IMPLEMENTATION OF BUILDING INFORMATION MODELLING IN THE UK INFRASTRUCTURE SECTOR – A CASE STUDY

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Abstract

The Building Information Model concepts includes a range of IT tools supporting the collaborative processes in an organisation. This approach allows all stakeholders to have an integrated system in which editing and retrieving up to date information on shared models will become easier changing the businesses processes. This paper will be presenting a review of research on the Building Information Model in practice. The Building Information Model has been around for some time and is becoming more popular as of its mandate in the UK back in April 2016. This research is based on case studies on BIM in practice in the transport infrastructure sector. The methodology for this research is a case study on a Tier 1 contractor in the UK who are using BIM as one of their processes. A brief overview of BIM will be explained and the key findings in the research will be highlighted identifying the business value of BIM, the results will demonstrate how BIM is being practiced within the organisation and to improve design management, the challenges with the implementation of the new processes will be outlined, this paper will also show how the construction company have utilised the adoption of BIM to mitigate and manage communication issues within their projects. Research has shown that the key communication and management problems such as loss of documentation, poor communication and quality can be mitigated with the use of BIM. Finding out these challenges will allow the issues found along with the potential of BIM to be outlined and allows the conclusion that BIM is the future of construction. This research allows professionals and academics to understand the process of the Building Information Model and how it can benefit the infrastructure sector. The research will provide challenges faced by the case studies which will enable readers to overcome these challenges as they are aware of what to expect, hence finding solutions.

Keywords: Building Information Model, Communication, Engineering and Construction, Collaboration, Infrastructure.

1. Introduction

The UK economy has been growing over the years averaging at 0.6% growth in three months back in September 2018 which has been the strongest increase since the last quarter of 2016 (Ferreira, 2018). The construction industry has played a major part in the economy growth as the UK government has invested over £600 billion over the next decade on infrastructure and at least £44 billion on housing (UK Gov, 2018). On a global scale, construction projects are becoming more complex, construction project now include several stakeholders and with the rapid growth within the industry communication challenges arise. Communication can affect the quality of the design which can have an impact on project costs.

Construction projects also go through frequent design changes and these changes need to be fed back to the construction team as soon as possible to ensure projects are built to the updated and latest designs. The Building Information Model has in a major topic in the construction industry globally as benefits of its use within construction have come to light. It has been noted that BIM can provide various benefits to the construction process, from the design stage to asset management. To better understand BIM this paper presents a case study to demonstrate the key challenges faced within the project. Key communication challenges are analysed and the key lessons learned are documented. The project currently uses the Building Information Model as one of its processes, this will be investigated, and this paper will highlight how the Building Information Model is being used within the project and if there have been any challenges with the use of BIM. The paper will be split into four sections which answer the research questions:

Research question 1: How important is design management within construction projects?

Research question 2: How does BIM benefit the construction Industry and what technologies are being used in the construction industry?

Research question 3: What is the current state of BIM within the case study project and what challenges and benefits are being faced?

Research question 4: what are the future recommendation for the use of BIM within this project?

Based on the research questions, the main objective for this paper is to conduct a literature review by providing an overview of construction practices and design management within the project. The paper is structured to present the literature review answering research questions 1 and 2. Research question 3 is conducted using the case study research methodology, which will contain the practice of BIM in the construction industry, and finally research question 4 will explore the results from the case study with the finding and challenges explored this will then lead to future recommendations on this research.

2. Literature Review

2.1 Building Information Model (BIM)

In about 1957, Dr. Patrick J Hanratty, the creator of CAM (Computer Aided Manufacturing) took chance to present the AEC (Architecture, Engineering, and Construction) with the Building Information Model and this was the first the model was heard of (Mandhar & Mandhar, 2013). BIM has become more popular over the past 10 years, this is mainly because it contains a lot of benefits compared to most of the other software's. The biggest benefit of using the BIM if used from the start of the project is within the area of design development. With BIM being a 3D model, it is an ideal standard for examining the relations between a number of features of the project and also evaluating their compatibility with the local topography. Transportation Infrastructure has a long lifespan and as mentioned before with BIM being helpful with maintenance aspects, it would be a suitable match to use it with the project. BIM does not only benefit the owners, but also the contractors, architects and everyone involved in the project at hand. For the contractors, it assists with communication be being visual. At the tendering stage, it gives the contractor an opportunity to give the client a display of how they would intend to go on with the project and how he has limited some of the construction in order to get the best quality as long as best price (Smith, 2012). The software would not only benefit in the sense

it could potentially win them the contract, it also provides an opportunity to have an overview of the designer's detail and challenge it if a better outcome could be achieved.

