Impact of BIM on the Construction Industry in the United Kingdom

Aaron Chadee
Faculty
Department of Civil and Environmental Engineering
The University of the West Indies, Saint Augustine Campus, Trinidad and Tobago

Hector Martin
Faculty
Department of Civil and Environmental Engineering
Queeens University, Belfast, England,
UK

Preeya Moonilal
Faculty
Department of Civil and Environmental Engineering
The University of the West Indies, Saint Augustine Campus,
Trinidad and Tobago

Kailas Sekhar Banerjee
Faculty
Department of Civil and Environmental Engineering
The University of the West Indies, Saint Augustine Campus,
Trinidad and Tobago

Kiran Tota-Maharaj
Professor
Department of Water Resources Management & Infrastructure
Royal Agricultural University (RAU) Cirencester,
Gloucestershire GL7 6JS, England, UK

Abstract

This research topic will focus on the impact that BIM (Building Information Modelling) has provided in the construction industry whilst exploring the origin of BIM, the advantages of the tool, the opinions on BIM, and many more topics. This study will prove that BIM is beneficial to all relevant construction practitioners and why it has become a mandatory practice to follow in the industry in the United Kingdom (UK). The paper indicates how BIM has been overlooked within the construction industry and that many people are not aware of the benefits of BIM. This is concerning as BIM has recently become mandatory for large government projects and still, there is a large percentage of industry professionals who have chosen to ignore the tool, mainly due to lack of knowledge. This research will explore how BIM can contribute to one of the largest industries in the UK thereby making it more efficient in every aspect throughout a construction project life cycle. Evidence from this study shows that there are construction companies, currently active in the field, who have chosen not to expose their staff to BIM-related training. This is distressing as the tool has been proven to bring a positive change to most aspects of a project.

Keywords- Building Information Modelling, Built environment, Computer-Aided Design, Infrastructure, Construction engineering

I. Introduction

Construction project managers in the UK have recently embraced BIM whereas other areas of the world such as Malaysia and other South Asian countries are way ahead in terms of utilizing this technology to drastically improve their construction projects (Mustaffa et al. 2017). This is so since, at the design stage of a project, models require various alterations to fit the criteria from clients and contractors' ends and BIM can meet these requirements whilst improving the process. This research will expound on the benefits of BIM on the relevant practitioners in the construction industry in the UK now and in the future. Also, an investigation on why some construction managers are reluctant to embrace the components of BIM will be carried out. There are three objectives of this study. Firstly, it is conducted to analyse the impact of BIM on the construction industry. Secondly, the study allows persons to evaluate the role of BIM and lastly; to prove how can construction managers use BIM to their advantage instead of outdated conventional methods.

II. Literature review

The definition of BIM is "a computable representation of physical and functional characteristics of a facility." It is a shared knowledge resource for information about a facility (Jonathon 2020). BIM is the foundation of digital transformation in the architecture, engineering and construction industry. It is the process of creating and managing information for an asset (Autodesk 2022). According to Wen et al. (2021), "Building Information Modelling can broadly be described as an approach to digitalise buildings and making a virtual model using common data environment which allows all relevant stakeholders to input their thoughts and share information easily." This technology enables clients and contractors to use a 3D software to draw out structures, such as

the proposed or existing building. BIM is an advanced and revolutionary technology for generating, visualising and analysing architectural models which changes the way the buildings are designed, built and operated (Huang et al. 2022). BIM dates to the 1970s however, between the 1970s and 1980s what we know as "Building Information Modelling" it was referred to as "Building Production Modelling" in the United States of America and at the same time countries in Europe was referring to the method as "Product Information Modelling". By 1990 the two names merged into Building Information Modelling. As per Hoseini et al. (2018), BIM became "digital, parametric, smart and object based, full of data display based on users' needs, and any view can be extracted and analysed from this model."

A. Role of Building Information Modelling (BIM)

Building Information Modelling (BIM) is a modern construction technique that is used for creating and managing information on a construction project through every stage of the life cycle (Hamil 2021). Using this technique creates a virtual model of a building and makes it so that every aspect of that building holds digital data. This could be anything such as materials, dimensions and costs. This advanced technology has been made to help most construction professionals. It does this by increasing the collaboration aspect of a project, by creating a 3D model of a building which can help identify weaknesses, it can also give a better cost certainty and reduce waste. By implementing BIM in infrastructure projects, a more accurate model is rendered as opposed to using 2D CAD or other traditional approaches. This is as a result of the benefits that come with it like viewing the model in every angle possible to make sure the building is not incomplete.

BIM can be used for planning, design, construction and even present operation of the building. The technique can help many professionals, namely: quantity surveyors by way of getting more accurate pricing, architects to visualise what is being built, and contractors to see what is being designed to give an accurate visualisation of what is required.

B. BIM is better for the environment

The use of BIM is to improve efficiency and sustainability in the construction industry, it helps speed up the design stages throughout the project and is said to deliver substantial gains to the field.

Many construction projects tend to face some sort of delays throughout its lifeline and when projects get delayed "emissions – heavy equipment and generators run for longer periods, polluting the air" (Morrison 2021). This sector is heavily reliant on fossil fuel-powered machinery and as such, poor efficiency further increases the industry's huge carbon footprint. Morrison (2021) stated that "In 2018, the construction industry accounted for 39% of total energy-related emissions." These states are enough to make the use of BIM mandatory in the UK as the use of it will allow construction companies to become more efficient and decrease their carbon footprint.

BIM has made an enormous impact on projects as it drastically improves communication and the use of it makes design and workflow decisions accessible to all stakeholders. This decreases the likelihood of delays and disruptions to the project so workers do not have to sit around and wait while the team are resolving conflicts, implying that heavy machinery does not need to run longer than it should.

Another way BIM reduces emissions is that it features clash detection, which helps the relevant stakeholders to resolve their issues before the buildings work starts. This is so as claimed by Morrison (2021), "Rework accounts for 30% of total construction work." Clash detection saves a lot of time meaning machines need not run as much. If BIM is being used and can reduce "rework" it also means it can reduce waste due to a higher efficiency rate, which is crucial to reduce emissions as it will result in the decrease of the industries carbon footprint. BIM also provides an extended insight into a projects' measurements which means the contractors can accurately measure the materials that are required, which also reduces waste.

In the design phase of a project, because of how quick and easy digital modelling is the design team can create several design alternatives to present to the client and contractors who can analyse the advantages and disadvantages of each, in order to find the most efficient building that could save power and be more eco-friendly. This is important as "Domestic buildings are responsible for 30-40% of primary energy use in the UK," (The Greenage 2015). The use of BIM will not clear this statistic but can drastically reduce it to make the UK more sustainable.

