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The Implementation of Building Information Modelling (BIM) Level 2 in the UK Construction Industry
The Case of Small and Medium Enterprises

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The Implementation of Building Information Modelling (BIM) Level 2 in the UK Construction Industry: The Case of Small and Medium-sized Enterprises.

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Abstract

This thesis investigates the implementation of Building Information Modelling (BIM) Level 2 in Small and Medium sized enterprises (SMEs) in the UK construction industry. The research has found that the main focus of literature and existing frameworks regarding BIM adoption and implementation has been on larger companies and so the implementation of this technology in SMEs has been lagging behind. . This slow adoption, has led to a competitive disadvantage for SMEs in public projects and possibly private projects, in particular, after the UK government has mandated the use of BIM Level 2 in all public projects from 2016. Therefore, the main aim of this thesis is to bridge this gap by exploring the current situation of BIM Level 2 implementation within SMEs, as well as proposing a validated framework which supports SMEs in BIM Level 2 implementation process.

The present thesis has adopted an interpretivist research philosophy and the approach was inductive in nature. To collect the data from the selected case studies, a semi-structured interview protocol was designed in accordance with the research objectives which was aimed at getting the views and opinions of a sample of 25 professional in the UK construction industry in three case studies.

This study has identified 15 critical success factors which have influenced the adoption and implementation of BIM Level 2 within SMEs, which included 12 critical factors previously mentioned in the literature and 3 new proposed critical success factors, which were: control of performance, use of an external consultant and knowledge transfer. All 15 factors were classified into four categories, which included: human factors, organisational factors, process factors and external factors. They were then mapped into the implementation lifecycle based on their importance for achieving a successful implementation. In addition to these theoretical contributions, this thesis also makes a contribution to practice for SMEs in the UK construction industry by identifying the critical success factors that are important for successful implementation and by providing SMEs a framework and a set of recommendations to assist them throughout the implementation process.

Keywords: Building Information modelling Level 2, Small and Medium Enterprises, Critical Success Factors, Implementation Lifecycle, UK Construction Industry, Validated Framework.

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It has been a long road but I have made it. It is time to move on and to keep my head up high to my next career journey. Finally, I would like to say to all who ever read my thesis; ‘a winner is a dreamer who never gives up’ (Nelson Mandela).

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List of Abbreviations

AEC: Architecture, Engineering and Construction industry.

BIM: Building Information Modelling.

CABE: Charted Association of Building Engineering.

CDE: Common Data Environment.

CIC: Construction Institute Council.

COBIE: Construction Operations Building Information Exchange.

CSFs: Critical Success Factors.

GDP: Gross Domestic Product.

ICT: Information Communication Technology.

IFC: Industry Foundation Class.

ML: Management Level.

NBS: National Building Specification.

NIBS: National Institute of Building Sciences.

SMEs: Small and Medium-sized Enterprises.

TL: Technical Level.

UK: United Kingdom.

CHAPTER ONE Research Introduction

1.0 Research Background

In the last few years Building Information Modelling (BIM) has gained attention and has been acknowledged as one of the new ideas which can develop and transform the Architecture, Engineering and Construction industry (AEC). The SEC Group (2013) explained that BIM is a new process of working, where digital modelling is used by stakeholders to share information and knowledge, increase collaboration, minimise waste and enhance efficiency through all phases of construction projects.

Globally, many governments around the world are mandating the use of BIM in order to meet their cost saving strategies and reshape the public construction sector. In the UK, the government has mandated the use of BIM Level 2 in all public companies within the construction sector by 2016 (British Standards Institute 2013). A statistic published by SmartMarket Report (2012) shows that BIM adoption has increased from 17% in 2007 to 71% in 2012. Moreover, the National Building Specification (NBS) has published a report in 2013 which shows that the percentage of the industry using BIM has increased from 13% in 2010 to 39% in 2012. According to the latest NBS report in 2017, 62% of the industry were using BIM, and, according to SmartMarket Report (2014) 47% of contractors have been using BIM for 1-2 years and 41% have been using it for 3-5 years.

In the UK, the Architecture Engineering and Construction (AEC) industry is the sector which contributes the most to the UK economy. In general, 99% of the companies in the sector are SMEs. One of the main characteristics of SMEs when compared with larger companies is their limited resources and experience which has limited their adoption of technologies and innovations. It is commonly believed that the growth in BIM adoption and implementation is only a concern for large companies, while small and medium enterprises (SMEs) are still lagging behind in embracing this new technology. Moreover, it has been argued that the UK government has not identified how the implementation will occur despite 2016 mandate. This made SMEs feel like this technology is not for them.

It is commonly believed that BIM will bring new developments and innovations to the AEC industry and will help stakeholders to work as a team by enhancing collaboration between them. However, is crucial that SMEs start embracing BIM Level 2 in order to meet the UK government mandate which will result in the development of the whole construction industry since they constitute 99% of the entire UK construction industry.

1.1 Problem Statement and Rationale

The evolution of Information and Communication Technology (ICT) has created significant opportunities for improving project delivery. The benefits of ICT have encouraged many construction companies to invest in this new technology (Peansupap et al., 2005). However, the adoption of the technology for construction has been slow when compared to manufacturing and aerospace. KPMG's annual report (2016) reported that 75% of construction and engineering executives were not using advanced data to control project estimation and performance.

The reason for this slow adoption, according to Peansupap *et al.,* (2005) was due to: the unique aspect of construction, the complex nature of the industry, the immaturity of ICT, financial restrictions, and a lack of understanding of BIM implementation. Stewart et al., (2004) added that the slow adoption was due to: supply-chain decomposition, an absence of client leadership, resistance to change, a lack of technology awareness, a low level of training and the need for investment.

In the UK, the Architecture Engineering and Construction (AEC) industry is the sector which contributes the most to the UK economy (Myres 2013). According to the British Standards Institute (BSI), 99% of the companies in the sector were SMEs (Department for Business Innovation & Skills, 2014). Also, according to Robson *et al.*, (2014), in the UK there are 950,000 SMEs which account for almost 80% of the total production cost in the UK construction industry.

Despite this, BIM Level 2 was mainly used by large companies, while SMEs were lagging behind in the adoption of the new technology (SmartMarket Report, 2012). Indeed, SMEs were slow to embrace BIM, and thus were missing out on both public and private sector projects. It has been reported that 40% of SMEs miss out on 90% of the public projects they bid for, and more than 50% of SMEs have recognised a drop in their success rate on bidding for public construction projects in the last 5 years (Federation of Master Builders 2013). Blackwell (2012) argued that if SMEs continue to be slow in embracing this new technology, they could lose out in both national and international markets.

The implementation of new technology in smaller companies can be difficult in comparison to large companies, research indicating that large companies are more viable, adopt innovation more easily and achieve tangible working outcomes (Sexton et al 2006). However, it should be admitted that most of the small and medium sized enterprises (SMEs) in the UK are "BIM infants", this terminology being first used by Jayasena (2013) to describe companies which still needed to start their journey to implement BIM. In addition, most of the maturity models available in the literature are likely to be less applicable to infant companies and the use of an unsuitable BIM adoption strategy could result in a waste of resources and time.

On the other hand, many frameworks have been developed to assess relevant areas, recognise factors for practical BIM effectiveness (Jung and Joo *et al.* 2011), to identify frameworks for integrative collaboration, construction planning and simulation (Singh *et al.*, 2011**)**, and for providing best value in construction projects (Porwal *et al.*, 2013; Liu *et al.*, 2015). Despite this, by providing these frameworks the efforts of researchers had little influence on the adoption of BIM in SMEs. The reason behind this was because most of the policies and strategies provided by researchers were concerned mainly with large companies, and SMEs received little attention (Smart Market Report 2012; Daynti et al. 2017). As reported by NBS (2017), 52% of SMEs firms have not used BIM at all and only 5% of small companies have made any effort to adopt and implement Level 3 (Hosseine et al. 2017).

It seems that the flow of studies intended to increase BIM adoption had so far limited success in persuading SMEs to adopt the technology. This limited adoption was mostly due to a lack of understanding of the advantages of BIM which has caused SMEs to ignore BIM. The main reasons for not using BIM are complicated. However, Mellon and Kouider (2016) pointed out that the lack of appreciation of the financial benefits which investment in BIM can bring, and how long it will take to see any returns on that investment, were two of the main barriers which have prevented the implementation of BIM in SMEs. Certainly, the lack of financial and human resources, as well as the disruption to the normal work process that BIM implementation can bring, could be other reasons why adoption in SMEs has been slow. Therefore, although the outcomes from implementing BIM have significant benefits, they also carry many risks. According to Chien *et al.* (2014), it is difficult to achieve a balance between the risks and benefits when investing in BIM. On the other hand, there is also a lack of understanding about BIM Level 2 itself. NBS (2014) and Turpin (2016) stated that there was a general awareness of the different levels of BIM among companies in the construction sector. However they also argued there was still debate related to the benefits which can be achieved from each level as well as how they should be implemented, especially with the government pressures on them to implement Level 2 by 2016. Other problems responsible for the lack of implementations in SMEs were a lack of knowledge and limited affordability of the technology (Eastman *et al.* 2011).

Poirier et al. (2015) argued that in order for SMEs to gain benefits from BIM they need a clear strategy for guiding the adoption and only a few companies will have the ability to create a systematic approach for BIM implementation. Currently, few studies are available for assessing the requirements of infant SMEs and helping them to design a clear strategy for BIM adoption and implementation (Arayici, et al. 2011). Moreover, there are limited guidelines for SMEs on how to implement BIM level 2. The lack of frameworks to assist SMEs in how to implement BIM is reflected by the low adoption rate by these companies (Liu et al., 2010; Eastman et al., 2011; Migilinskas et al., 2013; Mellon and Kouider, 2016; Kokkonen & Alin 2016).

It can be perceived from these evidences that SMEs need assistance to help them adopt and implement BIM level 2 in order to meet the 2016 UK government mandate. Therefore, this study will attempt to address these issues by developing a framework which will aid SMEs in the implementation of BIM Level 2 as a response to the lack of studies concerning small and medium companies in the literature.

1.2 Aim and Objectives of the Research

The aim of the research is to explore the implementation of Building Information Modelling (BIM) Level 2 in Small and Medium sized Enterprises (SMEs) in the UK construction industry. To achieve this aim the following objectives must be met:

1. To identify the barriers to the adoption and implementation of BIM Level 2.
2. To explore the current situation of BIM Level 2 in SMEs in the UK construction industry.
3. To investigate and analyse the critical success factors (CSFs) influencing BIM Level 2 adoption and implementation.
4. To map the CSFs on to the BIM level 2 implementation lifecycle based on their importance.
5. To develop and validate a framework for implementing BIM level 2.

1.3Research Questions

1. What are the barriers faced when adopting and implementing BIM Level 2?
2. What is the current situation regarding BIM level 2 implementation of SMEs in the UK construction industry?
3. What are the CSFs which influence BIM Level 2 adoption and implementation in SMEs?
4. How do these CSFs influence the BIM Level 2 implementation process in SMEs?
5. How can a successful implementation of BIM Level 2 in SMEs be achieved?

1.4 Expected Research Contributions

1.4.1 Contribution to Theory (Knowledge)

This research is expected to contribute to knowledge by identifying the CSFs for BIM Level 2 implementation in SMEs in the UK. Moreover, a framework mapping the identified CSFs onto the BIM Level 2 implementation lifecycle will be proposed. The originality of the research has been ensured by the identification of three new CSFs, which are: control of performance, the use of an external consultant and knowledge transfer.

1.4.2 Contribution to Practice

Beside the contribution to knowledge, this research also contributes to practice within SMEs by providing an in depth understanding of the CSFs that influence BIM Level 2 implementation. Furthermore, these factors are prioritised based on their importance, clustered under specific categories and then mapped onto the BIM Level 2 lifecycle, providing a more detailed and comprehensive understanding of the importance of each factor. By taking into consideration the factors, recommendations and guidelines provided by this research, SMEs will be helped to achieve a successful adoption and implementation of BIM Level 2. The aforementioned contributions aided the researcher in designing the conceptual framework by mapping the critical success factors onto the BIM Level 2 lifecycle which was the fourth objective of this research.

1.5 Outline of the Research

The process of carrying out this research is shown in figures 1.1.

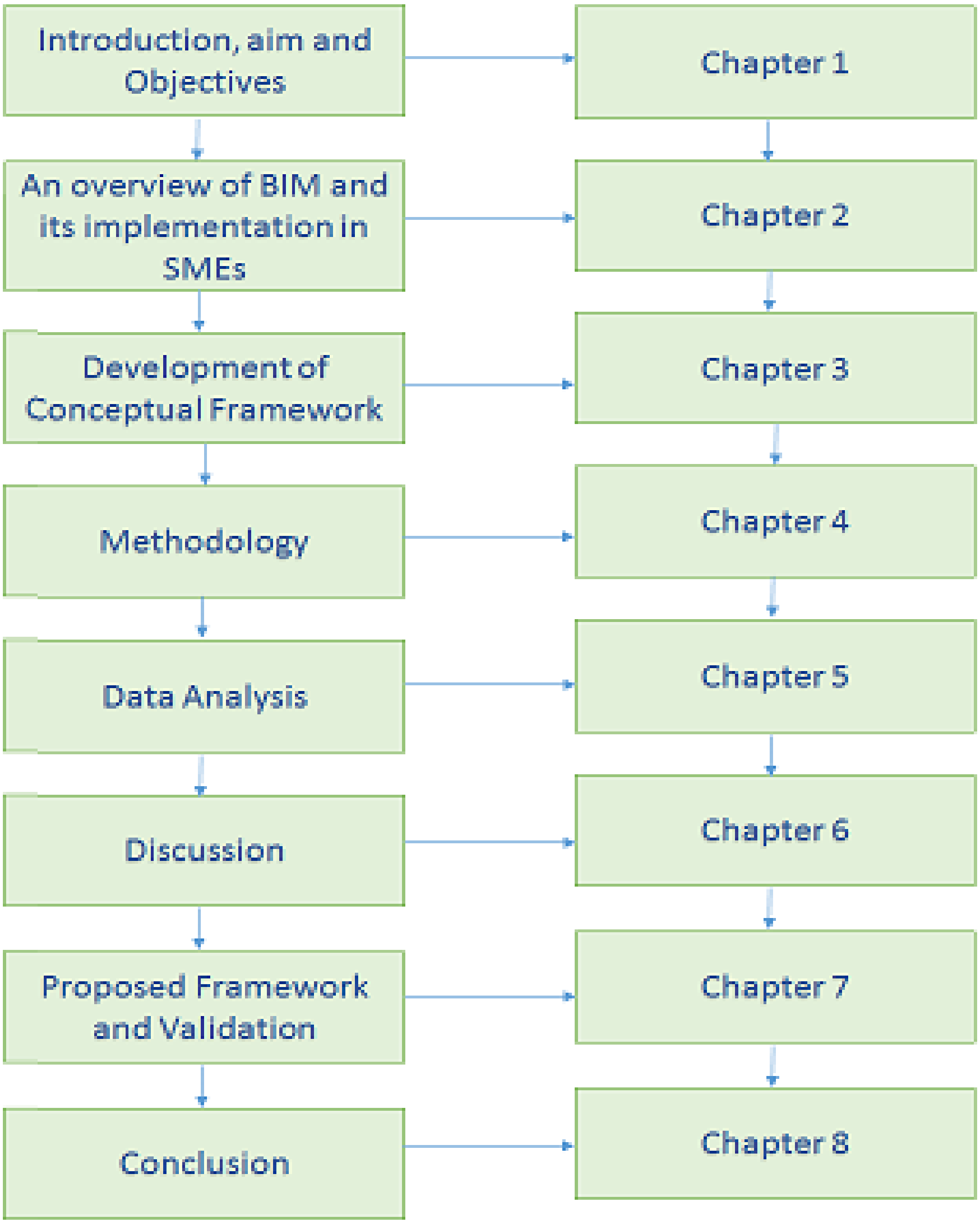


Figure 1. 1 Outline of the research (Source: the researcher)

CHAPTER TWO Literature Review

2.0 Chapter Overview

This chapter provides an overview of Building Information Modelling, giving a clear definition of this technology and the benefits provided, as well as clarifying the maturity levels, dimensions and barriers faced when implementing BIM Level 2 in the UK. The chapter will also discuss the UK construction industry and the current situation regarding BIM Level 2 implementations. Finally, an overview of Small and Medium sized Enterprises (SMEs) will be given, identifying their contribution to the UK economy, deficiencies, and where they stand in terms of BIM Level 2 implementation in order to meet the UK government 2016 mandate. The information provided in this chapter will achieve the first two objectives of this study. **Research objective 1** will be obtained by identifying the barriers which hinder BIM level 2 implementation, in addition **research objective 2** will be addressed by exploring the current situation of SMEs regarding BIM Level 2 adoption and implementation.

2.1 Building Information Modelling (BIM)

2.1.1 Definition of Building Information Modelling (BIM)

There are significant possibilities for the Architecture, Engineering and Construction industry (AEC) to achieve more advanced outcomes by adopting new technologies for project delivery. It has been reported by the US General Administration (2007) that the adoption of new approaches in the AEC is taking longer when compared with other industries. Using technological innovation has helped other sectors to obtain remarkable quality and productivity improvements. In the construction sector, the use of new technologies has enhanced the quality of design by using virtual modelling. Advances in construction technology has improved the economic and environmental aspects of construction (Umar et al 2013). Also, greater awareness of new technologies between academics and the industry should be encouraged in order to adopt new technologies in construction (Bui et al. 2016).

Due to the continuing efforts of construction experts, an innovative application called Building Information Modelling (BIM), was developed, with the intention of solving issues of fragmentation in the industry and lack of communication between the parties involved. The National Institute of Building Sciences (NIBS) (2007) have defined BIM as "*a digital representation of the physical and functional characteristics of a facility, which serves as a shared knowledge resource for information that forms a reliable basis for decisions during its lifecycle from inception onward*". According to the Royal Institute of British Architects (RIBA), BIM is ''*a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information and forming a reliable basis for decisions during its life cycle, from the earliest conception to demolition*''. One more definition of BIM is also given by BuildingSMART, which is, ''*a new approach to describe and display the information required for the design, construction and operation of constructed facilities. It is able to bring together the different threads of information used in construction into a single operating environment thus reducing, and often eliminating, the need for the many different types of paper documents currently in use*''.

Eastman et al. (2011) defines Building Information Modelling as *"a modelling technology and associated set of processes to produce, communicate and analyse building models. These building models are characterised by:*

1. Building Components that are represented with intelligent digital representations that 'know' what they are and can be associated with computable graphic and data attributes and parametric rules;

2. Components that include data that describe how they behave, as needed for analyses and work processes, e.g., take-off, specification and energy analysis;
3. Consistent and non-redundant data such that changes to component data are represented in all views of the component;
4. Coordinated data such that all views of a model are represented in a coordinated way."

It can be seen from the previous four definitions that BIM is not just software, but it is the result of an integrating process, people and software together. According to (Hardin 2009), BIM is not just a three-dimensional representation of a building but a method which can improve the whole construction process. Recently, the term BIM has been defined by Philp (2013), as being based on open communication, collaboration, and better quality information which together give better end results.

Race (2012) argues that there is no specific definition and explanation for BIM, therefore various definitions have been created which differ based on its respective disciplines. Consequently, due to the lack of a unified definition, Miettinen et al (2014) p.84 claims that BIM has to be "analysed as a multi-dimensional, historically evolving, complex phenomenon," in order to be perceived in different ways including an advance model for digital illustration of building or a store where project data can be deposited which ease the exchange of information between different software (Miettinen et al, 2014).

In this research, the definition of BIM adopted by the researcher is a virtual place which gets stakeholders and data working together in more efficient and effective way through specific processes and technology (RICS 2014). Mainly this definition emphasizes on the effectiveness achieved through collaboration of people and information exchange which is basically the core of BIM Level 2.

2.1.2 Concept of BIM

The vast increase in BIM implementations in the last few years has attracted the interest of the AEC industry. With this technology there arises a phenomenon with the ability to change and improve the construction sector, thus construction professionals who contribute to project delivery need to change their mind-set so as to be part of a more collaborative environment which is offered by BIM. However, there are many people in the construction sector who do not fully understand the concept of BIM and the way it works.

This concept was firstly presented to the industry in 1970 as a "Building Description System" (Eastman 1975). The reason BIM first appeared was for the introduction of computer software with the ability to provide models for buildings. However, due to the cost of BIM and the success of Computer Added Design the development at that time was limited (Eastman et al. 2011).

In the last decade, BIM has seen a gradual maturation which has been achieved by the introduction of accompanying software and its implementation on many complex projects. The rapid expansion of Information Technology (IT) in the 2000s allowed the AEC industry to relate more with BIM than in the past. Recently, the concept of BIM was the main interest of companies in AEC, and it was defined as a collaborative working environment based on 3-Dimensional Modelling (Lee et al. 2006). Although Different from traditional working methods which are usually based on 2D CAD and 3D CAD, BIM enables faster and more detailed models to be produced by supporting parametric object-based modelling technology. Also, it offers the integration of information into a single collaborated 3D model which can be used by facilities managers during construction and after project completion for maintaining the building (Lee et al 2008). Comprehending the benefits offered by BIM in terms of improving the AEC industry has motivated governments around the world, to mandate the use of BIM with the aim of improving the productivity and performance of the construction industry (SmartMarket Report, 2014).

2.1.3 BIM Maturity

In the 2016, the UK government mandated the use of BIM Level 2 in all public projects worth £5M and over (Cabinet Office 2012). To make this possible, many frameworks have been developed to support organisations and governments to achieve their strategies (Wu et al 2017). One of the most acknowledged frameworks was presented by Bews and Richards (2008) which shows the components added at each level of a BIM implementation as shown in figure 2.1. This diagram is composed of three main stages, introduced by a PreBIM or level 0 stage (Thinkspace 2015). The National Building Specification (NBS) published a guide which clarifies and defines each BIM level (NBS 2017) as shown below:

Level 0: This level requires no collaboration. At this level 2D CAD is utilised for product data. The results are either produced on paper, electric prints or both. Currently, most of the companies in the industry have advanced past this level.

Level 1: Many organisations are presently working at this level. This includes a mix of 3D CAD and 2D CAD to create data and information. This data is shared electronically which is carried out from a Common Data Environment (CDE), which is usually managed by the contractor. However, the models are not shared between the stakeholders of the project.

Level 2: This level is where collaboration takes place, but although all stakeholders use their own 3D CAD, it is not essentially a shared model. The collaboration element is evidenced by the sharing of information between parties which is vital at this level. The design data is shared by using a common file format which shows the association between information for all parties in order to form a BIM model. Consequently, any CAD software used by parties should be capable of being exported to the common file formats of IFC (Industry Foundation Class) or COBie (Construction Operations Building Information Exchange).

Level 3: This level represents full collaboration of all the parties using one shared model referred to as *n*D. All parties can have access and make modifications to this model, which helps to remove the risk of information conflicts. The single *n*D model created in this level represents an unlimited number of dimensions in the BIM environment with specific characteristics for each dimension, which are: 4D (which includes time); 5D (which includes both time and cost) and 6D (which includes time, cost and facilities management).