Many benefits of BIM have been documented such as reduction in project costs, saving time, improving projects communication and collaboration and project quality (Diaz, 2016). This Building Information Model also provides the means to increase design quality through detecting clashed between the different disciplines on the design prior to construction, BIM also improves the sharing of Information within the different stakeholders via a Common Data Environment (CDE), this allows the construction teams to always have access to up to date information for construction.

There are many benefits that have been recognised through the use of BIM however there are also challenges faced when implementing and adopting BIM which have been found as follows:

• *More work at the start*

As BIM would require training for the prime contractors, designers and so on, it requires a lot of effort at the beginning of the project. All of these parties need a sit down to produce a collaborative model (Carlin, 2010).

• *Programmes' ability to work with other software*

With the programmes difficulty to work with other software, the company using BIM should consider how they are going to "consolidate, interpret and utilise the increasingly mountainous volumes of data" (Mason, 2014).

• *Stakeholder's software compatibility*

For the stakeholders to have compatibility, it is not necessary for them to be using the same software platform, however it is necessary for the software being used by each stakeholder to be compatible as they would be able to exchange data and files. The issue that can arise from BIM is incompatibility between software's for these stakeholders. This however has a solution, as the IFC software programme enable compatibility between BIM and other software's (Dowhower, 2010).

Just to name a few.

BIM is a process and includes a wide range of other technologies which work together to provide more benefit to a project, this use of technologies is known as Industry 4.0 as the construction industry is going through a digitisation era.

2.2 Industry 4.0; IoT Technologies

The UK have now entered a new industrial era known as Industry 4.0, this is known as the trend towards the digitalisation and automation of the manufacturing and construction industry. Industry 4.0 comprises of various technologies including BIM to enable a digitalised environment for the construction and manufacturing industry (BCG, 2019). The results of the use of Industry 4.0 have proved to improve quality and decrease time while improving performance within a project, despite all these benefits, the construction industry have yet to integrate these technologies as well as the automotive and manufacturing engineering sectors have (BCG, 2019).

Some of the technologies linked with Industry 4.0 are mentioned below:

Cloud: The construction Industry contains a lot of data which is to be stored at all stages of construction to enable a better asset management. Loss of data during the construction stage is a big issue, having a cloud to access data and store data can increase productivity and prove profitable for an organisation (IBM, 2019).

Artificial Intelligence/Virtual Reality: Virtual reality is becoming more popular in the construction industry compare to Artificial Intelligence. With Virtual reality, the project can be view prior to its construction and its purpose can be viewed with the client and stakeholders making them confident in the project, the like of High Speed 2 railway in the UK have used this technology to show the public

(IBM, 2019).

Drones: Drones can be used for a variety of things in the construction industry, site data can be collected cutting surveying time to hours instead of days. Up-to-date and accurate site information can also be collected which can be used to check for the sites progress and productivity (Propeller, 2010).

Simulation: Simulations are becoming more popular in the construction industry, they are extensively used for plant training which allows operators to use machines at its trial period in the virtual world before using it on site (BCG, 2019).

Additive Manufacturing: The construction industry has been using Additive manufacturing, it is where products are pre-constructed off-site such as modular blocks, and then transported to site to allow for construction. This allows for complex designs to be constructed in an environment where the detail can be constructed accordingly and then placed of the site with no delays (BCG, 2019).

