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BIM adoption in UK PPP construction projects

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Abstract

Building Information Modelling (BIM) is an innovative technological advancement which has played a vital role in transforming the construction industry in terms of design, construction and management. The issues identified in literature would contribute in accelerating the adoption of BIM in the UK construction industry, especially for designers and contractors. It is essential to interact with the construction industry, and investigate which factors form the basis of impacting the performance of construction industry. From the following dissertation it is observed that construction industry undergoes a great deal of risk by investing time and money in promotion of BIM, especially during times of economic recession. Advantages of BIM as well as a lack of awareness of value added of BIM are identified. The problems associated with BIM interoperability as well as the degree of information leveraged from BIM are clearly understood. With the increase in governmental efforts to integrate BIM into the construction industry, the UK will soon become a global leader in BIM. Further research in this area is required.

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Chapter One: Introduction to the Study

1.1 Introduction to the study

Building Information Modelling (BIM) is an innovative technological advancement which has played a vital role in transforming the construction industry in terms of design, construction and management (Hardin, 2009; Azhar et al., 2008). The use of BIM across construction industries in the UK has been increasing steadily over the years and is forecast to be the most widely used tool in the UK construction sector. Furthermore Eastman et al. (2011) remarked that the use of the BIM in the construction industry forms the stepping stone to unify disparate technologies used in the life cycle of the construction project. Aranda-Mena et al. (2009) identified that the BIM enabled effective functioning of interdependent processes of planning, analysis, designing and construction.

HM Government (2012) identified that the UK government has given importance to the construction sector, as it is observed to be one which contributes a great deal to the economy. The construction sector in the UK is highly diverse in nature and is found to be made up of different subsectors. It is observed that in the year 2010 a total of one hundred and seven billion pounds were contributed to the UK economy by the construction sector. In addition BIM Taskgroup (2011) identified that this sector is also found to employ 2.5 million workers and thus is a key contributor to the success of the UK economy. It is also observed that the government construction projects are greatly impacted by the private sector and at least 30% of projects promoted by the government are found to be public-private partnerships (PPP).

Currently competitive advantage has been established in the UK in certain construction sectors including lean engineering, low carbon built environment solutions and other such aspects. BIM Taskgroup (2011) identified that these advantages have been made possible due to the increasing influence of technological advances in the form of construction engineering software. In order to promote a more effective capability assessment, the government and the industry will take measures to create further opportunities for the UK construction sector. One of the vital measures promoted by the government is Building Information Modelling (BIM).

The strategy adopted by the UK government in order to deliver a structured capability to the construction industry is to increase the overall take-up of BIM by all construction projects in the UK over a five year period. To start off, the government has taken efforts to involve BIM in all public sector projects. The government, in line with the 'mobilisation and implementation plan', is found to promote the BIM strategy by ensuring that BIM is embedded in a number of government-procured construction projects. It is observed that local governments are increasingly adopting BIM in order to ensure cost reduction, environmental protection and lean design.

By making use of this government-led input, there have been a number of responses from the industry which enable rapid and positive adoption of BIM on a large scale. Today the UK construction sector is recognised as one of the leaders in adoption of BIM technology with a government-led central program. This study examines the adoption of BIM by public-private sector partnerships in UK.

1.2 Background

The BIM continues to be in the limelight as it is considered to be a main stream of income contributing to diverse construction projects. McGraw Hill (2008) reveals that 61% of the surveyed contractors felt BIM had a positive impact on the operation of construction management. In contrast amongst the design engineers only 39% accepted that BIM had a positive impact. Furthermore a great deal of negative impact of BIM was observed by the owners as the report revealed that only 10% of them were happy with BIM.

According to Rowlinson et al. (2010) and Boktor et al. (2013), the main reasons that BIM showed presence of negative impacts are down to problems in costs and training. However, despite these views, BIM was still looked upon as a measure to overcome different challenges that are faced by an organisation. Zuppa (2009) says that a certain amount of non-value added work is associated with the inoperability or improper communication of information. This has resulted in poor adoption and acceptance of new technology in the construction industry. He also indicated that this trend is bound to continue despite advances made.

Castro-Lacouture (2009) recorded details among architects, engineers and contractors to determine their views on the BIM software and how it performed. Since it is a very new product in the industry there is a dilemma amongst the owners whether they should adopt the model or not. The current UK government guidelines for the general contractor, the engineers or the architect to use this product and monitoring of the progress of the project have resulted in greater awareness.

Furthermore Porwal and Hewage (2013) identified that difficulties associated with BIM implementation arise due to the lack of a single authoritative person assigned for developing a BIM plan for a particular project.

This only highlights that creating a BIM plan at the earliest opportunity will lead to the success of the project and in some rare situations the BIM plan has to be contracted by a third party. This leads to a number of conflicts as it results in the involvement of too many types of construction contracts. This study examines the value addition, advantages and interoperability issues associated with BIM adoption.

1.3 Objectives

i. To arrive at the perceived benefits of BIM
ii. To identify the areas of value addition in the construction industry
iii. To identify the KPI of the construction industry
iv. To identify the type and degree of information which can be leveraged from using BIM
v. To identify the interoperability issues of BIM

1.4 Structure of thesis

This dissertation is organised into five chapters. Chapter One provides the introduction and background of research. Chapter Two presents the review of literature associated with BIM. Chapter Three presents the methodology. The final two chapters present the results and conclusion to the study.

Chapter Two: Review of Literature

2.1 Introduction

The Egan Report (1998), presented to improve the quality and efficiency of the UK construction industry, identified Building Information Modelling (BIM) as a measure of improving coordination and communication between different stakeholders in the construction industry. Since then a number of reports and academic papers have examined the growing importance of BIM in construction (Eastman et al., 2011; Succar, 2009; Tse et al., 2005). A Building Information Model, built up of intelligent building components, helps present a three dimensional digital representation of a building by ensuring that the views of different stakeholders are taken into account (Goedert and Meadati, 2008) The use of BIM enables virtual design and construction of a building throughout its lifecycle and forms the platform for sharing knowledge and communication between different project participants (Azhar et al., 2008). This chapter presents a review of literature concerning the characteristics of BIM, the use of BIM in construction, the advantages and drawbacks of BIM, value added to construction industry by using BIM and finally identify the research gap.

2.2 Definition of BIM

It is vital to have thorough knowledge and understanding of the definitions of a Building Information Model and Building Information Modelling, in order to apply the same in the construction industry. According to Kymmel (2008), the use of software and hardware related to computer application in order to identify a virtual representation of a building in a manner which promotes identification of physical characteristics of the project is the basis of a Building Information Model. This model conveys all the information which is contained or attached to the components of the model. Such a model provides information of all or any of the following features including 2D image, 3D image, time scheduling using 4D, cost information identification related to 5D or *n*D related to other aspects like sustainability, energy, and management of available facilities.

With few other variations Lee et al. (2006) identified Building Information Modelling as the process of making and/or utilising a Building Information Model. According to this definition, Building Information Modelling is to be promoted as an essential tool that plays a major role in attaining the objectives associated with the construction project.

On the other hand, the definition of Building Information Modelling as a tool has been acknowledged. According to AIA (2007), BIM is defined as a digital, three-dimensional model which is found to be associated with a database providing all aspects of project information. It is also promoted that BIM can blend with other criteria denoting construction project success, including design of construction, availability of information fabrication, instructions related to construction, and logistics related to project management in a single database. It encourages the blending of project goals throughout the project's design and construction.

Eastman et al. (2011) made a contradictory statement that BIM is not solely a software package, but a process. According to them, BIM can be identified as a modelling technology with well-knit procedures to create, interact and examine building models. Building Information Modelling is a word utilised for the description of tools, processes and technologies that are associated with digital, machine-readable documentation. This documentation is about a building, its functioning, its planning, its construction and, last but not least, its operation. Hence, BIM is said to depict an activity and not any type of entity or substance.

Furthermore Ashcroft (2008) identified BIM to be the outcome of a modelling function which can be further described as a digital, machine-readable record of a construction, the related performance, the degree of planning and the delay in construction.

According to Hardin (2009), Building Information Modelling cannot be considered as a simple tool, but it a process involving the use of software to achieve the goals of construction project management. This is in agreement with the views of Eastman et.al. (2011). They further present the view that a number of contractors proceed with a false conception that the purchase of BIM software automatically promotes integration of BIM software successfully in their operations.

Heesom and Mahdjoubi (2004) supported this view by indicating that there is lack of awareness among contractors with regards to the perceived use of BIM. Building Information Modelling not only comprises usage of three-dimensional modelling software, but also requires expertise and innovation on the part of the user.

Furthermore Howard and Bjork (2008) proffered that the moment a company begins to implement BIM technology it will begin to experience a change in its processes.

Other procedures that have been suitable for CAD-type technology are not as good as BIM. BIM is capable of adapting to changes in any stage of construction and therefore is the ideal software tool which can be used by a construction organisation.

In line with these views, in this dissertation BIM is considered to be both software and a process which can be used to identify a number of parameters associated with the construction project. However, it is also important to note that the use of BIM involves adapting to the complexities of the project and requires expertise and innovation. As the technology is liable to change, so are the techniques and procedures of the technicians who are handling the technology.

2.3 Use of BIM in Construction Management

Different stages in construction management find different functionalities of Building Information Modelling. The following Figure 1 identifies these aspects involved in the planning, design (pre-construction), construction and operation (post-construction) phases.

