the technology for productivity and safety simulation.

The knowledge gap in the section between all samples varied from the productivity literature by 19%, followed by VR methodology at 13%, with the third highest ranked variation as BIM productivity (which is directly related to VR productivity) at 11%.

Figure 28 shows simply how VR can be used to establish safety zones, flagging any potential issues before they arise on site and cause injury, and figure 29 shows how the simulation can project works on site to establish the most productive methods labour force can follow to complete the tasks with figure 30 simulated fasted method of task for productivity.

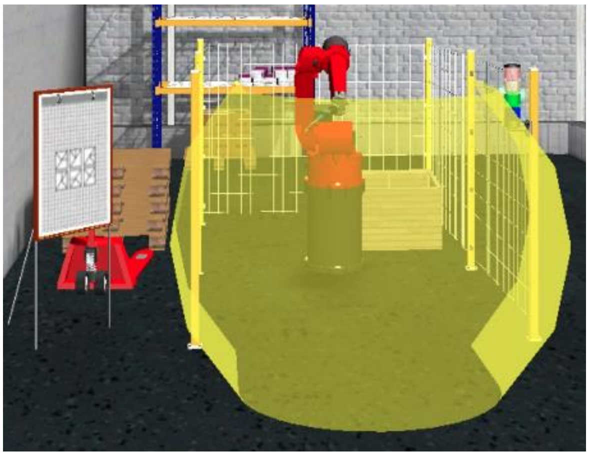

Figure 32 - VR for Safety

(IFA, 2018)

Figure 33 - VR for Productivity

(Hypergrid Technology, 2014)

Implementing these methods has the potential to result in far greater in the productivity evaluation to offer efficiency, greater profit, and less on-site incidents and should be heavily considered by management during the planning phase of a project.

4.3.4– Management Issues

It is suggested the management methods have a large impact on delaying the implementation of such technology. This statement is evident when considering the technological intelligence comparatively with age and experience in relation to the findings that the strategic management of commercial construction is perceived to be a leading aspect in slow implementation. Analysing appendix 2, a lack of strategic direction, and lack of trained staff scored highest overall technologies as the leading cause of implementation delay seen below:

Table 19 - Leading Perceived Implementation Impediments

Technology	First Impediment	%	Second Impediment	%
BIM	Lacked of trained staff	85	Lack of strategic management	80
VR	Lack of trained staff	87	Lack of strategic management	81
AR	Lack of strategic management	86	Lack of trained staff	84

Interestingly, these figures stay relatively similar among all demographics evaluated, excluding construction sectors, where is it established residential management are sceptical of the financial viability and are not using such programs due to resource restraints.

Residential Construction				
Technology	First Impediment	%	Second Impediment	%
BIM	Lacked of trained staff	85	Lack of strategic management	80
VR	Lack of trained staff	87	Lack of strategic management	81
AR	Lack of strategic management	86	Lack of trained staff	84
Commercial Construction				
Technology	First Impediment	%	Second Impediment	%
BIM	Lacked of trained staff	85	Lack of strategic management	80
VR	Lack of trained staff	87	Lack of strategic management	81
AR	Lack of strategic management	86	Lack of trained staff	84

Forming the leading impediments information scarcity and corporate vision gives indication that the industry would greatly benefits by reducing the knowledge gap and improving management methods in order to create a paradigm shift in the process to approaching construction related tasks through training.

4.3.5 – Training

Interestingly, implementation impediments appear to portray notable disproportionate variance when cross-analysing demographical construction sectors. Specifically, the residential attitude in contrast commercial views shows evidence of higher agreeableness, though failing due to financial uncertainty, rather than the lack of strategic management of the latter. This finding at face value, could suggest two plausible hypotheses; that residential management are failing to comprehend the rule of proportionality recognised in the current literature; and/or that commercial management, are currently lacking the resources and direction required to develop. This however, directly contradicts the findings of performance perceptions and perceived necessity seen in table 21. A further conceivable concept to consider is that the residential subjects are collectively, and unknowingly complying with rules of psychological scarcity with current standards providing lack of sufficient equipment, which could result in the misrepresentation of data shown. Again, the nature of the theory poses serious questions to this ideation when analysed holistically (see figure 19). Therefore, under subjective analysis, the scattered data presents it is reasonable to assume that the industry, as a whole, requires an updated structured training program in order to remain relevant with the emerging modelling and transforming digitalisation.

There is an evolutionary tendency when faced with simplistic results like these, to become overly enthusiastic about a single solution to a tenacious problem. Experience should tell us that such problems rarely yield to a simple remedy. That is no doubt the truth in this case. The boundaries of implementation impediments are far more complex than a standard blanket approach. Before we can be certain of an archetypal training program, much more research is needed to determine the ideal frequency, size, approach and sectors, in which development strategies are most effective. We must also establish the best ways for teachers to institute new methods – provided we institute them at all.

Finally, we must realise the major impediments within the ACI with respect to emerging technology, is ironically complicated by the speed in which it is developing itself. Although establishing the necessity for updated personalised programs is important, the question is then posed on how to better manage individuals in order to increase overall efficiency whilst developing alongside the technology bubble. Therefore, we could propose regulatory programs at intervals congruent with those of the program updates, seen in 2.5.1, as biannually.

4.4 – Negative Aspects Of Implementation

Addressing section 1.3.1 (8), the implementation of BIM, VR, and AR, are not expected to be transitioned into construction culture without a level of revolt. Take for instance the integrated BIM, VR system evaluated throughout the literature. Theoretical studies by Stanford Universities Faculty of Engineering, and further validated through the case studies of RMIT, provide evidence of eliminating unbudgeted change by 40%, reducing quantity surveying and contract administration task durations by up to 80%, and reducing the cost and length of projects by 10% and 7% respectively (USQ, 2017). Further integrating smart contract programming then adds to the reduction of lawyers required for standard form contracts considerably. Then reflect on robotics; as seen in section 3, operational products have increased production by upwards of 300%. Is this good? Not always. It is important to establish that the marginal variances are mathematically derived in comparison to human labour. The technological movement to acquire exceptional ROI, and proportional tax savings from government projects, is also a movement towards professional insignificants.

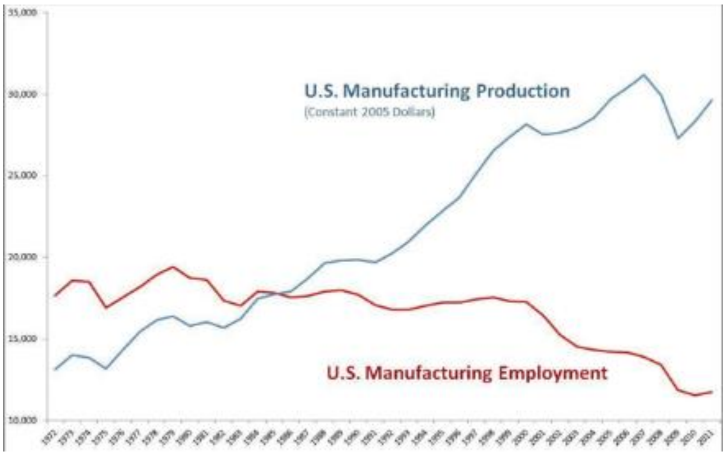

Figure 34 - Automations effect on labour

(David, H, 2015)

Due to this, we may see implementation of automation in the construction industry hindered significantly from employment relations unions, and if not, would certainly require constant transition and professional development coaching (seen in section 4.3.5) in order to stay relevant.

4.5 – Future studies

The findings throughout this report present a number of important factors that are indirectly related to this professional relevance verse technological displacement balance, that call for further investigation. Specifically, the major factors that have been found, and left unconsulted throughout this dissertation are as follows:

- The use of virtual reality simulation for project safety and productivity
- Automation of smart contacts for construction projects
- The use of augmented reality to reduce contingency costs
- The use of virtual reality for educational exposure training
- Reducing procurement costs using BIM automation
- Enhancing technological strategic management in commercial construction
- The benefits and implications of implementing BIM in residential construction
- Case Study: Using integrated BIM, VR & AR to increase performance

Chapter Five – Conclusive summary

As of 2018, the Australian construction industry is slowly beginning to embrace the technological change. This is prevalent throughout the civil sector and is anticipated to manifest its way throughout the industry as integration and bandwidth evolves in accordance with Moore's laws. This projecting acceptance of technology of the integrated systems is congruent with a perceived ease of use and usefulness of operation program, known as the Technology Acceptance Model (TAM). This model suggest that system usage is due to the stated factors in addition to attitude, intention and external variables (Howard, R., Restrepo, L. and Chang, C.Y., 2017).