These are just a few of the technologies that are related to Industry 4.0, the Building Information Model is also one of the technologies linked with Industry 4.0, however BIM in cooperates some of these technologies to provide more benefits (Oesterreich & Teuteberg, 2016). Drones can be used with BIM to compare site data with the 3D model of the design to check progress. BIM Level 2 also requires a Common Data Environment (CDE) in which most companies use a cloud to store all their data.

3. Research Methodology

For this research, a combined methodology was used, for the purpose of answering research question 1 and 2, a systematic literature review was conducted to explore construction processes and identify the technologies linked with Industry 4.0 and BIM. For the purpose of answering research question 3, a case study research approach was adopted to investigate the Building Information Model in practice, identifying and analysing its use. To further this research and explore other technologies beyond BIM, semi-structured interviews were conducted within 3 projects in the UK to explore what is the current knowledge of Industry 4.0 technologies in the infrastructure sector in the UK. A triangulation strategy was adopted for this part of the research which offers the ability to explore the research topic from different perspectives allowing the research questions to be answered with a variety of data (Bekhet, 2012).

3.1 Systematic Literature Review

A systematic literature review is produced through aiming to identify an issue, evaluating the issue and integrating. This method was chosen as one of the research methods as it allows the research to address a broad range of questions hence minimising limitations to the research. A systematic literature review can be defined as:

> *"A review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyse data from the studies that are included in the review. Statistical methods (meta-analysis) may or may not be used to analyse and summarise the results of the included studies"*

First, a literature review was conducted to gain a solid base of data for the context analysis, scholarly context was analysed which enabled the findings of the basics of technologies used in the construction industry and BIM, it was clear that the research had to be broadened which was conducted by using Google search with the key phrases of this research.

A wide range of sources were covered to gather a representative of the general outlook on this topic, these are listed below in order of academic quality:

- Journal articles
- UK government published reports
- Books
- Professional bodies such as the ICE (Institute of Civil Engineering)

3.2 Qualitative and Quantitative context analysis

It was clear that one form of analysis would not provide as much data as a combined methodology, within the qualitative analysis, recommendations from (Mayring, 2000) was followed:

- Preparation of the research questions
- Introduce categories of definitions
- Check categories are relatable to topic
- Interpretation of the results collected

3.3 Case Study Research

The aim of this case study research is to examine BIM in its natural settings and by employing multiple methods of data collection and obtaining data from professionals in the business, during this investigation we follow a framework strategy recommended by Robert K. Yin (Yin, 2014). Two factors are to be considered when interpreting the results. First, due to the limitation of investigated research paper from the year 2010, it cannot be guaranteed that all relevant publications have not been covered hence the research should be validated with further studies, e.g. expert interviews or empirical study. Secondly, a few of the research publications are non-peer reviewed, for example blog posts which may contain information that cannot be verified. Data collection was obtained through 15 interviews and questionnaires were handed out to 20 employees. 8 observations were held with different disciplines within the project.

Through observing the employees, key interactions between the different disciplines were recorded, important points within meetings and communication methods were recorded. During the interviews the responses were recorded and the main analysis method for the interviews was classifying the patterns and arguments. Notes were also taken during the interviews which were studied, and the document analysis method was adopted to support the findings from the data collecting methods.

3.4 Interviews

Semi-structured interviews: These generally consist of a variation of key questions that would assist in defining the areas of the topic that is of interest, it also at the same time allows the interviewer to pursue the answer in more detail which would be useful. The answers obtained from the responder are not limited hence more detail can be explored (Gill, 2008).

Unstructured: Unstructured interview do not reflect any ideas put into the research. These are generally very time consuming and are difficult to manage and participate. Lack of questions provided can prove difficult to explore the topic and subjects to talk about (Gill, 2008).

Interviewing is a method of its own, however there are a number of forms on interviews that can be undertaken to obtain results for a research (UTSA, 2015). Below are the two main forms of interviews that can be done:

Phone interviews: This form of interview is usually used if the respondent lives in another city or state. In these situations, it is critical for the investigator to be well prepared and undertake the interviews in a quiet area for the information being passed through the phone to be clear and understood.