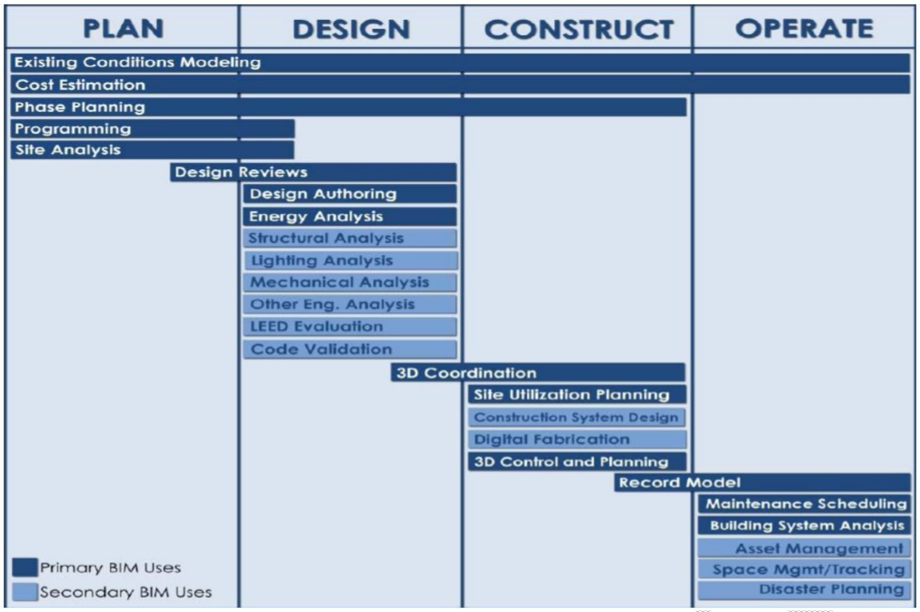


Figure 1: BIM application in project life-cycle (Haron et al., 2010)

Baldwin et al., (1999) are of the opinion that the utilisation of BIM in the design phase will be favourable for the project as it can have a direct control over the cost factor and enables balancing of the cost involved during construction. The design team will have the ability to come out with innovative ideas and will also be able to find solutions in case any cost issues arise. Such a degree of integration at design level can be promoted only if there is complete unity and co-ordination amongst the members of the team. Pektas and Pulter (2006) support this view by stressing the need for unity among staff members. The degree of collaboration is strongly identified during the design phase.

Moreover Fernie et al. (2006) remarked that, once the design is completed, the architect and the engineer can be called to examine the design and test sustainability, time and cost delay projections as well as conduct an energy analysis.

Following this the construction manager is summoned to furnish constructability of the project, sequence related information, construction value and engineering reports. 3D coordination can also be completed among subcontractors and vendors in the primitive stages of the design phase.

Woo (2006) and Azhar et al. (2008) identified the involvement of the owner in the design phase of a construction project by making use of BIM. According to them, the use of BIM facilitates understanding of the construction design the current design is his main focus. Azhar (2011) supports the views of all authors cited in this section and identified that the role of BIM is to help all important stakeholders.

Various positive qualities of the use of BIM during the construction phase have been identified in extant literature (Azhar et al., 2011; Eastman et al., 2011). The three main features are detailed below.

The post-construction phase comprises scheduling maintenance, identification of lifecycle asset management, planning for disaster scenarios, modelling of records, management of space and building system analysis (Lee and Sexton, 2007). Smith and Tardiff (2009) are of the opinion that the use of BIM enables maintenance of the building throughout its existence. Eastman et al. (2011) especially promotes the idea that building automation systems (BAS) help to restrict and keep an eye on the efficient utilisation of the electrical and mechanical equipments. In addition, building system analysis helps in restricted usage of electricity, lighting and mechanical equipments in order to be cost effective and helps in the increase of the building's performance. The following roles of BIM in construction have been identified.

2.3.1 Visualisation

According to Yan et al. (2011), Building Information Modelling (BIM) is a dynamic visualisation tool. It projects a three dimensional virtual representation of the building under construction. In addition to this the role of BIM in project bidding is promoted. Hallberg and Tarandi (2011) identify that, in the bidding phase, the construction manager can present the advantages of their building design by providing images and walkthroughs as well as providing stage-wise sequencing of the model by using the BIM in 3D.

According to Succar (2008), visualisation or a mental assumption of the end product helps in achieving a better idea about the appearance of the end product. The collaboration of the 2D views to arrive at a 3D view with all the details can be achieved by visualisation. Moreover Sacks et al., (2010) present that the owner and the designer have the privilege to possess virtual mock-ups such as laboratories or building envelopes. This process helps in securing a more precise interpretation of the design and will be useful to arrive at effective conclusions based on the aesthetics and the operational quality of the area provided. Furthermore Mihindu and Arayici (2008) are of the opinion that the use of tools like virtual mock-ups encourages interaction and coordination among different stakeholders. It also encourages the planning and sequencing methodologies during the curtain wall construction.

2.3.2 3D Coordination

The degree of coordination and collaboration between different team members of the project is most important. All stakeholders including the owner, architect, engineer, field supervisor, construction manager etc. use BIM and present a greater degree of coordination from the initial stages of the design phase (Eastman et al., 2011). Olofsson et al. (2008) supports this view and identifies that this aspect is mainly because of the immediate implementation of the Building Information Modelling which is best when it commences at the earliest.

Aranda-Mena et al. (2009) identified that such an early implementation delivers the time and space for the conversion of the architect's 2D drawings into 3D intelligent models which is later on transformed by the efforts of the construction manager. When niche contractors like the speciality contractors, MEP contractors and the steel fabricators are involved, a certain amount of focus must be provided for them to combine the model spatially and work effectively. Furthermore Bryde et al. (2013), indicates that, immediately after the construction of the model, the 3D coordination or any discussions based on this can commence; this is mainly done to avoid interference due to similar space (hard clash) or clearance clash (soft clash).

In summation Jung and Joo (2011) identified that, in order to avoid huge design errors and for the better understanding of the project, collaboration between the construction manager and speciality contractors must take place in advance. This will provide space and time for the contractors and construction managers to understand each other and promote 3D coordination.

2.3.3 Prefabrication

Prefabrication is used mainly to decrease the field labour costs and time, which in turn helps improve the degree of accuracy and quality of construction. This methodology also offers various tools in a monitored environment within the work area (Sebastian, 2010). These tools help to perform cost effective work within a very short time span. Prefabrication therefore promotes design and field accuracy.

Wang et al. (2012) and Eastman et al. (2011) identify the role of BIM in prefabrication. The construction of BIM leads to the acquisition of the required amount of accuracy by identifying criteria such as sequence, finishes, and 3D visual for every single attribute of construction management.

Furthermore Sacks et al. (2010) present the view that the construction team must ensure that the BIM can be operated from both sides with the software handled by the fabricators. The degree of interoperability of BIM is vital, as explained in depth in the following sections. This will also help the contractors utilise the BIM and access product details from the software used by the fabricators.

Kymmel (2008) identified that following the approval of details the products are allowed to be fabricated with the help of Computer Numerical Control (CNC) machines. In addition to this, the construction managers are required to monitor the procurement schedule of the construction management projects. Finally, the prefabricated products should be transported to the work area within the scheduled time.

2.4 Advantages of BIM

The BIM or Building Information Modelling is distinct in its qualities and is very ahead of time when it comes to exhibiting its abilities. It renders architects, engineers, and construction managers the required interoperable program in order to fulfil their entire wish list. BIM is declared to be completely limitation free during utilisation except for the potentiality of the users. The advantages achieved while using the BIM are:

- Conflict resolution – all flaws including conflicts are found out in advance, hence any modification in the drawings can be performed ahead of the construction process (Bryde et al., 2013).
- Adjusts costs as changes occur –modifications in the projects can be identified as time moves on. The amount spent on certain processes is observed as an investment in the BIM, following which modifying different objects will not only help collaborate with the design section but also enable real time cost estimation (Demian and Walters, 2013).
- Speeds up design/construction process – BIM helps in quick completion of processes such as programming, preliminary design development, or preplanning for construction. However, the only process that cannot be influenced by the speed of BIM is the drawing process performed by the architect. Effective and creative designs are time consuming and cannot be

created in a pressured environment. This program can be used to increase the speed during the creation of construction drawings (Underwood and Isikdag, 2010).

- Reduces ultimate cost – this takes place by reducing time for construction, accumulating a certain amount of revenue for transformation and taking care of changes as and when they occur (Eastman et al., 2011).

- Single entry – according to Aranda-Mena et al. (2009), when there is recording of a single aspect into the plan view of a drawing, it will be exhibited in the scheduling of doors and elevations (interior and exterior), as well as sectioning interior elevations, exterior elevations, and sections. If any changes are done, when an object is modified everything associated with it in the BIM change as well. Any modification in the estimation will definitely create a change in the BIM. Not only that, but it will also help to identify anything that changes right from substitutions of objects - i.e. electrical demands on panels after changing lighting for the building, etc.

- Alternates – as alternative scenarios and substitutions are not difficult to modify and change in a BIM, it provides the owners with a privilege to ask for different types of alternative designs and schedules in order to check how cost can be balanced (Jensen and Johannesson, 2013).

- Design optimisation – vital for handling LEED issues (Flager et al., 2009)

- Conflict identification and resolution – this is appropriate for identifying locations for the working of suitable operations such as mechanical, electrical, and communication. The only constraint is that the contractor should see to that all the operations perform in the allotted spaces, otherwise there are chances for the occurrence of unnecessary conflicts, especially when the employees are asked to commence work in tight spaces (Garber, 2009).