C. Key Advantages of using BIM

Additionally, "BIM can improve productivity as it has a benefit that it enables the stakeholders to voice their opinions in the design stages which allows the team to create a far more sustainable model," (Morrison 2021). This is a massive positive impact that BIM has provided to the industry and evidently does not cost too much time whereas if there was an issue with a CAD drawing of a building it would be very inefficient as all other drawings would have to be altered.

The use of BIM does not end when the building works have finished, once the project has been successfully completed, property managers, and other relevant professionals can make use of BIM to manage the building for future purposes as it is all digital and the models come with a lot of detail and information to assist the owners to make sustainable decisions and more efficient maintenance (Morrison 2021).

The UK must take advantage of BIM to fix what the industry is lacking. The correct use and implementation of BIM can lead to increased efficiency and sustainability, decrease in waste and allow more collaborations to happen (Morrison 2021).
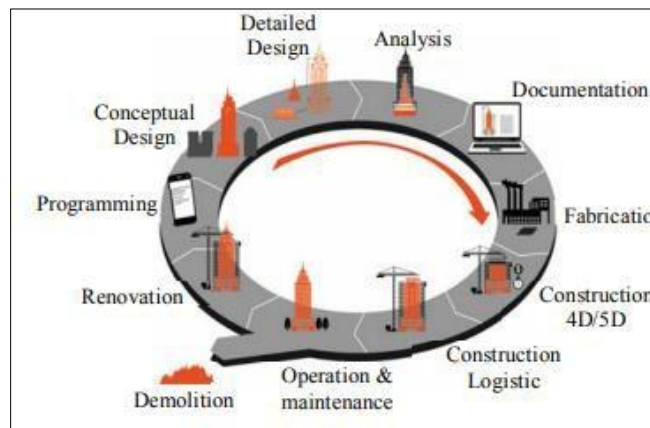
Fig. 1: Use of BIM during project life cycle (Hoseini et al. 2018)

One of the main values BIM brings to the field is that it facilitates informed decision making at early stages as opposed to during or near the end of a project life cycle (Nikologianni et al. 2022). This reduces the occurrence of wasted time and resources.

D. BIM Software

One of the most popular BIM software in the UK's construction industry is Autodesk's Revit. The Revit software supports architecture, construction and engineering teams to construct high quality 3D models of future or current buildings. The tool is used to "design, document, visualise and deliver architecture, engineering and construction projects". This can assist in the design stage, construction stage and post-construction maintenance stage. The tool allows for model shapes, structures and systems to be made with parametric accuracy, precision and ease (Autodesk 2022). It also allows quick and easy revisions to drawings, elevations and schedules. Revit allows for projects to run more efficiently to manage deliverables, document design and ease the production process (Autodesk 2022). What makes Revit stand out from the rest is the collaboration approach, as the software has many tools for scheduling, annotating and with Revit cloud, work sharing is quick and simple.

E. Traditional Methods versus Modern Construction Approaches

The origins of 2D drawing, architectural sketches and plans, can be traced back to ancient Egypt. Before BIM was implemented, from history, 2D drawings served for the presentation/visualisation aims of a construction project as well as its function as an analytical tool during the design stage (Amor 2016). Over the last few decades architects, engineers and designers only started with hand drawings as that was the only technology at the time. Then came Computer Aided Design (CAD), CAD became so popular in the industry as it was the key to create quality, cost-effective drawings for proposed projects. Then, BIM was introduced which was more advanced compared to CAD and came with a list of competitive advantages (Amor 2016). The introduction to 3D design improved every aspect of the life cycle of the project. It represents all the characteristics of a project including time, design, construction and sustainability.

F. Computer Aided Design (CAD)

For years, graphic representations have been a main form of communication (Clark 2001). Computer Aided Drafting first arrived at the industry in the mid-1960s and at that time, only the largest companies could afford computers capable of CAD. In the 1970s, Computer Aided Drafting developed into Computer Aided Design (Jonathon 2020). CAD took two separate routes; one headed to 'general-purpose geometric drafting systems' and the other was towards a 'specific building type modelling'. This is when large companies started to create systems based around geometric 3D shapes. Building design research was largely funded by the government through either National Health or Universities (Jonathon 2020). 2D illustrations for buildings came into effect at the beginning of the 20th century (Clark 2001). In 1987, a CAD programme based on solid geometry and feature based parametric techniques was released (Cohn 2010). In the 1990s every PC could run CAD (Cohn 2010). Fast forward to 2022, in the construction industry, BIM has developed into a better, more efficient version of CAD and now that BIM is being adopted worldwide, the users of CAD have decreased significantly since BIM is essentially CAD but better.

1) *Advantages of 2D CAD:*
- Easy constructability
- Only focuses on 2 dimensions in individual views
- Gives true size and shapes for facilities and is very accurate

2) *Disadvantages of 2D CAD:*
- Difficult to visualize
- Requires interpretation and is very limited (Clark 2001)

G. A Comparison of BIM versus CAD

For starters BIM saves time, and time is a very important aspect of every construction project. BIM was introduced to improve the construction industry. In other words, it is the evolution of 2D CAD drawings. Regarding CAD, one disadvantage is a change/modification to a certain part of a drawing must be altered manually across all drawings (different levels like in the case of elevations and floor plans). BIM fixes this issue as it is one large 3D model that can be seen, edited, corrected in one file. This completely changes the design stage by making things much smoother for construction managers and all other professionals involved.

Another important area to investigate is that BIM is more accurate than the 2D drawings. When it comes to visualizing a project, you need to use a "significant amount of imagination in order to see the end project," (Tesla CAD UK 2020). Whereas when using BIM, the end project is in front of your eyes and little to no imagination is required to view the end goal. "The intelligent 3D model does not just take in the environment but also allows estimation of earthworks, terrains etc.," (Tesla CAD UK 2020). This allows a correct estimation of materials which ultimately reduces waste and alterations during the project life cycle.

Clash Detection is a problem solver and saves countless hours. Through 2D drawings they may look accurate to architects and designers but when applied to the construction site it can lead to clashes. To detect a clash in CAD ideally multiple drawings are made of different layers in different colours and then placed on each other for others to visualize. Since all the designs are in 2D the model has no depth to it making clashes more likely to occur. As opposed to BIM, all "multidisciplinary models are combined in one file," (Tesla CAD UK 2020), making it obvious to designers if any clashes will occur early in the design stage.