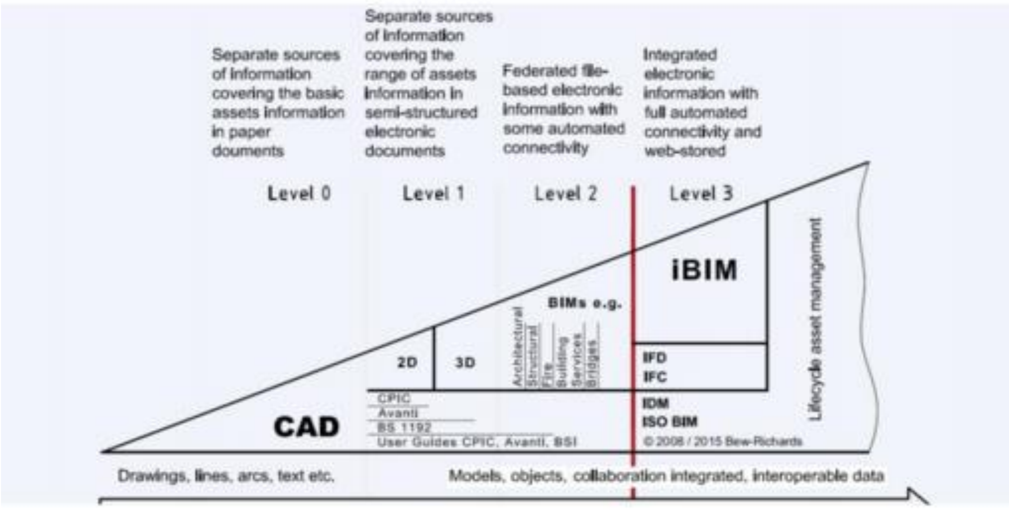


Figure 2. 1BIM maturity level (Source: Bews and Richards 2008)

One more representation of BIM maturity was given by Succar (2009) which shows a sequence of stages where stakeholders are required to implement steadily as shown in figure (2.2). Those stages are comparable to the levels in the Bews and Richards diagram, and emphasise the movement from unmanaged, to completely managed and then integrated work.

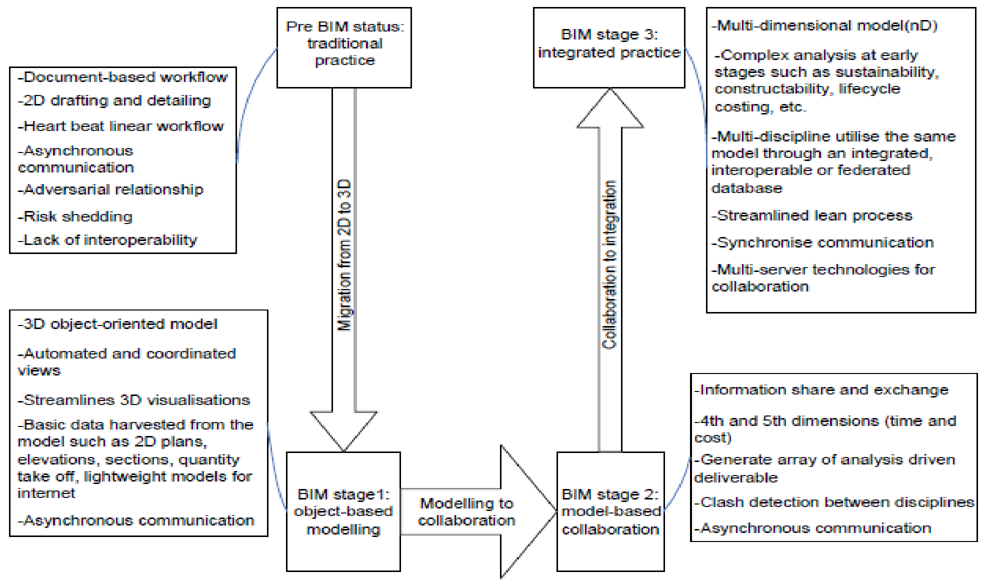


Figure 2. 2 Maturity stages in BIM implementation (Source: Succar 2009).

At each stage of the maturity diagram a new BIM dimension can be used in order to aid the project team in effective information exchange. These dimensions are explained in the next section. As mentioned previously, this research focuses on BIM Level 2 due to the lack of research regarding this specific level in the context of SMEs.

2.1.4 BIM Dimensions

At every stage of the BIM maturity level, different dimensions can be used in order to support information exchange and collaboration. This has been defined by Aouad et al, (2006), as the multidimensional capacity of BIM to add countless number of dimensions "nD". This definition has been supported by Eastman et al. (2011) and Kamardeen (2010), who defined the capability of BIM to add an unlimited number of dimensions "nD" to the building model, as illustrated in figure 2.3. This capacity "nD", allows the adding of all the related building information to the model, which allows the creation of a comprehensive representation of the building in order to improve the efficiency of the delivery. According to (Lu and Korman 2010), BIM technology, if used correctly can improve significantly the construction process by changing the way the stakeholders communicate and interact with each other.

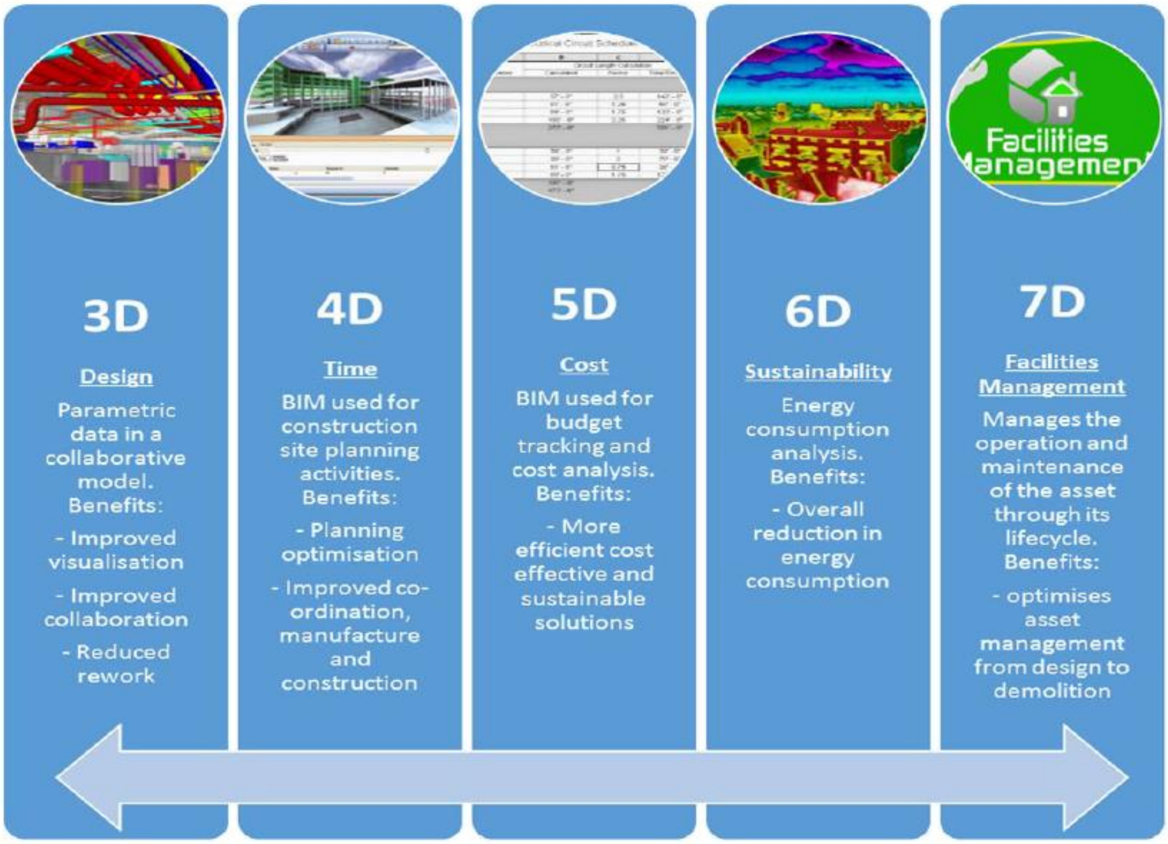


Figure 2. 3 BIM Dimensions (Source: Philip 2013)

3D BIM refers to the stage where all project information and documentation is provided in an electronic format (Bryde et al 2013). 4D BIM is created when a time element (dimension) is added to a 3D BIM model.

4D BIM is defined by Kamardeen (2010, p.285) as:

"A planning process which links the construction activities represented in time schedules with the 3D models to develop a real-time graphical simulation of construction progress against time. Adding the 4th dimension 'time', offers an opportunity to evaluate the buildability and workflow planning of a project. Project participants can effectively visualise, analyse, and communicate problems regarding sequential, spatial and temporal aspects of construction progress. As a consequence, much more robust schedules, and site layout and logistic plans can be generated to improve productivity."

On the other hand, 5D BIM permits the project team to have a better visualisation of the construction progress as well as the related cost of each activity, to support the project team in accurate estimation of the overall project cost. Moreover, it allows real-time extraction or development of fully parametric components within the BIM model. Consequently, 5D BIM offers approaches to analyse cost and assess different scenarios. This has been defined by Mitchell (2012) as a "5D Living Cost Plan". Technological techniques and method are discussed which can be used within traditional methods and frameworks, however the way the technology is being used is more important than the software.

6D BIM supports sustainability and energy consumption analysis which will result in a better energy consumption estimation early in the design phase. Moreover, it supports measuring and analysing energy consumption during the building occupation and also supports the evaluation of the building at the post-occupancy stage.

7D BIM assists in the operation and maintenance of the project during its life cycle. It helps the project team to extract and track the asset data such as materials, components status, specification etc.

The above-mentioned dimensions can be adopted by the project team to help them during the different work stages of the project lifecycle, improving collaboration and communication between the team and in the decision-making process.

On the other hand, despite the maturity frameworks for BIM implementation and studies to clarify BIM dimensions at each stage of the maturity diagram, it can be argued that many companies are at different levels of adoption. According to Turpin (2016) many companies in the UK are still using a mix of 3D models and 2D drawings (BIM Level 1), while only a small number of organisations were able to see the benefits of BIM and embrace it. Therefore, there is a need to identify the benefits offered by BIM in order to encourage companies to adopt it. The next section will provide a more in-depth understanding of these benefits.

2.1.4 The Benefits of BIM Adoption and Implementation.

It is clear that using BIM in construction projects has brought many different features and significant benefits. Zuppa et al. (2009) stated that according to the point of view of the architects, coordination, operation and productivity have been enhanced in construction projects. Similarly, from the point of view of the contractor, BIM has helped in enhancing scheduling and estimation. As stated by Roger et al (2012), BIM can be a noteworthy method to improve the interoperability existing in the supply chain. In general, communication, integration and cooperation between stakeholders and departments are the main factors that drive companies to adopt BIM in order to decrease interoperability by enhancing information sharing. According to a study conducted by Mostafa et al. (2018), the reduction in the time to exchange information was one of the main reasons behind the adoption of BIM in companies.

Other benefits to the business process from adopting BIM are: cost reduction, enhancing information sharing and unlimited access, guiding the integration of numerous parties in the construction industry (Roger et al. 2012). As such, London and Gu (2010) pointed out that an integrated model development can improve collaboration and minimise unpredicted risks within small and large projects. Moreover, BIM offers a model which can be used for: better visualisation of the project, use of off-site fabrication, facilities management, cost estimation, scheduling, clash detection and rapid project delivery (Blackwell 2012; Stowe et al. 2014).

According to the Co-operative Research Centre for Construction Innovation (CRC 2007), the main benefits of adopting BIM are easy sharing of information, enhancing collaboration, and better design by using simulation. In the long and short term, the SmartMarket Report (2012) has recognised the most important benefits of BIM Level 2. In the short term, BIM Level 2 can help stakeholders to minimise errors and the need for reworking throughout the process. The results from the use of the features of BIM Level 2 come out favourably when compared with traditional construction methods which are based on 2D drawings. This is because BIM Level 2 provides more advanced 4D, 5D and 6D models, which present all the components and information related to a project. Unpredicted risks and conflicts can be seen and detected before the execution phase (Stowe et al. 2014).

From the investigation of 32 complex projects conducted by the Centre for Facilities Engineering at Stanford University, Azhar et al. (2011) concluded that the benefits of integrating BIM into projects are: more than 40% reduction of unbudgeted change, 80% reduction in time to create cost estimation, a saving of 10% of contract value through clash detection, a reduction of project time by 7%, a saving of project cost, an improvement in accuracy and quality, automating of documents, minimising of risks and quicker decision making.

Despite all the benefits companies can obtain from adopting BIM, there are many significant barriers and issues related to the conversion from traditional project delivery methods to BIM. Hence, is important to identify the barriers to the adoption of BIM, in particular BIM Level 2 since it is the first mandatory level required by the UK government to be adopted by companies in all public projects.

2.1.5 Barriers influencing BIM Level 2 adoption and implementation.

Despite the opportunities offered by BIM in improving the project delivery method, there are many barriers which can impede the diffusion of this technology. Underwood and Isikdag (2011) argued that in order to implement BIM, companies and organisations should be realistic about their actual abilities. The barriers to implementing BIM Level 2 in companies can be identified as: lack of readiness to use Information and Communication Technology (ICT), problems related to management and culture within the organisations, marketing barriers, legal issues, and contractual issues (Smith 2014).

According to Alreshidi *et al*, (2017), another of the barriers to implementing BIM Level 2 is the initial cost. A significant investment is essential for the transformation of software and hardware and the training of staff to ensure an effective implementation of BIM. It may be argued at first that the cost of upgrading software and training seems overly cumbersome when compared with the total cost of a construction project, however, in this case, the initial cost has been found as one of the top four barriers of adopting BIM Level 2 (NBS 2014).

On the other hand, the benefits from adopting BIM Level 2 are not easily evaluated. Generally, benefits can be tangible and intangible, and usually take effect during the lifecycle of a building project. Joo and Jung (2011) indicate that the implementation of a new system requires changes within the organisation which can lead to conflicts between parties and requires highly skilled BIM users. .

One of the main barriers to the implementation of BIM Level 2 has been identified as training the employees to adapt to the new ways of working demanded. Training should not be restricted on the new software, but should include training on the whole new process since it helps to reduce the resistance to change from employees during the adoption of BIM (Eastman 2011; McGraw Hill 2014; Alreshidi 2017). Besides that, legal issues exist when implementing BIM which centres mainly on the ownership of BIM data (Diaz 2016). Problems regarding the ownership of the model only appears when different parties work to generate and deliver models in a collaborative environment. Other studies have found that interoperability between software can delay the implementation and success of BIM Level 2, since it can obstruct the flow of information during the project lifecycle (Stapleton et al. 2014).

Beside the aforementioned barriers, there is evidence of an obvious lack of knowledge and awareness of BIM within the sector. Practitioners in the industry still believe BIM to be a kind of software or just a synonym for 3D CAD (NBS 2015). In addition, Turpin (2016) states that there is a lack of understanding of the BIM maturity levels and the requirements of each level, particularly for BIM Level 2. A study conducted by Ahmed (2018), ranked all the critical barriers delaying the implementation of BIM Level 2. He stated that the lack of knowledge and awareness was responsible for some of the failures when implementing BIM in the construction industry and led to the parties involved being reluctant to adopt BIM.

Also, the lack of awareness and knowledge of BIM Level 2 is causing a shortage of expertise in the industry, particularly in small practices. According to NBS (2015), a lack of experts is a critical barrier when implementing and adopting this technology, as organisations do not have the required experience and skills in ICT demanded by the introduction of BIM. This barrier has also been recognised in the study conducted by Ahmed (2018).

2.2 An Overview of BIM Level 2 in Small and Medium Companies.

2.2.1 The Contribution of the UK Construction Sector to the Economy.

The construction sector makes a significant contribution to the economic growth of any country, and provides the high levels of employment and the necessary infrastructure required by a growing economy. This sector produces the necessary infrastructure and structures for many applications, which include: commerce, services, housing, local roads, major highways, power systems, and agricultural systems. (Khan 2008).

According to Anaman and Amponsah (2007), the output from the UK construction sector is significant and is expected to aid in the growth of the national economy as well as stimulating industrial development. Construction is recognised as making an important contribution to the Gross Domestic Product (GDP). The share of the value added to GDP by construction was found to be around 7%–10% for developing countries and 3–6% for more developed countries (Wibowo 2009).

The construction sector has been acknowledged as one of the industries which consumes a significant amount of resources and affects the environment. Klotz *et al.* (2007) states that constructions can use up to 36% of the overall energy, in addition to 30% of raw materials and 12% of potable water in the US. A survey conducted by the National Institute of Building Sciences (NIBS) (2007) reported that 40% of the world's raw materials and energy are consumed in buildings, this indicates that 40% of carbon emission is generated from buildings and is released into the atmosphere. Moreover, Gidado (1996) indicates that the construction sector is complex and hard to manage. This typically arises from the risks related to the use of uncommon resources, environmental issues, inappropriate details of materials, and lack of technology adoption (Dubois *et al.* 2002).

The construction sector in the UK is recognised as one of most noteworthy supports for the UK economy (Myers 2013). In the past, there have been concerns that this sector has not been able to meet the challenges from both public and private clients. Therefore, the sector went through a bad experience during the recession in 1990s. Indeed, the output reduced by 39% from 1990 to 1993 and half a million workplaces and almost 35,000 small business failed during this period due to bankruptcy (Adamson *et al.* 2006). According to Latham (1994) the main reasons that this happened was the fragmentation of the construction sector due to the poor capability to embrace innovation, a lack of communication and an absence of trust between the parties involved. Actually, the fragmentation of the sector could be the reason for the noteworthy effects on construction owners and operators. Eastman *et al.* (2011) states that about 10.6$ bn of additional cost was generated in 2012 due to the fragmentation between parties in the USA construction sector. Furthermore, the traditional nature of the players in this sector has been recognised as one of the main factors causing a low level of development in the industry. This was responsible for the low adoption of new technologies and a reluctance to change the ways of working (Hardin 2009; Arayici *et al.*, 2011). Like other countries, the construction sector in the UK has been negatively affected by the lack of communication and interoperability. Consequently, the projects in this sector became more complex to manage due to problems between the parties and involved in the process of project delivery (Dulaimi *et al*., 2002).

Recognising the important contribution of construction to the economy and the high demands from both public and private clients, the UK construction sector has improved and now makes a significant contribution to the total economy. According to the Office of National Statistics (2010), the UK construction sector contributed 4.5% of the total workforce which means that more than 1.9 million people were employed in construction, adding annually £93.5 bn to the GDP. These statistics continue to increase in 2012. As Myers (2013) stated, the construction sector contributed to the UK economy with £90 M of gross value which amounts to 6.7% of the UK GDP. This sector offers 2.93 million jobs which was almost 10% of the people employed in the UK. The Department for Business Innovation and Skill (2013) summarised the composition of the UK construction sector as contracting, services and products as shown in figure 2.4 below.

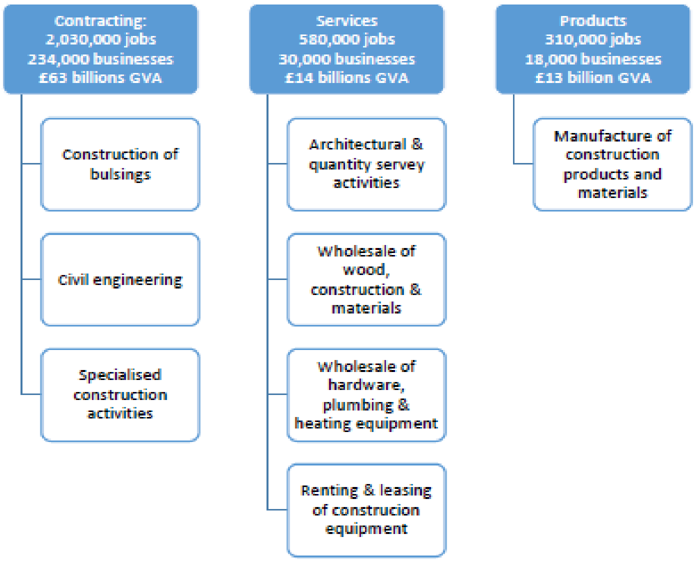


Figure 2. 4The composition of the UK construction industry (Source: The Department for Business Innovation and Skill 2013)

The largest sub-sector is contracting, which hold almost 70% of the Gross Value Added (GVA) and the sector's jobs. The products and materials sub-sector occupy a smaller size; however, they play a major part in contributing to the sector performance and the overall economy (Business Innovation and Skill 2013). In order to help the construction sector to become the leading sector in the world, the government has set significant foundations for innovating the industry by adopting BIM as a solution for the challenges faced in construction. A more detailed discussion of the progress on the uptake of BIM as a solution will be provided in the next section.

2.2.2 BIM Level 2 adoption in the UK Construction Industry

The BIM agenda was first launched by Tony Blair in the New Labour Government who emphasised the need to enhance collaboration in construction. The government appointed Sir John Egan to produce a report called 'Rethinking Construction' which pointed out that the change would be to create a network where members can collaborate with each other to enhance and improve construction methods, skills and interchange ideas and opinions for improving effectiveness and quality (Egan 1998). The aim of the suggestions in this report was to make the construction industry more collaborative, concentrating on information exchange in order to improve efficiency. The report aimed at improving the efficiency of the industry with the intention of reducing the cost of government construction projects by 15-20% (Cabinet Office, 2012).

On 31st of May 2011, the UK government Construction Strategic Report mandated the use of BIM Level 2 in all public projects (BIM Industry Working Group, 2011). As shown in figure 2.5, the maturity levels were set by the BIM Industry Working Group to illustrate the path through the different levels and remove the uncertainty regarding what can be achieved in a full implementation.

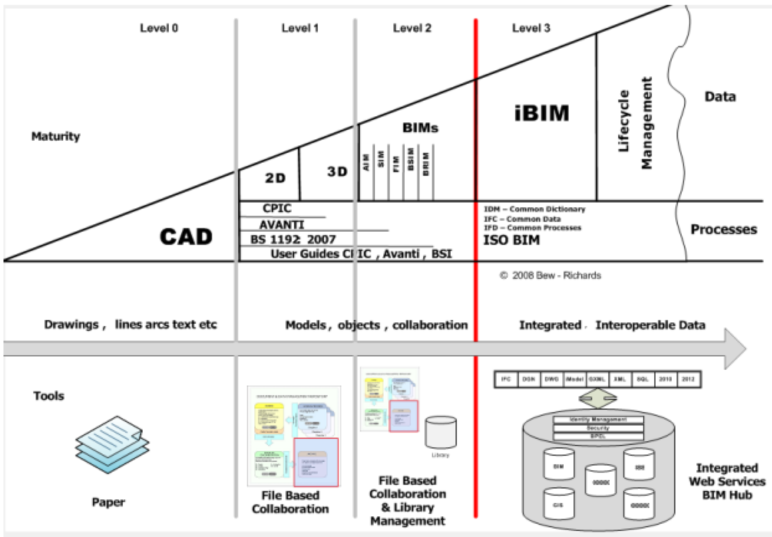


Figure 2. 5BIM maturity levels (Source: Barlish et al. 2012).

Principally, CAD represents the starting level of the BIM journey which is defined as Level 0. It is important to understand that BIM is not just a graphic representation of drawings in 2D CAD or 3D CAD. The crucial feature of BIM is the capability to offer object-based data which includes detailed information about the project to enhance information exchange of the model and induce collaboration between parties and stakeholders at various phases of the building lifecycle (Smith 2007). Consequently, using BIM in projects will help to increase clarity, collaboration and integration within the design and construction process. The outcomes of using BIM will be reflected in higher quality, reduced timescale and reduced cost (Reddy 2012).