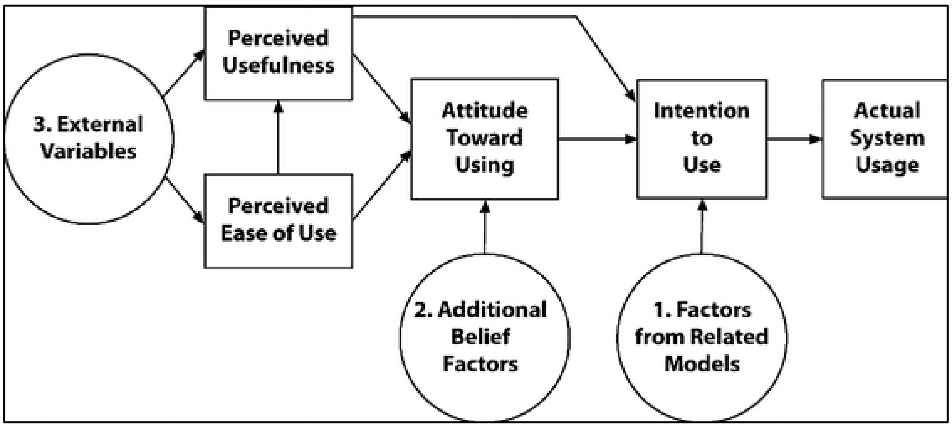

Figure 35 - Technology Acceptance Framework

(Marangunić, N, Granić, A, 2015)

This model can be used to justify historic events, as well as predicting future application and development of programs. Over the four decades we have seen the creation of predominantly every modern technology we use in modern day business. We are now completely tasks at a much faster rate, with far better accuracy.

The technological advancement projected to influence performance, methodology and productivity in over the next decade, in accordance with the TAM such as BIM, VR and AR and will revolutionise safety, labour efficiency, miscommunications and programming to decrease project time and cost. Already in the past decade we have recorded notable increases in the quest to enhance construction projects through digital platforms.

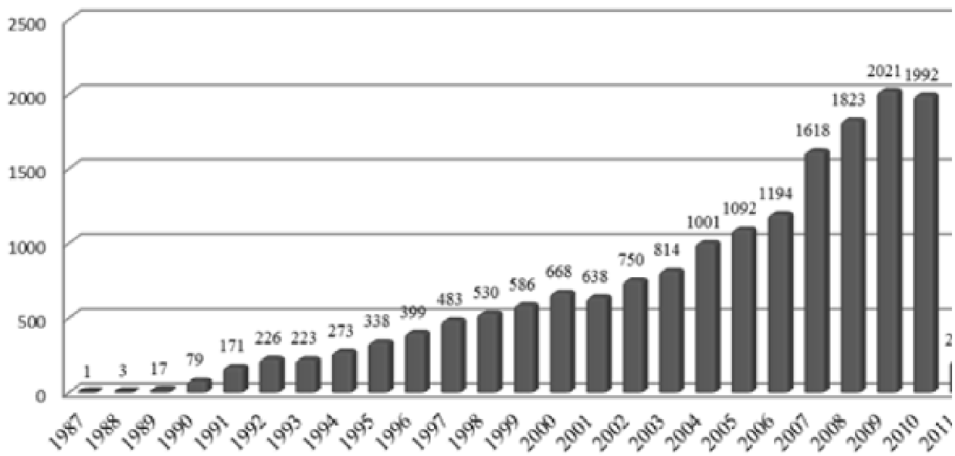

Figure 36 - Technological Construction Papers Over Time

(Skibniewski, M.J. and Zavadskas, E.K., 2013).

The important finding are based upon how these technologies will influence certain subsections of the industry, and what we should to focusing on in terms on education is summarised below.

5.1 – Building Information Modelling

Building Information Technology is currently leading the industry in terms on execution from the majority. The programs are of widespread application and can affect a project on multiple levels of the performance, methodology and productivity. By using these programs, the performance of companies are projected to increase significantly with a reduction of cost and decrease in lifespan. The decreased timeframe is primarily due to the process in which both management methodologies, and on site tasks can be preformed to a much more efficient degree through automation and simulation techniques. Of the evaluated tools, the industry had a much better understanding of BIM, though more information needs to be directed towards the productivity aspects and visualisation attributes, rather then the well-known estimation abilities.

5.2 – Virtual Reality

Virtual reality has been progressively cementing its aura within the industry, as integration with BIM has developed substantially over the past decade and is projected to influence projects within the next 2 years (2020), specifically with reference to the productivity strand of analysis. The programs have gained traction due under the presumption of their ability to project plans effectively for stakeholder, dramatically increasing satisfaction and performance, though this is a misguided representation of the functional ability. VR is projected to greatly enhance project productivity using such devices as site safety inspection, and simulation of ‘fasted method' tasks to increase labour on site. The visualisation aspect of both VR and AR also offer management a method to crosscheck methodology in order to decrease unforeseen events and validate clash detection assumptions.

5.3 – Augmented Reality

Augmented Reality requires a highly level of integration, calibration, and pre-construction planning. The technology offer offers a limited simulation function in comparison to VR and is seen as a more pragmatic approach to improvement and thus, is projected implementation will occur at a slower rate to its relative. After 2020, it foreseen that many projects with be using AR technology to enhance inspections, defect rectification, and safety precautions, in sense reducing costs and time required for re works. This is to say, the AR will greatly affect productivity and on site (rather than management) methodology. In order to establish itself as an industry standard application, a higher level of programmable integration is required between AR and both VR and BIM, as well as a higher level of understanding amongst the industry.

5.4 – Conclusion

Educational practice is currently aiding in closing the industry knowledge gap, and further developing technical aspects of the programs, but with the exponential growth of Moore's Law at play, industry professionals will be required to constantly monitor and develop their methods through extensive training in order to offer the most up to date resources in order to further increase construction project performance, methodologies and productivity. Due to this, it is concluded the hypothesis of this report, has been partially proved correct in that the construction management industry, certainly requires more extensive and practical training with respect the three established emerging technologies addressed, due to the discovered 10.7% knowledge gap deviation derived through the industry survey of 22 samples.

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October 1

Appendix One– Survey Questionnaire

University Of Southern Queensland

Evaluating The Impact of New Technology on Construction Project Performance, Methodologies and Productivity

You are invited to take part in a research project evaluating the use of emerging construction technology to enhance project performance. This study is being undertaken by Jace Thimios and will contribute to a thesis for the completion of a Bachelors of Construction Management.

This study will ask you to complete an online survey at your own pace and with consent. The 54 survey questions aim to establish the general industry consensus, and demographical differences of technology implementation within the industry through a structured questionnaire related to key components of performance.

To partake in this study you must be working within the construction industry, performing tasks related to management, planning, costing, controlling etc. If you know anybody who would be willing to partake in this study, please feel free to pass on the information/link.

All responses and contact details will be strictly anonymous. The data from the study will be used in research publications and reports in table and graph form. If you have any questions about the study, please contact Jace Thimios (Principal Investigator) or Nateque Mahmood (Supervisor).

Principal Investigator: Jace Thimios
University: University Of Southern Queensland
Faculty: Health, Engineering & Science (Engineering & Surveying)
Email: [redacted]umail.usq.edu.au

Below are optional videos that may help further your understanding of building information modelling, virtual reality, and augmented reality:

Building Information Modelling (BIM) - https://www.youtube.com/watch?v=suNadRnHy-U

Virtual reality (VR) and Augmented reality (AR): For construction - https://www.youtube.com/watch?v=8lY4qaVvR8c

Virtual reality (VR) and Augmented reality (AR): For design -https://www.youtube.com/watch?v=ESBNmW-9Hgk

How Augmented reality (AR) works - https://www.youtube.com/watch?v=HprQbTlYHuQ

* Required

Demographical Data

1. **What is your gender?**
   Mark only one oval.

   - Male
   - Female

2. **What is your age?**
   Mark only one oval.

   - 20-30
   - 31-40
   - 41-50
   - 51-60
   - 61+

3. **How many years of experience do you have within the industry**
Mark only one oval.

- 1-5
- 6-10
- 11-15
- 16-20
- 21-30
- 31+

4. **What is the main sector of construction you work in?**
Mark only one oval.

- Residential
- Commercial
- Civil

5. **What position/title best suits your role?**
Mark only one oval.

- Construction Director
- Construction Manager
- Contract Admin
- Architect
- Estimator
- Engineer
- Builder
- Sales, Marketing
- Other

6. **What is your highest education attainment?**
Mark only one oval.