- Constructability – details can be gathered to display how building components are assembled.

- Construction sequencing as well as scheduling – to view the progress made, the model has to be sequenced and scheduled. The use of 4D BIM modelling will help maintain the schedule of construction projects.
- Life cycle evaluations – solar energy and other non renewable sources of energy use in building can be evaluated. This can be utilised for performing energy calculations in order to find out the cost for running the HVAC for a building. This is an added advantage for budgeting cost over time (Zabalza Bribian et al., 2011).
- Operational simulations: BIM enables real time view by animating the model in order to display the activity, e.g., how a medical facility would be used. It can be used to present how the patient would be transferred from ICU to a normal ward; or can depict real time simulation of operational function of the plant in order to ensure that all functionalities of the building can be met (Yan et al., 2011; Tse et al., 2005).

Having understood the different areas of value added and the advantages of BIM in construction industry, the following section examines the current perceptions of BIM.

2.5 Interoperability of BIM

BIM is clearly a vital subset; however, the main ingredient that makes BIM crucial is its "interoperability", which is nothing but its ability to coordinate and interact as a consistent representation of the same building for all of the purpose built models. According to Howell and Batcheler (2012), the success of BIM depends upon the sharing of information among the various BIM models. Various software applications may be required for the various ways in which BIM can be used and therefore it is important for BIM that the software remain interoperable. According to Kiviniemi et al. (2009, p.64), “Synchronisation issues, project management, partial model exchange and software interfaces all require high interoperability and would definitely appreciate further research.” BIM is constantly evolving and as it keeps evolving more tools are being introduced, and once again interoperability becomes an important matter.

According to Moon et al., (2011), “eight in ten BIM users say there is a significant need to improve interoperability.” Different software applications and packages from various vendors may not interact with each other harmoniously and this could lead to issues related to exchange of information which in turn can hold back the development of BIM. By agreeing early on issues related to connectivity and interoperability, some of the issues can be mitigated.

The main expectation after the BIM is implemented is that all the members working on the project will adapt to a uniform BIM system. However, in reality project teams consist of a number of companies, each of which would want to use their own software system and applications for the design and management of projects (Porwal and Hewage, 2013).

At the same time, it is not possible for one software program to handle all functions, such as specification writing program and the cost estimation program. Therefore separate software programs have to be used and these separate systems would require access to a common database. According to Eastman et al. (2011) it is extremely rare that a single program is used to handle all the different functions.

In a bid to resolve some of these interoperability issues, the Industry Foundation Classes (IFCs), developed by the International Alliance for Interoperability (IAI), has introduced rules and protocols. These protocols go a long way in providing consistency when it comes to the manner in which the data representing the building in the model are defined in accordance to the agreed specification of classes of components. These common specifications help in fostering a common language in the construction industry (Azhar et al., 2008).

The technological interface between the construction and the design industries is an area where a lot of the issues crop up on BIM models. The file formats and the various programs have to be compatible if a virtual model is to be created. These programs and files should be capable of being opened by different software that is being used by the different companies. In cases where some of the files cannot be opened up, or they require additional software, then the implementation of BIM is said to have failed (Furneaux and Kivits, 2008).

2.6 Conclusion from theoretical analysis

Although BIM is the future, there are still a number of issues that have to be sorted before the industry can benefit fully from it. BIM's ability to produce three dimensional visualisations is very useful, but the limitations it currently faces keep it from being fully exploited. BIM first has to be fully integrated. BIM is not just about buying and installing a number of different software but, according to Eastman (2008), it is in fact about the software and the process. This point is reiterated by Azhar et al., (2008), who say that in order to fully implement BIM, a lot of changes have to be made to the business practices that are being used currently as well as the cultural and behavioural transition of the industry. There is also a need for increased cooperation and interaction between the various parties during the project planning and construction. Therefore, the issues identified in literature would contribute in accelerating the adoption of BIM in the UK construction industry especially for designers and contractors. It is essential to interact with the construction industry, and investigate which factors form the basis of impacting the performance of construction industry.

Chapter Three: Research Methodology

3.1 Introduction

According to Creswell and Clark (2007), there are two important considerations for any type of research that is to be conducted and they are the objective of the study and the facts behind conducting the research. This chapter has a particular goal, which is to display the monitored process with regards to the response of establishing BIM in UK public private sector partnerships.

3.2 Research design

The primary step in research design is to find out the research objective as per the intention that was first exhibited by Saunders et al (2009). This particular design consists of six varied elements that will transform into the foundation of the research procedure for the present study.

3.2.1 Research philosophy

The philosophy used for the current research is mainly dependent on the researcher's mentality and what kind of intelligence the researcher would have used during the analysis of the study. The present study utilises both realistic as well as interpretivistic philosophy. This will be of great help while providing a goal including the present condition of BIM usage in the UK PPP sectors, the effect of BIM on KPI in the construction industry and the advantages and disadvantages in the system.

This system can be further familiarised amongst social constructs and is not controlled by the ideologies of the researcher (Bryman and Bell, 2007).

3.2.2 Research approach

The current study makes use of a deductive approach, mainly as it is easier to gather empirical information after the formulation of a set of hypotheses (Leedy and Omrad, 2005). The proposed hypotheses involve realising the value added of BIM to the construction industry, calculation of pros and cons while implementing BIM and strategic implications of KPI implementation.

3.3 Research strategy

The three most common strategies that can be utilised in this type of research are: qualitative, quantitative and mixed. The present study states that mixed method strategy is what is used in common these days. As per Bryman and Cramer (2011), reliability and generalisation of the chosen research strategy can be done by quantitative tolls of data analysis. Furthermore, according to them, qualitative tools are best suited to analyse content that is non-numerical in nature. Since the current study aims to gather information from both numerical format (related to advantages and disadvantages of BIM technology, gaps in current process) as well as non-numerical format (impact on interoperability and degree of implementation), the mixed methodology is being chosen.

3.4 Data collection method

According to Saunders et al., (2009), the process of searching and collecting information pertaining to a research study is called data collection. There are two types of data collection. They are:

3.4.1 Primary data collection

According to Creswell (2003), primary data collection involves directly obtaining the relevant data from the sample population. In the current study, a questionnaire based survey method is used along with semi-structured interview methods to carry out primary data collection.

Questionnaires are part of data collection methods and they involve gathering information through oral or written questioning. The current study makes use of a closed ended questionnaire which is based on a structured framework. The objectives of the study were kept in mind when the questionnaire was being framed.

A semi-structured interview is also used as part of the data gathering process for the current study. Using this type of method allows the researcher to modify the questions based on the interviewees' replies. Furthermore it also aids in determining the interoperability issues of BIM implementation and arrives at identifying the impact of the system implementation in the UK construction industry.

The survey was developed using Microsoft Word software and sent out via emails to all people who are working within the companies that are the champions of the BIM software.

The study primarily targeted those who are part of the design and the construction phases. The validity of the information is increased by gathering direct information from the supervisor whose job it is to oversee the implementation and use of BIM in their respective offices. The results were saved in PDF format and were not named. They were subsequently sorted into two different groups: field operations personnel and design engineers. Then they were printed and were given randomly assigned numbers in order to maintain anonymity.

3.4.2 Secondary data collection

Secondary data collection is the process of gathering information from sources such as newspapers, research articles, electronic databases, etc. This method of data collection is also vital for any research study.

3.5 Sampling and study population

3.5.1 Sample size

The PFI market is limited to large size contractors. According to a survey carried out by Bing et al. (2005), 13.2% of the operation's net present value (NPV) and 15% of the construction cost of the 53 PFI projects are less than £10 million. Such contracts involve special managerial and financial requirements that increase the complexity of the relationships between the concerned parties which in turn necessitates the use of BMI. Therefore these smaller projects are targeted in this study. The researcher identified the relevant construction companies from records of Partnership UK (http://www.partnershipsuk.org.uk/PUK-Projects-Database.aspx).

3.5.2 Sampling method

The researcher in the current study adopted a random sampling approach in which every second respondent was approached for taking part in the survey. This ensures that all the people have a chance at taking part in the survey. The disadvantage of this method is that there is a possibility that segment-wise representation of all the demographics would not be possible.

In the case of interviews, the researcher approached five managers (field operation heads and design operation heads) and these managers were selected through a purposive sampling method.

3.6 Study duration and time frame

Cross sectional study and longitudinal study are two types of time based research studies. A cross sectional study involves observation of a research population at a particular point of time whereas a longitudinal study involves taking observations of the sample population numerous times over a prolonged period of time. The current study utilises a cross sectional study design as time is of essence in the current research study.

3.7 Data analysis

SPSS software would be made use of in order to carry out the quantitative analysis and a thematic analysis will be used to carry out the analysis of the qualitative responses from the respondents.

3.8 Validity and reliability

In order to ensure the viability of the different data collection instruments, the researcher has developed the questions in such a manner that the responses provided would only contain information relevant to the research study. A pre-test will be conducted among twenty sample respondents to check the validity of the data collection instruments and also to check if the respondents are comfortable enough and understand all the questions.

3.9 Ethical approaches

According to Burton (2000), there are a number of elements among the data collection methods or instruments used to gather the information that can give rise to ethical concerns. In order to ensure that all the procedures were ethical in nature and that appropriate ethical approaches were taken at all times, the researcher took great efforts.