An aspect CAD is also lacking in, is its cost effectiveness. Though BIM requires heavy training which will cost companies an extra capital investment, its advantages pay this off substantially. That is, it makes its money back by causing an increase in productivity, clash detection, accuracy and saving time as well as allowing for clearer communication. Because of BIM, using one 3D model any change/alteration due to communication from a client for example, can be altered there and then, adjusting all drawings and dimensions. Whereas one minor revision in CAD results in all drawings needing to be corrected, leading to more hours being spent this early in the project. In other words, it has a domino effect.
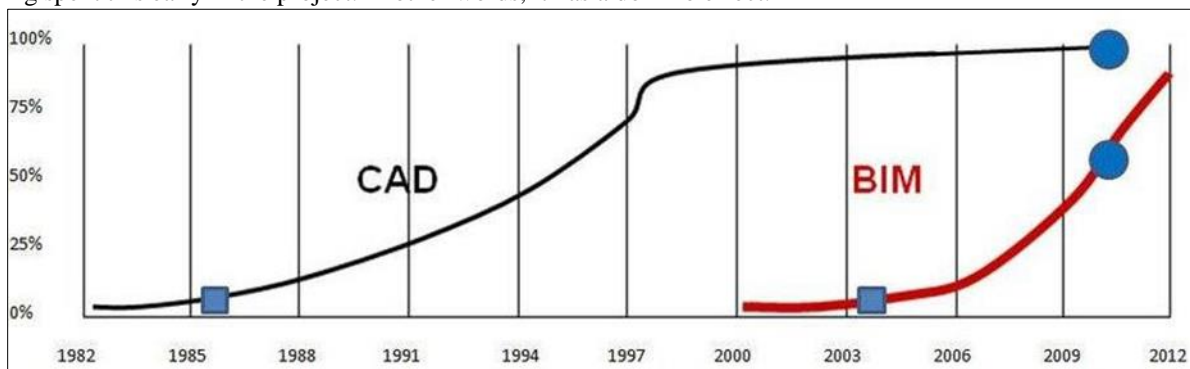

Fig.   2. CAD versus BIM adoption (Neeley 2009)

Figure 2 represents the CAD versus BIM adoption throughout the years. Blue squares indicate the rate of adoption at the time each chart was created, and the blue circles represent the adoption rate in 2010 (Neeley 2009). From the graph above it shows BIM's adoption rate is double that of what CAD's adoption rate has been over the years.

H. BIM Becoming Mandatory in the UK for Government-funded Projects

"Building Information Modelling was mandated in April 2016," (Tuckwood 2016). The regulatory move came as a retaliation to Hackitt Review about building safety in the UK after the Grenfell Tower Fire (United BIM 2019). The bold move that the UK government made can be seen as an attempt to show the public (especially construction firms) how useful BIM is for making projects safer as it provides visibility from all angles for all stakeholders.

In 2016, The Grenfell Tower Fire led to the loss of 72 lives which made the UK realise how serious residential building safety precautions are (United BIM 2019). Hence, BIM became mandatory for high-rise buildings and government-funded projects. Since 2016, the BIM mandate in the UK resulted in improved safety and growth of the construction industry. The mandate recommended that all the relevant parties (architects, contractors and managers) must be made accountable at every stage of a building project (United BIM 2019). The responsibilities include:

- To follow clear guidelines regarding the production
- To create an accountability framework for the stakeholders
- To bring residents to understand the building safety procedures

I. How BIM Impacts Construction Managers

Terry (2021) defines management as "a process, consisting of planning, organizing and controlling, performed to determine and accomplish common goals." Construction managers are responsible for the practical management and planning of every stage of a construction project. Their tasks include overseeing the construction from design to completion, analysing and managing risks,

collaborating with stakeholders and clients, to ensure health and safety on site and to keep track of logistics. With BIM being introduced to the industry, the way in which construction projects are managed will change.

J. BIM Standards

BIM has a number of standards that define "BIM information structures and internal processes". The information structures are ISO 16739-1:2018 'Industry Foundation Classes (IFC) for data sharing in the construction sector', and ISO 12006- 2:2015 'Building construction – organization of information regarding construction works used as a framework for classification'. The UK lists this as the classification system for BIM. Another popular framework is ISO 23386:2020; BIM and other digital processes used in construction (Hamil S, 2021). The ISO 19650 series of standards define the BIM process globally. The basis to this framework is from the UK PAS 1192 series of standards. The point of these standards is to help and support the individuals who work in the construction industry in the UK to understand the fundamentals of BIM.

K. The Construction Industry

According to GlobalData (2022), in 2021, the UK construction industry was valued at $448.7 billion, and the industry is expected to record an annual average growth rate of more than 1% between 2023 and 2026. This is due to the rapid advancement of technology and significant population growth. It has been estimated that the global population will hit approximately 9 billion by the year 2050. The industry itself accounts for approximately 3 million jobs which is around 10% of total employment in the UK. Being one of the largest sectors in the UK, the construction industry must maintain and grow continuously to keep up with the current climate.