Face to face interviews: This form of interviews needs to be scheduled before hand and the

questions presented are to be in the same order for each respondent. These are preferred as the conversation can be semi-structured hence more information can be collected.

For this research, semi- structured interviews were conducted to collect data from staff in practice of the use of BIM and innovative practices within the case studies.

3.5 Limitation to this study

There were a few limitations within this study, as observations were undertaken with the with the employees, the observations were not consistent as employees attended meetings and also went onto having their data to day busy work life go ahead. This disrupted the observation process. due to the researcher being in the industry, there was also not enough time to observe the second project case study as the second project was at a distance. Travel became a limitation for this data collection process which also lead to some phone interviews to be undertaken instead of face-face interviews.

4. Results

The following section will start by providing related work to demonstrate the uniqueness of this contribution. The results are the presented as well as the findings from the case study research and finally future work and recommendations will be demonstrated.

4.1 Project description

The UK government has invested in smart motorways all over the country in the hopes of converting normal motorways with three lanes and a hard shoulder into All Lanes Running motorways. The M23 Junction 8-10 is one of the current projects which commenced construction in 2018 and is expected to last a duration of three years.

The proposed All Lane Running scheme would provide four permanent running lanes through converting the hard shoulder into a running lane and various technologies will be in cooperated to assist with safety and keep traffic moving. These technologies include installation of 26 new gantries (the existing gantries are to be demolished/ retained and upgraded where possible), which will be fitted with message signs and AMI's (Advanced Motorway Indicators, strategic signs and variable message signs. Speed limits will be displayed based on traffic conditions to allow traffic to keep flowing and CCTV cameras and loop detectors will be fitted to provide information support to a control centre. The central reserve will also be hardened, and a rigid concrete barrier will be fitted. The projects overall view can be seen in Figures 2 and 3.

Figure 1 3D model of project; Junction 8

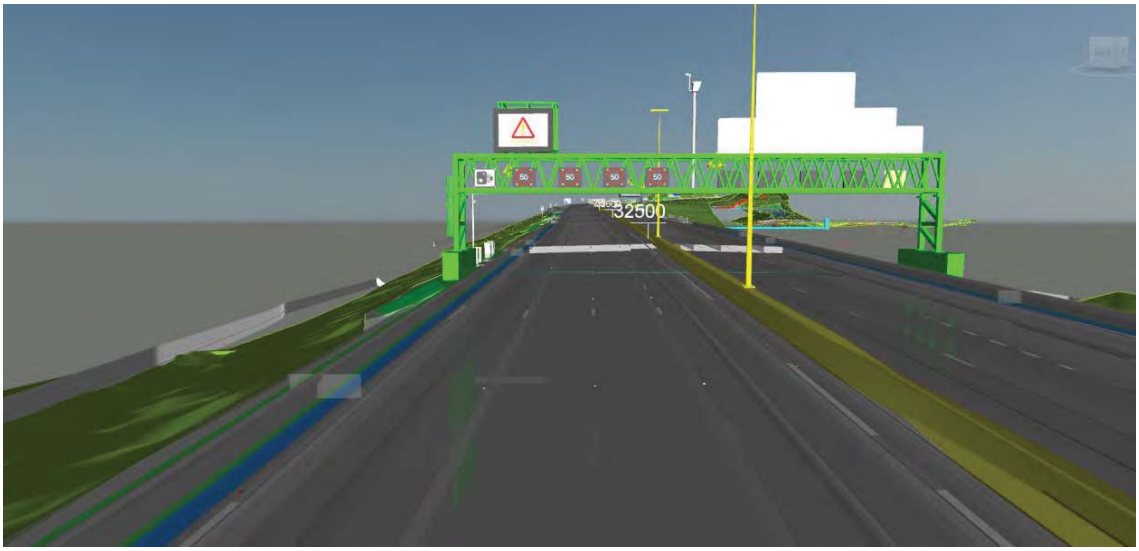

Figure 2 3D Model of project; New gantry to be constructed

The project has adopted as required by the UK government and a design 3D model was created as demonstrated in Figure 2 and Figure 3. The project comprises of three different organisations, the designers, the contractor and the client, and sub-contractors. The project has a BIM coordinator, BIM manager and BIM Coordinator of the designer's company.