3.10 Conclusion

The research methodology section provides all the information that the researcher used while conducting the study. The next chapter will provide the results that were obtained after the relevant data was collected.

Chapter Four: Results

4.1 Introduction

This chapter presents the results of the study in the form of questionnaire and interview analysis. The results of the questionnaire analysis are presented in the form of charts and tables. It is further seen that the qualitative results are examined in the form of thematic analysis.

4.2 Response rate

For the questionnaire analysis a total of 80 respondents were reached. Of these 60 respondents were willing to take part in the study. It is further observed that only 48 responses were found to be complete and these were taken into account. It is further observed that of these 48 responses, the 26 responses which were from a design department were taken for the results of the qualitative analysis. It was observed that only five respondents agreed to take up the study of which only three responses were complete and taken for the study.

4.3 Quantitative results

4.3.1 Company characteristics and understanding of BIM

Table 1: Number of years in construction business

Number of years your company has been in construction	Frequency	Percentage
1-3 years	8	16.7
4-5 years	17	35.4
5-10 years	19	39.6
More than 10 years	4	8.3
Total	48	100

The above table presents the number of years the construction company has been in business. It is observed that majority of the respondents worked in companies which have been a part of the UK construction sector for 5-10 years (39.6%) and 4-5 years (35.4%). Very few respondents were from companies which had more than 10 years' experience (8.3%) or 1-3 years of experience (16.7%). These statistics indicate that the representative sample population is employed in companies which have been in a construction sector for a number of years and have greater chances of using BIM in their design and construction process.

Figure 2: Number of years in construction business

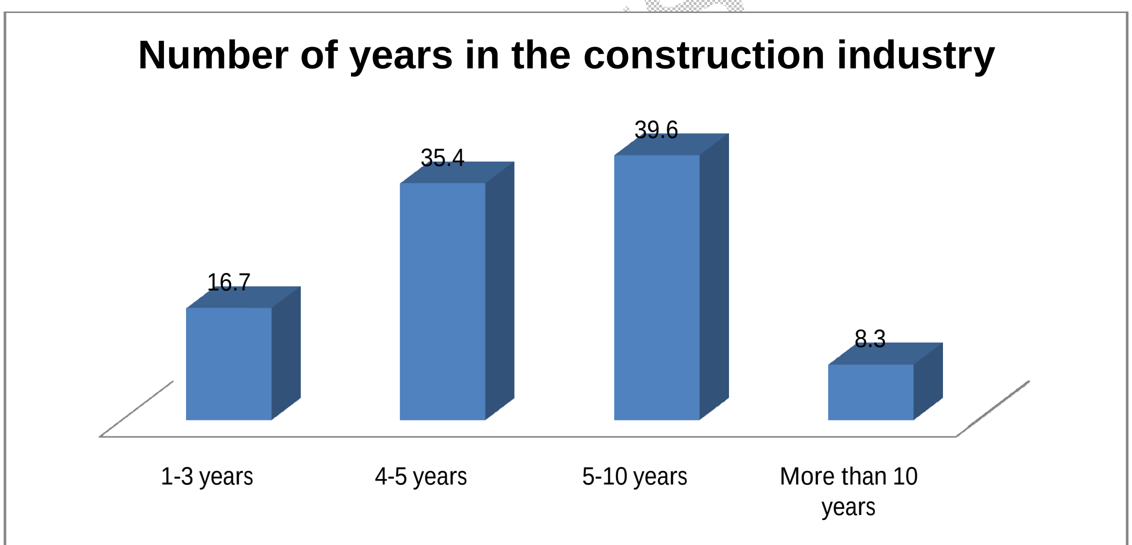


Table 2: Type of construction operation

Expertise of your company	Frequency	Percentage
Buildings	16	33.3
Transport	13	27.1
Infrastructure	11	22.9
Hydraulic structures	5	10.4
Industrial buildings	3	6.3
Total	48	100

The above table presents the type of construction operation of the companies which have been in business. It is observed that majority of the respondents worked in companies which were involved in construction of buildings (33.3%), transport (27.1%) and infrastructure (22.9%). Very few respondents were from companies which were involved in rising of hydraulic structures and industrial buildings (10.4%) and (6.3%) respectively. The above statistics indicate that respondents work in construction companies which are involved in building, transport and infrastructure operations. Since the BIM tool is largely applicable to buildings construction, representation by a majority of the sample population in this section presents a greater advantage of them having used the BIM tools personally.

Figure 3: Type of construction operation

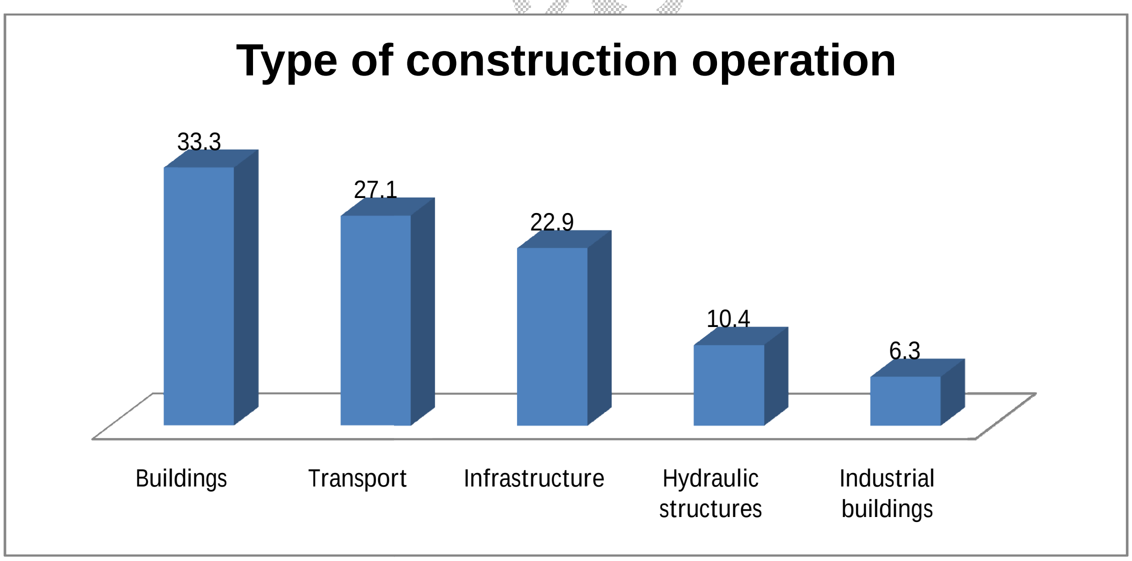


Table 3: Department of employment

Which department are you currently employed in?	**Frequency**	**Percentage**
Design and engineering department	26	54.2
Field operations department	22	45.8
Total	48	100

The above table presents the department of employment of the construction employee. It is observed that the majority of respondents were found to be employed in the design and engineering department (54.2%) with a limited number of respondents in field operations (45.8%). A more or less equal distribution of employees between the two sectors will facilitate comparison of views on BIM across these two departments.

Figure 4: Department of employment

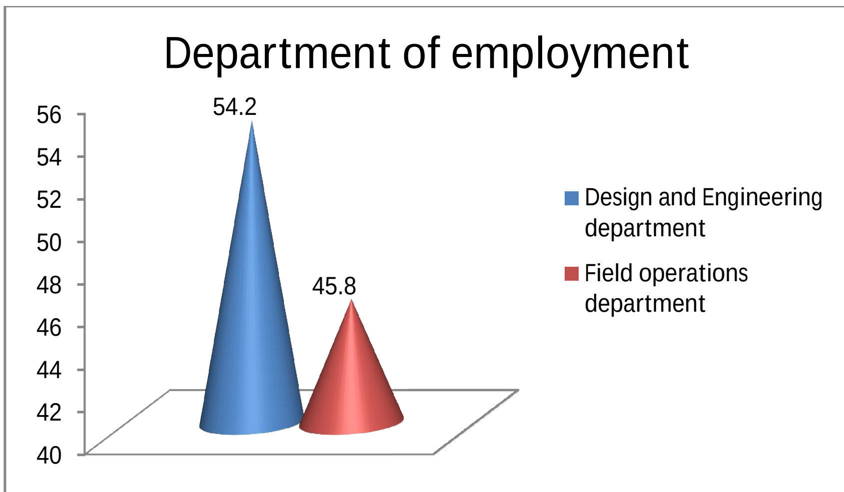


Table 4: Definition of BIM

Department of employment	Definition of BIM				Total
	BIM is 3D CAD tool	BIM is an open standards based information repository	BIM is general contractor's virtual tool	BIM is government supported tool for property management	
Design and Engineering department	13	13	0	0	26
	100.0%	100.0%	0.0%	0.0%	54.2%
Field operations department	0	0	11	11	22
	0.0%	0.0%	100.0%	100.0%	45.8%
Total	13	13	11	11	48
	100.0%	100.0%	100.0%	100.0%	100.0%
Pearson Chi-Square 48.0			p-value 0.001**		