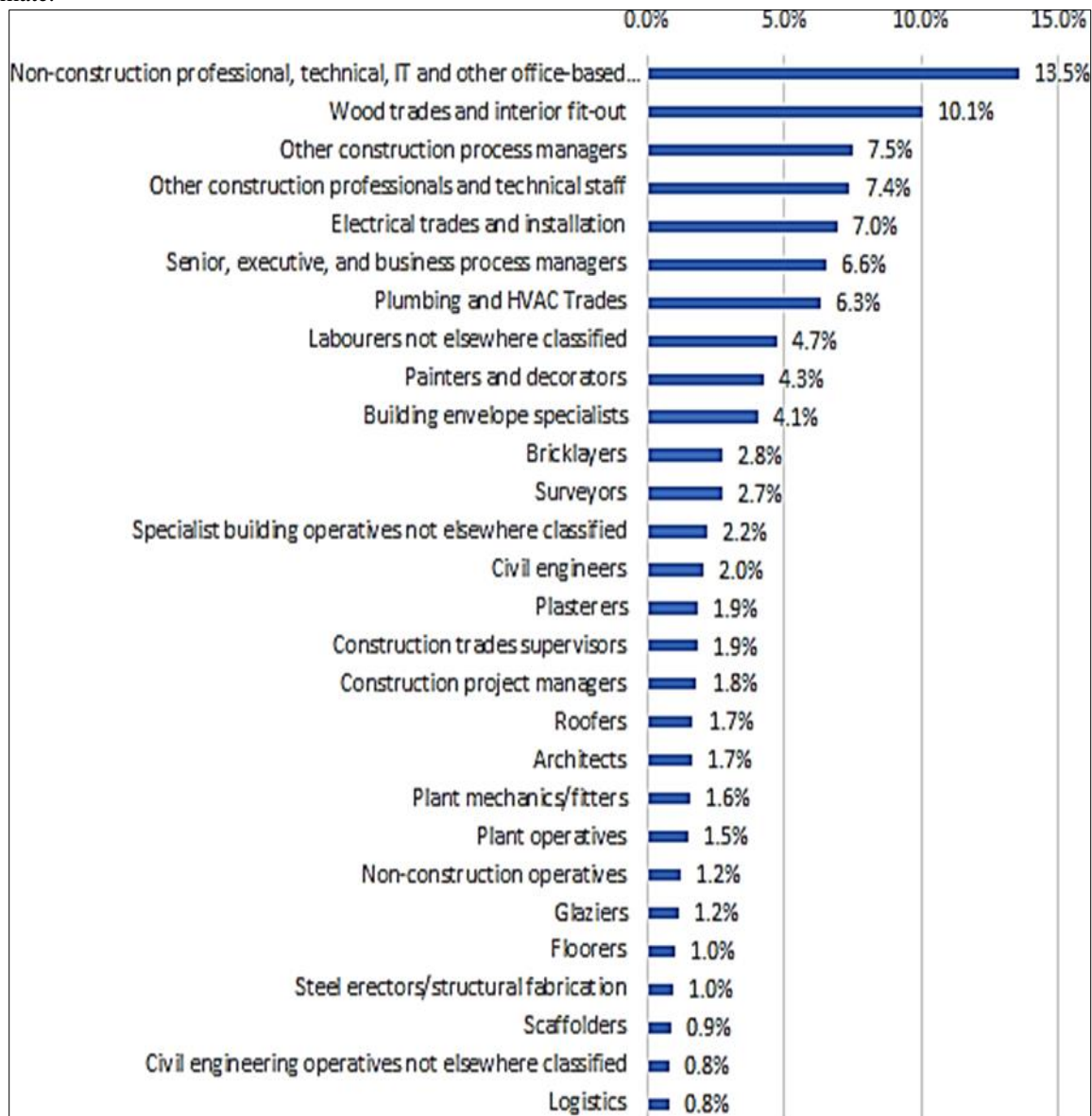| Occupation	Percentage
Non-construction professional, technical, IT and other office-based...	13.5%
Wood trades and interior fit-out	10.1%
Other construction process managers	7.5%
Other construction professionals and technical staff	7.4%
Electrical trades and installation	7.0%
Senior, executive, and business process managers	6.6%
Plumbing and HVAC Trades	6.3%
Labourers not elsewhere classified	4.7%
Painters and decorators	4.3%
Building envelope specialists	4.1%
Bricklayers	2.8%
Surveyors	2.7%
Specialist building operatives not elsewhere classified	2.2%
Civil engineers	2.0%
Plasterers	1.9%
Construction trades supervisors	1.9%
Construction project managers	1.8%
Roofers	1.7%
Architects	1.7%
Plant mechanics/fitters	1.6%
Plant operatives	1.5%
Non-construction operatives	1.2%
Glaziers	1.2%
Floorers	1.0%
Steel erectors/structural fabrication	1.0%
Scaffolders	0.9%
Civil engineering operatives not elsewhere classified	0.8%
Logistics	0.8%

Fig. 3: UK Construction Occupations Percentages in 2017 (CITB 2017)

The graph in figure 3 represents the percentage of people working in different positions in the construction industry. This data was recorded in 2017 from CITB. The percentages are recorded based on approximately 2 million workers.

L. The future of Building Information Modelling

The COVID-19 pandemic prompted substantial technological advancement in the UK in a short period of time as everyone became a part of the digital world as everything took place online. "COVID-19 accelerated the pace of digitalization in the construction industry," (RICS 2020). When the pandemic hit the UK the construction industry had no option but to adapt to the environment, causing BIM to evolve massively. It has been estimated that due to the acceleration of BIM advancement in a 2–4-month period during covid, it is now 5 years ahead of schedule (RICS 2020). The NBS 2019 survey based on approximately 1000 surveys from the relevant practitioners had reported significant growth in BIM adoption, which in 2011 was 10% that jumped to 70% in 2019. Making a digitalized software has made a huge impact to the industry and the lives of the people who take part in construction projects. When faced with an issue or an alteration is needed, technology is resorted to in order to solve the problem. Hence, it is vital for everyone who works in the construction industry to become familiar with BIM. The huge growth in the last few years, compared to the last two decades, has been massive and at the current rate of growth the entire industry will be digitalized in the next decade. It has even been recently observed that projects are being made with 3D printed materials, resulting in a much swifter construction process. Digital surveys show that cloud computing, blockchain and artificial intelligence are all on the rise (Hamil 2021). As time by, the manual tasks of structuring, classifying and naming data will become automated and this will help accelerate the speed of which BIM is being adopted internationally.

In 2008, "McGraw-Hill Construction" conducted a questionnaire to understand current and future trends of BIM. The survey consisted of 101 engineers, 80 contractors, 82 architects and 39 construction company owners, from the United States (Azhar 2011). The findings were that architects were the biggest users of BIM. Interestingly, 43% of participants used the tool on more than 60% of their projects. And contractors were the least of the group to use BIM. Another finding was that over 80% of BIM users felt that BIM had a large impact on productivity for the better. Almost 80% of BIM users stated that the use of the technique improved overall project outcomes. Two thirds of the correspondents believe that the implementation of BIM in their company allows them to win a project compared to companies who don't use BIM (Azhar 2011). For a survey that was conducted 15 years ago, it demonstrates how technology advanced the United States construction industry putting them at a much greater position, compared to the UK, as the findings from a more recent survey shows below.
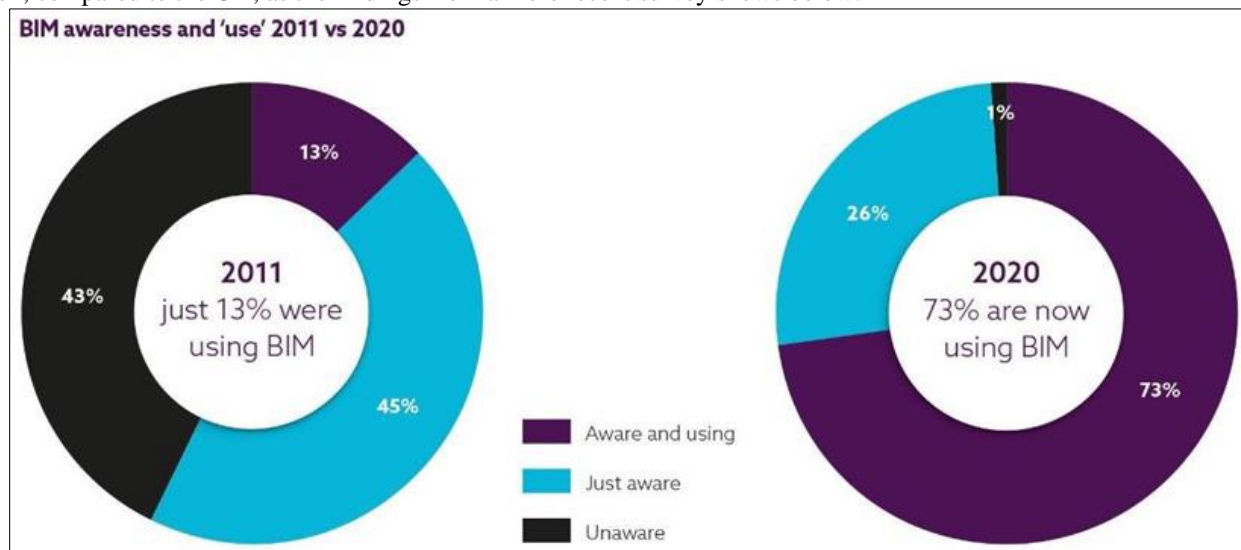