To motivate and encourage BIM Level 2 adoption within the industry, BIM support groups, frameworks and standards have been applied. Among these groups, the BIM Task Group is recognised as the main innovator which aims to bring together skills and knowledge from industry, academia and government to reinforce the capability of the public sector in the use of BIM Level 2 and offer the needed information to the industry to meet the 2016 government's mandate (BIM Task Group 2013). In addition, the Construction Institute Council (CIC) was charged with creating a network of hubs to guarantee that up-to-date and consistent information is spread across the United Kingdom and feedback is given to the BIM Task Group (Designing Building Wiki 2016). Moreover, BIM4SME was given the task of providing support to SMEs to get them to adopt and start using BIM Level 2.

In addition to these groups, several frameworks have been developed to assist BIM Level 2 implementation. They comprise framework for recognising factors for BIM effectiveness and evaluation (Jung and Joo 2011), framework for a BIM acceptance model for construction organisation (Lee et al. 2015), and framework to achieve best value from construction projects (Porwal and Hewage 2013; Lu et al., 2015). Therefore, through the use of these frameworks, the adoption of BIM within the UK construction industry has increased in the last few years. The National Building Specification (NBS) conducted a survey in 2013 which showed an increase in BIM Level 2 usage from 13% in 2010 to about 39% in 2012. A recent report published by NBS in 2017 in the UK, one year after the UK government mandate to implement BIM Level 2 within all the public projects, shows that 62% of companies are using BIM (compared to 54% in 2016) while 35% were just aware of BIM.

On the other hand, a paper by McGraw Hill Construction (2013) showed that 47% of contractors have been using BIM from 1-2 years and 41% have been using it from 3-5 years. Based on this report, the UK shows a low level of BIM engagement when compared to other countries (McGraw Hill Construction 2013). This low rate of engagement was the motivation behind the government BIM Level 2 mandate on the construction sector to use BIM level 2 on all public projects, which started from 2016. Indeed, another report published by McGraw Hill Construction in 2014 compares the impact on construction companies of US and UK government policy regarding the introduction of BIM. The report shows that since the mandate of 2016, 67% of UK companies have been influenced to adopt BIM level 2, while the US percentage amounts to 12% (McGraw Hill Construction 2014).

It can be argued that although the various reports which studied BIM, and the many frameworks which aimed to facilitate its implementation, there is still a lack of knowledge of BIM within the industry. A survey conducted by Dunton (2016) showed that generally the UK construction industry is ‘Level 2 BIM positive’ but not ‘Level 2 BIM aware’. According to Hunt (2015), there is a lack of awareness in BIM, where all the emphasis is on the use of tools and software and little attention is given to collaborative processes and the collaborative working environment which is the real core of the BIM approach in construction practices. In addition, Boutle (2017) states that the level of awareness in the UK is even worse in smaller companies and their supply chain organisations, where they are still facing issues with BIM Level 1. This can be supported by the study conducted by the Chartered Association of Building Engineering CABE (2015), which found out that 71% of non-manufacturing respondents assumed that the supply chain was slowing down BIM Level 2 engagement.

This lack of knowledge and awareness of BIM Level 2 was reflected on practitioners in the industry who believed that BIM was all about software rather than a new approach to deliver construction projects. Ahn and Kim (2016) pointed out that limited awareness and knowledge of BIM restricted the adoption and implementation of BIM, therefore education was vital in this case in order to overcome this problem and change the conventional construction process for BIM. Moreover, NBS (2016) conducted studies every year from 2010 to 2017 with 1000 practitioners in the industry. The findings indicated that the use of BIM increased from 3% to 54% within this period of time. However, the survey showed that 18%-28% of the participants believed that BIM was just about software, and 11%-15% believed that BIM was only a 3D CAD model.

Despite the increasing use of BIM in the UK construction sector as shown in the aforementioned statistics, there is an evident lack of knowledge regarding the different levels of BIM implementation and especially the understanding of BIM Level 2. Moreover, although the adoption rate for BIM adoption is increasing, there is evidence that this growth is unequal across companies. These indications show that large companies are mainly implementing BIM level 2 while small and medium sized enterprises (SMEs) are dropping behind. The next section will introduce and define SMEs, in addition to explaining their current situation in term of BIM Level 2 adoption.

2.2.3 Overview of Small and Medium-sized enterprises (SMEs) in the UK.

As argued in the previous section, complexity and fragmentation are two common features of the construction industry, which includes a high number of SMEs and a few large companies (Langford *et al.*, 1991). Consequently, in order to improve the construction sector, governments need to pay attention to SMEs since they have a high impact on the sector (Forstater *et al.* 2006). In addition, defining these types of companies has been concerning researchers, since the definition has differed based on country, industry and sector. According to Ibrahim *et al.*

(1986), characteristics such as: number of employees, asset size and turnover are what define SMEs. Based on this, Anon (2005) suggests a more specific and simple definition according to the standards of European countries This definition is based on the number of employees and the annual turnover of the company, as shown in table 2.1 below.

Table 2. 1 Definition of SMEs (Source: Anon 2005).

Size of Company	***Num. of Employees***	***Annual Turnover***
Micro	From 1-9	≥ 2 million Euro
Small	From 10-49	≥ 10 million Euro
Medium	From 50-249	≥ 50 million Euro

Wedawatta *et al.* (2016) points out that a vast number of SMEs belong to the private sector, those companies are mainly categorised as micro companies as they are either privately owned, partnerships or a company consisting of one employee-director. While the majority of companies are small firms, a small portion are medium-sized. Because of the large number of SMEs, hundreds of companies make up the supply chain which contributes in the delivery of construction projects (Stewart *et al.* 2004).

According to Love et al. (2004), SMEs are recognised as the backbone of numerous major economies all over the world. The position which SMEs occupy in the improvement of economies across the world cannot be denied. SMEs hire about 80% of the world's workforce, produce 54% of the total global economy and form more than 90% of firms all over the world (Hsu et al 2012). Harty et al. (2016) conducted a study which included 28 countries of the European Union (EU), and has found that the in these countries there are 23 million SMEs which make up 99% of all companies and consist of almost 75 million workplaces.

According to Robson *et al.* (2014), there are about 950,000 SMEs in the UK which account for 80% of the production in the construction industry. At the beginning of 2014, 99.4% of the 5.2 million private businesses were found to be small, while 99.9% were found to be small and medium-sized companies (Department for Business Innovation & Skills, 2014). In addition, there are about 4.9 million businesses in the UK which provide 24.3 million workplaces with a total turnover of £3,300 bn (Harty *et al.* 2016). In the UK, 99.9% of companies in the private sector are SMEs which produce 48.2% of the turnover of this sector. Consequently, SMEs are the main source of economic growth, improvement and employment.

The distinctness between large companies and SMEs is recognised in the number of resources and the structure of the company. Typically, in SMEs there is a shortage of workers, knowledge and financial resources. In addition, there is a notable lack of knowledge regarding the adoption of new technology and strategies of development (Jutla *et al.*, 2002; Caskey *et al.*, 2001). Usually, SMEs, have informal procedure management (Kotey *et al.* 2005). Consequently, they face problems related to management and health and safety standards (Vassie *et al.* 2000). Moreover, in these types of organisations the workforce is cheap and the number of employees are fewer when compared to larger companies. This leads to a shortage in highly skilled staff and results in problems with the training of employees in the adoption of new technologies and new working methods. Once the industry needs to change in order to improve, SMEs find it difficult to deal with this change and encounter barriers and limitations (Eurostat 2012). This can result in a variance in the adoption of new technologies according to the size of companies. The next section will outline the adoption of BIM Level 2 in SMEs in the UK, especially after the government mandate its use on all public projects starting from 2016.

2.2.4 The Current Situation of BIM Level 2 within SMEs in the UK

SMEs play a significant role in the development of economies in countries across the world. Generally, the structure of the construction industry is made up of many organisations, where most of them are SMEs. These SMEs incorporate a workforce, materials, assets and information (Harty et al. 2016). According to Kotey et al. (2005), the management processes in SMEs are informal and, consequently, they encounter issues relating to health and safety and management (Eakin *et al*, 2000; Vassie *et al*, 2000). In addition, the workforce is small and less skilled than in larger companies, thus, they face problems of re-training when adopting new technology or methods of working. Because of the characteristics of SMEs previously mentioned, they have problems in conducting huge and complex projects so, as a matter of choice, they prefer to collaborate with other organisations to deliver them (Stewart *et al.* 2004). Therefore, the efficiency of the construction sector, particularly in major projects, has been affected by SMEs.

Generally, to encourage the construction sector to suggest appropriate policies when adopting new technologies, such as BIM, it is vital to consider the growth of BIM adoption by SMEs (Boktor *et al.*, 2013). Although large companies are willing to embrace BIM, SMEs seem to be lagging behind. (SmartMarket Report, 2012; Hong et al 2016). According to the SmartMarket Report (2012), the number of large companies adopting BIM is three times more than smaller companies. A recent survey in the UK, by the Electrical Contractor Association in 2015 reported that there was a notable gap with regards to BIM adoption in organisations, showing that 89% of large companies were ready for BIM adoption, while 54% of smaller companies were not (Electrical Contractor Association, 2015). This has been supported by NBS (2017), as it has been reported that 52% of small firms in the UK have not used BIM Level 2 at all, and only 5% of small companies have made the effort to adopt and implement Level 3 (Hosseine et al. 2016). Moreover, Vidalakis et al. (2019), have identified in their study that three years after UK government mandate, SMEs are still facing low BIM adoption rate due to their limited financial capacity. Moreover, Mellon and Kouider (2016), indicated in their study that the gap between large companies and SMEs could increase if the government and the construction industry will not undertake initiatives to aid SMEs in embracing BIM. Moreover,

According to Jamieson e*t al.* (2012), the policies and strategies in the UK to improve and innovate the sector, by adopting and implementing BIM level 2, seem to ignore the needs of SMEs. Vega et al. (2015) support the argument that SMEs in the UK are crucial for BIM policy implementation as they account for most of the companies in the construction industry, however it is unclear how implementation can happen within these smaller companies. Consequently, they are not able to see how BIM will help them to improve the construction process, and especially to see the advantages and disadvantages of adopting the technology. Also, because the focus of BIM level 2 was on complex major projects in the public sector which necessitated collaborative procurement, many SMEs felt that BIM was not suitable for them (Jamieson et al., 2012). In addition, the cost of implementing even the first level of BIM, was one of the main barriers faced by SMEs, particularly when a large sum of money was needed to be spent over a short period of time. Therefore, SMEs in the UK were dropping behind in BIM level 2 implementation, and they were missing out on both publicly funded and private projects (Federation of Master Building 2013).

Obviously, there is a need for BIM Level 2 to be adapted for organisations of different sizes if it is to be used to deliver construction projects. Although, as shown above, SMEs, have received little consideration in strategies from government or the construction sector, or work by researchers. According to Dainty et al., (2017), the existing policies were framed to serve companies which already have the power and resources for implementation, while other companies were left unnoticed. Poirer at al. (2016) suggested that in order to benefit, SMEs needed a clear strategy to guide the adoption of BIM. However, Dainty et al. (2017) claimed that in reality only a few SMEs had the ability to develop an approach for BIM adoption and implementation. Also, due to the limited research on adoption by SMEs, they appeared to have shown little interest in BIM (NBS 2014).

SMEs could lose national and international projects if they continue to lag behind with BIM adoption. Harris (2013) stated that this will result in an undesirable impact on them, and could make them less ambitious and competitive. This tendency will continue if SMEs do not start integrating this new technology into their organisations to meet the demands of government and industry. Also, the UK government have mandated the use of BIM Level 2 in all public projects by 2016, which signifies that companies which are not using BIM Level 2 will be unable to bid for government projects (HM Government 2015). This will cause SMEs to bid only for private projects where BIM Level 2 is not a requirement.

2.2.5 Chapter Summary

Generally, the construction sector plays a significant role in the economy of any country. The output of this sector helps in the development and growth of the national economy. Despite this, there are issues related to the management of this sector particularly when new technologies need to be adopted. The reasons behind these problems are mainly the fragmentation of the sector, poor capability to adopt new technologies and a lack of communication and collaboration between the players within the industry. The UK government has mandated the implementation of BIM Level 2 in order to improve the industry by integrating this new technology to deliver construction projects. In addition, frameworks and guidelines have been released to encourage companies to adopt this technology. However, the literature points out that despite these efforts, the rate of BIM adoption across different companies is unequal and most implementations have been in large companies, while SMEs are still lagging behind in the UK. This slow adoption of BIM is impacting negatively on SMEs, as they are failing to win public and private projects. Therefore, there is a need to carry out more studies related to SMEs in the UK, in order to develop a framework to support these companies when implementing BIM. The following chapter will discuss the process for developing a framework to assist SMEs in BIM Level 2 implementation.

CHAPTER THREE Developing a Conceptual Framework

3.0 Chapter Overview

To investigate the research issues that emerged from Chapter Two, this chapter reviews and critically discusses the literature related to BIM Level 2 implementation. The aim of this chapter is to identify the factors that lead to the successful implementation of BIM. Based on the information highlighted by the literature review, a conceptual framework will be developed as a theoretical underpinning for this research.

In order to achieve this, the chapter starts by reviewing the literature and analysing different frameworks related to BIM. The limitations of these frameworks and the gaps identified in the literature, will aid the researcher in identifying the main components of the proposed framework. Critical Success Factors influencing the implementation process of BIM Level 2 will also be reviewed from the literature and the most common factors identified by previous scholars and researchers will be taken into consideration. The proposed conceptual framework of this study is presented in section 3.5.

3.1 Review of Existing BIM Adoption and Implementation Framework.

In the last few years, companies and organisations, in order to grow and develop their competencies and innovations have faced an exceptional increase in the adoption of new technologies. This has introduced new fields of research in order to develop models to assist technology adoption. BIM has become the new technology used in construction project delivery and has captured the attention of governments in many countries. The international construction sector is changing and traditional methods for delivering construction projects have been substituted by a new process which focusses on more collaboration and coordination (Eastman *et al.* 2011). Consequently, there have been large number of studies associated with BIM, contained in books, journals, conferences and academic theses. These publications have been developed to influence companies in the construction sector all over the world to embrace BIM. More than 1500 publications related to BIM have been found in the last 25 years. Generally, research published in Asian countries have covered topics related to monitoring and visualisation, while research conducted in North America and Europe have paid more attention to standardisation and building-information services. These differences in the research interest could be the reason for the variations in maturity among companies in different countries. In addition North America and Europe have already recognised the benefits of BIM, therefore studies are moving to more profound process standardisation and interoperability. In terms of research interests, it has been found that the majority of research (22%) is related to simulation and monitoring, followed by building information services (16%) and standardisation (14%), while the rest of the research interest is concerned with other topics, such as: sustainability, energy consumption and facilities management (Badrinath *et al.* 2016).

Moreover, according to Bradinath *et al.* (2016), there is little research focusing on BIM adoption, and only 6% of publications focus on organisational adoption. This result confirms the findings from a study by Jamieson *et al.* (2012), which stated that small and medium companies felt that BIM was not for them since they were ignored by policies initiatives. The limited research and frameworks for assisting the adoption of BIM that has been performed previously, particularly for SMEs, has been reflected in the low rate of BIM adoption (Liu *et al.*, 2010; Migilinskas *et al.*, 2013; Kouider, 2013).

Indeed, it is important to achieve advantages from the current BIM frameworks, by studying the existing frameworks related to BIM research areas or by analysing and exploring the issues which have been investigated, and as a result, much additional knowledge and experience can be gained (Succar 2009). Therefore, the next section will present some of the current frameworks published in the literature in order to promote BIM adoption and Implementation.

1. **BIM maturity stages.**

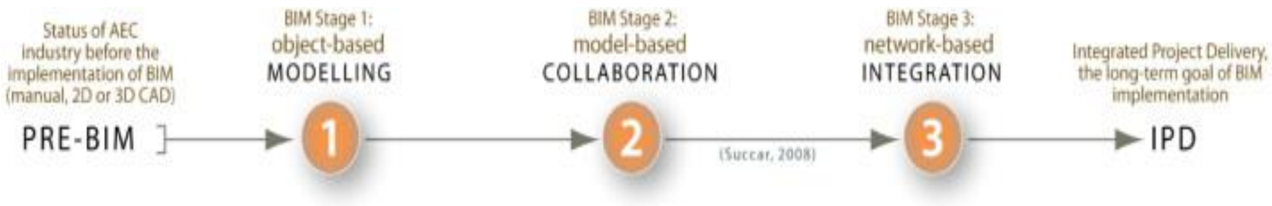


Figure 3. 1BIM maturity diagram (Succar 2008)

The framework in Figure 1 was presented by Succar (2008) which illustrates the level of BIM maturity for organisations, projects and the construction industry. The framework shows a series of stages which stakeholders should implement progressively and successively in order to achieve the Integrated Project Delivery (IPD) which is the final aim of this framework. Each of these stages is divided into three steps, of BIM maturity, which are modelling, collaboration and integration, which comprise respectively of technology, people and process components. Succar (2009) argues that the more the BIM implementation maturity is advanced the more changes need to be applied in the business processes of the organisation. This will not just involve certain individuals, but the whole organisation will be impacted by the changes. Consequently, at the more advanced stages of the implementation the organisations need to focus more on team work.

2. BIM and Practical Implementation.

This has been developed by Jung and Joo (2010) for practical BIM implementation with the purpose of recognising the driving factors for practical BIM effectiveness. The framework is based on six variables which are categorised under three main dimensions, including: BIM perspective, BIM technology and construction-business functions. Moreover, they explained that BIM implementation occurs at three different levels, starting with the industry level, then the organisational level and finally the project level. In general, they described BIM standards as being developed at the industry level, while, to serve the aims and strategies at the organisational and project level standards and policies are more specific. The framework integrates BIM technologies, which include: data property, relation, standards and utilisation across project, organisation and industry (Jung and Joo 2010).

3. BIM acceptance model in construction organisation

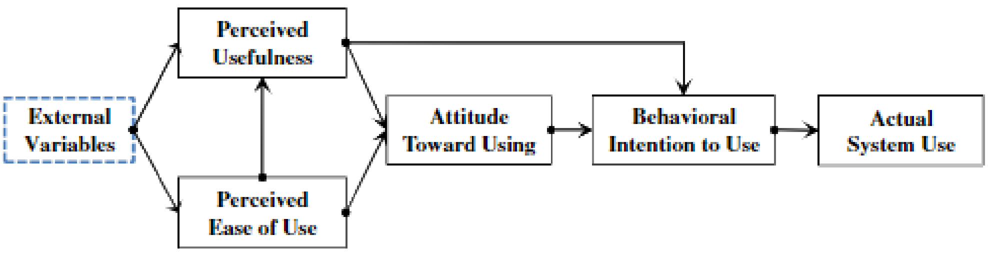


Figure 3. 2BIM acceptance model in construction organisation (Lee et al. 2015).

The aim of this framework presented by Lee *et al.* (2015) is to explain the reason behind adopting BIM within organisations and identify the factors which improve the implementation. The framework recognises factors affecting two main perspectives which are individual and organisational. Consequently, the framework can evaluate if an individual or organisation is ready to adopt and implement BIM, although, this framework mainly emphases the technological viewpoint. The key element of this framework has been identified after investigating the literature related to BIM technology acceptance.

4. **Normative and activity-theoretical /evolutionary frameworks**

Miettininen and Paavola (2014) have recently developed two frameworks to understand BIM implementation, which are the normative framework and the activity-theoretical /evolutionary frameworks. The first framework, "normative", is being characterised by the need to achieve efficiencies and economies in the technological system. The maturity model developed by Succar is demonstrative of such frameworks. On the other hand, the activity-theoretical model/evolutionary framework were not generally adopted in the literature as they focussed on cultural and historical theory, organisational studies and the evolutionary economics of innovation (Ziman 2000, Miettinen 2009). Miettininen and Paavola, (2014), argued that historical and cultural theory could be used in the context of BIM since is related to the learning and development of IT systems and design of collaboration.

3.2 Limitation in Current Frameworks.

In general, frameworks are developed to address a certain gap in knowledge, and can be achieved by the modification of an existing framework, according to its limitations, or the development of a new framework from scratch. In this research, the aim is to develop a framework based on the existing limitations as identified in the literature. The frameworks presented in the previous section, represent just a small number of the existing frameworks related to BIM adoption, which could be found in the literature. It can be seen that they differ in terms of concepts, aim and terminology, however all of them were developed to help the construction sector in the adoption of BIM.

Commonly, consideration has previously been given to the BIM maturity levels (Bew and Richards 2008) and levels of maturity (Succar 2009). As construction organisations started to adopt BIM they moved from uncertainty to growth and finally to more controlling levels of maturity (Land and Jarman 1992). Each of these levels of maturity which the companies go through, bring with them organisational changes, until they are typified by expansion and decentralisation. Investigation into BIM implementation at a certain maturity level is rare in the literature, despite the UK government's emphasis on implementing BIM Level 2 across all public projects by 2016 (Gledson and Greenwood 2017). On the other hand, despite the encouragement of the UK government to apply level 2, it did not define in the requirements how this could be achieved by organisations in the construction industry (Ganah and John 2014). It has been argued in the literature that the implementation of BIM within organisations requires more than a basic technology adoption (Howard and Björk 2008). Though the literature supports the business case for BIM adoption, Fox (2014) argues that the BIM implementation plan presented in the literature is overly basic and simplistic which leads those responsible with its implementation to substandard decisions, based on a lack of information. The absence of a detailed plan for BIM implementation, in particular for Level 2, will delay meeting the UK mandate to use BIM Level 2 in all public projects from 2016. This will mostly affect SMEs, as only a limited number of them will be able to develop a clear BIM implementation plan (Dainty et al. 2017). Moreover, Vidalakis et al. (2019) argue that a one-size-fits-all approach to BIM implementation has restricted potential in helping SMEs to embrace the technology, since they differ from larger companies in terms of resources and capabilities.

On the other hand, there are several studies investigating the critical success factors influencing BIM adoption and implementation. However, from a survey conducted by Mohammad et al. (2018), it has been identified that the UK has the lowest number of studies investigating the CSFs influencing BIM adoption and implementation compared with other countries, such as Malaysia, Korea and Australia. In addition, except for the few number of studies related to CSFs for BIM implementation in the UK, there is limited research exploring the importance of these factors through the implementation process, starting from the pre-implementation until the post-implementation phase (Ahmad et al 2012).

The idea of mapping the critical success factors into the implementation lifecycle has firstly introduced by Somers and Nelson in 2014 in the ICT sector. Their work mapped the critical success factors within a five-stage model, which included initiation, adoption, acceptance, routinisation, and infusion. This integration of critical factors and lifecycle stages was the first one of its kind in the ICT sector, where it has been implemented successfully in the context of Enterprise Resource Planning (ERP) (Basoglu et al. 2007). On the other hand, in the context of BIM, there are different studies exploring the implementation lifecycle of BIM (Arayici and Aouad 2012; Kumar 2015). However, after reviewing the literature, the researcher has concluded that there were no studies similar to the work of Somers and Nelson in the context of BIM, which explore the critical success factors within the different stages of the BIM implementation lifecycle. Also, reviewing the literature suggests that most studies were concerned with the implementation stage, although studies such as the one presented by Kumar (2015) proposed that companies go through a post-implementation phase where an evaluation of the implementation was performed and the ultimate impact of the implementation was observed.

Currently, BIM has been developed and implemented in many different countries, however there are many published reports stating that there are difficulties and barriers to its implementation (Dowsett and Harty 2018; Ahmed 2018). Many have reported that SMEs are facing problems in BIM implementation due to limited research concerning smaller companies and a lack of guidance for its implementation (Vidalakis et al. 2019).

As a response, this study will present a framework which will guide SMEs through BIM level 2 adoption and implementation, by mapping the proposed CSFs into the BIM implementation lifecycle.