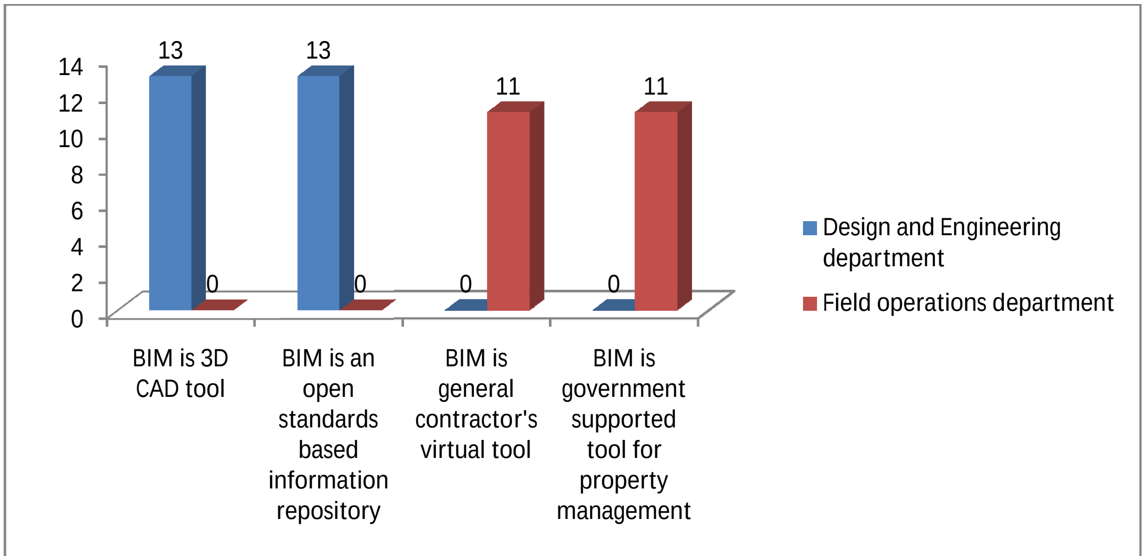
**statistically significant at 1% level

The above table and following figure presents comparison of the perception of definition of BIM by respondents based on their department of employment. The majority of the respondents in the design and engineering department identified that the role of BIM is to be presented as a 3D CAD tool (13 respondents) and as a standards based information repository (13 respondents). In contrast, when respondents in the field operations were considered, BIM was considered from the perspective of a contractor as a virtual tool (11 respondents) and a tool supported by the government for management of property (11 respondents). This, accompanied by a Chi-Square value of 48.0 and p-value of 0.001, indicates that there is a degree of association between perception of BIM and the designation of the employee.

These views are comparable to those in literature. Eastman et al. (2011) identified that presenting a uniform definition of BIM is difficult, as it provides different functions to different stakeholders in the construction industry. They identified that there is a difference in perception of use of BIM across engineers, construction managers and owners. This correlates with the views observed in the current study.

Figure 5: Definition of BIM

Next Page



4.3.2 Advantages and disadvantages of BIM

Table 5: Descriptive statistics of advantages and disadvantages of BIM

Advantages and disadvantages of BIM	N	Minimum	Maximum	Mean	Std. Deviation
Advantage BIM	48	2.00	4.29	3.1042	.39177
Disadvantage BIM	48	1.83	3.67	2.9618	.46029

The above table presents the descriptive statistics of advantages and disadvantages of BIM. It is observed that the respondent perception of advantage is across a spectrum ranging from 2.00 (Disagree) to 4.29 (Agree). Similar trends are observed with respect to perception of disadvantages of BIM ranging from 1.83 (Strongly Disagree and Disagree) to 3.67 (Neutral and Agree).

Figure 6: Descriptive statistics of advantages and disadvantages of BIM

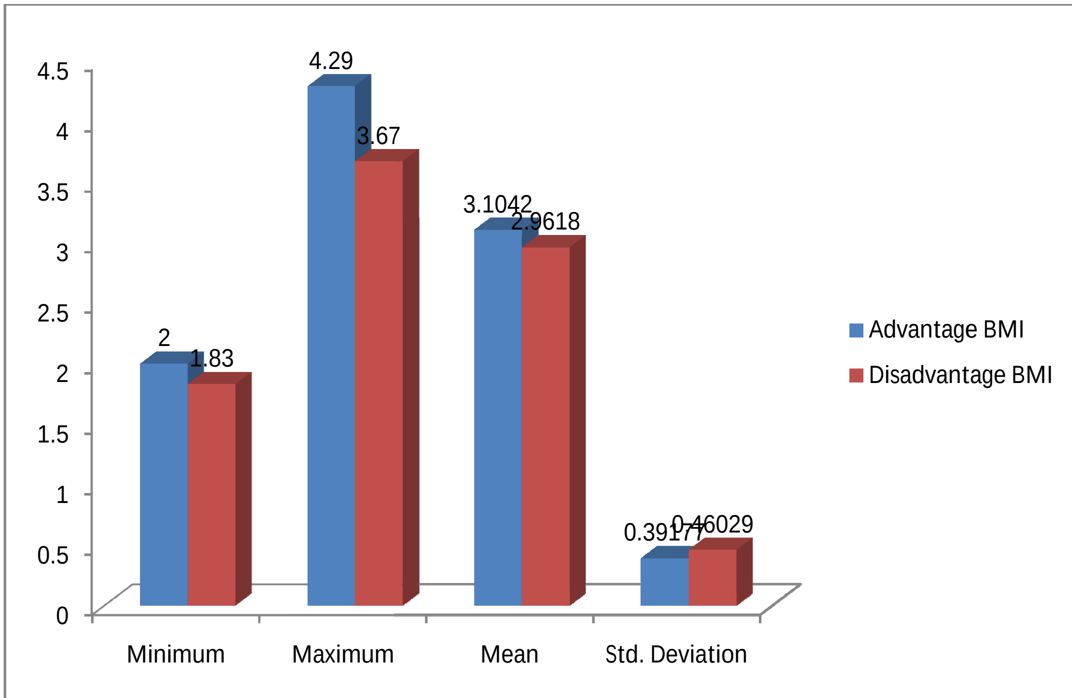


Table 6: Perception of advantages of BIM

Advantage BMI	Mean	Std. Deviation	t-test	p-value
BIM plays a vital role in conflict resolution	3.96	1.091	25.143	0.001**
The use of BIM adjusts costs as changes occur	4.13	1.178	24.255	0.001**
The use of BIM reduces overall cost	4.08	1.108	25.540	0.001**
There is speeding up of the design process	3.02	.812	25.779	0.001**
There is optimisation of the construction process	2.96	.459	44.620	0.001**
Operation simulations can be carried out	1.81	1.024	12.259	0.001**
Life cycle evaluations can be carried out	1.77	1.016	12.080	0.001**

The above table presents the respondent perception of advantages of BIM.

It is observed that different aspects including role in conflict resolution (Mean = 3.96, SD = 1.091), adjustment of cost (Mean= 4.13, SD=1.178) and reduction in overall cost (Mean=4.08, SD=1.108) present an above average mean score. This indicates that the majority of respondents felt these attributes to be major advantages.

However, the majority of respondents were of the opinion that there is limited impact of BIM on the actual design process (Mean = 3.02, SD=0.812). These views are supported and questioned in literature. Hallberg and Tarendi (2011) presented the view that BIM plays a limited role in the architectural design process; however Succar (2008) presented the view that BIM plays a vital role in design.

Furthermore the majority of respondents questioned the role of BIM in the construction process (Mean = 2.96, SD=0.459), operation simulations (Mean =1.81, SD=1.024) and life cycle evaluations (Mean =1.77, SD=1.016) by showing a very low score. This is indicative of most of them presenting disagreement with the advantages of the above attributes. These views are in contrast to those expressed in literature. Eastman et al. (2011) strongly identify the importance of BIM in easing construction field operations while its role in simulation and visualisation has been promoted by Boktor et al. (2013). The difference in results of this study and others may be explained by the need for better awareness of BIM. Baldwin et al. (1999) had presented the view that BIM is used more in boardrooms rather than field operations and a greater degree of awareness of operations is required.

Table 7: Perception of disadvantages of BIM

Disadvantage BMI	Mean	Std. Deviation	t-test	p-value
Lack of interoperability	4.15	1.031	7.698	0.001**
Lack of standards of BMI	4.10	1.096	6.978	0.001**
Reluctance to use electronic data transfer	1.75	.887	-9.761	0.001**
Legal risks are associated with BIM	1.90	.994	-7.693	0.001**
Number of personnel trained in BIM is less	4.00	1.130	6.132	0.001**
BIM has a steep learning curve	1.88	.914	-8.529	0.001**

The above table presents the employee perception of disadvantages of BIM. It is observed that different aspects including role in interoperability (Mean = 4.15, SD = 1.031), lack of standards of operations (Mean= 4.10, SD=1.096) and lesser number of trained personnel (Mean = 4.0, SD=1.130) are found to show above average mean scores. This indicates that the majority of respondents felt these attributes to be major disadvantages. The problems with interoperability are strongly identified in literature. It is observed from the views of Gu and London (2010) that the main problem that BIM users in construction have to overcome is interoperability issues. The problems of lack of standards have been highlighted (Howard and Bjork, 2008); however, with the current efforts by the UK government to present BIM as an integral part of the construction sector, this disadvantage may be easily overcome in a few years. The number of trained personnel in BIM is fewer and this has been acknowledged in literature.

However, other attributes like reluctance to use electronic data (Mean=1.75, SD=0.887), legal risks (Mean = 1.90, SD=0.994) and steep learning curve (Mean =1.88, SD=0.914) show very low mean scores. This indicates that the majority of respondents did not consider these attributes to be major disadvantages. These views are found to be supported and questioned in literature. Pishdad and Beliveau (2010) are of the opinion that there are still some legal risks associated with BIM implementation. However, Azhar et al. (2008) presented that there is an increasing number of training manuals and experts to teach BIM, thereby reducing the steep learning curve of BIM adoption. Furthermore Azhar (2011) indicated that field operation employees are learning to use electronic data in the field with the increase in the amount of portable electronic equipment available.