- High school - year 10
- High school - year 12
- TAFE diploma
- University degree
- Post-graduate degree (masters, PhD etc)

Industry Evaluation

7. **I could, in my workplace, use BIM to decrease timeframe** *
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

8. **I could, in my workplace, use BIM to increase customer satisfaction**

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

9. **I could, in my workplace, use BIM to decrease project costs**

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

10. **I could, in my workplace, use BIM to increase safety**

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

11. **I could, in my workplace, use BIM to increase labour efficiency**

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

12. **I could, in my workplace, use BIM to decrease miscommunications**

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

13. **I could, in my workplace, use BIM for costing projects**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

14. **I could, in my workplace, use BIM for project planning and workflow**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

15. **I could, in my workplace, use BIM to benefit documentation**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

16. **I could, in my workplace, use VR to decrease timeframe**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

17. **I could, in my workplace, use VR to increase customer satisfaction**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

18. **I could, in my workplace, use VR to decrease project costs**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

19. **I could, in my workplace, use VR to increase safety**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

20. **I could, in my workplace, use VR to increase labour efficiency**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

21. **I could, in my workplace, use VR to decrease miscommunications**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

22. **I could, in my workplace, use VR for costing projects**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

23. **I could, in my workplace, use VR for project planning and workflow**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

24. **I could, in my workplace, use VR to benefit documentation**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

25. **I could, in my workplace, use AR to decrease timeframe**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

26. **I could, in my workplace, use AR to increase customer satisfaction**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

27. **I could, in my workplace, use AR to decrease project costs**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

28. **I could, in my workplace, use AR to increase safety**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

29. **I could, in my workplace, use AR to increase labour efficiency**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

30. **I could, in my workplace, use AR to decrease miscommunications**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

31. **I could, in my workplace, use AR for costing projects**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

32. **I could, in my workplace, use AR for project planning and workflow**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

33. **I could, in my workplace, use AR to benefit documentation**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Implementation Impediments

34. **I believe I have sufficient background knowledge of BIM**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

35. **I believe BIM could positively impact my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

36. **I believe implementing BIM is financially viable in my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

37. **I believe there is a lack of trained BIM staff in my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

38. **I believe BIM will influence my future workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

39. **I believe BIM is not a requirement for my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

40. **I believe there is a lack of strategic direction at my workplace with respect to BIM**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

41. **I believe I have sufficient background knowledge of VR**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

42. **I believe VR could positively impact my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

43. **I believe implementing VR is financially viable in my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

44. **I believe there is a lack of trained VR staff in my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

45. **I believe VR will influence my future workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

46. **I believe VR is not a requirement for my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

47. **I believe there is a lack of strategic direction with reseat my workplace with respect to VR**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

48. **I believe I have sufficient background knowledge of AR**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

49. **I believe AR could positively impact my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

50. **I believe implementing AR is financially viable in my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

51. **I believe there is a lack of trained AR staff in my workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

52. **I believe AR will influence my future workplace**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

53. **I believe AR is not a requirement for my workplace**

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

54. **I believe there is a lack of strategic direction at my workplace with respect to AR**

Mark only one oval.

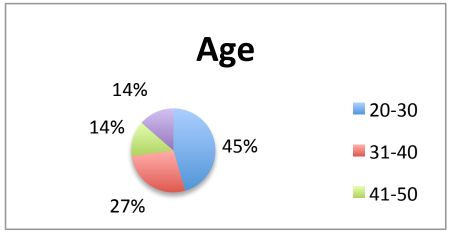
- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

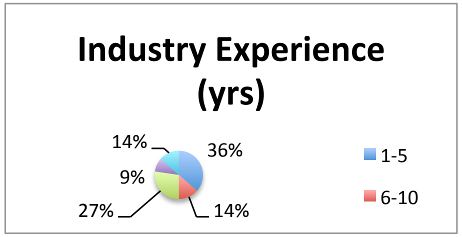
October 1

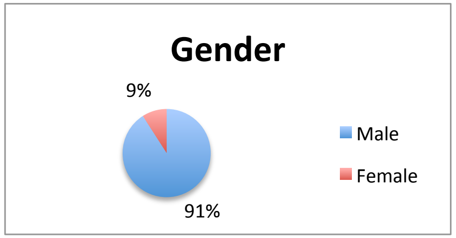
Appendix Two– Survey Results

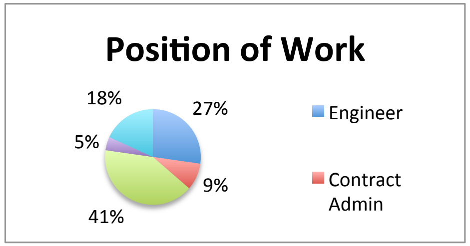
Demographical Breakdown of Participants - Emerging Technologies

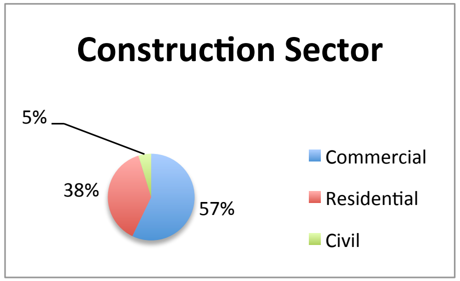
Age (Yrs)	20-30	10	45.45%
	31-40	6	27.27%
	41-50	3	13.64%
	51-60	3	13.64%
	Total	22	100.00%
Experience (Yrs)	1-5	8	36.36%
	6-10	3	13.64%
	11-15	6	27.27%
	16-20	2	9.09%
	21-30	3	13.64%
	Total	22	100.00%
Sector	Commercial	12	57.14%
	Residential	8	38.10%
	Civil	1	4.76%
	Total	21	100.00%
Position	Engineer	6	27.27%
	Contract Admin	2	9.09%
	Construction Manager	9	40.91%
	Construction Director	1	4.55%
	Architect	4	18.18%
	Total	22	100.00%
Education	TAFE diploma	2	9.09%
	University degree	19	86.36%
	Post-graduate degree (masters, PhD etc)	1	4.55%
	Total	22	100.00%
Gender	Male	20	90.91%
	Female	2	9.09%
	Total	22	100.00%

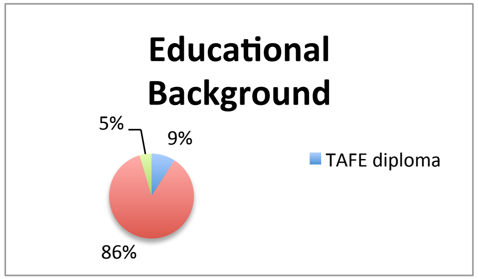








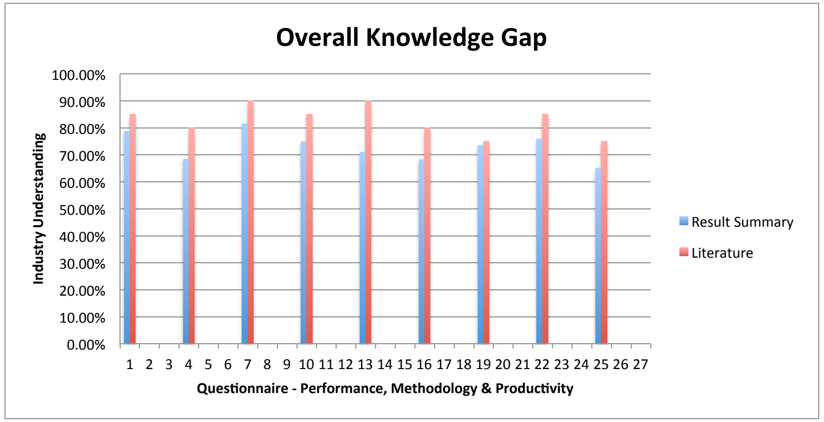




Overall Survey Results

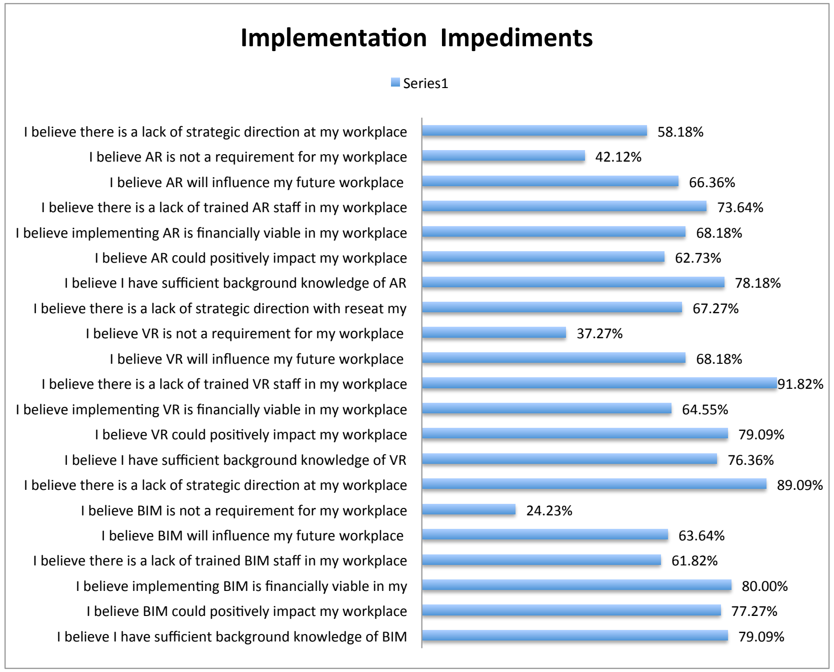
Questionnaire Overview

Reasoning	Description	Results	Result Summary	Literature	Difference
Performance	Question 1	79.09%	78.79%	85.00%	6.21%
	Question 2	77.27%			
	Question 3	80.00%			
Productivity	Question 4	61.82%	68.49%	80.00%	11.51%
	Question 5	63.64%			
	Question 6	80.00%			
Methodology	Question 7	89.09%	81.51%	90.00%	8.49%
	Question 8	76.36%			
	Question 9	79.09%			
Performance	Question 10	64.55%	74.85%	85.00%	10.15%
	Question 11	91.82%			
	Question 12	68.18%			
Productivity	Question 13	67.27%	70.91%	90.00%	19.09%
	Question 14	67.27%			
	Question 15	78.18%			
Methodology	Question 16	62.73%	68.18%	80.00%	11.82%
	Question 17	68.18%			
	Question 18	73.64%			
Performance	Question 19	66.36%	73.33%	75.00%	1.67%
	Question 20	95.45%			
	Question 21	58.18%			
Productivity	Question 22	70.91%	75.76%	85.00%	9.24%
	Question 23	69.09%			
	Question 24	87.27%			
Methodology	Question 25	60.00%	65.15%	75.00%	9.85%
	Question 26	66.36%			
	Question 27	69.09%			