Fig 4: BIM awareness and use 2011 vs 2020. Survey taken in 2020 based on responses of 1,000 industry professionals (Viewpoint Blog 2020)

Figure 4 shows how the population has adjusted at a rapid growth rate in terms of adopting BIM. The rate of BIM has grown significantly due to the number of benefits it has and how much it can help construction professionals in their jobs.

Fig. 5: The future of BIM software (Global Associates 2021)

This figure shows how projects in the future will be designed, maintained and built, indicating that BIM supports collaboration and communication in several different ways. Future projects will be made with ease and the life cycle of these future construction projects will be more efficient than ever. The project may be separated into teams to each focus on different aspects of a building then, once that has been finalized, the different sections can be combined, and the final design can be reviewed.

In addition to being a design program, BIM goes beyond and can be used after the design phase. At this point in time, technology is advancing at a rapid level. Whilst BIM is mainly being used for construction and design, not everyone has accepted BIM as a maintenance tool. As a matter of fact, only 14% of building owners use BIM as a tool for building maintenance and only 47% of building companies use it to accelerate project completion (Global Associates 2021).

With the current rate of evolution in technology, it is only a matter of time until more people become familiar with BIM, and for BIM itself to become a much more powerful tool.

M. *Literature Review Conclusion*

The aim of the literature review is to explore the fundamentals behind BIM and to research its impact on the construction industry in the UK. The research highlights the advantages of using BIM, and how much it can improve the industry as a whole and the efficiency of construction projects. Additionally, the review highlights the features of CAD, and why BIM is the better tool to use for construction projects by exploring the advantages and disadvantages of both. Research was also done on why implementing BIM is better for the environment instead of using conventional methods for buildings as well as, on the evolution of both BIM and CAD and the difference in rate of adoption between the two. From Figure 1 above, the data shows how much faster BIM was adopted in comparison with CAD. The impact BIM has had on the sector is huge, and anyone who has not taken advantage of it is missing out on support which can help them with their work and increase efficiency when managing the cycle.

III. RESEARCH METHODOLOGY

A. *Research Perspective*

The main aim of conducting this research is to gain first-hand insight into the use of BIM and how it has impacted the construction industry whilst exploring the aforementioned objectives by getting the relevant practitioners' opinions on the surrounding topics of BIM.

This research will be in three steps: collection of data, analysis of data, and presentation of data. The major source of data will be gathered through a questionnaire that will be distributed to the construction industry professionals as part of an interview-style survey. These include BIM coordinators, construction managers and architects. In order to conduct a thorough survey and

emphasize the challenges surrounding people's opinions of BIM, questionnaires will, whenever possible, be administered at professionals' places of employment. The interview will take place over a phone call or a zoom meeting, should the possible interviewees have time or location restrictions.

An advantage to using an interview approach for this research will be that it will provide first-hand information on the open-ended questions. The benefits of using a questionnaire/interview as primary research are that the data collected is more specific to the topic of the report. The questions are meant to gauge people's thoughts and the effects of BIM, including the favorable transition from traditional to modern approaches.

To analyze this research data, the quantitative data will be displayed using charts and graphs for a visual understanding of the impacts of BIM, and the qualitative data will be analyzed and reported. The interviews conducted will be digitally recorded to make it easier to evaluate. The professionals that are being interviewed will only be recorded with their permissions to comply with ethical standards and that this data is used only in this dissertation.

The results of the interviews will be compared to the secondary research integrated in the literature review to build a credible dissertation expounding on the benefits of BIM.

a. Types of Questionnaires for Data Collection

Questionnaires are classified as either quantitative or qualitative depending on the nature of questions. A questionnaire's objective is to obtain information to analyse into finding an answer for a particular hypothesis or just to gain knowledge on a particular subject. In this case, a questionnaire was used as our research to analyse the impact of BIM on the construction industry in the UK and to have an insight of what the future holds for BIM. Usually questionnaires with a close-ended questions will fall into the quantitative category. Quantitative questionnaires count results. This is excellent for data analysis as the findings of the survey can be illustrated using graphs, charts and percentages. However, qualitative questionnaires are based on open-ended questions and is typically answered in a paragraph. The aim of these questions is to obtain people's opinions and experiences on a particular subject. In other words, "quantitative data will tell you what your respondents are doing, whilst qualitative data offers deeper insight into why," (Alchemer 2021).

Most of the data collected from the questionnaires will be qualitative. The questions have been structured to obtain the opinions of construction managers and other relevant practitioners on their experiences with BIM.

B. Data Collection

Ten people working in the construction business were each given a questionnaire. BIM coordinators, architects, construction managers and quantity surveyors made up the group of respondents. The responses will allow for the following to be learnt: how each individual got involved with BIM, how does the individual use it, and how does the individual view it as a tool. The primary data from the interviews was analysed to examine the impact BIM has had on the sector in the UK.

The primary data collected from the interviews was compared to the information found in the literature review from secondary sources, explaining the benefits and impact of BIM on the construction industry.

Name: __Construction Company: __Occupation:
Q1: Are you familiar with Building Information Modelling? (If No, please state your reason)
Q2: Do you currently use BIM in any of your projects? (If No, please state your reason)
Q3: (Answer if you said NO to Question 2) How does your company plan on competing with local firms that have adopted BIM?
Q4: (Answer if you said YES to Question 2) At what stage of the construction project do you use BIM?
Q5: How many times have you used BIM?
Q6: Has there been anything blocking you to implement BIM on every construction project?
Q7: What form of BIM-related training have you been involved in?
Q8: Has BIM's adoption made your construction projects easier to complete? And why?
Q9: In your opinion, what benefits has BIM had on construction managers in the industry?
Q10: Do you believe that the United Kingdoms' decision to make BIM mandatory for government-funded projects came too soon? Why?

Table 1: Questionnaire presented to Interviewees

Table 1 shows the 10 questions which were asked to the 10 individuals who took part in this study. The practitioners who took part in this study came from several different construction firms in the UK's construction industry such as Tilbury Douglas, National Highways, PM Group, and Turner and Townsend.