4.2 Project Analysis

The following section details some of the issues being faced within the project which have been identified after the data analysis regarding the use of the Building Information Model. The discussed issues include communication tools, implementing BIM, collaboration with sub-contractors and up-skilling.

Table 1 Challenges of BIM within Case Study Project

Implication Challenge
• Acceptance: The project has adopted BIM from the start and training session are held in order to be Level 2 BIM compliant and utilise the Common Data Environment. All project information is uploaded on the contractors CDE and distributed to the relevant disciplines, however when distributed, there is a lack of responses as the disciplines do not download the updated documents form the CDE as they would grab a paper copy from team members. This is an issue because the printed copies may be previous revisions.
• Process Changes: The implementation of BIM must take place at all levels of the organisation which requires re-engineering the business practices, as most employees in the organisation have been in the industry for over 15 years, the reluctant to change the way of working is quite difficult. Training sessions are held every week to allow employees to understand the BIM Level 2 processes, however once training is completed most employees tend to revert to their old ways of working.
• Communications: Within this project there are three CDE's. The client has their own CDE which a number of people have access to and is used for Technical Queries and raising PMI's (Project Managers Instruction), the designers also have their own CDE which the client, Document Controller of contractors and themselves have access to where documents are issued, and the contractors have their own CDE which everyone has access to, as there are three CDE's with limited access for employees to two of them this can be difficult as not everyone has access to view all project information.
• Use of 3D model: the 3D model is available for use and everyone on the project has access to it, however not everyone uses it to gain the benefits it provides even though they have been trained.
• Communication Tool: the contractors CDE contains a communication tool which can be used to communicate with sub-contractors etc. however this has not used, and emails are mainly sent which can cause loss of data.

Even though there a number of issues with the use of BIM on this project, there are various benefits which BIM is providing to the project which are demonstrated in Table 2.

Table 2 Benefits of BIM to Case Study project

Implication Benefits
• 4D planning: The project has produced a 4D sequence which was requested by the client, this allowed the Planners, Operational team, CAD technician, BIM team and designers to collaborate as the design model was needed along with the programme and works sequence to produce the 4D model. The 4D sequence was produced at a section where major works were to be conducted and there were a lot of risks involved with the works. the sequence allowed the operational team to view the programme and justify that there will be enough space for the machinery and plant.
• Visualisation: The model is being used for visual purposes, to encourage the use of the model, the project has invested in a BIM station, this is a pod with an interactive monitor which consist of the model for collaboration during meetings and also consists of the CDE training videos and BIM Level 2 requirements for employees to have a look through. This has been quite a success as the pod being interactive made employees eager to play around with the model and encouraged them to attend training sessions in order to learn how to operate the software's.
• CDE: There are pitfalls with the CDE as there are three of them, however the CDE being used by the contractors takes a major role in the works, the contractors CDE is where all construction information in obtained by the operational team, however there is still to be a push for employees to adapt to obtaining the current revision of drawings uploaded.
• Asset management (Life cycle benefits): At this project, as the construction process is happening, asset data is being collected and this will be inputted into the model, the will allow the asset to be maintained in an easier way as all asset data is stored in one place and is attached to the model itself.

• Clash Detection: At the early stages of the project the model was used for clash detection between the sub-contractors and the contractors, the model was used to visualise where the proposed temporary CCTV cameras were to be placed and to check if it clashes with the proposed works, a number of clashes were found which enabled the team to move the CCTV cameras to locations where there were no clashes. this saved time of re installing the CCTV bases if the clash detection was not conducted.
• Walk through of job: A fly through of the job has been recorded by the BIM Team, which is regularly used to show stakeholders and visitors to the site and the works. Most visitors visit the site office and do not get to see the job, however with the fly through in place that is possible and reduces the safety risk as visitors do not physically go on site.