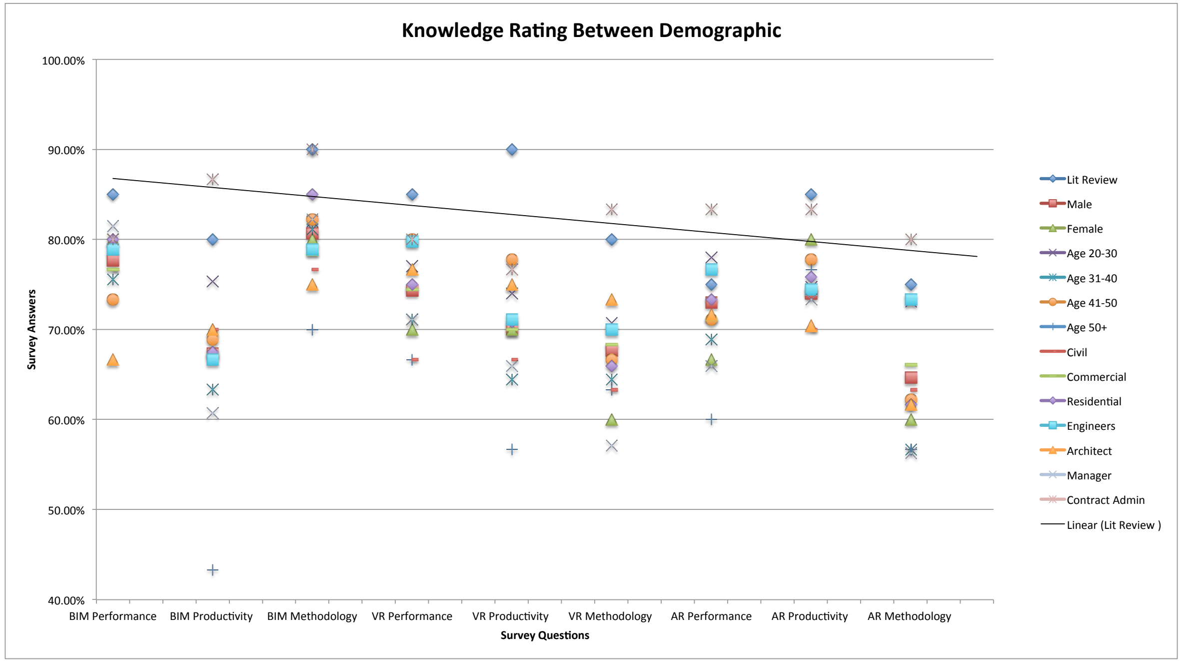
OVERALL IMPLEMENTATION IMPEDIMENTS

	Questions	Results
BIM	I believe I have sufficient background knowledge of BIM	79.09%
	I believe BIM could positively impact my workplace	77.27%
	I believe implementing BIM is financially viable in my workplace	80.00%
	I believe there is a lack of trained BIM staff in my workplace	61.82%
	I believe BIM will influence my future workplace	63.64%
	I believe BIM is not a requirement for my workplace	24.23%
	I believe there is a lack of strategic direction at my workplace with respect to BIM	89.09%
VR	I believe I have sufficient background knowledge of VR	76.36%
	I believe VR could positively impact my workplace	79.09%
	I believe implementing VR is financially viable in my workplace	64.55%
	I believe there is a lack of trained VR staff in my workplace	91.82%
	I believe VR will influence my future workplace	68.18%
	I believe VR is not a requirement for my workplace	37.27%
	I believe there is a lack of strategic direction with reseat my workplace with respect to VR	67.27%
AR	I believe I have sufficient background knowledge of AR	78.18%
	I believe AR could positively impact my workplace	62.73%
	I believe implementing AR is financially viable in my workplace	68.18%
	I believe there is a lack of trained AR staff in my workplace	73.64%
	I believe AR will influence my future workplace	66.36%
	I believe AR is not a requirement for my workplace	42.12%
	I believe there is a lack of strategic direction at my workplace with respect to AR	58.18%



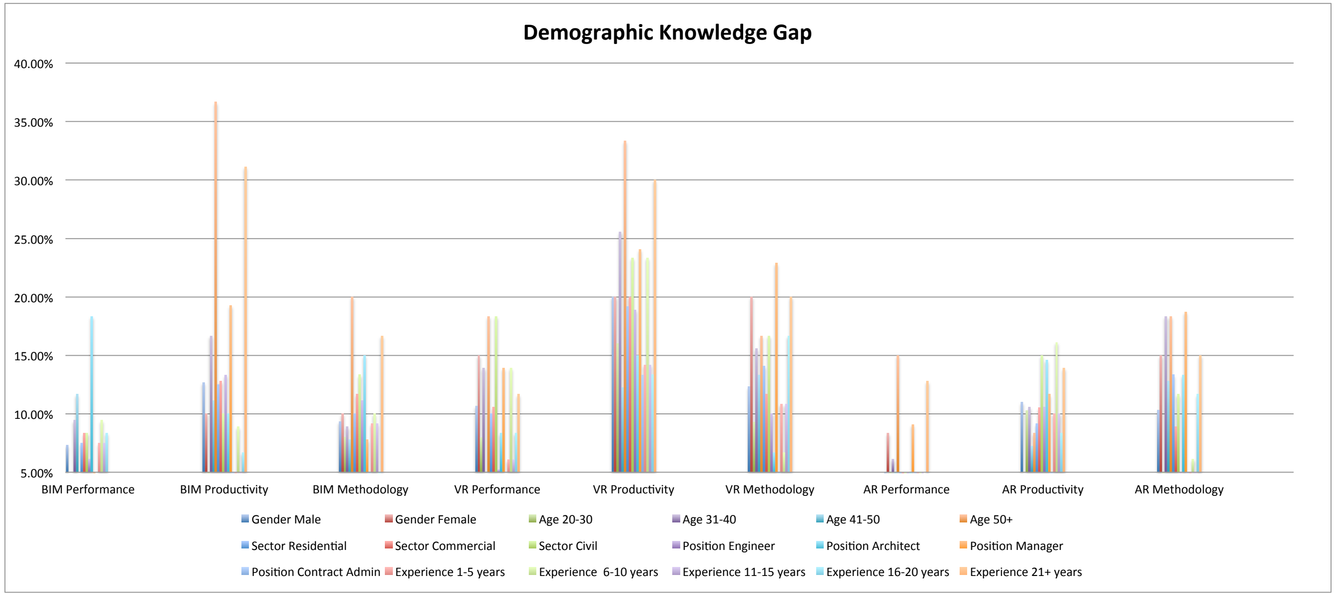
Overall Knowledge Breakdown

	Lit Review	Male	Female	Age 20-30	Age 31-40	Age 41-50	Age 50+	Civil	Commercial	Residential	Engineers	Architect	Manager	Contract Admin
BIM Performance	85.00%	77.67%	80.00%	80.00%	75.56%	73.33%	80.00%	76.67%	76.67%	80.00%	78.89%	66.67%	81.48%	80.00%
BIM Productivity	80.00%	67.33%	70.00%	75.33%	63.33%	68.89%	43.33%	70.00%	67.22%	67.50%	66.67%	70.00%	60.74%	86.67%
BIM Methodology	90.00%	80.67%	80.00%	82.00%	81.11%	82.22%	70.00%	76.67%	78.33%	85.00%	78.89%	75.00%	82.22%	90.00%
VR Performance	85.00%	74.33%	70.00%	77.04%	71.11%	80.00%	66.67%	66.67%	74.44%	75.00%	79.78%	76.67%	71.11%	80.00%
VR Productivity	90.00%	70.00%	70.00%	74.00%	64.44%	77.78%	56.67%	66.67%	70.00%	70.83%	71.11%	75.00%	65.93%	76.67%
VR Methodology	80.00%	67.68%	60.00%	70.73%	64.44%	66.67%	63.33%	63.33%	68.33%	65.94%	70.00%	73.33%	57.12%	83.33%
AR Performance	75.00%	73.00%	66.67%	78.00%	68.89%	71.11%	60.00%	76.67%	71.11%	73.33%	76.67%	71.67%	65.93%	83.33%
AR Productivity	85.00%	74.02%	80.00%	74.73%	74.44%	77.78%	76.67%	70.00%	74.49%	75.83%	74.44%	70.42%	73.33%	83.33%
AR Methodology	75.00%	64.67%	60.00%	73.11%	56.67%	62.22%	56.67%	63.33%	66.11%	61.67%	73.33%	61.67%	56.30%	80.00%