The questions consisted of both quantitative and qualitative questions to achieve an insight into people's experiences with BIM, to create visual data in the form of graphs and charts on the implementation of BIM, and to understand these professionals' opinions on this modern construction approach.

The data collected from this research was analysed to identify any trends in the field and to look at what BIM can achieve in the future for the construction sector globally.

IV. RESULTS AND DISCUSSION

The results consist of the responses from the following practitioners: three architects, three BIM coordinators, two construction managers and two quantity surveyors. From the results, it was clear that everyone who was interviewed was familiar with BIM, however not everyone had a decent amount of knowledge and history with the use of BIM.

Interestingly the professionals that had little to no knowledge on BIM had a shared opinion that the UK's decision to make BIM mandatory came too soon. These individuals were the quantity surveyors and one of the architects. These three relied on more traditional methods using 2D CAD and hand drawings of construction plans without realizing the benefits of BIM, which can make their lives much easier and make the whole construction phase more efficient. For example, it reduces costs and wastage, it improves cost estimates, it maximized efficiency, it provides a better insight into projects, it helps communication and collaboration, and it provides less risk (Bimspot 2022).

One of the construction managers and the three BIM coordinators argued that the decision should have been implemented sooner as they understood the benefits of BIM and had knowledge that other areas of the world have been using BIM years before the BIM Mandate that arrived in 2016. The remaining individuals believed it came at the perfect time and called it a "problem solver" and "life saver". This was due to the incident at Grenfell tower that gave the construction industry in the UK a "wake up call", from which the government chose to come up with the mandate to make sure something like this is not repeated.

The second question in the interview asked whether they have used BIM before, the professionals who embraced BIM responded with yes and used the modern technique in at least two past projects. The ones who had not used it before made it clear that they were not against BIM, but they have not been exposed to any relevant training in the field and felt quite overwhelmed with the amount of detail and information BIM comes with. One of the surveyors stated his opinion that the government should have provided training for the use of BIM but when asked why he had not taken time out to learn himself, he stated that his work colleagues do not use BIM either and his company has not provided them with relevant training in this area.

The people that answered that they had not used BIM before was asked "how does their company plan on competing with other companies who implement BIM?". Interestingly, no one could state one positive reason that benefits the company in any way as to why they do not use BIM in their projects. One stated that because 2D CAD is so easy and cost effective to learn their company has hired a team for designing whereas there are some smaller companies who have only hired a small number of trained BIM-coordinators. This individual also stated that the design process is a much quicker whilst using CAD. Which, technically, it can be, as long as there are no alterations that need to be made as that is where CAD loses its speed in designing. This answer made it clear that there are still people in the industry that have no idea of what implementing BIM can do to a project and this is clearly due to lack of knowledge.

Question four was asked to the individuals who use BIM often, at what stage do they use BIM. The BIM-coordinators replied that they use it at the start of the concept design stage. The surveyors that were interviewed did not have much history using BIM so they could not answer. The other architects and construction managers said at the concept and at the initial design stage too. Therefore, it is fair to say that if professionals were aware of all the benefits in using BIM, it would be utilized in every stage of the project and because of how advanced the technology is, it can improve every aspect of a construction project.

Question five asked the respondents on "how many times they have used BIM?". The results are illustrated in a bar chart below for a visual representation of who uses BIM more. However, these results cannot be considered entirely accurate as the research was based on 10 individuals only. The graph below (Figure 4) shows the expected that the BIM coordinators use BIM the most. The surveyors reported that they have never implemented BIM. One stated it was not by choice but that he was not exposed to any BIM-related training from his company. The other surveyor confessed that he prefers using 2D CAD drawings instead as he believes that BIM is overwhelming with the amount of knowledge required in order to use it efficiently. Surprisingly, only one of the architects had used BIM multiple times whereas the other two have rarely used it. The reason for this is because they work in a large firm where projects typically take 1-2 years and as such, the number of times using BIM depends on how long they have been working for.
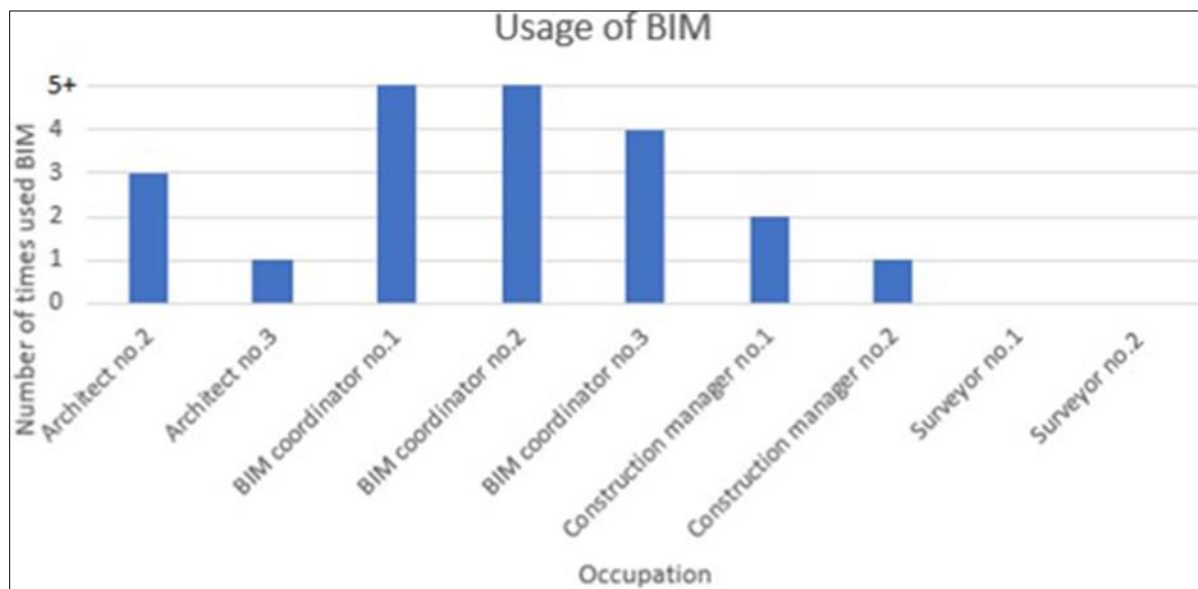
Fig. 6: Graph displaying results from a questionnaire showcasing how many times the participants used BIM before. Sample number of 10 correspondents. Study period taken from January – March 2023

The sixth question asked, "has there been anything stopping you from implementing BIM on every project?" The individuals who are not familiar with BIM replied with either it is too much information to learn, or that their companies have not trained them to learn the technique. The architect who has no experience stated that he wants to learn BIM, but he has not been exposed to any material regarding the subject. The professionals who have not or have rarely used BIM, made it clear that it was not up to them but the project managers to determine whether a project requires the use of BIM, as not every project does. That would be the only reason not to use it in every project as it makes the whole construction cycle faster.