4.3.3 Value addition of BIM

Table 8: Descriptive statistics for value added of BIM

Perception of value added of BIM	N	Minimum	Maximum	Mean	Std. Deviation
Planning	48	2.33	5.00	4.2847	.57113
Marketing	48	2.33	3.00	2.9931	.40382
Corporate strategy	48	1.00	3.00	1.8194	.46615
Collaboration	48	3.00	5.00	4.1250	.46446
Operation	48	2.33	4.00	3.0903	.38739

The above table presents the descriptive statistics of value added features of BIM. It is observed that the respondent perception of collaboration, planning, and operation range between neutral to strongly agree. In contrast respondent perception of corporate strategy and marketing ranges from disagree to neutral. The comparative statistics are presented in the following figure.

Figure 7: Descriptive statistics for value added of BIM

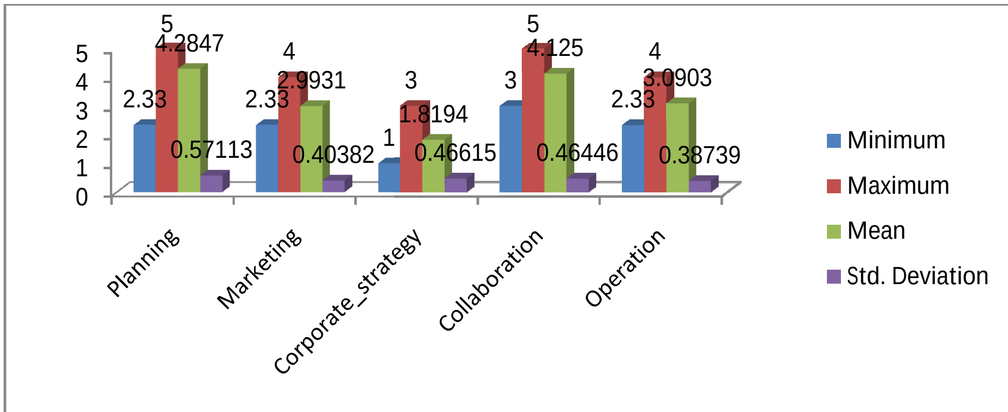


Table 9: Perception of value addition of BIM

Perception of value added of BIM	**Mean**	**Std. Deviation**	**t-test**	**p-value**
Effective project scheduling is carried out through BIM	4.38	1.024	29.610	0.001**
The use of BIM is implemented in the material and equipment staging	4.35	.911	33.125	0.001**
BIM models are used in both designing and construction phase to plan the work progress	4.13	1.084	26.359	0.001**
There is effective recognition of business and marketing aspects of BIM in our organisation	2.92	.739	27.345	0.001**
Previously designed BIM models can be used for future business	2.98	.601	34.340	0.001**
BIM strategies are firmly integrated into the firm's marketing content	3.08	.710	30.104	0.001**
Implementation of BIM in my organisation is by a dedicated BIM department	1.73	.844	14.194	0.001**
There is clear delineation of BIM capabilities to clients	1.77	.994	12.337	0.001**
Established BIM vision linking into firm's philosophy and goals is present	1.96	1.010	13.437	0.001**
Development of detailed BIM models for construction use is by design teams	4.02	1.062	26.238	0.001**
Construction superintendents have the final say on design of BIM models	4.27	.962	30.764	0.001**
BIM enables better translation of design to implementation	4.08	.942	30.046	0.001**
BIM use in field enables automation of layout erection and construction and thereby ensures calculation of plans	3.15	.652	33.428	0.001**
All field personnel have access to BIM software	3.08	.710	30.104	0.001**
BIM for the construction project is designed within the company	3.04	.582	36.212	0.001**

The above table presents the employee perception of value added of BIM.

It is observed that different aspects including role in effective project (Mean = 4.38, SD = 1.024), management of material and equipment (Mean= 4.35, SD=0.911) and work progress (Mean=4.13, SD=1.084) shows high mean scores. This is indicative of respondents strongly agreeing to the role of BIM in project planning. This is supported by views in literature. The role of BIM in the planning phase is strongly advocated by Eastman et al. (2011), who identified that BIM not only enables tracking of progress of work but also enables management of material used, material required and ensures no delays due to logistics.

When the role of BIM in promoting marketing operations is observed, it is seen that BIM plays a role in promoting the firm's marketing (Mean =3.08, SD=0.710). However the role of BIM in generating future business (Mean = 2.98, SD=0.601) is limited. When compared to literature the role of BIM in promoting marketing is strongly supported. This correlates with the views of this study. In contrast the role of BIM in generating future business is also strongly identified by Howard and Bjork (2008) which is in contrast to the views propagated in this study.

When the role of BIM in promoting identifying corporate strategy is observed, it is seen that problems are associated with implementation by separate departments (Mean=1.73, SD=0.844), clear delineation of role of BIM (Mean = 1.77, SD=0.994) and promotion of role of BIM in firm's philosophy (Mean = 1.96, SD= 1.010), which are all found to show a low score. The importance of these factors has been identified in literature. According to the views of Aranda-Mena et al., (2011) and Ashcroft (2008), the role of corporate strategy in promoting BIM is strongly presented.

It is observed that aspects related to operations including design teams (Mean = 4.02, SD=1.062), role of superintendents in deciding BIM (Mean=4.27, SD=0.962), design to implementation (Mean= 4.08, SD=0.942) were found to show an above average mean score, indicating that this is a very important aspect as identified in literature. According to the views of Boktor et al. (2013) it is observed that operations of construction industry are established.

However it is also found that attributes of operation are found to be understood in a limited manner. Attributes including automation of layout (Mean=3.15, SD=0.652), field personnel (Mean= 3.08, SD=0.710), construction design (Mean=3.04, SD=0.582) are found to show neutral mean score, indicating lack of importance given to operation related aspects.

4.3.4 Impact of BIM on KPI

Descriptive Statistics

Table 10: Descriptive statistics for impact of BIM on KPI

Impact of BIM on KPI	N	Minimum	Maximum	Mean	Std. Deviation
Operational factors	48	2.50	5.00	4.2708	.66010
Efficiency factors	48	1.00	3.67	1.7431	.54247
Strategic factors	48	2.50	4.25	3.4271	.42200

From the above table it is observed that impact of BIM on KPI is recognised. It is observed that the respondent perception of operational factors and strategic factors range from disagree to strongly agree. In contrast efficiency factor ranges from strongly disagree to strongly agree. The comparative statistics are presented in the following figure.

Figure 8: Descriptive statistics for impact of BIM on KPI

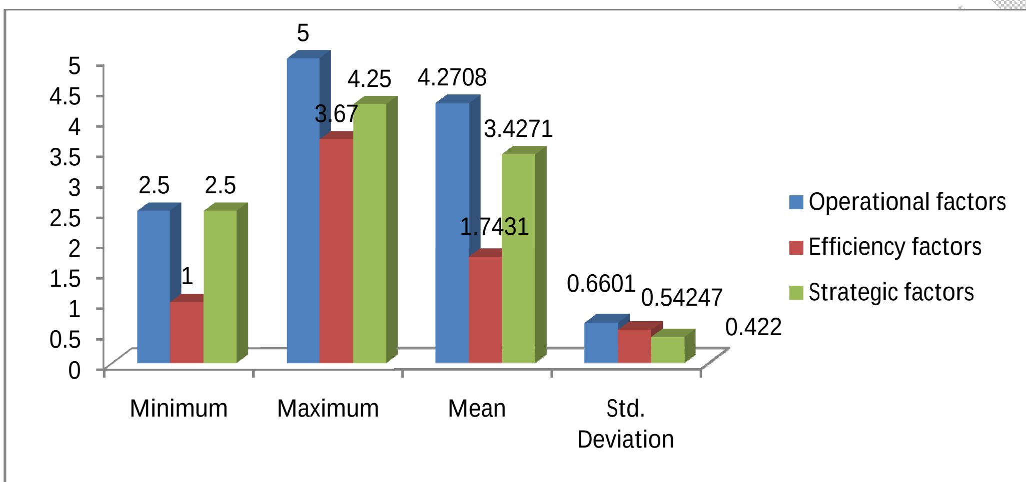


Table 11: Perception of impact of BIM on KPI

Impact of BIM on KPI	Mean	Std. Deviation	t-test	p-value
Cost per hour of operation	4.25	1.062	27.728	0.001**
Information carrying cost	4.29	.922	32.264	0.001**
Cost of distribution	1.71	1.010	11.722	0.001**
Labour utilisation	1.73	.844	14.194	0.001**
Overhead percentage	1.79	1.051	11.811	0.001**
Order lead time	3.48	.772	31.241	0.001**
Flexibility of service systems to meet particular customer needs	3.44	.823	28.948	0.001**
On time completion	3.35	.838	27.742	0.001**
Quality and Safety	3.44	.681	34.959	0.001**

The above table presents the employee perception of impact of BIM on KPI. It is observed that different aspects including efficiency factors like role in cost per hour of operation (Mean = 4.25, SD = 1.062) and information carrying cost (Mean= 4.29, SD=0.992) and strategic factors including flexibility of service (Mean = 3.44, SD=0.823), on time completion (Mean =3.35, SD=0.838), and quality and safety(Mean =3.44, SD= 0.681) are found to show above average mean score. However operational factors including cost of distribution (Mean=1.71, SD=1.051) and labour utilisation (Mean = 1.73, SD=0.844) are found to show a below average mean score.