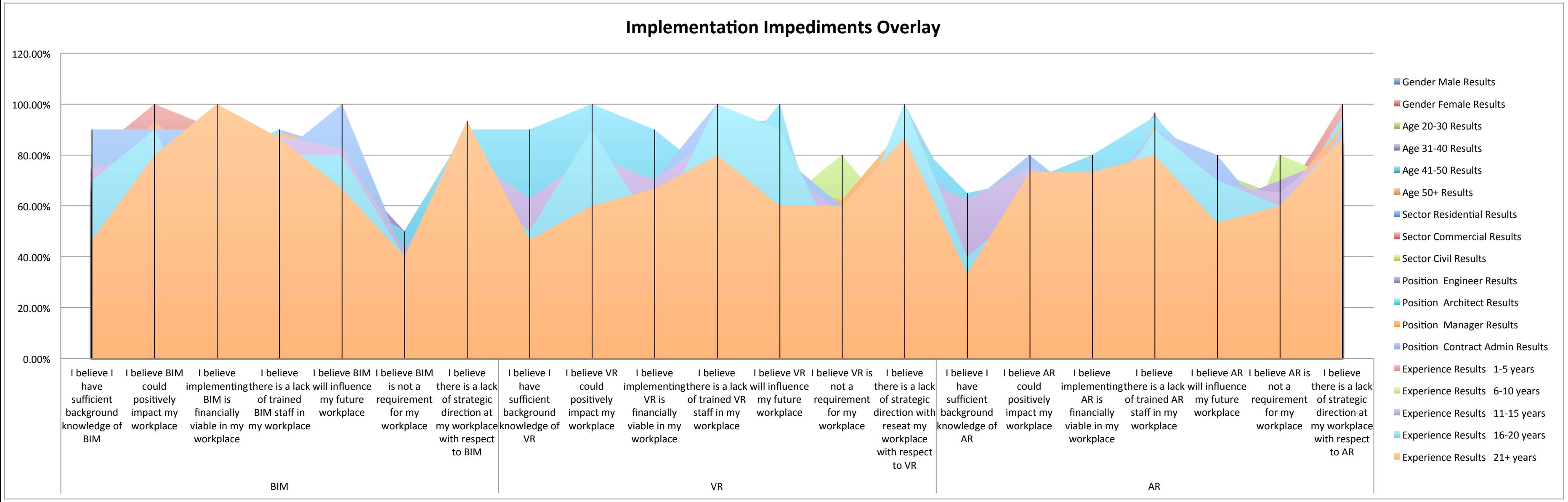
Overall Knowledge Gap

	Gender		Age				Sector			Position				Experience				
	Male	Female	20-30	31-40	41-50	50+	Residential	Commercial	Civil	Engineer	Architect	Manager	Contract Admi	1-5 years	6-10 years	11-15 years	16-20 years	21+ years
BIM Performance	7.33%	5.00%	5.00%	9.44%	11.67%	5.00%	7.50%	8.33%	8.33%	6.11%	18.33%	3.52%	5.00%	7.50%	9.44%	7.50%	8.33%	5.00%
BIM Productivity	12.67%	10.00%	4.67%	16.67%	11.11%	36.67%	12.50%	12.78%	10.00%	13.33%	10.00%	19.26%	-6.67%	4.07%	8.89%	4.07%	6.67%	31.11%
BIM Methodology	9.33%	10.00%	8.00%	8.89%	7.78%	20.00%	10.00%	11.67%	13.33%	11.11%	15.00%	7.78%	0.00%	9.17%	10.00%	9.17%	3.33%	16.67%
VR Performance	10.67%	15.00%	7.96%	13.89%	5.00%	18.33%	10.00%	10.56%	18.33%	5.22%	8.33%	13.89%	5.00%	6.07%	13.89%	6.07%	8.33%	11.67%
VR Productivity	20.00%	20.00%	16.00%	25.56%	12.22%	33.33%	19.17%	20.00%	23.33%	18.89%	15.00%	24.07%	13.33%	14.17%	23.33%	14.17%	13.33%	30.00%
VR Methodology	12.32%	20.00%	9.27%	15.56%	13.33%	16.67%	14.06%	11.67%	16.67%	10.00%	6.67%	22.88%	-3.33%	10.83%	6.67%	10.83%	16.67%	20.00%
AR Performance	2.00%	8.33%	-3.00%	6.11%	3.89%	15.00%	1.67%	3.89%	-1.67%	-1.67%	3.33%	9.07%	-8.33%	-0.83%	-0.56%	-0.83%	5.00%	12.78%
AR Productivity	10.98%	5.00%	10.27%	10.56%	7.22%	8.33%	9.17%	10.51%	15.00%	10.56%	14.58%	11.67%	1.67%	10.00%	16.11%	10.00%	8.33%	13.89%
AR Methodology	10.33%	15.00%	1.89%	18.33%	12.78%	18.33%	13.33%	8.89%	11.67%	1.67%	13.33%	18.70%	-5.00%	4.52%	6.11%	4.52%	11.67%	15.00%