Question seven asked, "what type of BIM-related training have you been exposed to?". Some replied none, the reason for this was that their occupation at their company does not require them to learn the fundamentals of BIM (based on the opinion of their firms). The others replied with a mixture of online courses were required to be completed. Another said YouTube tutorials were shown to them, and one replied with being trained from their work colleagues and independent research. The BIM coordinators learnt BIM from University and experience with different software and stated that the primary reason they got the job was their background in BIM, meaning that their firm did not need to provide training in this field. Hence, it can be inferred that the existing mixed opinions surrounding BIM is due to lack of training and exposure to relevant material provided by companies. The eighth question asked the individuals for their opinions on whether the adoption of BIM made it easier to complete construction projects. The individuals who use BIM all stated that it does make projects more efficient in multiple ways. One mentioned the following advantages of using BIM, supporting that found through the literature: the increased efficiency, the decrease in waste, easier to collaborate, makes the design stage more visual for all stake holders to see the end project and many more. The main opinion from this selection was that BIM makes their jobs a lot easier and speeds up the cycle of a project significantly whilst minimising risk and keeping cost consistency.

Question nine asked what benefits BIM has had on construction managers in the industry. The two construction managers that were interviewed stated that it helps with collaboration and when there are any alterations that need to be made, the BIM coordinators can adjust this instantly. The BIM coordinators mentioned that it is easier to showcase the design stage of projects to stakeholders which allows them to visualise the buildings more clearly. The two architects who are familiar with BIM also stated a similar response to the BIM coordinators that in the design stage BIM is used to create a 3D model to help the relevant stakeholders visualise the end product. However, one architect who is not as familiar with BIM, expressed his opinion that 2D CAD drawings showcase the same end product to stakeholders the same way BIM does. This is not fair to state as it may be more difficult to visualise a 2D drawing as a complete building in comparison to a 3D model which, with the help of some BIM software such as Revit, allows for the rendering of a model that can be viewed at all angles.
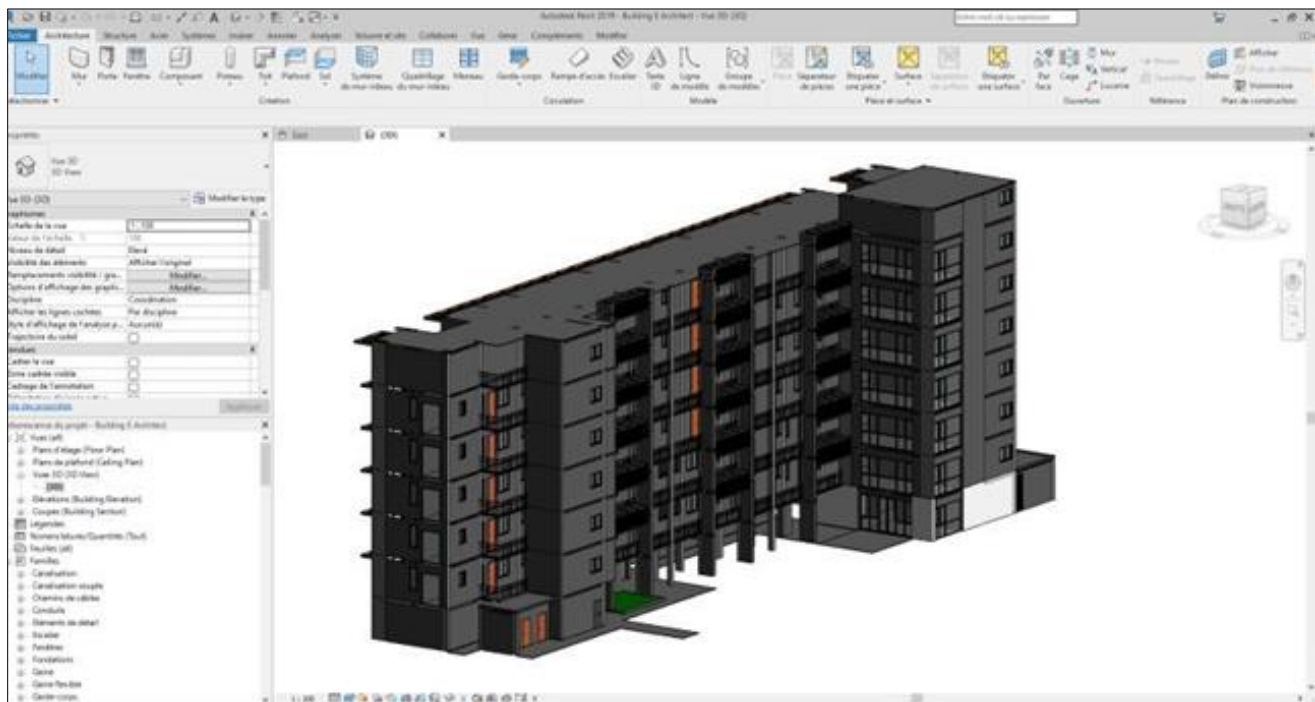
Fig. 7: Sample 3D model of a Building presented in a Building Information Modelling software

Figure 7 shows what a rendered building can look like in a BIM software which validates the point that 2D drawings cannot show a clear representation of a completed project in the same way that BIM does. In the case of the two quantity surveyors, BIM can assist them in their requirements for pricing and estimating as a 3D model can be used to ensure that they have not missed anything in a take-off or a bill of quantities. Despite this, both stated that there are no significant benefits that BIM provides to the construction managers as their role is to complete a project start to finish with the help of all the other professionals, to present the costs to the clients and to make sure everything runs smoothly. Whilst this may be a justifiable opinion, the contrary opinion is also fair that BIM can make construction managers' jobs easier. For instance, when presenting the model and drawings to clients, when doing quality checks around the project site and many other areas in the cycle.