These results can be compared to those in literature. It is observed from the views of Bryde et al., (2013) that BIM enables better utilisation of labour force. However this is not strongly understood by the respondents of the current study. The importance of BIM in impacting strategic factors of KPI is strongly supported by the views of Aranda-Mena et al., (2011).

4.4 Qualitative interview results

The respondent views on interoperability issues are identified from this section.

4.4.1 Benefits of promoting interoperability

When the design engineers were questioned about the benefits of promoting interoperability it was observed that productivity, coordination and reduction in labour were the most commonly identified attributes, as seen in the following statements.

DM1: "I think interoperability promotion in BIM will help increase productivity in document development and coordination."

DM 2: "I find that better interoperability will promote better building design."

DM3: "I think interoperability will help a faster less labour intensive drawing review."

These views are supported by those in literature. According to Grilo et al. (2010) and Eastman et al. (2011), increased collaboration is a result of better interoperability of BIM software. Furthermore Azhar et al. (2008) supports the reduction in labour when BIM software is used in an interoperable manner.

4.4.2 Issues of Interoperability

When the design engineers were questioned about the interoperability issues that arise by using different BIM software from the same vendors, most of them indicated that there are limited problems. However, they also indicated that this is not practical and may not be useful in designing an entire building. These views are observed from the following statements.

DM1: "I think there are limited issues of BIM interoperability when it comes to the same vendor. In my organisation we use same vendor; this reduces the problems which arise."

DM2: "In my organisation the service engineer, architect and the structural engineer may all work on separate models of the building but we use the same software. This helps us align and combine the designed model. However, this cannot always be done."

DM3: "There are no interoperability issues when we use software from the same vendor. We find that this gives us ease of coordination. But, I don't think this is practically applicable."

When questioned about the problems that arise due to interoperability issues among different software vendors the most commonly identified problem is the inability to agree on communication roles. However, the respondents feel that vendors are taking efforts to overcome the interoperability issues. This is observed in the following statements.

DM1: "When designing a building I find that it is next to impossible to use software from a single vendor. The specifications needed by the design team require details of different products and solutions. I find the greatest problem with interoperability being the inability to agree on communication roles."

DM2: "I find that most of the software vendors take efforts to deal with interoperability issues. For example the design specifications using NBS create can be used in

ArchiCAD. I find that conflicts in drawing and specifications between the software are often clearly indicated."

DM3: "I think interoperability between software from different vendors will help reduce coordination of project information."

This is supported by views in literature. From literature it is clearly observed that there are problems associated with interoperability as observed from the views of Eastman et al. (2011) and Azhar et al. (2008), who identify that if the interoperability issues of BIM are addressed then it is easy to overcome the problems associated with the process.

4.4.3. Type and degree of information

It is observed from the research that during the preconstruction phase the degree of information leveraged is related to visualisation of design as well as collaboration between the design teams.

DM1 "I think we are able to clearly visualise the final building even before ground breakup."

DM2 'I think the use of BIM has helped us share information between design architects, structural engineer and construction managers.'

In the construction phase respondents presented the view that they strongly identified with the role of BIM to leverage information on coordination, cost adjustment as well as time delay

DM3 "During the construction phase, the delay forecast (time and cost) is clearly presented using BIM. This information is very useful"

DM4 "I think the information on collaboration and degree of coordination between design team and operations team is clearly observed."

4.5 Conclusion

From this chapter the results of the qualitative analysis as well as the quantitative analysis are identified. The final chapter presents the conclusion, implications and recommendations of the study.

Chapter Five: Conclusion

5.1 Implications

To arrive at the perceived benefits of BIM

In this study it is observed that perceived advantages related to conflict resolution, process enhancement and cost are understood. However, advantages of operations management are not clearly observed. It is further seen that disadvantages in terms of interoperability as well as lack of standards are observed. Further research is required in this area. The importance of BIM in contributing to conflict resolution has been examined by Bryde et al. (2013), who identified that any flaws which may occur are predicted in advance; hence any modification in the drawings can be performed ahead of the construction process. Furthermore the importance of BIM in reducing overall cost as well as adjusting the projected cost has also been supported in literature. Demian and Walters (2013) identified that BIM plays a much greater role in presenting the degree of cost delay when compared to overall cost reduction.

To identify the areas of value addition in the construction industry

From the results of the questionnaire analysis it is identified that project planning, marketing operations, and collaboration are found to be areas of value added. Furthermore it is observed that corporate strategy is not strongly promoted, presenting the need to examine this approach of construction companies. The importance of construction in collaboration and coordination has been strongly expressed in literature. Aranda-Mena et al. (2009) identified that such an early implementation will give the time and space for the conversion of the architect's 2D drawings into 3D intelligent models which is later on transformed by the efforts of the construction manager. The importance of BIM in operational activities is important. The growing impact of BIM in construction should involve greater availability of BIM at the field operations, as identified by Bryde et al. (2013).

To identify the KPI of the construction industry

The role of BIM in impacting the KPI of construction industry has been examined by the questionnaire analysis. It is observed that a number of efficiency factors and strategic factors like order lead time; flexibility and timely completion are impacted to a great degree. In contrast, attributes like labour utilisation are found to be impacted to a lesser degree. Extant literature (Azhar et al., 2008; Eastman et al., 2011) has identified that the implementation of BIM will improve labour utilisation and cost distribution. There is a need for UK PPP projects to examine these areas of interest and identify possible means to improve the KPI.

To identify the degree of information leveraged and interoperability issues of BIM

When the design engineers were questioned about the benefits of promoting interoperability it was observed that productivity, coordination and reduction in labour were the most commonly identified attributes. Problems of interoperability between different software vendors were identified. Furthermore, the respondents indicated that there was a great deal of efforts undertaken by software companies to improve this problem. The respondents have also identified the use of BIM in promoting visualisation, information sharing, coordination, cost adjustment and forecast of delay.

From the above views it is established that despite acknowledgment of problems of interoperability, there is a positive view about interoperability among respondents. The respondents also identify with different attributes which help promote information leverage.

5.2 Limitations of the study

- The results of this study indicate a lack of awareness of certain factors including operational processes, operational efficiency and the importance of corporate strategy. The focus of BIM on different types of construction projects is found to be a new area of research in BIM. This study, having adopted a random snowball sampling method, did not target BIM adoption regionally or sector wise. Future research can focus on this area and identify if there are differences in trends.
- This study had taken into account only construction projects which have previously adopted BIM. This is a limitation. Future research should concentrate on construction companies which are yet to adopt BIM to identify the difficulties associated with the adoption.

5.3 Conclusion

From the above dissertation it is observed that the construction industry subjects itself to a great deal of risk by investing time and money in promotion of BIM, especially during times of economic recession. Advantages of BIM as well as a lack of awareness of value added of BIM are identified. The problems associated with BIM interoperability as well as the degree of information acquired from BIM is clearly understood. With the increase in governmental efforts to integrate BIM into the construction industry, the UK will soon become a global leader in BIM.

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Appendix Frequency Tables

Table 12: Advantages of BIM

BIM plays a vital role in conflict resolution		Frequency	Percentage
	Strongly Disagree	2	4.2
	Disagree	5	10.4
	Neutral	2	4.2
	Agree	23	47.9
	Strongly Agree	16	33.3
	Total	48	100
The use of BIM adjusts costs as changes			
	Strongly Disagree	3	6.3
	Disagree	3	6.3
	Neutral	3	6.3
	Agree	15	31.3
	Strongly Agree	24	50
	Total	48	100
The use of BIM reduces overall cost			
	Strongly Disagree	3	6.3
	Disagree	2	4.2
	Neutral	3	6.3
	Agree	20	41.7
	Strongly Agree	20	41.7
	Total	48	100

There is speeding up of design process			
	Strongly Disagree	3	6.3
	Disagree	2	4.2
	Neutral	38	79.2
	Agree	1	2.1
	Strongly Agree	4	8.3
	Total	48	100
There is optimisation of construction process			
	Disagree	5	10.4
	Neutral	41	85.4
	Agree	1	2.1
	Strongly Agree	1	2.1
	Total	48	100
Operation simulations can be carried out			
	Strongly Disagree	22	45.8
	Disagree	19	39.6
	Neutral	3	6.3
	Agree	2	4.2
	Strongly Agree	2	4.2
	Total	48	100
Life cycle evaluations can be carried out			
	Strongly Disagree	23	47.9
	Disagree	19	39.6
	Neutral	2	4.2
	Agree	2	4.2
	Strongly Agree	2	4.2
	Total	48	100

Table 13: Disadvantages of BIM

Lack of interoperability		Frequency	Percentage
	Strongly Disagree	2	4.2
	Disagree	2	4.2
	Neutral	4	8.3
	Agree	19	39.6
	Strongly Agree	21	43.8
	Total	48	100
Lack of standards of BMI			
	Strongly Disagree	2	4.2
	Disagree	4	8.3
	Neutral	2	4.2
	Agree	19	39.6
	Strongly Agree	21	43.8
	Total	48	100
Reluctance to use electronic data transfer			
	Strongly Disagree	21	43.8
	Disagree	22	45.8
	Neutral	2	4.2
	Agree	2	4.2
	Strongly Agree	1	2.1
	Total	48	100