3.3 Critical Success factors (CSFs) Influencing BIM Level 2 adoption and Implementation among SMEs

Based on the previous section, in order to develop the framework for this research it is essential to first identify the critical success factors which influence SMEs when adopting and implementing BIM Level 2. Different studies have been carried out in order to understand the process of adopting BIM (NBS 2016; NBS 2017), and the factors which influence its adoption (Gu and London 2010; Linderoth 2010; Sawhney 2014; Xu et al. 2014). However, this research will explore and investigate the factors influencing both the adoption and implementation of BIM Level 2 in the context of SMEs.

An approach was adopted by the researcher in order to select the relevant articles to be included in this research. This approach began by scanning the literature to identify articles which discussed the various methodologies for BIM adoption. For instance, the different journals searched were *Automation in Construction*, *International Journal of Construction management*, *Advanced Engineering Informatics*, *The Journal of Information Technology in Construction* and many other journals. In addition, other sources were found in the Coventry University library and other online databases. At the beginning, more than 400 citations were identified which were relevant to this study. Then, these were analysed in order to exclude articles that were not addressing the aim of this research. Once all the relevant articles were identified, they have been critically analysed in order to synthesise the data. At the end, only fifteen articles were selected for this study, which helped to classify the factors into four main categories, which were: human factors, organisational factors, process factors and external factors, as shown in the Table 3.1. All the factors were identified in the literature and were categorised based on the work of Enegbuna *et al.* (2015) and Ahn *et al.* (2016).

The factors selected in the table were chosen based on their frequency in the literature and their importance to BIM implementation in SMEs. They also play an important role in the BIM implementation process, as they offer adequate support for the researcher to identify the most influential factors to develop a framework for BIM Level 2 in SMEs.

Table 3. 1 CSFs influencing BIM Level 2 implementation in SMEs.

Category	Critical Success Factors	Definition	Cited by
Human Factors	People	Availability of qualified people within the company	NIBS (2007), HM Government (2012), Wong et al. (2010), Succar (2009), Khosrowshahi and Arayici (2012) and Lee et al. (2015)
	Training	Equipping the personnel with necessary knowledge and skills through training programs, seminars	Zuppa,Suermann and Issa (2009), Jung and Joo (2011), Arayici et al. (2011), Arayici and Khosrowshahi (2012), Succar (2009) McGrawHill Construction (2014) and Crowther and Arayici (2019)
Organisation Factors	BIM Awareness	Existence of awareness and knowledge of BIM Level 2 within the company	Succar (2009), Arayici et al. (2011), Khosrowshahi and Arayici (2012), Turpin (2016); NBS (2014), ahankoob (2019)

	Change Management	Manage and change people in the company to achieve the required business outcomes.	Gu and London (2010), Jung and Joo (2011), Enegbuma et al (2015), Morlhon et al (2014)
	Top Management Support	Facilitate BIM implementation from top management by enabling resources, funds and assistance	HM Government (2012), Lee et al (2015), Enegbuma (2015), Succar (2009), Arayici et al. (2011) Lee et al. (2015) and Ahuja et al. (2018)
	Company Vision and Strategy	Aligning the benefits offered by BIM with the vision and strategy of the company	Becerik-Gerber and Rice (2010), Azhar (2011), Hanna et al. (2013), Turpin (2016)
	Compatibility	A characteristic which allows software to operate together	Bernstein and Pittman (2004), Becerik-Gerber et al (2012), Azhar (2011), Hanna et al. (2013), HM Government (2012), Arayici et al (2011), Khosrowshahi and Arayici (2012), and Boktor et al. (2013)
	Resources	Availability of resources as: software, hardware and budget	Miettinen and Paavola (2014), Ganah and John (2014), Bryde et al. (2013), Linderoth (2010), Succar et al. (2009), Wong et al. (2010), and McGraw Hill Construction (2014)
Process Factors	Communication and Collaboration	Effective communication and collaboration during the process of implementation	Succar (2009), Eastman (2011), McGraw Hill Construction (2014), Ganah and John (2014), Peansupap (2005) and (Havenvid et al. 2016).
	BIM Policies	Existence and efficiency of a plan to implement BIM	Khosrowshahi and Arayici (2012), Becerik-Gerber et al. (2012), and Jung and Joo (2011), Bradinath *et al.* (2016)
External factors	Government Support	Pressure from the government to mandate a mandatory use of BIM Level 2 to deliver projects	Arayici et al (2011), Succar (2009), Azhar (2011), NBS (2017), Eadie et al (2016) Wong et al (2010) Ahmed (2018), Zakaria et al (2013)
	Client Demand	Existence of pressure exerted by the client	NBS (2016), NBS (2017), Ahmed (2018), Turpin (2016) Ghaffarianhosein et al (2017), Ganah and John (2014), Doolin and Al Haj Ali (2008)

3.3.1 Human Factors

This category was recognised based on the work of Enegbuna *et al.* (2015) and Ahn *et al.* (2016), and the factors recognised under this category were: people and training of employees. The availability of people with the required experience and training has been considered as critical for the implementation of BIM (Khosrowshahi and Arayici 2012; Lee et al. 2015). According to the literature, the implementation process of an information system such as BIM, requires the employees to have certain skills and knowledge, therefore the availability of qualified people within the company will ensure a successful implementation. Moreover, implementing BIM changes the ways of working, consequently, to ensure a successful implementation, training on the process is critical in order to ensure that all employees are at the same level of knowledge. A study conducted by Crowther and Ajayi (2019) found out that in order to embrace the potential of BIM it is important that companies provide training on the process rather than just the use of software.

3.3.2 Organisation Factors

Ahn et al. (2016) recognised this category as the factors which influence the implementation of BIM from inside the organisation. The level of awareness was identified to be a very important factor as it could facilitate or hinder the implementation. As stated by Turpin (2016), the awareness of BIM and the features introduced at different levels is critical for its implementation. Ahankoob et al. (2019) highlighted the fact that previous awareness of BIM can minimise the impact of resistance to change by employees during the adoption.

On the other hand, change management and top management support were recognised by many scholars in the literature to be very influential during the implementation. It has been commented that the ability of the management level to support the implementation, by providing training and financial support, is very important to overcome possible barriers, such as the high cost of adapting to the new system (Lee et al 2015; Ahuja et al. 2018).

Eastman et al. (2011) argued that the way the information is exchanged in organisations is vital to achieve a successful implementation of BIM. In addition, proper software and hardware are also vital for its success. On the other hand, the availability of financial resources has also had a great impact on BIM adoption and implementation. Ganah and John (2014) mentioned that an innovative process requires a significant amount of budget. Even if the organisations are willing to adopt BIM, the available financial resources can impede the start of the process. Moreover, it is critical to ensure the availability of compatible software which will operate together effectively, and result in better communication between parties and stakeholders involved in the process (Boktor et al. 2014).

3.3.3 Process Factors

One of the most significant outcomes of BIM Level 2 implementation is better communication and collaboration (Havenvid et al. 2016). However, Ozorhon and Cinar (2015) argued that managing the whole process could be challenging and present difficulties which could result in conflicts and misunderstandings. However, proper communication and collaboration will help to avoid these issues.

At present, there is limited guidance for BIM, especially on integrating BIM with the present practise in the construction sector (Jung and Joo 2011; Bradinath *et al.* 2016). Consequently, most of the construction practitioners tended to implement BIM in their own way which was causing the project management to be less effective. Thus, Daynti et al (2017) argued that is critical to standardise the process of BIM implementation and provide appropriate guidelines for its adoption, particularly when only a few SMEs have the ability to develop a clear strategy.

3.3.4 External Factors

Client requirements is a very important factor. Satisfaction of the client is critical since the client defines the responsibility of the contractor and sometimes specify the BIM level which should be used, all of these affect the implementation of BIM (Amponsah 2010). Havenvid et al. 2016) argue that client requirements are important when the company is implementing Level 2, because in this level cost and schedule are modelled so the client expectation will be more specific and need to be achieved by companies.

According to Eadie et al. (2016), government pressure is identified as a factors influencing BIM adoption especially for UK construction Industry. A study presented by Ahmed (2018) showed that this factor has become more important since 2016, because the UK government has made the use of BIM Level 2 mandatory in public projects

3.4 BIM Level 2 Implementation Lifecycle

Generally the implementation of BIM requires the collaboration and cooperation of different departments within the organisation. The implementation of BIM usually takes place in the form of a project or a system which influences every operation in the organisation. Consequently, there are specific procedures which need to be followed according to the particular characteristics of the organisation. Jung and Joo (2010) proposed that BIM implementation should occur at three levels, which are: industry, organisation and project.

They stated that at the industry level, standards and implementation processes are already established, however at organisational and project levels these standards and processes can differ due to the detail and scope of the managerial corporate strategy. Therefore, many studies have been conducted in order to develop a BIM implementation plan, these plans have been proposed by software vendors (Autodesk 2010), academics (Eastman et al. 2011; Arayici et al. 2011) and the AEC industry (Lin et al. 2005; BIM Road Map 2011). Despite the various proposed plans, Arayici and Aouad (2012) stated that all these plans were divided into three main phases which any organisation experienced during BIM implementation. This was supported by Ahmad et al. (2012), as in their study the three main phases for BIM implementation were identified as: the pre-implementation phase, the implementation phase, and the post-implementation phase. Other studies such as those by Dell (2011) and Kumar (2015), stated that each phase of BIM implementation lifecycle was comprised of different stages, where, amendments, re-implementation and updates are completed in each stage of the process. Those stages were recognised as following the pre-implementation phase (consisting of the adoption and planning stages), implementation phase (consisting of just the implementation stage) and the post-implementation phase (consisting of the evaluation and update-plan stages) as shown in figure 3.3.

It has been discussed by Dell (2011) that during the adoption and planning stages, it is important to concentrate on the people and their skills and competencies, as highly skilled and experienced staff will help to achieve a successful implementation. Moreover, in these two stages, to provide financial support as well as training and specify the level of BIM which is going to be implemented, managerial support is highly critical (Eastman et al. 2011). In addition, the goals from implementing BIM are defined in this phase, which need to be defined and planned, to be aligned with the organisation strategy and vision (Dell 2011). Moving forward in the implementation process, organisations will start their implementation phase which is composed of only one stage. Arayici et al. (2011) and Hardin (2009) stated that is important to maintain a high level of information exchange and collaboration during this stage since this is the one of the core elements of BIM Level 2. Finally, organisations will enter the post-implementation phase where the evaluation of the implementation is completed in order to define whether there is a need for applying changes or updating the implementation plan (Succar 2009). Figure (3.3) shows the implementation lifecycle, which comprises of the previously discussed phases and stages.

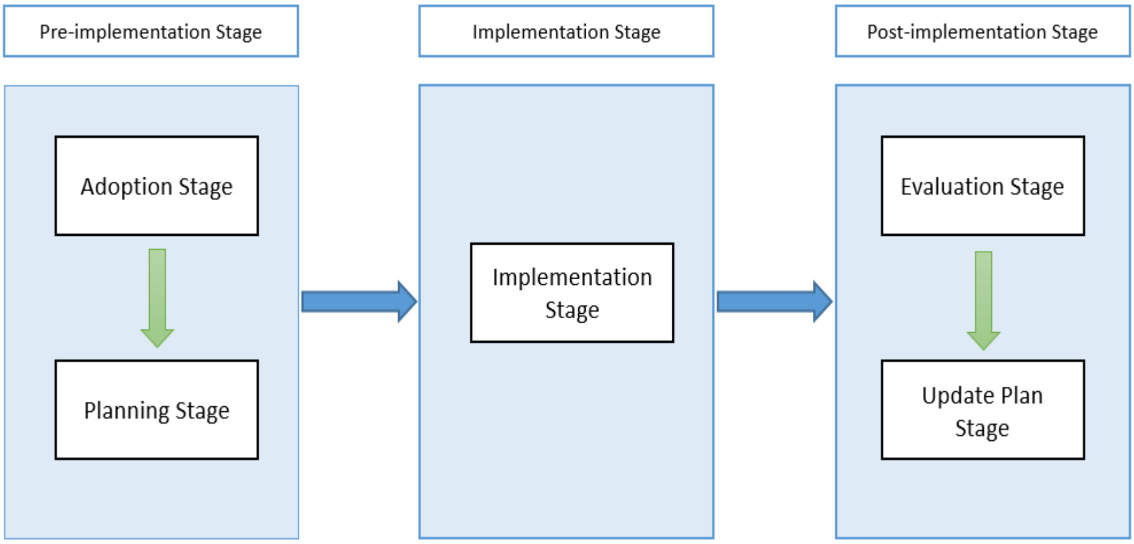


Figure 3.3 BIM Implementation Lifecycle (Source: the researcher)

3.5 Proposed Conceptual Framework

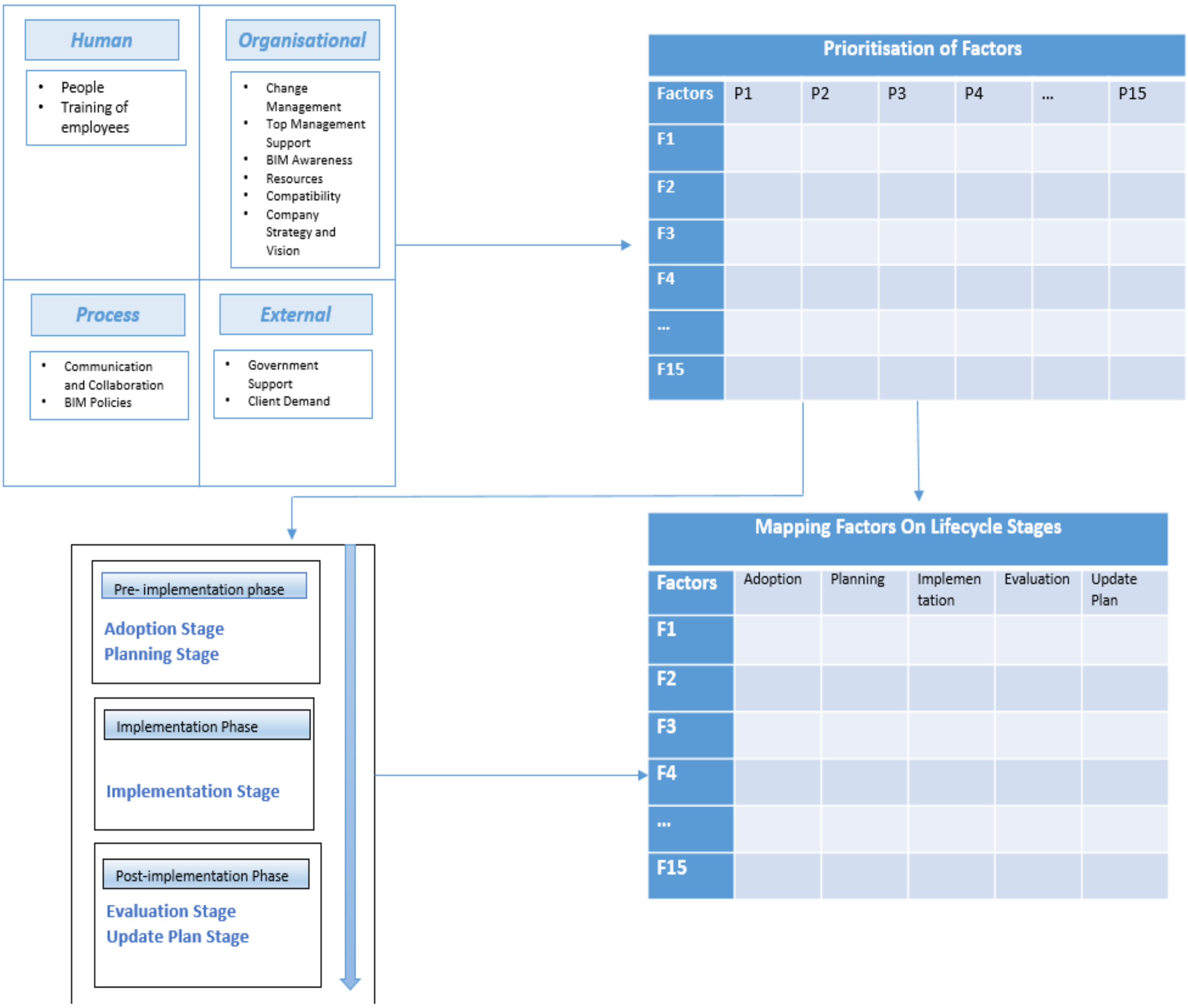
Based on the limitations mentioned in the previous sections, there is a need to address the gaps found in the literature which stressed that there were limited frameworks assisting SMEs through the BIM adoption and implementation process. In addition, there are restricted studies covering particular levels of BIM, such as BIM Level 2. Therefore, this study will propose a framework addressing the aforementioned issues. The conceptual framework, as shown in Figure 3.4, will be established based on the critical success factors influencing BIM Level 2 adoption in SMEs which will be prioritised based on their importance to the implementation, as well as mapping them into the BIM Level 2 implementation lifecycle. The framework will be based on the identification of the critical factors influencing the adoption and implementation of BIM Level 2 in small and medium companies in the UK. Moreover, the factors will be prioritized based on their importance during the implementation process, the importance will be established on three levels, high, medium and low. Consequently, the factors will be mapped in the implementation lifecycle of BIM Level 2 based on this importance in order to understand where these factors are influencing the most.

1) Identification of the factors influencing BIM Level 2.
2) Prioritisation of the influential factors based on their importance.
3) Identification of BIM Level 2 implementation lifecycle.
4) Mapping the factors into BIM Level 2 implementation lifecycle.

Figure 3. 4 Proposed Conceptual framework for BIM Level 2 Adoption and Implementation in SMEs.

3.6 Chapter Summary

In this chapter, the limitations of previous frameworks have been identified after assessing and exploring the existing frameworks, and the gaps in the literature related to BIM adoption and implementation have been extracted. This critique of the literature aided the researcher in establishing the foundation for the proposed framework as shown in Figure 3.4. Moreover,



twelve factors have been identified to be influential when implementing BIM Level 2 in SMEs. Based on the literature, these factors were classified into four main categories, which were: human factors, organisational factors, process factors and external factors. On the other hand, from the literature review, the researcher was able to identify BIM Level 2 implementation lifecycle phases and stages.

Then, the conceptual framework was developed based on an in-depth analysis of the existing frameworks in the literature and the framework proposed by Somers and Nelson within the ICT context. This framework was based on the critical success factors and the BIM level 2 implementation lifecycle and will help as a guide for this research.

CHAPTER FOUR Research Methodology

4.0 Chapter Overview

In Chapter Three, the framework for BIM Level 2 implementation in SMEs for this research was developed based on reviewing the literature and analysing existing frameworks. This chapter describes and justifies the research methodology adopted for this research. Information Communication Technology (ICT) research projects are ubiquitous and can be found in almost every field or discipline. The study of ICT is consequently complicated by their many sides in different surroundings, and the selection of the appropriate research methods is complex. ICT researchers in different contexts have had difficulties advancing the discipline with the end result being the development of different approaches (Mathiassen, 2002). There is agreement, however, that no single approach will fit every study and that a variety of research approaches, methods, and techniques should be considered for different situations and address the specific research questions (Yin, 2013).

The main components of the research methodology pertaining to this research will be based on the research philosophy, research design, and sample selection along with the sampling criterion. The collection of data will be from case studies. The reliability and validity of the research instruments will be covered followed by the ethics considerations to conclude the research methodology. Also, the case study method, its justification, and use of the case method will be discussed.

The choice of the methodology and methods for this research study have both been chosen to achieve the research objectives, and this chapter will present the justifications of the choices and the rationale for use. The research process, design, justification of the chosen methodology, and finally the case studies will be discussed and explained in detail.

4.1 Definition and Purpose of Research

Before determining a suitable research strategy for this study, it is important to clearly define the term "research" and its purpose (Creswell et al, 2007). Research is defined as the procedure of studying, developing and investigating a specific issue in order to produce a solution or approach to improve the current status (Ghauri et al, 2005). In general, the research focusses on answering the questions: "what", "why" and "how", and seeks the development of new knowledge in a specific field which will add singularity to its knowledge base. According to Blaikie (2009), research is characterised by five main drivers: to define, to clarify, to make change, to expect and to evaluate a certain issue. The aim of the research is to explore the implementation of BIM Level 2 in Small and Medium sized companies in the UK construction industry,

4.2 Research Philosophy

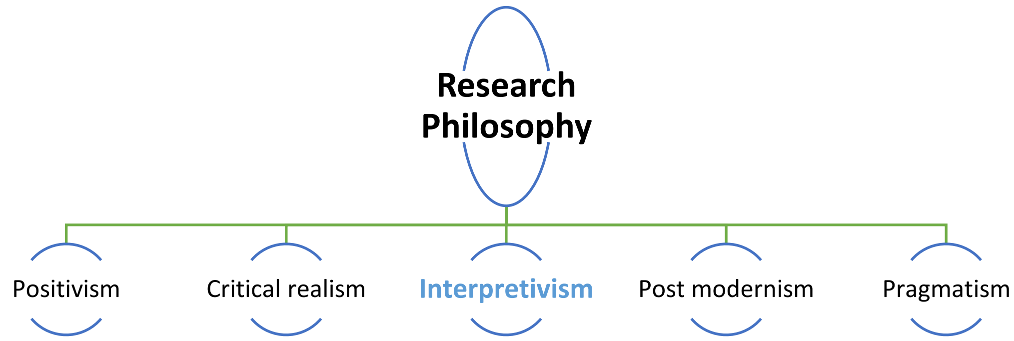


Figure 4. 1Research Philosophy (Source: Saunders et al., 2016)

Research philosophy is the complete term used to relate the development of knowledge and its nature (Saunders et al 2016). There are many controversies on which specific philosophy should be adopted, in addition to much debate related to positivist and interpretivist philosophies or qualitative and quantitative methods (Saunders et al, 2016). However, Niglas (2010), recently suggested that the adopted philosophy can be considered as a multi-dimensional set of continua instead of different positions. There are many different approaches which can be adopted, and the effect of this choice and its influence cannot be ignored, since failing to comprehend and reflect on philosophical problems can have a negative impact on the final quality of the research (Easterby-Smith et al., 2002).
Giving importance to the philosophies at the beginning of the research will help to recognise: the type of data required, the way to collect it and how to interpret this data to find an answer to the research questions. Focusing on research philosophies will allow the researcher to solve the research questions by recognizing and creating a specific research design which can be even beyond the researchers own experience and knowledge (Easterby-Smith et al, 2002).

4.2.1 Interpretivist Philosophy

Interpretivism includes human attention into a study. Interpretive research is defined as the research that ‘’assumes that access to reality (either given or socially constructed) is only through social construction such as language, consciousness, shared meanings, and instruments” (Myers, 2008, p38). Saunders et al (2015) argued that this type of philosophy allows the researcher to be a social actor to understand the differences between people. The key assumption of interpretive research is the connection to reality, which can be attained through social construction, such as language, consciousness and shared meaning. Boland (1985) mentioned that interpretive research is based on hermeneutics and phenomenology.

In general, interpretive research focusses on comprehending the phenomena according to the meanings given from different people. Interpretative research study emphasises the complete intricacy related to the human sense in any evolving scenario (Kaplan and Maxwell 1994). The interpretive study can be interpreted through qualitative methods.