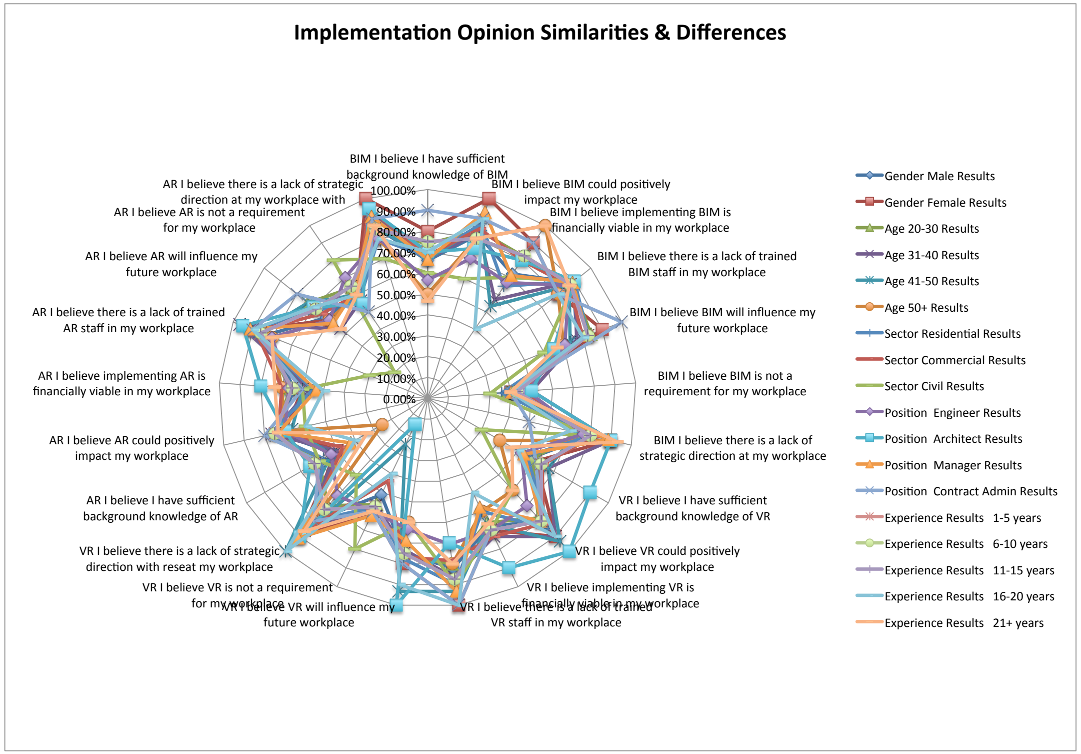


Implementation Overview

Technology	Questions	Gender		Age				Sector			Position		
		Male Results	Female Results	20-30 Results	31-40 Results	41-50 Results	50+ Results	Residential Results	Commercial Results	Civil Results	Engineer Results	Architect Results	Manager Results
BIM	I believe I have sufficient background knowledge of BIM	66.00%	80.00%	74.00%	66.67%	66.67%	50.00%	67.50%	68.33%	60.00%	56.67%	70.00%	66.67%
	I believe BIM could positively impact my workplace	82.00%	100.00%	84.00%	83.33%	86.67%	80.00%	87.50%	85.00%	60.00%	70.00%	75.00%	93.33%
	I believe implementing BIM is financially viable in my workplace	72.05%	90.00%	82.00%	57.22%	53.33%	100.00%	65.00%	80.14%	70.00%	67.22%	80.00%	71.11%
	I believe there is a lack of trained BIM staff in my workplace	89.00%	80.00%	88.00%	90.00%	86.67%	80.00%	90.00%	86.67%	90.00%	86.67%	90.00%	88.89%
	I believe BIM will influence my future workplace	77.05%	90.00%	84.22%	76.67%	73.33%	70.00%	82.50%	80.00%	60.00%	70.67%	65.00%	82.22%
	I believe BIM is not a requirement for my workplace	40.11%	40.00%	38.00%	50.00%	42.22%	40.00%	35.63%	45.00%	30.00%	48.00%	50.00%	40.25%
	I believe there is a lack of strategic direction at my workplace with respect to BIM	80.00%	90.00%	74.00%	90.00%	73.33%	90.00%	80.00%	81.67%	80.00%	76.67%	90.00%	88.89%
VR	I believe I have sufficient background knowledge of VR	57.00%	60.00%	57.78%	66.67%	66.67%	40.00%	55.00%	63.33%	30.00%	52.00%	90.00%	53.33%
	I believe VR could positively impact my workplace	80.00%	90.00%	78.00%	90.00%	93.33%	60.00%	85.00%	81.67%	60.00%	70.00%	100.00%	80.00%
	I believe implementing VR is financially viable in my workplace	68.00%	70.00%	66.00%	73.33%	66.67%	60.00%	60.00%	73.33%	70.00%	70.00%	90.00%	57.78%
	I believe there is a lack of trained VR staff in my workplace	82.05%	100.00%	80.20%	86.67%	93.33%	80.00%	90.00%	78.47%	90.00%	70.56%	70.00%	93.33%
	I believe VR will influence my future workplace	75.00%	80.00%	76.00%	73.33%	93.33%	60.00%	77.50%	76.67%	60.00%	63.33%	100.00%	68.89%
	I believe VR is not a requirement for my workplace	51.15%	60.00%	56.20%	56.67%	24.44%	60.00%	57.50%	43.75%	80.00%	60.00%	13.75%	62.22%
	I believe there is a lack of strategic direction with reseat my workplace with respect to VR	80.00%	90.00%	70.00%	86.67%	100.00%	80.00%	80.00%	86.67%	50.00%	63.33%	90.00%	91.11%
AR	I believe I have sufficient background knowledge of AR	52.05%	50.00%	60.00%	50.00%	53.33%	25.00%	57.50%	46.81%	60.00%	53.33%	65.00%	42.47%
	I believe AR could positively impact my workplace	74.00%	70.00%	74.00%	76.67%	66.67%	70.00%	77.50%	73.33%	60.00%	70.00%	70.00%	73.33%
	I believe implementing AR is financially viable in my workplace	64.00%	60.00%	66.00%	56.67%	60.00%	70.00%	55.00%	70.00%	60.00%	66.67%	80.00%	53.33%
	I believe there is a lack of trained AR staff in my workplace	83.00%	90.00%	84.44%	96.67%	86.67%	80.00%	90.00%	88.33%	30.00%	80.00%	95.00%	91.11%
	I believe AR will influence my future workplace	62.00%	60.00%	73.33%	53.33%	73.33%	60.00%	67.50%	65.00%	20.00%	60.00%	70.00%	57.78%
	I believe AR is not a requirement for my workplace	61.00%	60.00%	64.00%	56.67%	60.00%	60.00%	57.50%	60.00%	80.00%	70.00%	55.00%	62.22%
	I believe there is a lack of strategic direction at my workplace with respect to AR	86.00%	100.00%	84.00%	93.33%	86.67%	80.00%	80.00%	95.00%	70.00%	80.00%	95.00%	91.11%

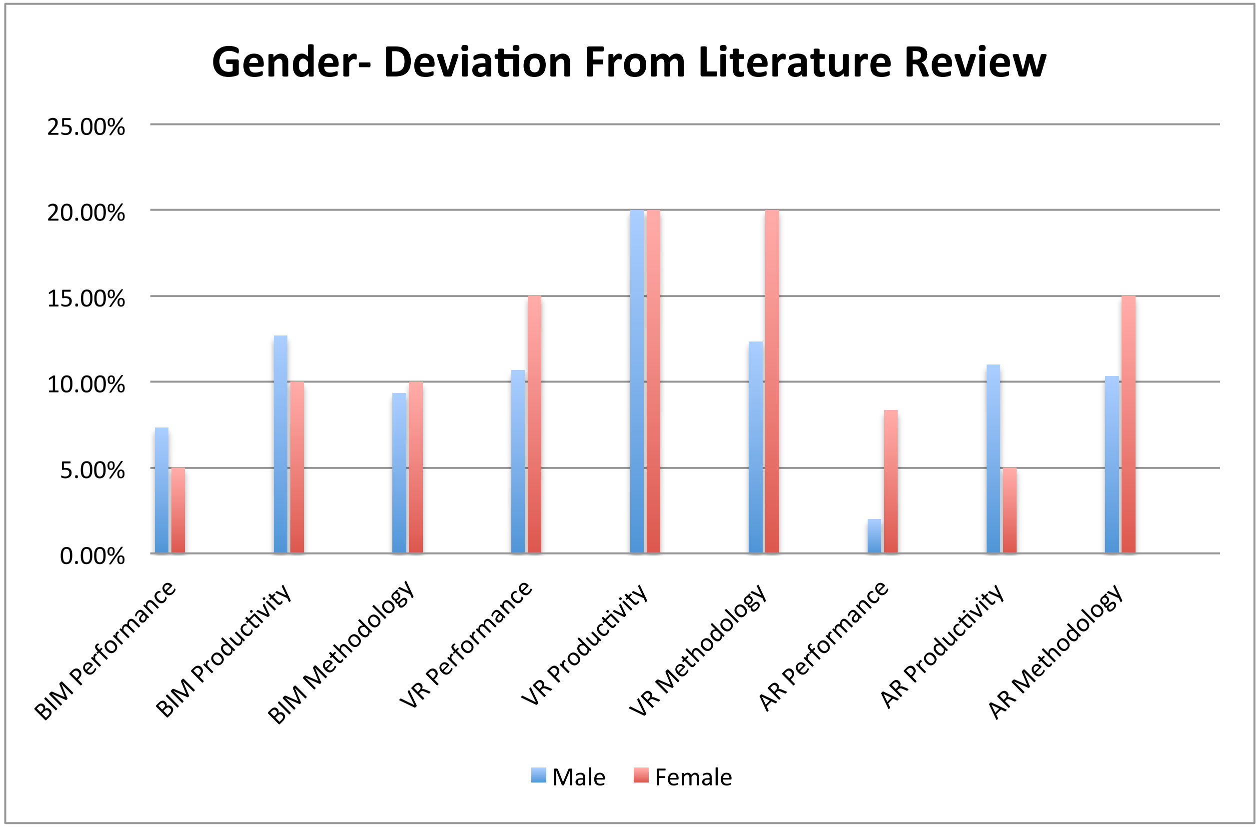


	Experience Results				
Contract Admin Results	**1-5 years**	**6-10 years**	**11-15 years**	**16-20 years**	**21+ years**
90.00%	75%	75%	75%	70%	47%
90.00%	80%	80%	80%	90%	80%
90.00%	83%	83%	83%	40%	100%
80.00%	88%	88%	88%	80%	87%
100.00%	83%	83%	83%	80%	67%
40.00%	43%	43%	43%	40%	40%
50.00%	80%	80%	80%	70%	93%
60.00%	63%	63%	63%	50%	47%
80.00%	80%	80%	80%	90%	60%
70.00%	70%	70%	70%	50%	67%
100.00%	88%	88%	88%	100%	80%
80.00%	75%	75%	75%	90%	60%
60.00%	58%	58%	58%	40%	60%
80.00%	73%	73%	73%	100%	87%
60.00%	63%	63%	63%	40%	33%
80.00%	75%	75%	75%	60%	73%
60.00%	65%	65%	65%	50%	73%
90.00%	86%	86%	86%	90%	80%
80.00%	69%	69%	69%	70%	53%
50.00%	65%	65%	65%	60%	60%
90.00%	85%	85%	85%	80%	87%



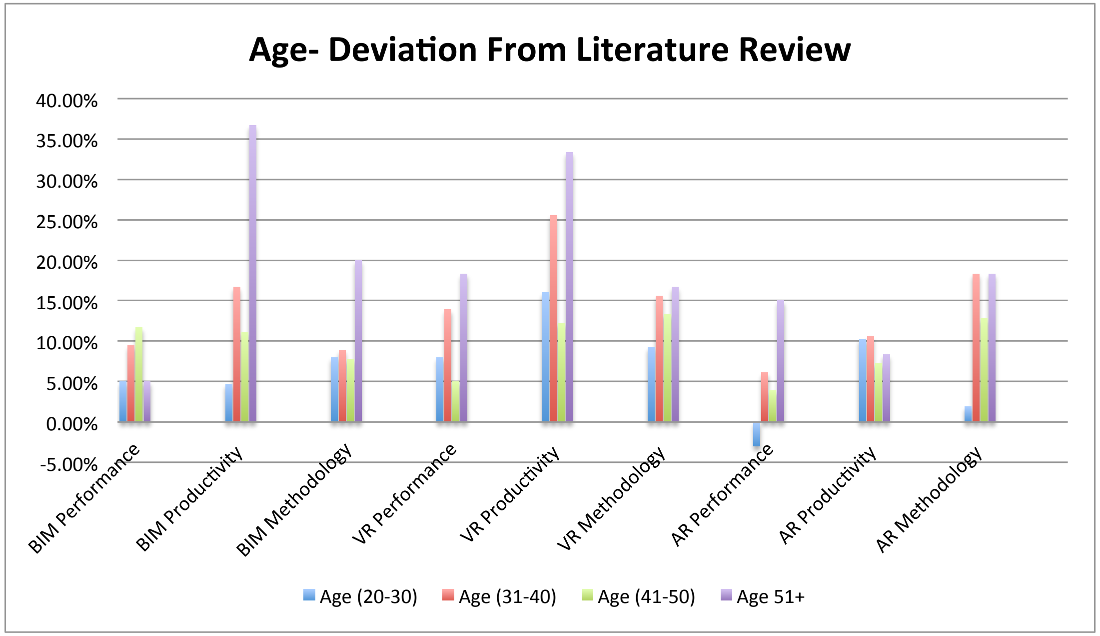
Gender Breakdown

	Male	Female
BIM Performance	7.33%	5.00%
BIM Productivity	12.67%	10.00%
BIM Methodology	9.33%	10.00%
VR Performance	10.67%	15.00%
VR Productivity	20.00%	20.00%
VR Methodology	12.32%	20.00%
AR Performance	2.00%	8.33%
AR Productivity	10.98%	5.00%
AR Methodology	10.33%	15.00%