To conclude the questions, the respondents were asked "Do you believe that the United Kingdoms' decision to make BIM mandatory for government-funded projects came too soon?" This question provided several mixed opinions from the professionals. All three BIM coordinators felt like the mandate should have arrived sooner rather than later with one of them even mentioning "The fact that the UK had to go through the Grenfell Tower incident for a wake-up call to fix the health and safety requirements in a project is a shame". One of the surveyors reported that BIM is overwhelming and is ahead of its time. The other surveyor also replied stating that the BIM mandate came way too soon. The surveyors' responses may be due to a lack of knowledge on the subject. Two of the architects felt that it came just on time as with the new technology in this century, 3D design was bound to arrive. The remaining architect also felt that it should have arrived sooner stating that 3D building design should have become popular when 3D printing was popularized. He also stated that other countries around the world are way ahead of the UK in terms of utilising BIM. The remaining construction managers stated the BIM mandate did not come too soon and that it arrived as a solution to the industry's problems.
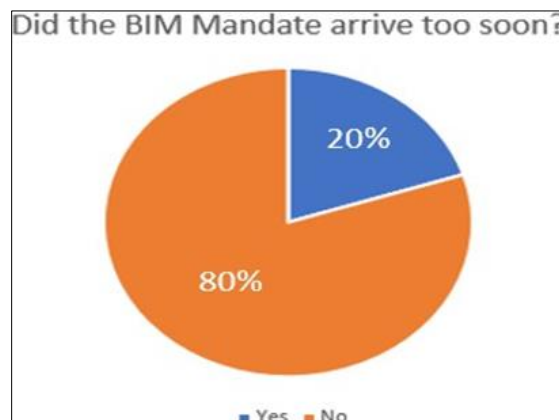

Fig. 8: Chart representing the 10 interviewees votes on if the United Kingdom's decision to make a BIM Mandate came too soon

The pie chart above (Figure 8) allows for the visualization of the results of the question "Do you believe that the UK's decision to make BIM mandatory for government-funded projects came too soon?". Out of the 10 construction related professionals, 20 percent of them had voted that the mandate came to the scene too soon. Whereas the remaining 80 percent voted it came either on time or it should have arrived sooner. This shows that for the majority, BIM has provided a beneficial impact to them, the industry and to construction projects.

A. Research Analysis

From the interview results, the main benefits of adopting BIM as well as the difficulties with utilising it was summarized.

Benefits of Adopting BIM	Difficulties in utilising BIM
• Improves collaboration significantly • Much less risk because of clash detection • Less human errors • Reduction of waste • Alterations made easy • Increased visualisation of projects • Improved health and safety • Maintenance of building after project completion	• Significant training required • An overwhelming amount of knowledge required • Advanced technical skills required • Lack of material that covers the topic • High training costs • Substantially different from 2D CAD

Table 2: Adopting BIM table

The secondary data from the literature review above correlates with the primary data from the interviewee's answers of the questionnaire. The objectives of this report were: to analyse the impact of BIM on the construction industry, to evaluate the role of BIM and to prove how construction managers use BIM to their advantage instead of using outdated, conventional methods.

The secondary research revealed how BIM has transformed the industry to make it more efficient and effective whilst the primary research showed a positive impact of BIM for most of the participants in the research. The questions were mainly open-ended, which allowed respondents to share opinions on the topic. Question eight asked whether BIM made construction projects easier to complete. The results of this question proved that BIM has made it easier to complete thus proving the positive impact that BIM has provided. Secondly, the evaluation of the role of BIM was expressed in the secondary research in the literature review showing where BIM originated from, some advantages and benefits of BIM and how BIM is being used in the industry.

The third and final objective was mainly proved from question nine in the primary research which asked the other professionals with different occupations "what benefits has BIM had on construction managers in the construction industry?". It was interesting to get a perspective from people other than construction managers i.e., noting the difference in opinion on this topic was worthwhile. Most interviewees replied with several different benefits of BIM as an advantage over 2D CAD (for example). The main benefits were BIM allows easier visualisation, increased collaboration and allows alterations to be made much quicker. These benefits and many more were also included in the secondary research which proves its accuracy that BIM is beneficial to construction managers.

Overall, the primary research technique of using a questionnaire and conducting interviews with professionals in the industry was successful and benefited the research topic very well. It was used in order to explore the three objectives and using secondary data helped explore the third.

V. OUTLOOK AND CONCLUSION

Compared to the McGraw-Hill Construction survey that was taken in 2008 in the US, the UK has been falling behind in terms of utilising this modern technology compared to other areas of the world. That survey was taken over a decade ago and approximately 66% of those who participated in it had heard of BIM, implemented BIM, have positive opinions on BIM, and see a very bright future for it. Compared to this study's questionnaire, there are still people who have not implemented BIM once and do not understand the fundamentals and benefits BIM can provide. In the built environment, with advanced technology, a tool such as BIM can be recognised globally to bring better value, increase in productivity and forming innovative solutions. It was revealed that the recent BIM mandate, made official in 2016, has triggered mixed opinions. Overall, the mandate has benefited most professionals in terms of building, designing and maintaining construction projects. However, in addition to the benefits, certain challenges were brought about. It is fair to say that BIM has transformed the industry by increasing efficiency through many different stages of the project cycle. The results from the research have shown the impact that BIM has had on the construction industry in the UK. Notably, as there were only 10 interviewees, the research cannot be entirely accurate in identifying the impacts, benefits and challenges of BIM but the acquired results give us an idea as to what BIM has done for the industry. Upon investigation, it was found that the negative opinions on BIM is mainly due to lack of knowledge on the professional's side and the lack of involvement in learning BIM, resulting in the majority of professionals disregarding BIM. This is partially due to some companies not exposing workers to the relevant training, probably due to high training costs. Due to the rapid and ongoing advancement of technology, training should be done every short term so that the software can be used most efficiently. As a result, maintaining this technique would require constant investment.

Although some construction managers may believe that for a certain project, BIM does not provide any benefits (likely, as only two construction managers were interviewed), the technique can make up for this in other ways, such as: minimising risk, clash detection and offering more of an accurate budget. Construction managers will be able to set themselves apart from other contractors by adopting Building Information Management on every project because it will eventually become a distinctive selling point due to its rising popularity across the construction industry.

As a summary of the research, this paper has covered all the objectives established and has looked at how BIM has affected the UK construction industry. The research gave an insight in to other people's experiences with using BIM as mixed responses were provided from the ten interviewees. The reason for negative responses was determined to be the lack of knowledge and training. Additionally, people are resistant to change and tend to stick with what they are familiar with, inhibiting their ability to understand how BIM might improve the quality of construction projects and make their jobs more efficient. According to the research, some smaller companies may not have exposed their personnel to BIM because of the high expense of training. Therefore, since the government declared the use of BIM to be mandatory for large government buildings in 2016, a valuable recommendation would be for the government to offer subsidized financing or grants for businesses to facilitate training and support the implementation of BIM on all projects.

Essentially, for BIM to be used worldwide, the technique must be understood by all relevant stakeholders in a construction project and though, its benefits can transform the construction industry, the lack of knowledge in the industry stands as the primary reason why many individuals are apprehensive toward the use of BIM.

A. Future Research and Recommendations

This study highlights the impact BIM has made on the construction industry in the UK. With additional time and research, the supplementary data will expound more on the topic. Additionally, since the primary research was based in the UK and with a selection of only 10 individuals, it is recommended that in future, this experiment should be carried out on larger sample size to garner more accurate results.

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CONFLICTS OF INTEREST

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