4.2.2 Rationale of the Interpretivist Philosophy

During any research there is a phase where the researcher should select the most suitable approach for conducting the research work. In this study, the researcher is intending to use the interpretive approach and justify the use of this philosophy based on the assumptions of the research for the investigation into the implementation of BIM Level 2 within SMEs in the UK construction industry. The reasons for using interpretive research are identified in the following paragraphs:

- In the previous chapter the literature related to BIM and Level 2 was reviewed in the context of SMEs. In addition, existing frameworks in the literature were given. However, the factors influencing the adoption and implementation of BIM, particularly Level 2, are rarely found in the literature, since most of the literature covers more general aspects of BIM. Consequently, a critical understanding of these factors is essential by the investigation of more detailed factors in various organisations. In addition, in order to achieve the objective of this study, which is: to map the identified CSFs in the lifecycle of BIM Level 2 implementation, there is a need to use the interpretive approach to expand knowledge regarding the process of Implementing BIM Level 2.
- The simple act of understanding the points of view of managers and stakeholders regarding BIM, without any bias, is another justification of using the interpretive approach. The results of using this approach will be a detailed and precise explanation of the subject. This type of philosophical approach is also known as a phenomenological paradigm, since the study is conducted to investigate the existing circumstances related to the question of the study. Bryman and Bell (2007) argued that the researcher prefers this type of study particularly when the aim of the research is to develop and design theories which are conceptual in nature.

- Seymour et al (1997) argued that in general researches related to construction management should embrace an interpretivist approach and focus on making more sense of the world, (contrary to positivism which focusses more on generalisations), since this will focus more on a practitioners point of views of the process which will result in a better reflection of the construction management realities. Consequently, the researcher's perspective is that the investigation of BIM Level 2 implementation in the construction industry needs a philosophy which promotes the understanding of such an industry. Thus, this will then facilitate all the necessary capabilities of the researcher, in order to cooperate with the respondent.

Choosing this type of philosophy will lead the researcher to choose an inductive approach. This approach will be explained in the following section and will demonstrate that the interpretivist philosophy is the best option for conducting this research.

4.3 Research Approach

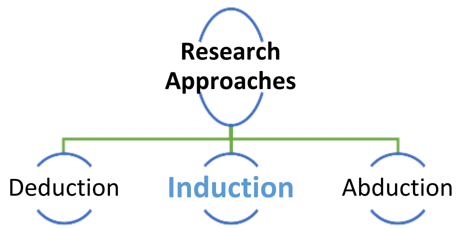


Figure 4. 2 Research Approaches (Source: Saunders et al., 2016)

After determining the research philosophy, the researcher should select the research approach which is best suited for the study, in order to present an accurate direction for the research design, as well as the suitable methods to collect the data and analyse it. Saunders et al (2016) argued that when selecting the research approach, the relationship between theory, method and empirical phenomena should be carefully examined. According to Dubois and Gibbert (2010) there are three major types of approaches: 1) Inductive 2) Abductive 3) Deductive. Each one of these approaches has its own connection to method, theory and empirical phenomena.

In general, inductive and deductive approaches are used to build new theories related to a certain phenomenon or data. The inductive approach builds an argument by commencing with the observation of a certain phenomenon or set of data and then attempting to create a general conclusion about the subject under research. The deductive approach builds an argument by beginning with an existing theory, then starts examining and investigating to determine if the theory can be applied on the detailed phenomena or set of data.

The abductive approach is usually used to develop a credible theory which is used in research. According to Ketokivi and Mantere (2010), the reasoning of this approach starts when observing an unexpected fact. This unexpected fact is usually the conclusion instead of the evidence. Depending on this conclusion, detailed explanations and data are provided that give the best explanation for this conclusion. It is rational to say that if the evidence is correct, consequently the conclusion would be correct.

The aforementioned approaches are used in research. Generally, if the study starts with a theory, and then the research aims to prove the theory, then the deductive approach can be used. However, if the study begins by collecting information and data to study a specific phenomenon and at the end builds a theory, which is often a theoretical framework, then the approach which will be used in this case will be inductive. However, if the aim of the study is collecting data to explore a certain phenomenon in order to create or generate a new theory or modify an existing one, then the approach used will be abductive.

4.3.1 Rationale of the Inductive Approach.

The low rate of adoption of BIM Level 2 reported in the literature allows the researcher to use an inductive approach for this research in order to comprehend and explain this fact. It is vital that enough representative and comprehensive data is collected in this research to thoroughly investigate this phenomenon, in addition to clarifying the types of issues that are causing the low adoption of BIM in the SMEs. Furthermore, the current study will incorporate these observations into a theoretical framework, consequently developing a theory to assist the implementation of BIM Level 2 into Small and Medium sized Enterprises (SMEs) in the UK.

4.4 Research Method

The aim of the research method is to develop a plan in order to answer the research questions and identify the appropriate strategy for collecting the required data. In the field of construction management there is not one main method of research. According to Amaratunga et al. (2002), in the built environment the choice of the research method can be qualitative or quantitative, or a combination of the two.

4.4.1 Quantitative Method

According to Bryman and Bell (2007), “Quantitative research develops and uses mathematical models, theories and hypothesis to describe relevant natural phenomena”. The main aim of this method is to give reasons which cause a certain phenomenon, comparing theories, recognizing differences and making connections (Crotty 1998; Cameron and Price 2009). The quantitative method is used when a researcher considers an objective social reality. However, in the qualitative method, quantitative research gathers and analyses information in the form of numerical data and focusses more on frequencies instead of words and meanings. In general, the approaches used with the quantitative method are surveys, questionnaires and structured interviews, in order to quantify the gathered data (Saunders et al, 2012). The aforementioned approaches use measures that allow the different perspectives and experiences of participants to be adapted into a defined number of determined responses to which numbers are assigned (Ghauri et al 2005). This method of study is usually used in the social sciences such as economics, marketing, sociology and political science (Tashakkori and Tedlie, 2010).

- The strength of quantitative method:

1. Removing or reducing judgment and reasoning (Kealey and Protheroe, 1996).
2. Explaining the research problem in a very detailed way (Frankfort and Nachmias, 1992).
3. Following decisively the original objectives of the research, which leads to more objectives, conclusions, and identifying the issues of causality.

- The weaknesses of quantitative method:

1. An inability to manage the environment in which the participants provide the responses to the questions in the survey.
2. Does not inspire the developing and continuous study of a research phenomenon.
3. Results can only be generalised to those defined in the original research proposal because of closed type questions and structured interviews (Matveev, 2002).

4.4.2 Qualitative Method

According to Bryman and Bell (2007), this type of research method covers phenomena which cannot be explained by numbers and indices, but only through views of the world given from the participant's perceptions. This method is intended to comprehend and investigate the attitude, performance or knowledge of a person or group (Dawson 2009). Information achieved by the participants are studied and compared in order to establish a theory via words and meanings. (Smith 2004).

Snape and Spencer (2003) identified the following characteristics of the qualitative method:

1. Generally, it involves small samples which are selected based on criteria.

2. During data collection, there is a close contact between the researcher and participant, which permit a better investigation of the rising issue.
3. The data obtained is detailed and rich.
4. The analysed data provides developed theories and explanations of phenomena.
5. The results are based on the understanding of meanings and words which represent the social world of the participants.

The qualitative method shows conditions, happenings, individuals, behaviours that can be observed. It represents what people say and experience, what they believe, as well as their ideas and thoughts (Silverman 2009). This research approach comprises many interpretive techniques which intend to develop and define the meaning, rather than the frequency, of a certain phenomenon in the social world (Yin 2013).

Commonly this research method uses strategies such as Grounded theory, Ethnography, Action research and Case studies. According to Creswell (2014), interviews or open-ended questionnaires are usually used in order to collect data. This method allows the in-depth views and beliefs in relation to the research questions to be collected. It engages less people when compared with the quantitative method but engages the participants for a larger amount of time. As stated by Berg (2009), the time taken to analyse qualitative data could be greater than quantitative data, therefore a computer program can be used to produce outcomes in an efficient manner.

- The strength of the qualitative method:

1. Achieves a more accurate feel of the world that cannot be experienced by numerical data.
2. Provides a flexible way to execute data collection.
3. Gives a complete view of the studied phenomena.
4. Has the capability to interrelate with the research subjects in their own language and on their own terms (Kirk and Miller, 1986).

- The weaknesses of the qualitative method:

1. Can produce different conclusions based on the same information depending on the personal characteristics of the researcher.
2. Is unable to investigate a connection between dissimilar phenomena.
3. Has difficulty in explaining the difference in the quality and quantity of information attained from respondents.

4. Requires a high level of experience from the researcher to obtain the targeted information from the respondent.
5. Lacks consistency and reliability because the researcher can employ different techniques (Matveev, 2002).

4.4.3 The Rationale of the Qualitative Research

The researcher has identified many different issues from the available literature related to the adoption of BIM Level 2 in SMEs. As mentioned in the previous chapter, there is a lack of understanding of the process of implementing BIM Level 2 in SMEs, especially since the UK government has mandated the implementation of level 2 within all the public construction projects by 2016. Also, the lack of research has slowed down BIM adoption and implementation for SMEs since they have not been specifically mentioned in policies and research in comparison to larger companies.

Consequently, this is the first justification affecting the researcher in the choice of the most suitable approach for conducting the study. The qualitative approach seeks to interpret non-numerical data extracted from the interviewee (Huberman and Miles 1994). This method is acknowledged as the gathering of interpretive data which intends to illustrate and transform the conditions with the meaning (Yin 2013). According to Denzin and Lincoln (1998), the qualitative research is a multi-dimensional method, with different methods requiring an interpretive and naturalistic approach to its topic. The term 'interpretive' in research is usually used in an interchangeable way with qualitative research in the existing literature (Galliers 1992). The argument has been supported by Hakim (2000) that highlighted qualitative research employed in the areas of studies where importance is given to clarification and explanation rather than studies emphasising on predictions. In addition, Hakim (2000) mentioned that perceptions and conventions can be found as theories in literature alongside the explanation of suppositions related to the qualitative approach of research study. Consequently, with the purpose of detailing the qualitative study, a comparative analysis is highlighted with quantitative study. This comparison is used by the researcher to deliver more comprehensive justifications of the choice of the qualitative method. The main rationale of selecting this particular method is the potential of the method to study and investigate problems in their natural surroundings, and more notably study people-behaviours as part of their daily life. Lincoln (1998) clarified that the researcher should consider the methodology which is going to be used, which will help in comprehending a specific phenomenon or a fact considering the meanings that people in their natural surrounding bring to them. The emphasis of this study is to explore the implementation of BIM Level 2 within SMEs in the UK. This research is based on opinions and activities of individuals in organisation in the construction industry, which can differ from one organisation to another.

Remenyi and Williams (1996) suggested the application of the qualitative method of conducting the study when the aim of the research is to study the opinions of individuals and organisations about a certain phenomenon. In general, the quantitative method is unsuitable in cases where it is not possible to distinguish between individuals and the object of the natural sciences. The discipline of information technology is allied to individuals, consequently a quantitative method should be aware of the inbuilt inconsistency inbuilt in activities of the individuals. With the epistemological point of view as part of the current study, the researcher decided that the qualitative method was the most suitable approach to conduct the study because the importance of qualitative research lies in the data and information that is gathered from construction companies.

As pointed out in the previous sections, the nature of the qualitative study is multi-method. This allows the researcher to make a suitable plan to question the participants in a more open and practical manner that suits this study. In the previous section of this study, it was highlighted that the implementation of BIM Level 2 in SMEs was not well investigated. From this viewpoint, the researcher states that the study can be supported with a qualitative method in order to investigate the implementation of BIM Level 2 in SMEs.

In this specific section, the presumptions and methods were presented where the researcher explained the choice of the qualitative method of research to achieve a better understanding of the phenomenon under examination. In the next section the researcher will present and justify choosing a case study method, as well as the method of sampling proposed for this study will be introduced.

4.5 Data Collection

4.5.1 Case Study Method

The case study approach includes the investigation of an argument through a single or multiple case within a certain system (Creswell and Clark 2007). Generally, the case study method studies a current phenomenon in a real-life context and involves a mixture of data sources (Yin 2013, Baxter and Jack 2008). Yin (2013) argued that a case study method can consist of one or more case studies. Selecting how many case studies are used depends on the issue being investigated and the available time of the researcher and participants. A single case study is used when leading an in-depth investigation into a specific phenomenon in order to offer a prosperous description (Yin 2013). On the other hand, multiple case studies are used to allow theoretical repetition where the purpose is to compare and analyse the different case studies (Darke et al. 1998). Generally, the findings and evidence from more than one case study are more robust than from a single case study (Herriott and Firestone 1983). In this research a multiple case study method is used, this method was selected to explore and question the different perceptions and meanings of BIM Level 2, the lessons learned from its implementation, and the CSFs affecting the implementation from the point of view of different stakeholders. The motive for selecting this approach is to permit these different phenomena to be explored.

As stated by Proverbs and Gameson (2008), using the case study approach is highly related to the construction industry, since the Industry is composed of different companies and businesses. In the last years the case study approach has been defined in many different ways (Stake 1995). For instance, according to (Yin 2013) there has been misunderstanding related to case studies as a research method where many researchers argued about its limitations. For example, authors such as Miles and Huberman (1994) connected the use of a case study to the use of a certain method. On the other hand, Yin (1981) recommended that the case study approach is not necessarily linked to a particular data collection method, but that it can be descriptive or explanatory. Yin (2014) presented a definition that includes all features of the case study method. He defined the case study method as an empirical study that explores a current issue in depth and within its real-world circumstances. This is particularly useful when limits between issues and context are not evident. Moreover, the case study method is an enquiry that endure the particular situation in which variables of interest overcome the data and depends on more than one source to achieve evidence.

It can be noticed from the above definition that the strength of this approach relies on its capacity to provide context for the phenomenon which is being studied. Since the phenomenon, which in this research is BIM and its implementation in SMEs, is complicated and needs an in-depth study.

According to Yin (2013) the method of case study usually involves collecting data from cases and then using that data to build a theory. Yin (2013) argues that this type of method can be used using theories as the main foundation of the research. In addition, he claimed that a very strong theoretical assumption lays in the basis for producing the results from the case study. In this research, the existing literature related to BIM Level 2, CSFs and life cycle implementation come to the conclusion that BIM in general is a complex topic and requires to be investigated from different perspectives, and the existing applications of BIM do not provide a rich assortment of information. These two assumptions form the foundation and guide for collecting the required data and to guarantee that the research question of this study will be answered.

Data Collection

4.5.2 Data Source

According to Yin (2013) there are many different approaches to collect data which can be defined as sources. Table 4.1 shows the different sources which will aid in the understanding of the phenomena studied in this research.

Table 4. 1 Various sources used for the research and their strength and weaknesses (Yin 2013)

Source	Strength	Weaknesses	The use of this source in the study
Documents	- Can be reviewed repetitively. - Covers long duration of time and many events.	- Some documents cannot allow access. - Reporting bias of the researcher.	- Case studies and annual reports. - Organisational documents related to BIM Level 2 and main plan of implementation
Interviews	- Attentions given directly to main topic. - Offers perceived casual implications.	- Interviewee provides what interviewer desires to perceive. - Bias because of poorly constructed questions.	- Semi-structured interviews are used in this research

Observation	- Covers events in real time.	- Takes too much time - Costly. - Events may be perceived differently from an observer to another.	- Used in the meeting with the respondents.

Secondary Data

According to Sekaran (2003), Secondary data is data which is previously presented in online and offline sources. This research uses secondary data as a tool for data collection as well as providing various types of information to be used by the researcher. The source from where the data is collected and the standard of data collected defines the reliability and efficacy of the secondary data. According to Saunders *et al.* (2016), this data used to be primary data when obtained from other researchers for their studies. Consequently, if this data is obtained from a reliable source and the researcher who collected the data has an elevated acceptance rate thus this data can be considered reliable and valid for other research.

The secondary data used for this study is highly-rated journals, books, online databases and government websites. Generally, secondary data takes less time to be collected than primary data, however the researcher can be overloaded with needless data. According to Flick (1998) this unnecessary data can increase the required time to analyse, code and categorise in order to give a significant interpretation. The right interpretation of this information and the quality of the secondary data can impact significantly the findings of the research. Despite the advantages of secondary data, there are some drawbacks related to it, which are: availability, sufficiency, accurateness and significance (Gray 2009).

In the current research, data triangulation is used as the method to collect data and identify its sources. Data triangulation is obtained from various trustworthy sources and from the different points of view and perspectives of the participants.

4.5.3 Sampling of Case Studies.

The case studies chosen for this research were selected from the bre.co.uk website where all the certified businesses which are using BIM Level 2 were selected. On the website, 38 companies across the UK were chosen which differ in their size, from large, medium and small companies. As mentioned in the literature review, according to the European standards, the number of employees in the organisation was used to identify SMEs. Based on that, the researcher was able to recognize 9 companies to be classified as small and medium companies. Initially the researcher sent official emails to all the nine companies to obtain acceptance from them to participate in the study. However, only three of these companies replied and agreed to be part of the study. Due to the limited time, only these three companies were considered for the research. Margarete (1995) stated that establishing the suitable sample size depends on the type of study, in some studies is sufficient having three to five case studies, and other studies needs more than five. Moreover, Yin (2003) clarified that qualitative research emphasises more on the logical generalisation rather than the statistical generalisation.

The first case study (C1) is a small consulting company working in the field of construction and mechanical engineering which has 48 employees distributed in 3 branches across the UK. The second case study (C2) is a medium-sized architectural engineering company which has 64 employees across 6 branches in the UK. Finally, the third case study (C3) is also a medium-sized architectural engineering company with 62 employees in two main branches in the UK. The three case studies have covered one small company and two medium sized companies. Moreover, BIM Level 2 has been implemented in these companies as certified by the BRE website and they have reached the post-implementation stage which will cover all phases and stages of the implementation.

The data will be collected from C1, C2 and C3 by semi structured interviews of the participants conducted by the researcher. The type of the study requires that the data be collected from those with a satisfactory level of experience of BIM Level 2 implementation.

4.5.4 Data Collection Protocol

The objectives of this study are the exploration of the current implementation of BIM Level 2 in SMEs, identification of the barriers which are slowing down the implementation of this technology and the investigation of the CSFs which influence its implementation. In order to meet these objectives an exploratory study was undertaken by using semi-structured interviews with people who have experience in using BIM Level 2. The interviews comprised 13 questions which were outlined in a specific way to allow the respondents to express their points of view and experience freely throughout the interview (see Appendix). The interview questions were designed based on the previous literature and are targeted on the topics brought out from the literature under the theme headings of BIM Level 2, critical success factors, and the challenges during the implementation and lifecycle of the implementation.

The period of each interview session was about 45-60 minutes and participants gave their permission for recording the dialogue of the interview. As mentioned in the previous section, confidentiality is very important in this methodology, therefore according to Chell (2004), to maintain confidentiality, a code was assigned to each respondent.

4.5.5 Interviews

According to Yin (2013), interviews represent the core source of data in a qualitative study. In the current study, semi-structured face-to-face interviews were used to collect information from the participant. These interviews were conducted in an open and flexible manner where the questions were clarified by the researcher as required by the participants. In this study, the case studies C1, C2 and C3 were selected for the purpose of this research, and the number of participants interviewed for each case was 7, 8 and 10 respectively. Though the number of interviews performed was 25, it is believed that this number met the requirements of the sample proposed by Creswell (2003). According to Creswell (2007), the suitable number of interviews is between 5-25 interviews for a phenomenology study. Therefore, the current research can be considered as a phenomenology study as it demonstrates the activities of the researcher to comprehend the character of the human as a social actor as well as to understand the phenomena based on the experiences of the interviewees. The interviews were conducted with BIM specialist, project managers, architects, a Revit specialist and engineers. The purpose of selecting participants from different backgrounds was to obtain a variation of results from different points of view.

4.5.6 Interview Protocol

The total number of questions asked to each participant were 13 (see Appendix), where they have been divided into sections with the intention of addressing the main objectives of this study as shown in table 4.2.

Table 4. 2 Section of the interviews question and its purpose

The total number is 13 questions asked to the participants	The purpose of these questions
2 Questions	**To help the participant feel comfortable**

3 Questions	**To collect basic and contextual information about BIM Level 2**
3 Questions	**To understand the main barriers faced by the organisation when implementing BIM Level 2.**
3 Questions	**To identify the factors that may influence Level 2 implementation**
2 Questions	**To identify the phases and stages of implementing Level 2 and recognize which factor influence in each phase and stage.**

4.5.7 Recording and Transcribing the Interviews

According to Kreugar (1993), high quality data needs high quality instruments. The instruments were chosen carefully, and a high-quality laptop and recorder was placed in an appropriate place in the room with limited access to noises and interruptions during the interview. In order to guarantee a high quality of the recorded statements, the participants tested the instruments and the participants were asked to speak clearly without any nonverbal communication. Then the sessions were transcribed and the transcripts were checked by the researcher to allow easier in depth analysis (Kvale 1996).

4.6 Coding Process

The data collection was addressed by developing a semi-structured interview protocol with the aim of obtaining the qualitative data from the participants. Two main categories of participants were mainly selected in each company, these two categories were the management and technical level.

- Management level in the company:

This level included directors and project managers in the companies. The reason behind this selection is that this level has the authority to implement BIM in their organisations (Smith and Tardif 2009).

- Technical level in the company:

This level comprises the technical employees as BIM managers, Revit specialist, IT engineers and architectures. This level within the company had the responsibility to act in accordance with the indications of the management level. In addition, they had the duty to implement BIM Level 2 and were the primary users of this new system.

Table 4.3 below shows the code assigned to each participant, their position in the company and the number of participants from each company.

Table 4. 3 Classification code of participants

Classification Code	Role in the company	CS1	CS2	CS3
ML1	**Director**	-	1	2
ML2	**Project Manager**	1	1	2
TL1	**BIM Manager**	1	2	1
TL2	**Design Manager**	-	1	1
TL3	**Architecture**	2	3	3
TL4	**IT Engineer**	-	-	1
TL5	**Revit Specialist**	2	-	-
TL6	**Mechanical Engineer**	1	-	-
Total		7	8	10

4.7 Coding and Analysis

4.7.1 Data Analysis Assumptions

The methodological assumption taken into consideration during the data collection was the provision of precise answers by the respondents regarding the implementation of BIM Level 2 in their company. In addition, it was assumed that the answers were correct, corresponding to the best knowledge of the respondents and the observations offered were an exact demonstration of their understanding. Moreover, it was assured that the outcomes would not be altered by the adoption of the semi-structured interviews protocol and that the empirical results from the analysis would not be affected by bias.

4.7.2 Data coding

Codes were assigned to the qualitative data collected using the semi-structured interviews. These codes were allocated to facilitate the analysis of the data through a pre-defined construct. The constructs were named sections in this study, and the researcher aimed to collate the results of the analysis under these sections. These sections were derived from the research questions of this study. Nvivo 12 software used these sections as reference points to arrange and analyse the data collected. The sections used in this study were divided into four sections as following:

Section 1: The state of BIM Level 2.

Section 2: The challenges in BIM Level 2 implementation.

Section 3: The critical success factors for BIM Level 2 implementation.

Section 4: The BIM Level 2 lifecycle implementation.

4.7.3 Content analysis technique

The data analysed was taken from the answers obtained from the semi-structured interviews given by the respondents during the face to face interviews. Therefore, the answers from the participants were transcribed in a certain format in order to be assigned a code and then categorised. In this phase of the process the data was further broken down into themes. According to Gray (2009), analysing qualitative data means explaining the data in regard to the theory, not just describing it. In this study, Nvivo 12 software was used as a content analysis technique for the data obtained from the interviews. The subsequent steps are used for content analysis as stated by Flick (1998),

- Grouping similar text together and remove irrelevant text.
- Defining the terms and concepts in the data.
- Identify a formal structure for the data and present the coded data.