4.3 Industry 4.0 Technologies Results

Within the construction infrastructure in the UK, results show that the Building Information Model (BIM) is the most known technology within Industry 4.0. 15 employees in the industry were interviewed and 12% out of the 15 interviewees have heard of Industry 4.0. 66% however have heard of some of the technologies which are involved within Industry 4.0. the most popular technology that the interviewees revealed that they have heard of is the Virtual Reality and Augmented Reality.

Within one of the projects, the designers of the project use photo realism, Virtual reality, augmented reality and aural representation to bring life to the route of the railway line enhancing the experience and impacting the planning and consultation process. The creation of the digital version of this so to be real railway line assisted in the decision making of the project teams as it involves major works. The project has had many members of the public against it, however with the media being provided with the footage it enabled the public to get an understanding of the project and what it will look like once finished, given the opportunity to see the future enable all parties involved within the construction and design process to make better decisions at all stages of the project to date.

Despite the project utilising VR and AR, 34% of the interviewees still were unaware of these technologies associated with Industry 4.0 and 88% have not heard of the industrial revolution. The results indicate that Industry 4.0 is a majorly under researched field and awareness within the industry is very low.

4.4 Discussion

Implementing BIM

This project uses Autodesk products to produce the 3D model, AutoCAD civil 3D is used to produce the civil elements of the job and Revit is used to model the structures, i.e. bridges, gantries, etc. 84% of the design team members were familiar with the specific software, where 16% were formed of a mixture of graduates and Planning/Commercial teams. On the contractors end, the BIM team were all familiar with the software which was a benefit as the training sessions held by them with the staff members was aimed at educating other members of staff who do not understand the way of modelling and how models are created.

The implementation of BIM within this project has been semi successful, the model is available for all project staff and so is construction information within the CDE, however the process change proves to be difficult for all staff to adopt. BIM can be an efficient way to exchange design information between disciplines, which is what is being practiced on this project, but with the reluctance from employees to attend training sessions and practice what has been learned from these training sessions, the full benefits of this are not clear.

Subcontractor involvement

There are some important subcontractors on this case project, with the construction containing various details such as drainage, structures, fencing etc. the contractors have many subcontractors to assist with the construction who are experts at their field. All the design details required for construction from the subcontractors are to be shared via the CDE, however this process is not commonly used. The

CDE provides the benefit of subcontractor communications to be sent and stored for record keeping however after analysing the data from this research, 12% of the commercial team use the CDE to communication and collaborate with subcontractors. When asked the questions about the reluctance, it was noted that most of the commercial team have attended CDE training however do not regularly go on the CDE to remember all aspects discussed in the training session.

Industry 4.0 Technologies

Industry 4.0 technologies are one of the leading drivers within the digitalisation of the industry. There is a major lack of awareness with the industry on these technologies which is why the revolution has not picked up yet. As shown in the results, only 12% of the interviewees were aware of Industry 4.0 which is extremely low. Raising awareness within this topic will allow organisations to invest in the technologies associated with Industry 4.0 which and as people are unaware of the technologies more research is to be conducted within this topic to allow the industry to take the measures to allow the revolution to succeed.

5. Conclusion

This research presents a detailed study which was executed between April 2018 and January 2019 on the Building Information Model in practice on a Smart Motorway Project. The case confirms several points identified: (i) The Building Information implementation process is a tough one, it involves a lot of awareness and training to staff for level 2 to be adopted in the right manner. (ii) communication can be improved with the use of BIM, the likes of subcontractors and different disciplines in the organisation can communicate easier with the use of a CDE while all data is also stored, this however is a process that team members must undertake and adopt. (iii) BIM can contribute to communication between team members, as the results suggested the 4D sequence was a collaboration between different teams showing the planned programme of works which helped the client understand how the works are going to be undertaken.

The two most important findings in the research were that the contractor should enforce a communication framework within the organisation to ensure the use of the right BIM processes to communicate between disciplines. Secondly BIM competencies between the different disciplines should be similar and although training is being provided, more awareness on BIM would enable the organisation to raise interest on the BIM level 2 standards and processes.

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