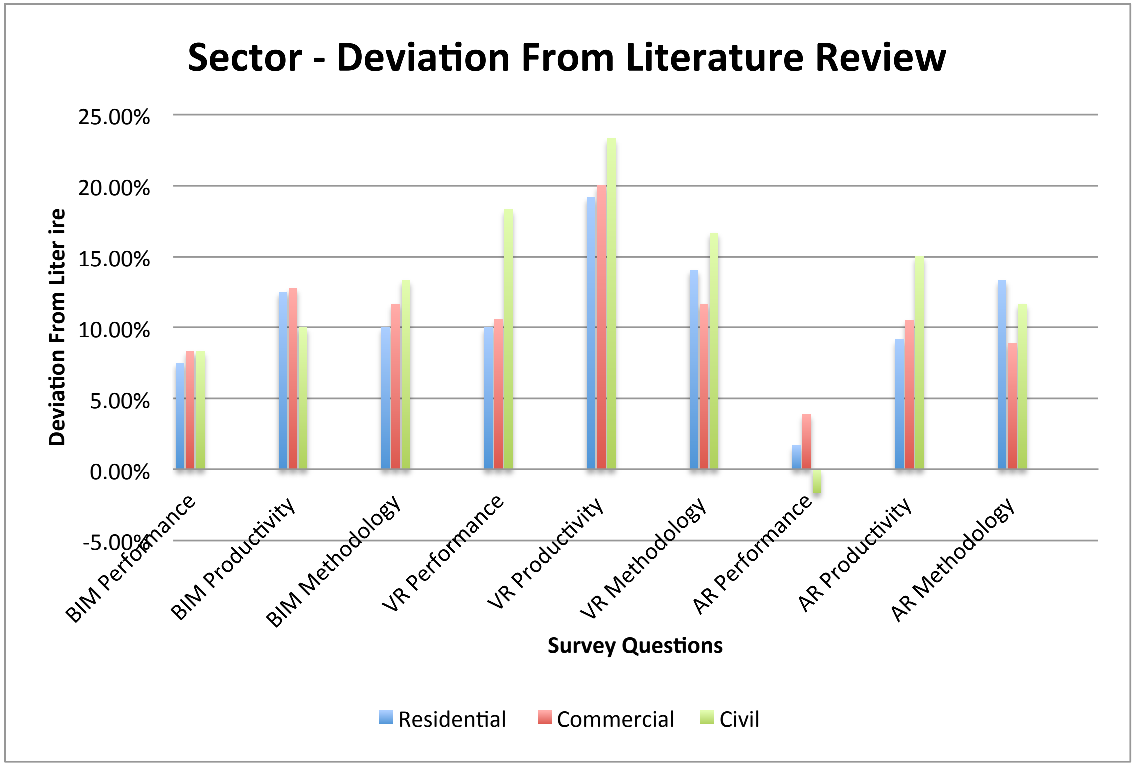
Age Breakdown

	Age (20-30)	Age (31-40)	Age (41-50)	Age 51+
BIM Performance	5.00%	9.44%	11.67%	5.00%
BIM Productivity	4.67%	16.67%	11.11%	36.67%
BIM Methodology	8.00%	8.89%	7.78%	20.00%
VR Performance	7.96%	13.89%	5.00%	18.33%
VR Productivity	16.00%	25.56%	12.22%	33.33%
VR Methodology	9.27%	15.56%	13.33%	16.67%
AR Performance	-3.00%	6.11%	3.89%	15.00%
AR Productivity	10.27%	10.56%	7.22%	8.33%
AR Methodology	1.89%	18.33%	12.78%	18.33%



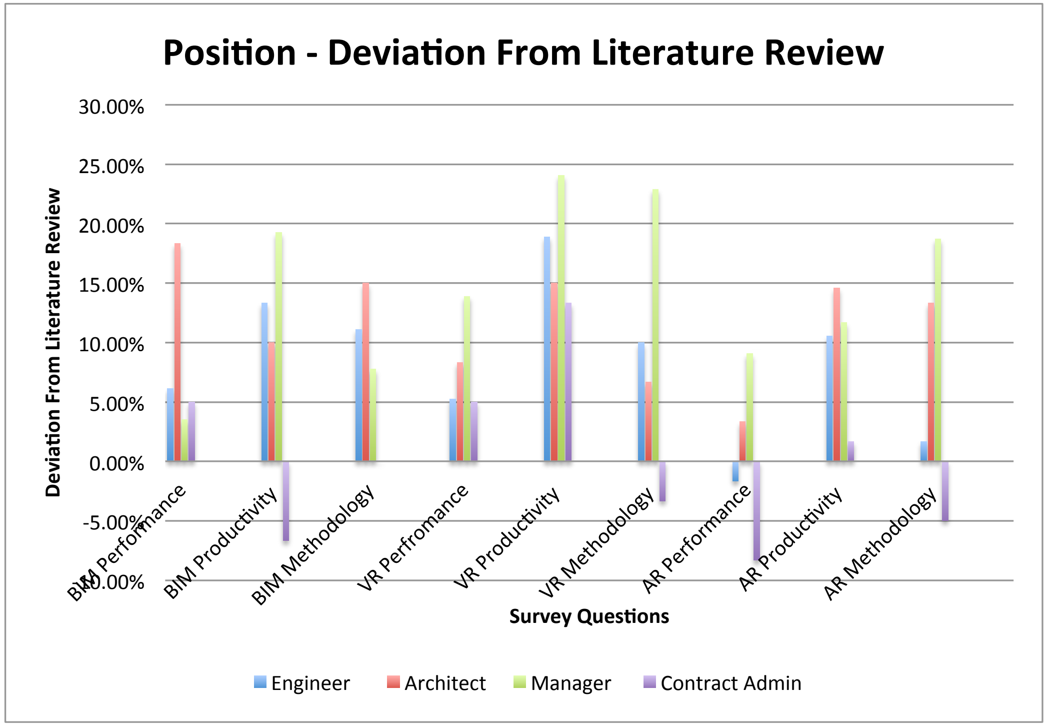
Sector Breakdown

	Residential	Commercial	Civil
BIM Performance	7.50%	8.33%	8.33%
BIM Productivity	12.50%	12.78%	10.00%
BIM Methodology	10.00%	11.67%	13.33%
VR Performance	10.00%	10.56%	18.33%
VR Productivity	19.17%	20.00%	23.33%
VR Methodology	14.06%	11.67%	16.67%
AR Performance	1.67%	3.89%	-1.67%
AR Productivity	9.17%	10.51%	15.00%
AR Methodology	13.33%	8.89%	11.67%