Content analysis is an effective way to analyse data in qualitative research. Though, according to Gray (2005) this method of analysis does not offer any association between the variables in the research. In general, qualitative analysis needs the comprehension of the language, and the recognition of the regularities and irregularities existing in the data and the content of the text. According to Saunders et al. (2007), this allows a systematic analysis of the data which makes the interpretation and presentation of the theoretical concept easier. Consequently, content analysis is the technique used for analysing the qualitative data obtained from the interviews since it is the most suitable method. Content analysis has been used by the researcher to make the proposition during the study, as well as to review and discuss the case study based on the content analysis and the responses from the interviews.

4.7.4 Nvivo 12 Software

The interviews were transcribed and used to categorize the themes and sub themes which were obtained from responses of the participants. These themes and sub themes were identified by using a manual approach. The researcher then aligned the responses with the identified themes, objectives and research questions which highlighted the implementation of BIM Level 2, challenges encountered during the implementation, critical success factors (CSFs), and the influence of the CSFs on the implementation lifecycle.

Moreover, in order to identify the themes and sub themes for the analysis process, Nvivo 12 software was used to achieve this objective. The Nvivo software was designed by Tim Richards 1999 for analysing qualitative data. The software helps to analyse rich transcripts, graphs, videos, audio etc. Some of the uses of Nvivo in analysing qualitative data are:

- Helps in organising and classifying non-numerical and un-structured data.
- Provides Links between various data and different theories.
- Analyses different formats as video, audio, word files, photos etc.
- Converts the recorded interviews into texts.
- Simplifies and supports different research methods such as grounded theory, phenomenology, organisational analysis and mixed method research.

A coding system in the software allows the automatic coding of data which helps to save time. The narrative data uploaded to the software can be easily accessed by using the One Note feature. The thematic categorised data can be presented in either narrative or tabular form with the integrated help from the quotes of participants and the related literature. Another feature in the Nvivo 12 software is the pattern matching logic, this feature allows the main components of the rich transcript to be identified. This was used to identify the critical success factors affecting BIM Level 2 implementation, to accomplish the qualitative data analysis of the data obtained from interviewing the participants. Figure 4.3 shows a representative chart of the adopted methodology for this research, presenting philosophy, approach, method and strategy adopted by the researcher to conduct this research.

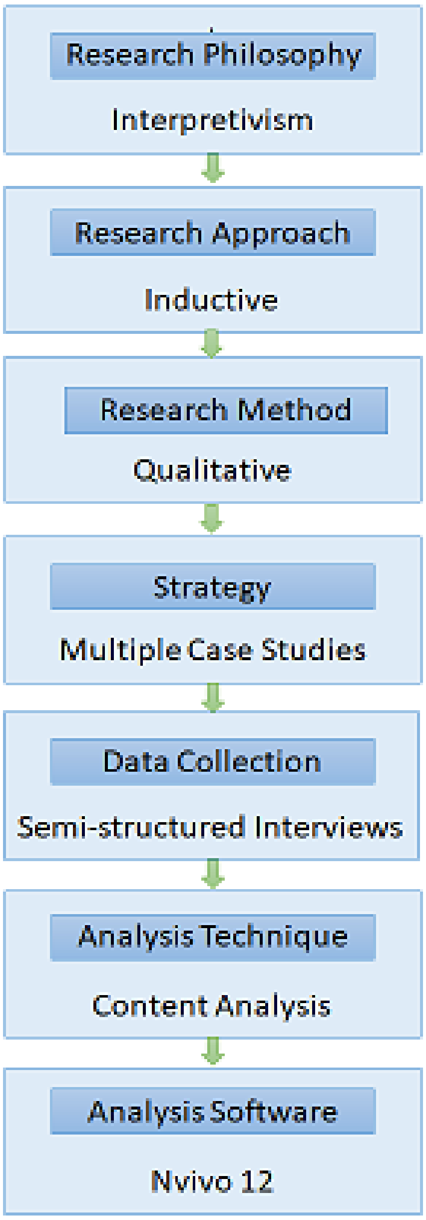


Figure 4. 3 Adopted methodology for the research (Source: the researcher)

4.8 Ethical Consideration

Gratton and Jones (2010) suggested that one of the standards of a high-quality research is that it should be absolutely conceived as an ethical concern. Moreover, it is supposed that researchers should accept the ethical norms regardless of research design, research method and sampling (Gratton and Jones 2010). The ethical standards based on the research aim have been proposed by Cooper and Schindler (2006), these standards assume that the researcher has clearly determined the aim of the research and data analysis. The researcher accepts the ethical standards required in respect of the research design and accepts the clause of privacy with respect to the participants in the study (Cooper and Schindler 2006). Moreover, the researcher accepts the ethical norms by following the ethical considerations as proposed by May (1997):

1. The researcher comprehends the duty concerning the society and would like to guarantee societal standards.
2. The approval of the participants will be obtained for the corresponding answer to the research questions.
3. The researcher will be responsible for all the enquiries regarding the research and will provide sincere answers to all the queries.
4. The researcher proposes to keep professional civility and confidentiality which is required to control the ethical code for the research (May 1997).

4.9 Reliability and Validity

As stated by Tellis (1997), there are three types of validity when using case study method, which are construct validity, internal and external validity. Construct validity is linked to subjectivity and biasness which can be avoided by the researcher by collecting data from more than one source to create a series of evidences and proofs which will guide the preparation of a report which contains all the essential information. On the other hand, the internal validity in this research was obtained by guaranteeing that the research was addressed in the interviews and that: each case study was clear and written appropriately; a proper design of the case study was embraced as per the interview questions; an authentic sampling strategy was been adopted for this study and correct techniques were used to analyse the data (Baxter and Jack, 2008). The external validity has been ensured by explaining the results and their application in different situations (Tellis 1997). The main reason behind the emphasis of the study on internal validity and credibility is the interaction of the researcher with the participants. In addition, the participant inspected their own written transcript for mistakes or any essential changes. Consequently, the small sample size tackled the problem of saturation since the themes were addressed to the participants continually.

When using the multiple case study method, it is important to comprehend the connection between the background of each case and the addressed objectives. In order to make the transcriptions which helped in increasing the transparency and aided in the many stages of the data collection, a proper protocol and schedule was applied, which resulted in a replicable research design (Cavaye, 1996). Using the multiple case study approach aided the researcher in imitating the research design at various companies, as well as matching the designs through these companies. The choice of three different companies and participants provided validity for the research, since this process helped to enhance the relevance and generalisation of the findings for the other companies.

As suggested by Yin (2003), to ensure the reliability of the research, an interview protocol was designed, an outline of the case study was given, the procedures used during data collection were explained, the questions asked in each case study were clearly identified and an overview of case study report was given. Moreover, the help of a linguistics expert was utilised to assure the reliability of the results. This should be reflected in a more reliable understanding of the opinions of the participants when the results are extracted from the data analysed.

According to Creswell (2012), a triangulation technique is "the process of corroborating evidence from different individuals (e.g. participants were from both the management and technical level), types of data (e.g. interviews), or methods of data collection (e.g. documents and interviews) in the descriptions and themes of qualitative research" (Creswell, 2012, p.259). In the current research, a pilot study was not required because a number of participants were requested to supply the researcher with feedback on the question wording to confirm their understanding. This feedback helped the researcher to make modifications to the wording of the interview questions which assured the validity and relevance of the answers given by the interviews. According to Yin (2013), triangulation is obtained by comparing the results from various sources. In the current research, triangulation will be obtained by comparing three sources: the responses given from the participants in the three case studies, public information accessible related to the case studies and the results of existing literature related to BIM Level 2 in SMEs in the UK.

4.10 Chapter Summary

This chapter presented the justification for choosing and using a specific set of research methods. These methods will help the researcher in building an appropriate structure and design for the research. The selection of philosophy, approach and method of collecting data was justified in this chapter. The selected research methodology was based on multiple methods which comprised of: an interpretivist philosophy, an inductive approach, a qualitative research method and a case studies strategy for collecting data. The research will be conducted using primary and secondary data. Interviews will be used to collect the primary data. Then in the following chapter the qualitative data will be analysed in order to provide answers to the research questions.

CHAPTER FIVE: Analysis of the Case Studies

5.0 Chapter Overview

In the previous chapters the research context was justified, then a theoretical framework was proposed for implementing BIM Level 2 in SMEs in the UK. Following that, the methodology chosen to complete this research was explained and justified. The current chapter examines the implementation of BIM Level 2 in the three case studies according to the proposed theoretical framework. The primary data collected from the semi-structured interviews was analysed to extract the results and conclusions, which helped in developing the framework for this study. Three case studies were analysed, and 25 participants were interviewed after they gave their permission to participate in the study. Data obtained from the participants' responses were then analysed with the help of Nvivo12 in order to identify themes and sub-themes. This chapter will present the results of the qualitative analysis. These qualitative case studies had the aim to identify how BIM Level 2 could be implemented successfully in SMEs within the UK construction industry.

5.1 Introduction to Case Study 1 (CS1)

CS1 is a small consulting company founded in 1991, working in the field of construction and mechanical engineering. The company is composed of 3 UK branches with a total number of 48 employees. The engineers in this company worked across a range of sectors to help architects, construction teams and designers to achieve successful projects.

CS1 invested in BIM in 2015 and acquired the necessary staff and technology to ensure that their clients gained the maximum benefit from the investment. BIM Level 2 was adopted in order to improve the overall efficiency of the company, to reduce the time required in the management of client projects and to ensure that work was completed on time and within budget. Since adopting and implementing BIM Level 2, the technology had been used for clients working in commercial, educational and healthcare sectors. BRE Global had accredited them as a certified company using BIM Level 2.

5.1.1 BIM Implementation in CS1

This section demonstrates the level of understanding of the participants regarding BIM Level 2, the reason for the implementation, and the current usage of BIM in projects. It presents the answers from interview participants for three questions which were: "What is your definition of BIM Level 2?"; "What are the reasons behind the selection of BIM Level 2?" and "In how many projects have you used BIM Level 2?" These questions were put to the participants in order to address the first research question of the current study, which was: "What is the current situation regarding the implementation BIM level 2 in SMEs?"

Nvivo 12 Pro was used as the data analysis software for the research. The semi-structured interviews helped to identify the main themes for this section known as parent nodes in the Nvivo software, while the answers from the interviews generated the sub-themes or child nodes. Table 5.1 below lists the themes and sub-themes.

Table 5. 1 Themes and Sub-Themes identified by Nvivo 12 pro.

Themes or Parent Nodes	Sub-Themes or Child Nodes
Definition of BIM	• Information • Models • Single environment
Number of projects where BIM was used	• Client • Type of Projects
Reasons behind the implementation of BIM	• Collaboration and Communication • Less time and Budget • Improve Efficiency • Government Mandate

5.1.1.1 Definition of BIM

This theme was identified from question 1 above (see Appendix), which was divided into sub-themes according to the responses from the participants based on their level of understanding of BIM. Figure 5.1 below shows the themes and sub-themes for this question as represented by Nvivo 12 pro.

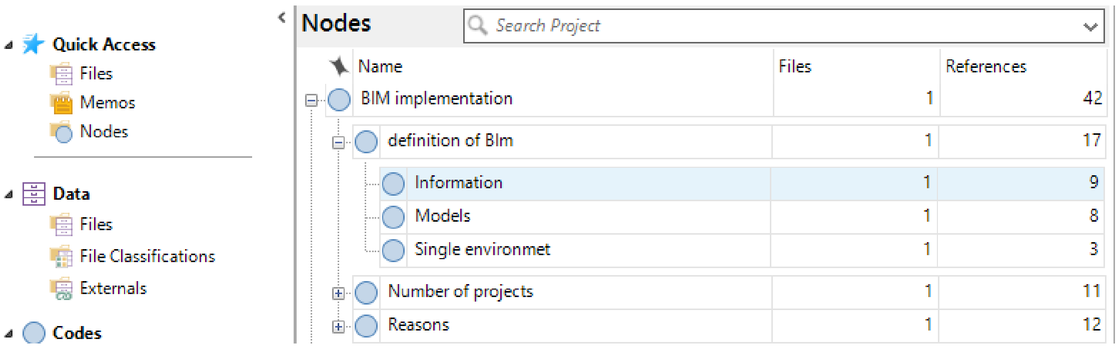


Figure 5. 1Sub-themes for the Definition of BIM

➢ **Information and Models**

Respondents commented that BIM Level 2 used more advanced models which incorporated more information than the more traditional 3D model. For instance, the technical staff referred to the modelling of time and cost to create 4D and 5D models which helps in the estimation of time and cost, collaboration, visualisation and better clash detection. As commented by TL5: *"BIM can be defined as a method which uses data and information to create more advanced and detailed models as 4D and 5D models"*.

➢ **Single Environment**

Only participants TL1, TL3 and TL5 (one of the Revit specialists) were able to offer a rich and comprehensive definition of BIM Level 2, mentioning information, 3D models and a single environment. As answered by TL1:

"BIM is a method where 3D models are used in order to share information. In terms of Level 2, this is the phase where all the parties involved in the project start collaborating together by using only 3D models and sharing information through it, in other words they are working on a single environment but no single model".

5.1.1.2 Reason for Implementing BIM Level 2 in CS1

This theme was identified from question 2 above (see 5.1.1), which was divided into sub-themes according to the responses from the participants on the reasons for Implementing BIM level 2. Figure 5.2 below shows the themes and sub-themes for this question as represented by Nvivo 12 pro.

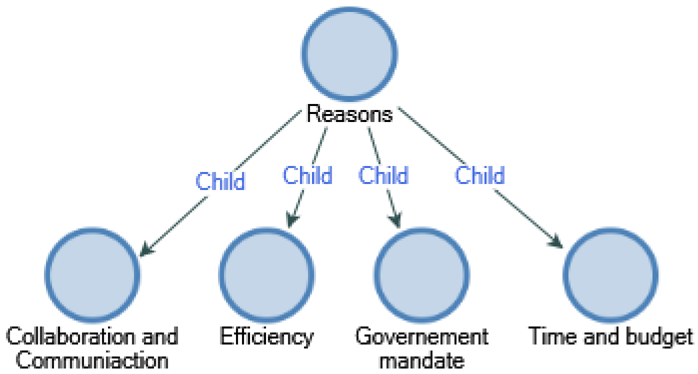


Figure 5. 2Sub-themes for the reasons for implementing BIM level 2

All the participants agreed that the four main reasons for implementing BIM Level 2 were:

1. To improve collaboration and communication between the employees within the company.
2. To improve the overall efficiency of the company.
3. To deliver the projects on time and within the expected budget.
4. To achieve the mandatory level required by the government.

- **<u>Collaboration and Communication</u>**

All the participants from both management and technical levels remarked that BIM Level 2 was a tool which enhanced collaboration and communication between all the parties involved in construction projects. For example, ML2 commented that:

"BIM level 2 was implemented in this company to allow everyone involved in projects to share information in an easier and quicker way. This will consequently improve communication and collaboration between all the parties".

- **Improve Efficiency**

The participants responded that the one of the main reasons for adopting BIM technology was to improve the overall efficiency of the company, since this was mentioned as one of the main goals of the company. As stated by TL6:

"One of our company's main objectives is always to increase and enhance the overall efficiency, therefore we implemented BIM level 2 as we believed it would make us achieve this goal".

- **Government Mandate**

ML2 and TL1 observed that BIM Level 2 was implemented because the government had mandated the use of this level in all public projects. This initiative from the government made the company realise the importance of BIM and they had implemented BIM Level 2 in order to win potential public projects. As per the words of ML2:

"Since we heard of the mandatory use of BIM in all public projects from 2016, we realised that in order to not lose any potential public projects we should be able to deliver projects using BIM, consequently this was one of the motivations which led us to implement BIM".

- **Less Time and within Budget**

All the responses from the participants agreed that BIM Level 2 was implemented in order to deliver projects on time and within the budget. According to the responses this can be achieved by using BIM level 2 since in this level, time and cost were modelled in 4D and 5D, which would provide more accurate project management data. As commented by TL3:

"Using BIM Level 2 means more advanced 4D and 5D models than the traditional 3D models. In these models, time and cost are integrated with the 3D model to give a more accurate and precise model which help us to anticipate when the final project will be finished and its final cost".

5.1.1.3 Number of Projects Accomplished by Using BIM Level 2

This theme was identified from the question 3 above (see 5.1.1) , which was divided into sub-themes according to the responses from the participants on the number of projects which used BIM Level 2. Figure 5.3 below shows the themes and sub-themes for this question as represented by Nvivo 12 pro.

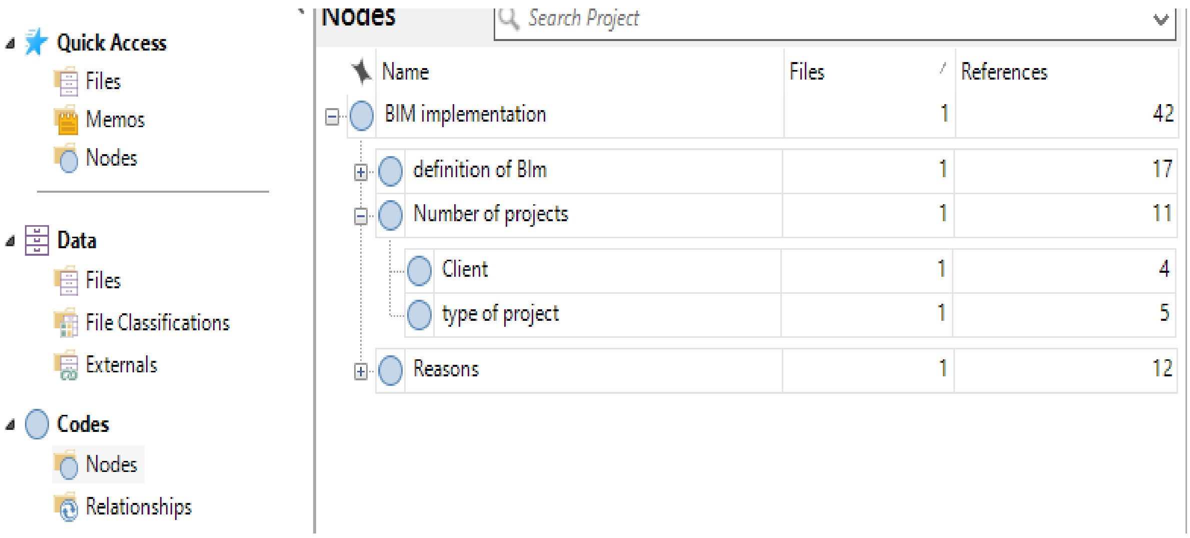


Figure 5. 3Sub-themes for the number of projects which used BIM Level 2.

Both management and technical levels commented that a total of 9 projects were accomplished by using BIM Level 2 from the early design phase until the delivery phase. Although, the company was accredited for using BIM Level 2, the respondents agreed that not every project was delivered by using this technology. Consequently, based on the responses, two sub-themes have been identified regarding the projects where BIM was used.

- **Client**

Only the project manager ML2 and the BIM manager TL1 mentioned that the client request was a condition for using BIM Level 2. They both commented that the lack of awareness between the clients impeded the utilisation of BIM in some projects, while they personally preferred traditional ways to manage construction.

They both mentioned that:

"If the client is not aware of BIM and ask that the project is done using traditional ways of construction, then we work according to that, since our first priority is to satisfy the client needs".

- **Type of Project**

Respondents TL3, TL5,TL6 from the technical level, and the project manager ML2 said that it was better to use BIM level 2 in large and compex projects since the benefits are clear. As mentioned by ML2

"All the 9 projects, where BIM was used, they were large projects and adopting BIM in these projects simplified their complexity and the benefits of it were perceived clearly".

On the other hand, although BIM was adopted just for large and complex projects, BIM has the abiity to be used in any type of project, regardless of size. As observed by the BIM Manager TL1:

"BIM can be adopted for any projects no matter if it is a small or a large project".

5.1.2 Barriers Faced During BIM level 2 Implementation in CS1

This section focusses on the barriers faced by the company when implementing BIM level 2. From the interview questions, themes were identified and then from the analysis of the answers to the questions it emerged that some of the issues were related to the company and others were related to the users of the technology. Table (5.2) below presents the themes and sub-themes from Nvivo12:

Table 5. 2 Themes and sub-themes for the first section in CS1.

Themes	Sub-Themes
Barriers of Implementation	• Lack of Knowledge • Client Demand • Cost • Resistance to Change
Handling the Barriers and Resistance	• Change management • Training • Compulsory Usage

5.1.2.1 Barriers of Implementation

While analysing the responses from both management and technical staff, the following sub-themes emerged as represented by Nvivo 12 pro and are shown in figure 5.4 below.

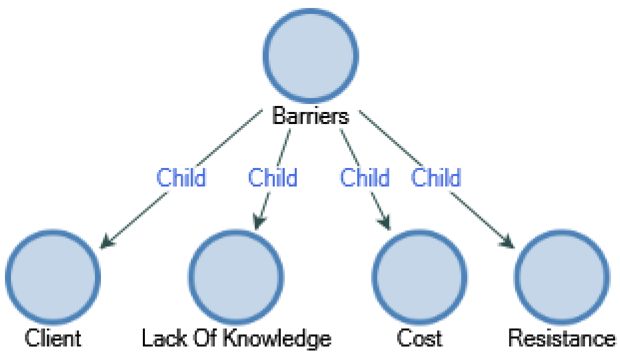


Figure 5. 4 Sub-themes for the barriers to implementation of BIM Level 2.

- **Cost of Implementation**

As commented by ML2, TL1 and TL5, one of the main barriers for BIM Level 2 implementation was the the cost. The high cost of the software and hardware, as well as cost of the intensive training which was needed for staff to adapt to the new process, was one of the main barriers faced by the company. As per the words of TL5:

"One of the first barriers faced was the high cost requiered to buy new software, hardware and to give the proper training to the staff".

- **Lack of Knowledge Regarding BIM Level 2**

Respondents TL3 and TL6 had no previous knowledge of BIM as the comments from TL6 indicated:

"Is not easy to work using a process you do not know anything about".

Participants ML5 and ML2 had limited knowledge about BIM, but were not aware of the update of BIM to level 2. As per the words of ML2:

"I used to hear about BIM, so I had little knowledge about it, but I did not know anything about Level 2".

- **No Client Demand for Using BIM**

All the participants agreed that one of the barriers faced by the company when Implementing BIM level 2 was that the clients were not aware that it was a government mandate that it must be used on public projects. They also doubted the need to use this new technology. As commented by TL1:

"clients are not aware of the benefits which BIM can bring to them, so they would stick with traditional ways, so no demand for using BIM was one of the challenges faced".

- **Resistance to Change**

It was mentioned that at the beginning the employees resisted the idea of using BIM level 2. As commented by ML2 this was one of the barriers faced by the company since some of the technical level participants were not ready to change the way they delivered projects. Moreover, it was mentioned that this barriers was mainly faced by elderly employees, who had no experience with the new technology. As per the words of ML2:

"Abviously there was resistance to change, it was not easy to convince the employees to start using a new process of working, this issue was more related to elderly people in the company who are only used to 2D CAD".

5.1.2.2 Handling the Barriers and Resistance

This section identifies the methods adopted by the company to handle the resistance to the implementation from some of the technical staff, as mentioned in the previous section. This question was put to both technical and management levels and based on the word similarity of the responses, three main methods were identified from the participants, which were: change management, training and making the use of BIM compulsory. as represented by Nvivo 12 pro in Figure 5.5 below.