Legal risks are associated with BIM			
	Strongly Disagree	17	35.4
	Disagree	26	54.2
	Agree	3	6.3
	Strongly Agree	2	4.2
	Total	48	100
Number of personnel trained in BIM is less			
	Strongly Disagree	3	6.3
	Disagree	3	6.3
	Neutral	3	6.3
	Agree	21	43.8
	Strongly Agree	18	37.5
	Total	48	100
BIM has a steep learning curve			
	Strongly Disagree	17	35.4
	Disagree	25	52.1
	Neutral	2	4.2
	Agree	3	6.3
	Strongly Agree	1	2.1
	Total	48	100

Table 14: Value added of BIM

Effective project scheduling is carried out through BIM		Frequency	Percentage
	Strongly Disagree	2	4.2
	Disagree	2	4.2
	Neutral	1	2.1
	Agree	14	29.2
	Strongly Agree	29	60.4
	Total	48	100
The use of BIM is implemented in the material and equipment staging			
	Strongly Disagree	1	2.1
	Disagree	2	4.2
	Neutral	2	4.2
	Agree	17	35.4
	Strongly Agree	26	54.2
	Total	48	100
BIM models are used in both designing and construction phase to plan the work progress			
	Strongly Disagree	3	6.3
	Disagree	2	4.2
	Neutral	1	2.1
	Agree	22	45.8
	Strongly Agree	20	41.7
	Total	48	100

There is effective recognition of business and marketing aspects of BIM in our organisation			
	Strongly Disagree	3	6.3
	Disagree	4	8.3
	Neutral	37	77.1
	Agree	2	4.2
	Strongly Agree	2	4.2
	Total	48	100
Previously designed BIM models can be used for future business			
	Strongly Disagree	2	4.2
	Disagree	2	4.2
	Neutral	40	83.3
	Agree	3	6.3
	Strongly Agree	1	2.1
	Total	48	100
BIM strategies are firmly integrated in the firm's marketing content			
	Strongly Disagree	2	4.2
	Disagree	1	2.1
	Neutral	39	81.3
	Agree	3	6.3
	Strongly Agree	3	6.3
	Total	48	100
Implementation of BIM in my organisation is by a dedicated BIM department			
	Strongly Disagree	21	43.8
	Disagree	22	45.8
	Neutral	3	6.3
	Agree	1	2.1

	Strongly Agree	1	2.1
	Total	48	100
There is clear delineation of BIM capabilities to clients			
	Strongly Disagree	22	45.8
	Disagree	21	43.8
	Neutral	1	2.1
	Agree	2	4.2
	Strongly Agree	2	4.2
	Total	48	100
Established BIM vision linking into firm's philosophy and goals is present			
	Strongly Disagree	16	33.3
	Disagree	25	52.1
	Neutral	2	4.2
	Agree	3	6.3
	Strongly Agree	2	4.2
	Total	48	100
Development of detailed BIM models for construction use is by design teams			
	Strongly Disagree	2	4.2
	Disagree	4	8.3
	Neutral	2	4.2
	Agree	23	47.9
	Strongly Agree	17	35.4
	Total	48	100
Construction superintendents have the final say on design of BIM models			
	Strongly Disagree	1	2.1
	Disagree	3	6.3
	Neutral	2	4.2

	Agree	18	37.5
	Strongly Agree	24	50
	Total	48	100
BIM enables better translation of design to implementation			
	Strongly Disagree	2	4.2
	Disagree	2	4.2
	Neutral	1	2.1
	Agree	28	58.3
	Strongly Agree	15	31.3
	Total	48	100
BIM use in field enables automation of layout erection and construction thereby ensures calculation of plans			
	Strongly Disagree	1	2.1
	Disagree	1	2.1
	Neutral	39	81.3
	Agree	4	8.3
	Strongly Agree	3	6.3
	Total	48	100
All field personnel have access to BIM software			
	Strongly Disagree	2	4.2
	Disagree	1	2.1
	Neutral	39	81.3
	Agree	3	6.3
	Strongly Agree	3	6.3
	Total	48	100

BIM for the construction is designed within the company			
	Strongly Disagree	1	2.1
	Disagree	2	4.2
	Neutral	41	85.4
	Agree	2	4.2
	Strongly Agree	2	4.2
	Total	48	100

Table 15: Impact of BIM on KPI

Cost per hour of operation		Frequency	Percentage
	Strongly Disagree	2	4.2
	Disagree	3	6.3
	Neutral	1	2.1
	Agree	17	35.4
	Strongly Agree	25	52.1
	Total	48	100
Information carrying cost			
	Strongly Disagree	1	2.1
	Disagree	2	4.2
	Neutral	3	6.3
	Agree	18	37.5
	Strongly Agree	24	50
	Total	48	100

Cost of distribution		
Strongly Disagree	25	52.1
Disagree	18	37.5
Neutral	1	2.1
Agree	2	4.2
Strongly Agree	2	4.2
Total	48	100
Labour utilisation		
Strongly Disagree	21	43.8
Disagree	22	45.8
Neutral	3	6.3
Agree	1	2.1
Strongly Agree	1	2.1
Total	48	100
Overhead Percentage		
Strongly Disagree	23	47.9
Disagree	19	39.6
Neutral	1	2.1
Agree	3	6.3
Strongly Agree	2	4.2
Total	48	100
Order lead time		
Strongly Disagree	2	4.2
Disagree	1	2.1
Neutral	18	37.5
Agree	26	54.2
Strongly Agree	1	2.1

	Total	48	100
Flexibility of service systems to meet particular customer needs			
	Strongly Disagree	3	6.3
	Neutral	19	39.6
	Agree	25	52.1
	Strongly Agree	1	2.1
	Total	48	100
On time completion			
	Strongly Disagree	2	4.2
	Disagree	3	6.3
	Neutral	21	43.8
	Agree	20	41.7
	Strongly Agree	2	4.2
	Total	48	100
Quality and safety			
	Strongly Disagree	1	2.1
	Disagree	1	2.1
	Neutral	23	47.9
	Agree	22	45.8
	Strongly Agree	1	2.1
	Total	48	100

Questionnaire: BIM adoption in UK PPP construction projects

Section I: Basic details

1	Number of years your company has been in construction ☐ 1-3 years ☐ 4-5 years ☐ 5-10 years ☐ More than 10 years
2	Expertise of your company (More than one option can be answered) ☐ Buildings (Housing, touristic facilities, trade centres, social and cultural facilities, hospitals, military facilities, universities, government buildings etc.) ☐ Transport (Highway, tunnel, bridge, railway, seaport, airport, etc.) ☐ Infrastructure (City infrastructure, water and waste water facilities, pipelines, etc.) ☐ Hydraulic structures (Dams, irrigation systems.) ☐ Industrial buildings (Industrial plants, power stations, petrochemical plants, refinery, telecommunication, energy transportation lines etc.)
3.	Which department are you currently employed in ☐ Design and engineering department ☐ Field operations department
4	The following are some of the different definitions of BIM given in editorials and websites. Which of these is close to your understanding of BIM? ☐ BIM is 3D CAD tool ☐ BIM is an open standards based information repository ☐ BIM is general contractor's virtual tool ☐ BIM is government supported tool for property management

Section II: Advantages and disadvantages of BIM

The following statements refer to the advantages and disadvantages of BIM. Identify your level of agreement with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Advantages of BIM					
BIM plays a vital role in conflict resolution					
The use of BIM adjusts costs as changes					
The use of BIM reduces overall cost					
There is speeding up of design process					
There is optimisation of construction process					
Operation simulations can be carried out					
Life cycle evaluations can be carried out					
Disadvantages of BIM					
Lack of interoperability					
Lack of standards of BMI					
Reluctance to use electronic data transfer					
Legal risks are associated with BIM					
Number of personnel trained in BIM is less					
BIM has a steep learning curve					

Section III: Value added due to implementation of BIM

The following statements refer to the value added perceived in different departmental operations with respect to BIM. Identify your level of agreement with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Planning					
Effective project scheduling is carried out through BIM.					
The use of BIM is implemented in the material and equipment staging.					
BIM models are used in both designing and construction phase to plan the work progress					
Marketing					
There is effective recognition of business and marketing aspects of BIM in our organisation					
Previously designed BIM models can be used for future business					
BIM strategies are firmly integrated in the firm's marketing content					
Corporate strategy					
Implementation of BIM in my organisation is by a dedicated BIM department					
There is clear delineation of BIM capabilities to clients					
Established BIM vision linking into firm's philosophy and goals is present					
Collaboration					
Development of detailed BIM models for construction use is by design teams					
Construction superintendents have the final say on design of BIM models					
BIM enables better translation of design to implementation					
Operation					
BIM use in field enables automation of layout erection and construction thereby ensures calculation of plans.					
All field personnel have access to BIM software					

BIM for the construction is designed within the company					

Section IV: Impact of BIM on KPI of construction

The following statements refer to the impact of BIM on KPI (Key Performance Indicators) of construction. Identify your level of agreement with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Operational factors					
Cost per hour of operation					
Information carrying cost					
Efficiency factors					
Cost of distribution					
Labour utilisation					
Overhead percentage					
Strategic factors					
Order lead time					
Flexibility of service systems to meet particular customer needs					
On time completion					
Quality and safety					

Interview questions:

1. What are the advantages of overcoming interoperability issues?
2. What are the problems associated with interoperability between software given by the same vendor?
3. What are problems associated with interoperability between software given by different vendor?
4. What type of information does your company leverage during pre construction phase using BIM?
5. What type of information does your company leverage during construction phase using BIM?