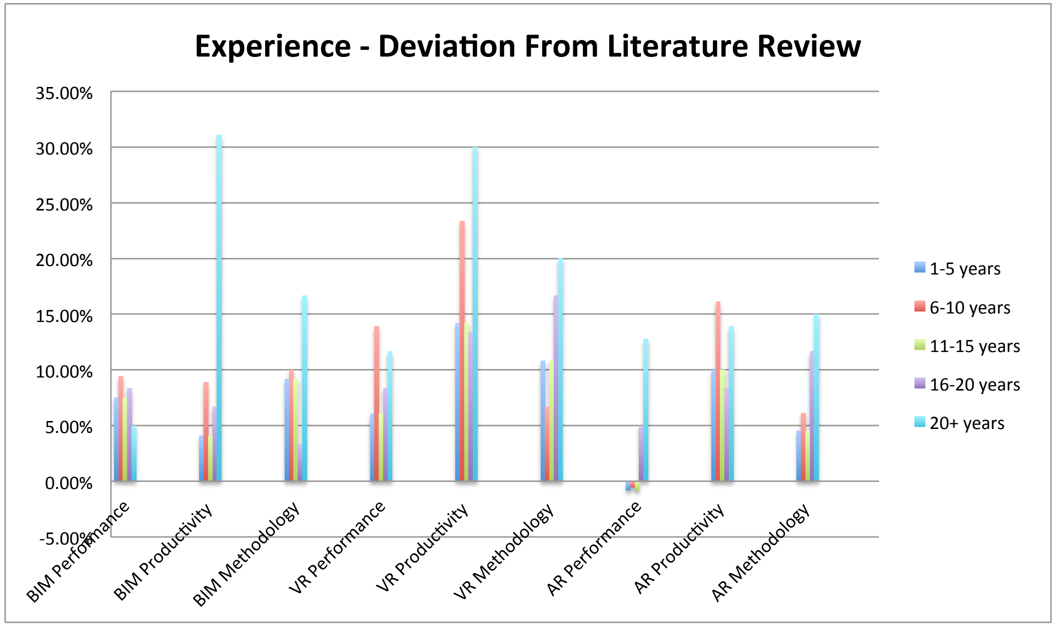
Position Breakdown

	Engineer	Architect	Manager	Contract Admin
BIM Performance	6.11%	18.33%	3.52%	5.00%
BIM Productivity	13.33%	10.00%	19.26%	-6.67%
BIM Methodology	11.11%	15.00%	7.78%	0.00%
VR Perfromance	5.22%	8.33%	13.89%	5.00%
VR Productivity	18.89%	15.00%	24.07%	13.33%
VR Methodology	10.00%	6.67%	22.88%	-3.33%
AR Performance	-1.67%	3.33%	9.07%	-8.33%
AR Productivity	10.56%	14.58%	11.67%	1.67%
AR Methodology	1.67%	13.33%	18.70%	-5.00%



Experience Breakdown

	1-5 years	6-10 years	11-15 years	16-20 years	20+ years
BIM Performance	7.50%	9.44%	7.50%	8.33%	5.00%
BIM Productivity	4.07%	8.89%	4.07%	6.67%	31.11%
BIM Methodology	9.17%	10.00%	9.17%	3.33%	16.67%
VR Performance	6.07%	13.89%	6.07%	8.33%	11.67%
VR Productivity	14.17%	23.33%	14.17%	13.33%	30.00%
VR Methodology	10.83%	6.67%	10.83%	16.67%	20.00%
AR Performance	-0.83%	-0.56%	-0.83%	5.00%	12.78%
AR Productivity	10.00%	16.11%	10.00%	8.33%	13.89%
AR Methodology	4.52%	6.11%	4.52%	11.67%	15.00%



October 1

Appendix Three – Resource Plan

University Of Sothern Queensland

For: Jace Thimios

Title: Evaluating the impact of new technology on construction project performance, methodology and productivity

Major: Construction Management

Supervisors: Nateque Mahmood

Enrolment: ENG4111, ENG4112

Project Aim: To increase knowledge and awareness of dramatic change modern and emerging technologies will have on the construction Industry.

Programme: Version 1 – March 13, 2018.

1. Review existing and developing technologies being used/projected to be used in the near future in relation to the impact it will have on the construction industry

2. Preform literature review to determine the technology that will likely influence the industry the most in the near future.

3. Review the emerging technology to evaluate its impact on methodology (planning and physical works incorporating safety)

4. Review the emerging technology to evaluate its impact on progress and time saving abilities

5. Review the emerging technology to evaluate its impact on overall performance of construction projects

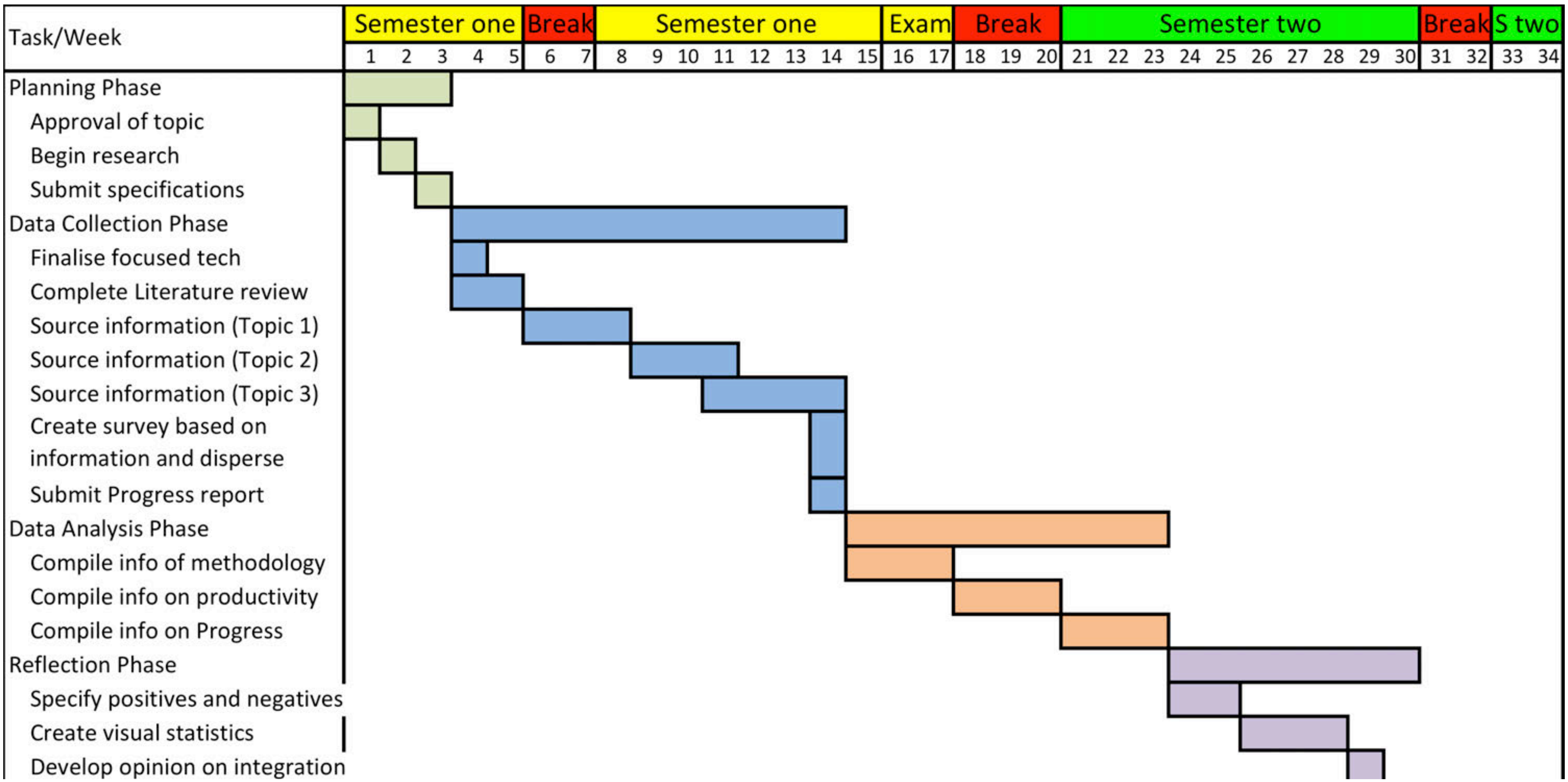
6. Create a questionnaire for people within the industry to visually depict general opinions of positive and negative benefits. review the data to create a number of statistical analysis'.

7. Make recommendation on future academia to incorporate such tech successfully

8. *If time and resources permit: Create BIM video representations for engagement*

ENG4111 Jace Thimios [redacted]

Timeline:



Resource Planning

To complete the works to a standard that is credible of reference, it has been elevated that the following items are essential within the report:

1. The current literature must be analysed
2. A detailed industry survey must be completed with an adequate sample size
3. An evaluation must summarise the two, giving direction to the industry, and to future studies

In order to ensure the evaluated items can be preformed successfully, the following resources are required.

Resource	**Location**	**Risk Evaluation**
Text books	Library	No risk
Journal Articles	Google scholar, Science direct, Reddit	Potential risk
Video dialog	Internet	Potential risk
Internet Access	All locations	No risk
Industry Network	Work, University, Industry peers	Risk
Microsoft Word	All locations	No risk
Microsoft Excel	All locations	No risk
Statistical Lab	All Locations	Potential risk
Plus Spec	All locations	Potential risk

Studies are to be preformed at the most convenient and efficient location to work in with work schedules, whether this be the office, home, or public library.

October 1

Appendix Four – Risk Assessment

University Of Sothern Queensland

Risk Assessment

The methodology of the approach, and resources required (as per resource plan) will be partial to the following risks:

Risk Description	Outcome	Mitigation
Online articles containing misguided information	Incorrect information in report	Ensure all unreferenced articles/videos are used for base research only and look further into topic with credible referenced pieces
Industry networking/ surveying time restraints	Insufficient time could result in reduces sample size	Create survey as soon as possible and send research out to network
Insufficient sample size	Increase margin of error	Expand network. Create survey as soon as possible and send research out to network
Lack of high level skills in plus spec and stats-lab	Time loss and decrease in overall report quality	Online YouTube tutorials in required
Time constraints	High stress, incomplete report, decrease in overall report quality	Complying to schedule

In order to manage this risk, I must abide by my schedule previously created. Weekly submissions to my supervisor must be sent through, and Skype meetings scheduled when required.