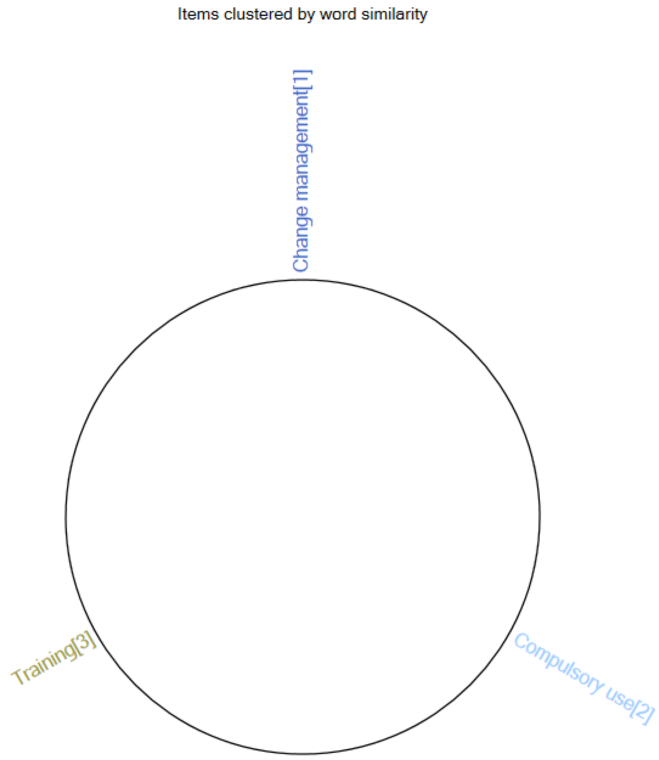


Figure 5. 5Sub-themes of how the company handled the barriers to implementation in CS1.

- **<u>Change Management</u>**

All the participants agreed that the introduction of change management was vital to handle the barriers faced at the beginning of the project. The lack of knowledge of technical staff and their resistance to the implementation were handled by a change management strategy which focussed on training. By giving training on the new software, the company hoped that with a better understanding of BIM and the benefits that it could bring would change their mindset and make them more cooperative.

The implementation of an ICT system would be unfamiliar to some and that should be taken account of by the strategy. Also change management should include, changing the company structure to incorporate the new role of a BIM manager. As commented by ML2:

"Changing the strategy of the company was an important step especially when using a new technologies such as ICT, the main strategy focused on training of employees to allow them to understand BIM more. And the strategy comprises hiring a new staff member to fill the new job position of BIM manager".

- **Training**

Deciding what the employees needed to learn and the duration of the training required was the responsibility of management. All the respondents provided the same answer regarding the training. The analysis of the responses of the participants showed that the duration of the training was two weeks and the main emphasis was on how to work in one single environment and how to deal with the new process. As commented by TL6:

"We were given two weeks training to learn more about BIM as a process and how to work in one single environmner since this is the core of BIM level 2".

- **Compulsory Use oF BIM**

ML2 commented that the top management of the company forced the employees to use BIM. The analysis showed that forcing the employees to use BIM was one of the ways to handle the issue related to the resistance to change, and as a consequence the staff had to adapt to the new system. In the words of ML2:

"The managemnet level forced the employees to use BIM Level 2".

5.1.3 Critical Success Factors Influencing BIM level 2 Implementation in CS1

This section addresses the interview questions,: 1) What are the critical success factors influencing BIM level 2 implementation? 2) How have these factors affected the implementation of BIM Level 2. Also in the interview the participants were asked to rank the critical success factors according to their importance and this was also addressed in this section. The themes and sub-themes emerging from the interviews of the participants as represented by Nvivo 12 pro are shown in table 5.3 below .

Table 5. 3 Critical success factors Influencing BIM Level 2 in CS1.

Themes	Sub-Themes

Human factors	• People • Training of Employees
Organisational Factors	• Change Management • BIM Awareness • Resources • Compatability • Organisation Vision and Strategy • Top Management Support
Process Factors	• Collaboration and Communication • BIM Policy • Control of Performance
Extrernal Factors	• Government Support • Client Requirement • Consultant

5.1.3.1 Human Factors

The participants from both management and technical levels emphasised the importance of human factors in order to implement BIM level 2 successfully. Both levels stressed the maximum utilisation of the staff was needed to achieve a successful implementation. The main factors identified in this category were categorised as sub-themes as represented by Nvivo 12 pro in Figure 5.6 below.

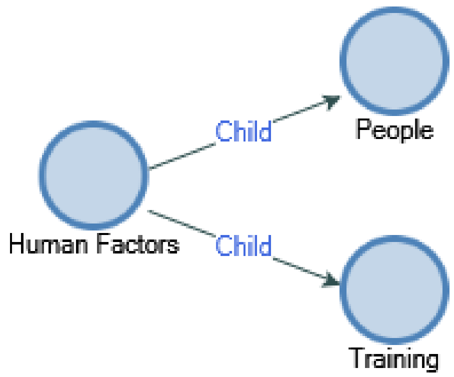


Figure 5. 6 Human factors influencing BIM Level 2 implementation in CS1.

➢ **<u>People</u>**

The availability of skilled people within the company was crucial in order to implement BIM level 2 successfully. Moreover, their acceptance and willingness to understand the software and the new ways of working and software was essential, both of which will make the implementation easier for the company. The management participants recognised the skills of the staff as a critical factor for the implementation. As commented by ML2:

"Skilled employees are essential for the implementation as well as them being open-minded to new ways of working".

- **Training of Employees**

When given training on how to work with new technologies, staff also needed to be shown how to work with the maximum efficiency. Participants recognised that training was a critical factor for the growth of both staff and company. Analysis of the answers given by participants showed that appropriate training for the implementation of BIM was required to both accomplish the company objectives, and, improve the overall efficiency of the company. As per the words of TL5:

"Training of employees is critical to achieve a successful implementation of BIM level 2".

5.1.3.2 Organisational Factors

The participants mentioned that organisational factors related to the improvement and growth of the company in order to achieve their pre-defined objectives were important. The following sub-themes, as represented by Nvivo 12 pro, emerged under this category and are shown in Figure 5.7 below.

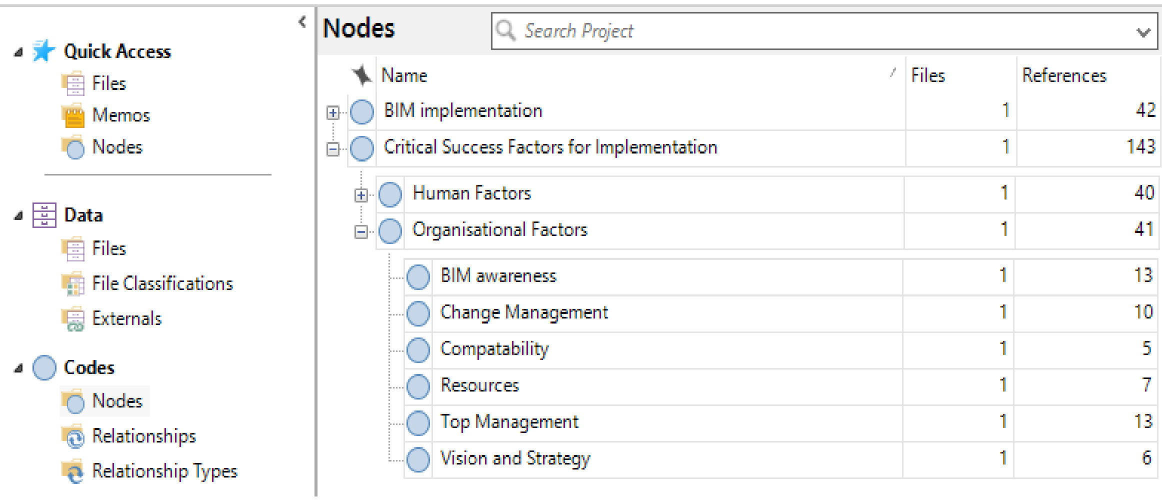


Figure 5. 7Sub-themes of organisational factors for CS1.

- **BIM Awareness**

For the staff to be made aware of BIM level 2 would facilitate and accelerate the implementation of BIM level 2. As commented by TL5, awareness of the benefits of BIM would make the implementation smoother and better prepared for the changes required. According to TL5:

"Awareness and previous knowledge about BIM is very important at the early stage of the implementation since it helps to define the level of difficulty which could be faced during the implementation".

- **Change Management**

The implementation of any new process imposes change on the company. Managing this change appropriately can aid in the successful implementation of BIM level 2. To achieve this, appropriate planning and management is required. As commented by ML2:

"Appropriate management and planning in a company can assist the implementation of BIM Level 2".

- **Top Management Support**

All the participants agreed that the implementation of BIM Level 2 cannot be achieved in quickly, many stages are involved and the support of the top management was essential to make the implementation of BIM Level 2 successful. As commented by ML2:

"In order to implement BIM Level 2, the support and commitment of the management level is required in order to achieve better results and make decisions which can affect positively the progress and overall performance of the company".

- **Resources**

Both management and technical levels mentioned that resources, including software, hardware and experienced staff was one of the factors which can influence the BIM Level 2 implementation. Technical staff mentioned that the existence of these resources can make the implementation go more smoothly and with less cost in the long run. As per the words of TL5:

"Software, hardware and staff with previous experience would make the implementation easier and cheaper".

- **Company Vision and Strategy**

As commented by ML2, the pre-defined vision and strategy of the company is one of the reasons for implementing BIM level 2. ML2 commented that the focus of the company was to increase the overall performance and deliver projects on time and within the estimated budget, therefore the company implemented BIM as they believed this technology will help in achieving these objectives. According to ML2:

"Our vision is to deliver construction projects on time and budget and we believe that BIM Level 2 will help us reaching this goal".

- **Compatibility**

Participants from the technical level, as TL3, TL5 and TL6, stressed that the compatibility of systems to be able to work together was essential for the successful implementation of BIM. As per the words of TL3:

"Compatible software in a BIM environment is very important in order to open the same document in different software".

5.1.3.3 Process Factors

In this section participants gave their opinions on which were the most important factors which needed to be considered for successful implementation. The sub-themes which emerged under the category of process factors as represented by Nvivo 12 pro are show in Figure 5.8 below.

Figure 5. 8 Sub-themes of process factors in CS1.

- **<u>Communication and Collaboration</u>**

All the participants commented that in order to implement BIM successfully, good communication and collaboration among the employees and among the different levels within the company is essential. These were required from the early stages of implementation. As commented by TL1:

"Although better communication and collaboration is one of the benefits offered by BIM Level 2, *they are required from the first stage of implementation to ensure an efficient implementation".*

- **<u>BIM Policies</u>**

Participants emphasised the importance of policies to implement BIM. They all commented that standards, guidelines, and frameworks can help to facilitate the BIM Level 2 implementation. As mentioned by ML2:

"One of the issues faced during the implementation was the limited guidelines and frameworks which shows how to implement BIM".

- **<u>Control of Performance</u>**

Whether the participants were from technical or management staff levels, they all expressed the view that successful implementation of a process cannot be achieved without continuous control of the overall performance. ML2 added that is vital to integrate evaluation measures for projects including: delivery time, client satisfaction and performance to ensure the best results are achieved from the implementation. As per the words of ML2:

"Controlling that the implementation proceeded as planned is important to ensure a successful outcome".

5.1.3.4 External Factors

The analysis of the responses showed that there were external factors which affected the success of the BIM Level 2 implementation. These were identified as government support, client expectations, and the need for an external consultant, which became the sub-themes as represented by Nvivo 12 pro and are shown in Figure 5.9 below.

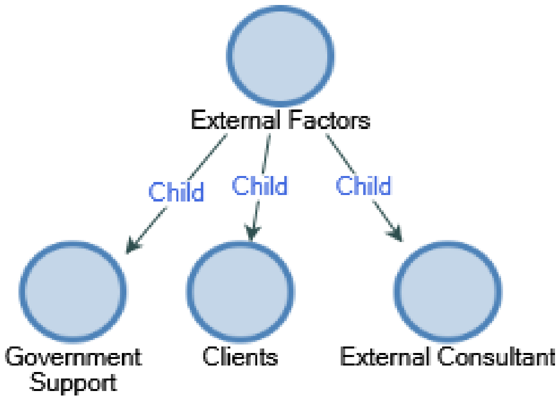


Figure 5. 9Sub-themes of external factors presented using Nvivo 12.

➢ **Governmental Support and Client Expectations**

All the respondents commented on the importance of these two factors for the successful implementation of BIM level 2. As mentioned by TL1, the client expectations were very high, since they were expecting the project to be delivered on time and within budget. Also, governmental support was acknowledged by the participants to be very important at the adoption stage, and the mandate of the government to force companies to work using BIM Level 2 will help the whole industry to move towards this new technology

As commented by TL1:

"Implementation of BIM Level 2 should be successful in order to meet the client expectations".

Moreover, TL3:

"The initiative of the government to force companies to deliver certain projects using BIM will accelerate the adoption of this new technology".

- **External Consultant**

This factor was stressed to by the participants to be critical during the whole implementation life-cycle. According to the participants, the hiring of an external consultant with the required BIM knowledge was essential to obtain a successful implementation, particularly when there was a lack of expertise within the company. The external consultant helped management to produce the implementation plan and was responsible for the management of all the phases of the implementation, including the training of staff and controlling performance. According to TL1:

"I was hired by the company to help in BIM level 2 implementation, my main responsibilities were designing the implementation plan, training the staff and controlling the performance".

5.1.3.5 Ranking of Critical Successful Factors Based on their Importance

This section focusses on the importance of the critical success factors for implementing BIM level 2. This importance was provided by the participants as they were asked during the semi-structured interviews to rank each CSF based on their importance through the implementation process.

In order to interpret the answers given by the participants, the researcher adopted Miles and Huberman (1994) scale. This scale was used to identify the importance of the factors based on a scale of high (●), medium (□) and low (○). The importance was based on the "most frequented importance" given by the participants. For instance, **people** was identified to be low important by four participants out of seven, and since four is the majority then this factor was given a low importance. Based on the same concept, **training of employees** was identified to be high important by six participants out of seven, therefore it was identified as a high important factor. The results of the overall identified importance for each factor are shown in Table 5.4 below.

Table 5. 4 Importance of the factors influencing BIM Level 2 implementation CS1.

Factor Categories	*Factors Influencing BIM Level 2*	*Participants and their Responses*							*Average of Importance*
		ML2	**TL1**	**TL3**	**TL3**	**TL5**	**TL5**	**TL 6**	
H u m	People	●	●	○	□	○	○	○	**L**

	Training of employees	●	●	●	□	●	●	●	**H**
Organisation Factors	Change management	●	●	□	□	○	□	□	**M**
	Top Management	●	●	□	●	●	●	●	**H**
	BIM awareness	●	●	●	●	●	●	□	**H**
	Resources	□	●	○	○	○	□	●	**L**
	Compatibility	○	○	○	□	●	●	□	**L**
	Company vision and strategy	●	□	□	□	○	□	●	**M**
Process Factors	Communication and Collaboration	●	●	□	□	●	●	●	**H**
	BIM policy	●	●	□	□	□	□	○	**M**
	Control of performance	●	●	○	○	□	○	○	**L**
External Factors	Governmental support	□	●	□	□	●	□	○	**M**
	Client demand	●	●	□	□	○	○	□	**M**
	External consultant	●	●	●	●	●	●	□	**H**

Nvivo 12 software was used to rank the factors from the most to the less important, based on their frequency during the interviews see Figure 5.10 below.

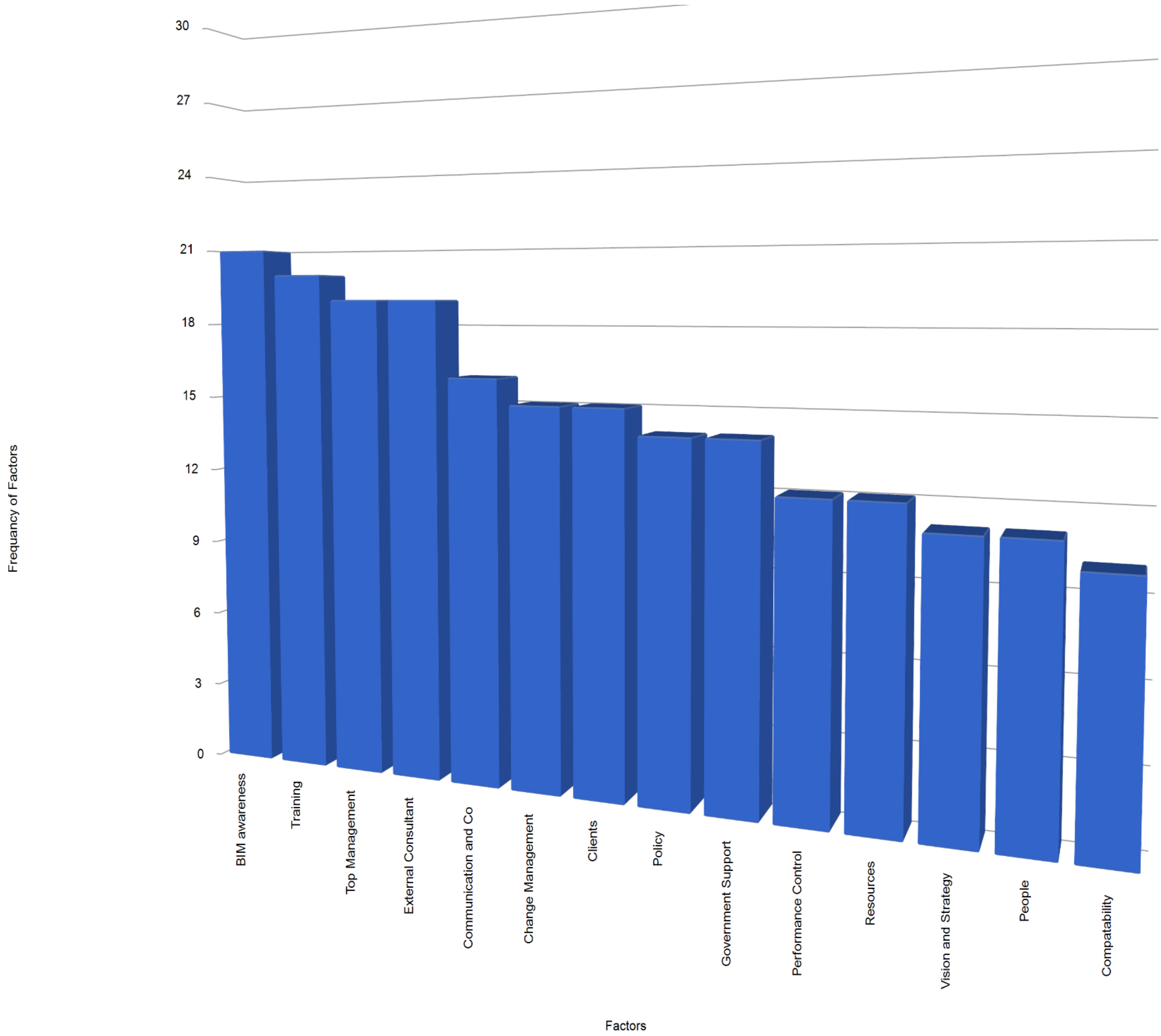


Figure 5. 10 Factors' frequency presented by Nvivo 12 for CS1.

5.1.4 Mapping Critical Success Factors Influencing BIM Level 2 across Lifecycle Implementation in CS1.

5.1.4.1 BIM Level 2 Lifecycle Implementation

This section identifies the main implementation lifecycle of BIM Level 2 in CS1. The implementation lifecycle can be divided in three main phases, which are: pre-implementation, implementation and post-implementation phase. Each phase contains two more stages. The phases were coded as themes and the stages emerged as sub-themes. Table 5.5 below shows the themes and sub-themes of this section.

Table 5. 5 Themes and sub-themes for implementation lifecycle in CS1.

Themes	Sub-Themes
Pre-Implementation Phase	• Adoption • Planning
Implementation Phase	• Implementation
Post-Implementation Phase	• Evaluation • Update Implementation Plan

5.1.4.2 Pre-implementation Phase

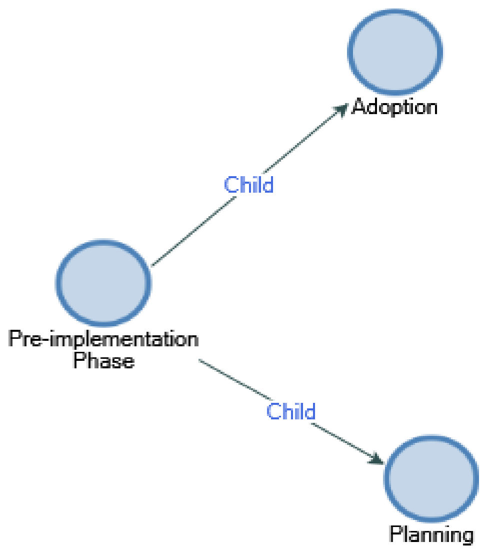


Figure 5. 11Pre-implementation phase and stages for CS1.

According to ML2 and TL1 the pre-implementation phase was divided into two stages. The first one was the adoption stage, where the management decided to embrace BIM technology and implement Level 2. The reasons behind this decision were mentioned previously in section 5.1.1.2. Then, the company moved to the second stage, which was the planning stage. According to ML2, this was one of the most important stages of the entire implementation, since success or failure depended on how the company intended to implement BIM Level 2. The participants commented that the company had hired an experienced BIM consultant to help management to design an appropriate implementation plan. ML2 stressed that to ensure a successful implementation, the planning stage needed to include staff training, identify required resources; and change management.

5.1.4.3 Implementation Phase

This phase comprises only one stage. According to all the participants, the company needed to be ready to use BIM technology and a BIM consultant should be hired and given responsibility for the management of the project. Whether the company was ready would be decided by management after the new software was acquired, staff were trained, and the organisation was 'BIM-aware'. Although the company were ready for the implementation phase, ML2 commented that BIM Level 2 would not be tested until it was used on a new project. As observed by management and technical staff, factors such as communication, project control and top management support were critical for the success of this phase.

5.1.4.4 Post-implementation Phase

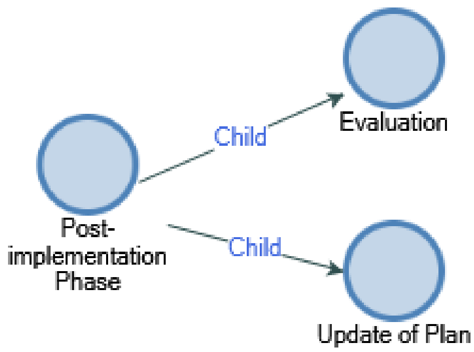


Figure 5. 12 Post-implementation phase and its stages presented by Nvivo in CS1.

The success of BIM Level 2 implementation was based on the constant updating of the plan. After BIM had been implemented on a project for the first time, the evaluation stage started. This aim of this stage was to evaluate the level of success of the implementation. The evaluation was based on the final cost and duration of the project together with an assessment of client satisfaction since that was one of the main priorities of the company.

During this stage, as commented by ML2, some issues emerged. These were resistance to the new way of working and dissatisfaction with the training. As per the words of ML2:

"Lack of training and lack of the enthusiasm to adapt to BIM level 2 was a challenge which emerged after evaluating the project".

The second stage of this phase was updating the plan based on the evaluation stage. According to TL1, the plan was updated to cover and solve the issues which appeared from the evaluation. The plan focused mainly on providing more training for the staff to help them to adapt to the new process for delivering projects. As commented by TL2:

"More training was required in order for the staff to adapt to the new system".

5.1.4.5 Mapping the Critical Factors into the BIM Level 2 Implementation Lifecycle in CS1.

This section addressed the last question of the interview protocol, where the participants were asked to identify the factors which affected each phase and stage of the BIM Level 2 implementation. All the participants answered this question based on their previous experience with BIM implementation. From the analysis it emerged that all the participants agreed as to the need to map the factors across the life-cycle of the implementation. The factors identified in each phase and stage are presented by Nvivo 12 in the below figures and shown in Table 5.6 below. The factors were marked with a symbol (✓) wherever they were identified to be critical at any particular stage based on the responses of the participants.

Table 5. 6 Mapping the factors influencing BIM Level 2 lifecycle in CS

Factors Category	*Factors Influencing BIM Level 2*	*BIM Level 2 Lifecycle Implementation in CS1*				
		Pre-implementation Phase		*Implementation Phase*	*Post-implementation Phase*	
		Adoption Stage	Planning Stage	Implementation Stage	Evaluation Stage	Update Plan Stage
Human Factors	People	✓	✓	✓	✓	✓
	Training of employees		✓			✓
Organisation Factors	Change management		✓	✓		
	Top Management	✓	✓	✓	✓	✓
	BIM awareness	✓	✓	✓	✓	✓
	Resources	✓	✓			
	Compatibility		✓	✓		
	Company vision and strategy	✓	✓			
Process Factors	Communication and Collaboration		✓	✓	✓	✓
	BIM policy	✓	✓			
	Control of performance			✓	✓	✓
External Factors	Governmental support	✓	✓			
	Client demand	✓	✓			
	External consultant		✓	✓	✓	✓

The figures 5.13, 5.14, and 5.15 in the following pages show the factors affecting each stage in the lifecycle according to the answers provided by the participants. The themes were identified from the interview questions and the sub-themes emerged from the responses.

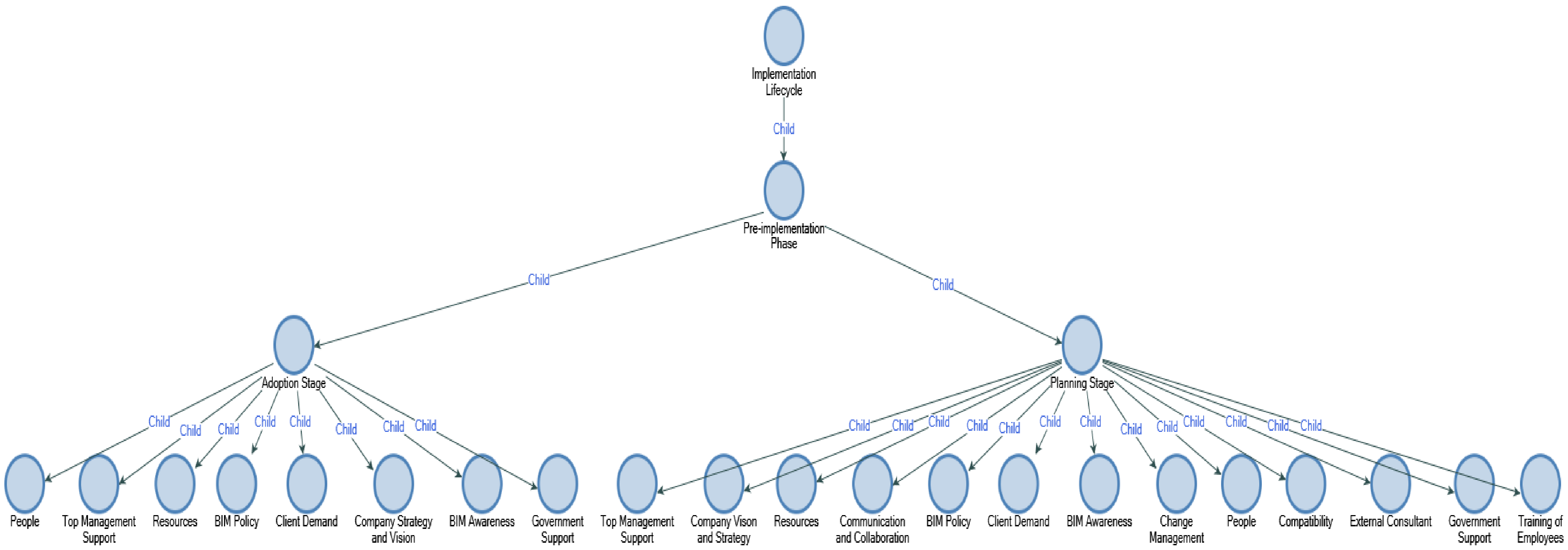


Figure 5. 13 Factors affecting adoption and planning stages for CS1.

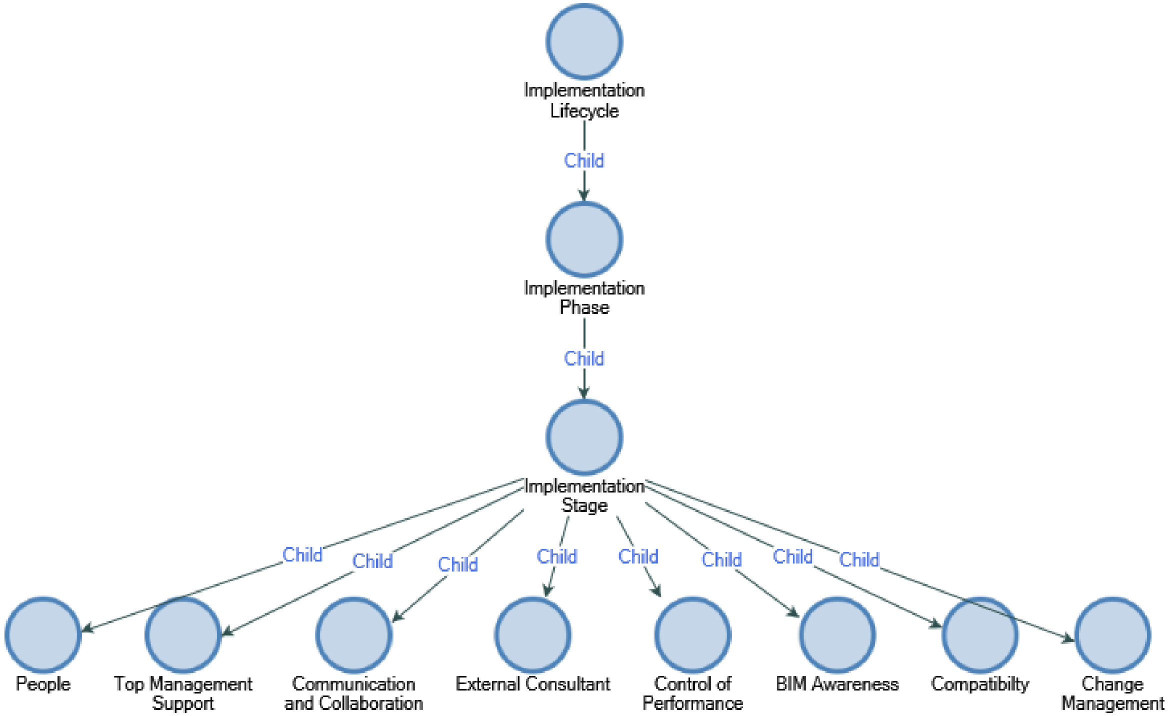


Figure 5. 14 Factors affecting the implementation stage for CS1.

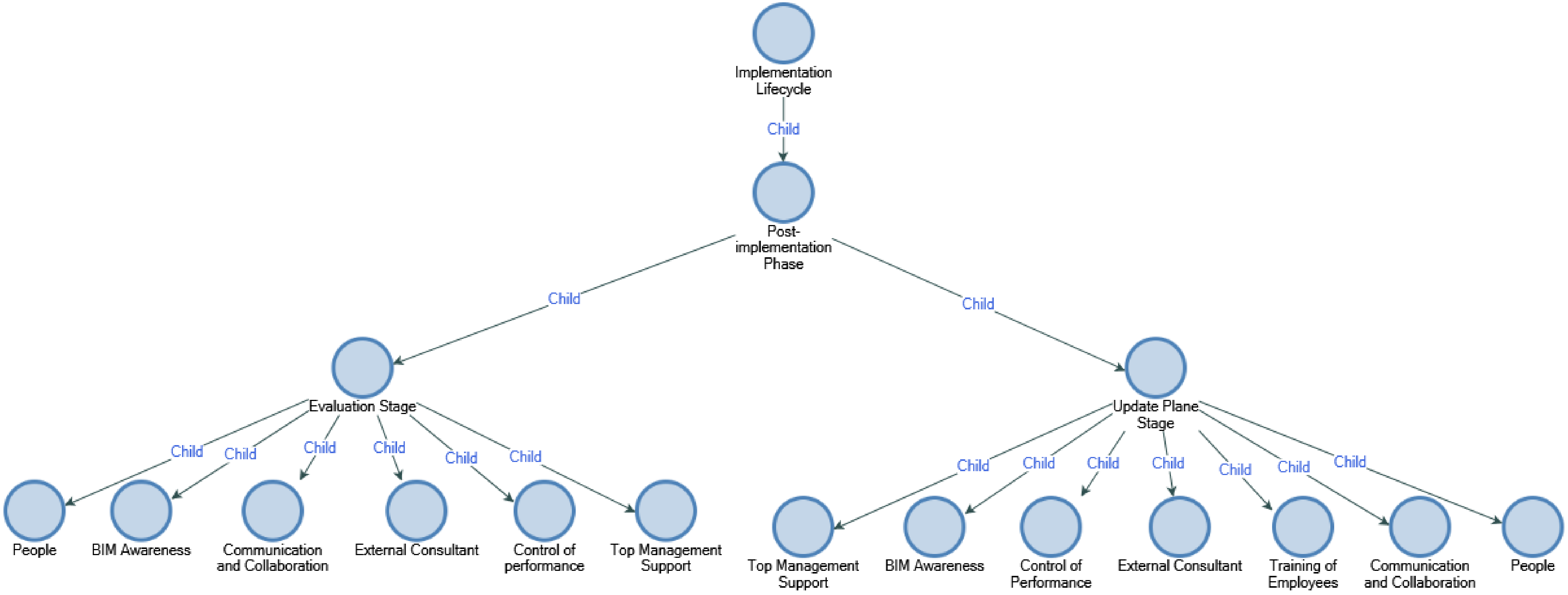


Figure 5. 15 Factors affecting the evaluation and plan update stages in CS1.

5.2 Introduction to Case Study 2 (CS2)

CS2 is a medium sized design company founded in 1983, composed of four branches across the UK. The company consisted of 64 employees, working in the industrial, leisure, residential, health, commercial and culture sectors. The company specialised in new building, building refurbishment and conversion projects. They supplied services for architectural design, interior design and landscaping.

When BIM was implemented in 2014 the company had been using 3D modelling for 10 years. BIM offered them more efficient and effective design using 3D model space which improved the coordination of the process. Moreover, it was implemented as a tool to obtain: 1) open communication; 2) collaboration between contractors, designers, clients and consultants; and 3) better management from the inception phase through design, construction until demolition.

In this case study 8 participants contributed in the study. Participants were from both management and technical levels including a Director ML1, a project manager ML2, two BIM managers TL1, a design manager TL2 and three architects TL3.

5.2.1 BIM Implementation in CS2

This section demonstrates the level of understanding of the participants regarding BIM Level 2, the reason for the implementation, and the current usage of BIM in projects. It presents the answers to three questions which were: "What is your definition of BIM Level 2?"; "What are the reasons behind the selection of BIM Level 2?"; and "On how many projects have you used BIM Level 2?". These questions were put to the participants in order to address the first research question of the current study, which was: "What is the current situation regarding BIM level 2 implementation in SMEs?".

Nvivo 12 Pro was used as the data analysis software for the research. The semi-structured interviews helped to identify the main themes for this section known as parent nodes in the Nvivo software, while the answers from the interviews generated the sub-themes or child nodes. Table 5.7 below lists the themes and sub-themes.

Table 5. 7 Themes and sub-themes identified by Nvivo in CS2

Themes	Sub-Themes
BIM Definition	• 3D Model • Collaborative environment
Reason of Implementing BIM Level 2	• Collaboration • Better Management • Team work • Efficiency and effectiveness
Number of Projects Achieved by Using BIM	• 14 projects

5.2.1.1 BIM Level 2 Definition

This theme was identified from the question 1, which was divided into sub-themes according to the responses from the participants on their level of understanding of BIM. Figure 5.16 below shows the themes and sub-themes for this question as represented by Nvivo 12 pro.

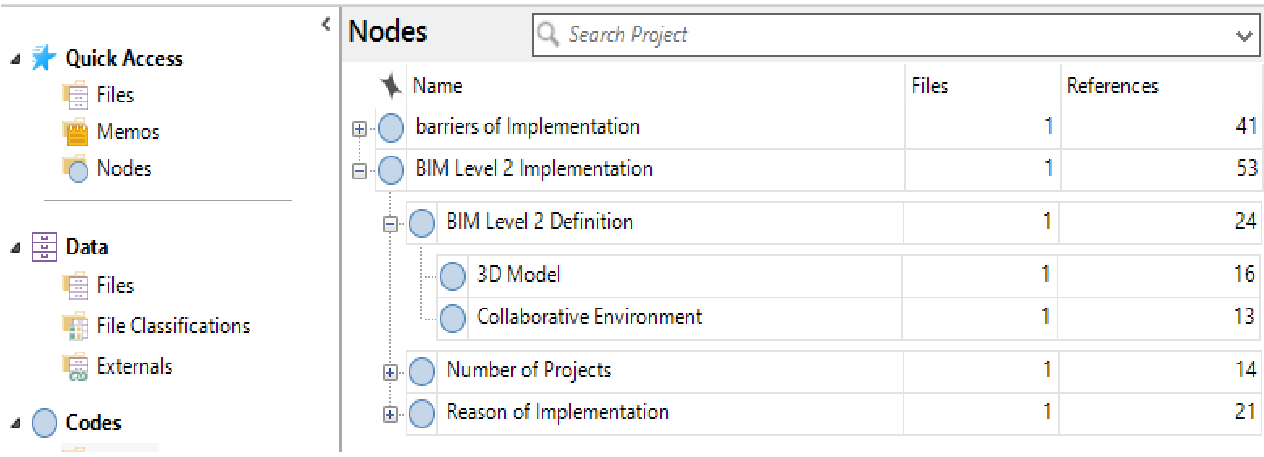


Figure 5. 16 Sub-themes which emerged from the BIM Level 2 definition in CS2.

<u>3D Model</u>

All the respondents from management and technical levels commented that BIM Level 2 used 3D modelling in order to design projects, and then more information was added to this model to make it more comprehensive. This detailed model offered a coordinated design process and better visualisation and simulation. As commented by TL1:

"BIM allows the creation of a detailed 3D Model which can be enhanced by adding information to create new models in 4D and 5D, those improved models help by improved design and visualisation of the project".

- **<u>Collaborative Environment</u>**

All participants commented collaboration was a key element of the definition. They mentioned that working in a single environment allows more collaboration between all the parties involved. In addition, it was mentioned that working in a Common Data Environment (CDE) will make the process for managing and sharing information between stakeholders faster and easier, which will improve communication and team work. As per the words of TL2:

"BIM Level 2 is about working in a Common Data Environment, where all models are shared in one single environment, this allow us to manage and transfer information in a better way between stakeholders".

5.2.1.2 Reason for Implementing BIM Level 2 in CS2

This theme addressed the question which aimed to understand the reasons for implementing BIM level 2. This question was addressed to staff at both management and technical levels and sub-themes emerged from the analysis of their responses. Figure 5.17 below shows the theme and sub-themes as represented by Nvivo 12 pro.

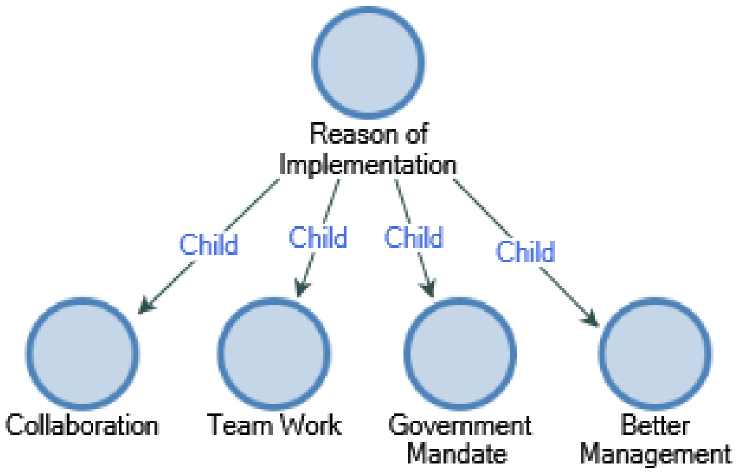


Figure 5. 17 Themes and sub-themes of the reasons of implementation in CS2.

- **<u>Collaboration and Team Work</u>**

Staff at both management and technical levels commented that one of the main reasons for implementing BIM Level 2 was to create a collaborative environment between designers, contractors, clients and suppliers, which will consequently improve team work in the company.

ML1 stressed that collaboration was very important for the success of any project, which will minimise conflicts between stakeholders.

As per the words of ML1:

"One of the reasons of implementing BIM Level 2 was to enable a collaborative environment in order to decrease conflicts between the team".

- **Government Mandate**

All the respondents commented that the pressure from the government to implement BIM in the industry was one of the reasons for adoption. In addition, ML1 emphasised that the government mandate to use BIM Level 2 in all public projects from 2016 was one of the main drivers, since the company worked continuously on public projects. As commented by ML2:

"Our company works continuously on public projects, so we had to implement BIM Level 2 to keep this ongoing".

- **Better Management**

Staff at both management and technical levels commented that collaboration, time and cost estimation, and information exchange, will improve the management of the project. Moreover, TL1 commented that management in BIM Level 2 goes beyond the construction phase, extending to the post-occupancy phase, where BIM can aid asset managers in the management, maintenance, reparation and replacement of the facility. As per the words of TL1:

"All the information stored in the model can improve management during the construction phase and in the post-occupancy phase".

5.2.1.3 Number of Projects Achieved by Using BIM Level 2

This theme identified the number of projects where BIM Level 2 was used. Staff at both management and technical levels mentioned that the system had been used in ten projects from design through construction and final delivery. From their responses, the sub-themes as represented by Nvivo 12 pro are shown in Figure 5.18 below.

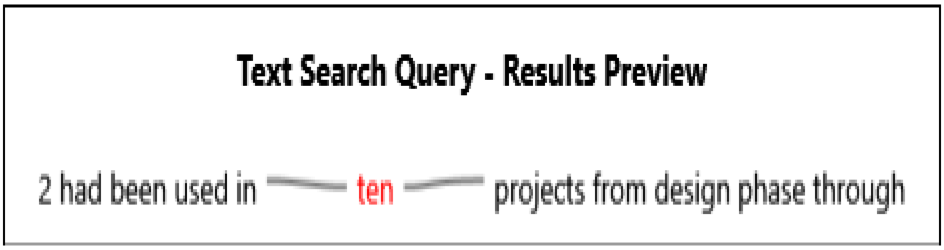


Figure 5. 18 Sub-theme for the number of projects where BIM Level 2 was used in CS2.

5.2.2 Barriers Faced during BIM Level 2 Implementation in CS2

From the interview questions, themes for this section emerged which emphasised the barriers faced by the company when BIM Level 2 was implemented and how the company handled these issues. Sub-themes were identified from analysing the responses given by the participants. Table 5.8 below shows the themes and sub-themes as represented by Nvivo 12 pro for this section.

Table 5. 8 Themes and sub-themes emerging for the barriers to implementation in CS2.

Themes	Sub-Themes
Barriers of Implementation	• Lack of Knowledge • Client Demand • Cost • Lack of expertise
Handling the Barriers	• Change management • Training • No Attention to Problems

5.2.2.1 Barriers to Implementation faced by CS2

The barriers which emerged from analysing the responses of staff at both management and technical levels were client demand, cost, lack of expertise and lack of knowledge. The sub-themes are presented using Nvivo 12 pro and are shown in Figure 5.19 below.

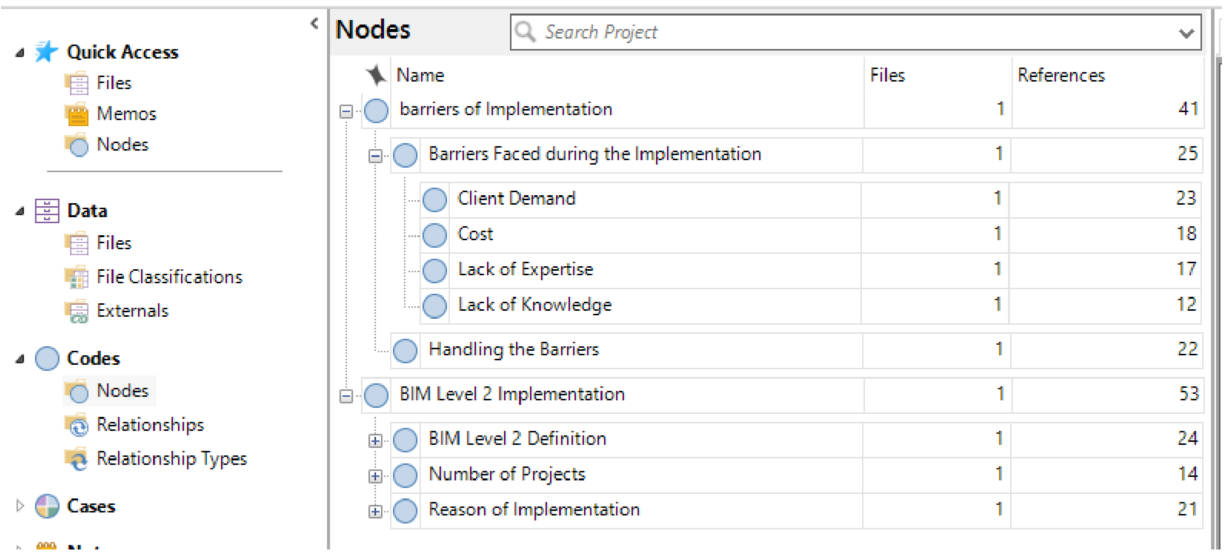


Figure 5. 19 Sub-theme for the barriers when BIM Level 2 was implemented in CS2

- **Client Demand**

Both levels commented that one of the barriers was the concern that there will not be any demand to use BIM from clients. Participants stressed that the reason for this was the lack of knowledge among the clients regarding BIM Level 2 and the benefits that it could bring. For instance, ML2 commented:

"Our first concern was that there will not be any requests from the clients to use it in their projects".

- **Cost**

It was mentioned in the responses that one of the barriers to adopting BIM was the high initial cost of the software. Moreover, the high cost of implementation was also a barrier since intensive training was needed for the staff to adapt to the new processes. As per the words of TL2:

"The company knew that implementing a new process will be expensive, but it was a risk we had to take".

- **Lack of Expertise and Lack of Knowledge**

During the interviews it was mentioned by the participants that the staff only had previous experience of 3D modelling, they had no knowledge or experience of BIM and working to the different standards required. The technical staff saw that these factors and having no experience of how to work with the BIM technology could result in a failure of the implementation and a loss of time and money. As commented by TL3:

"Even though we had previous experience in 3D modelling in the last decade, we did not have personnel with previous experience with BIM or staff with enough knowledge about this technology".

5.2.2.2 Handling the Barriers Faced during the Implementation in CS2

This theme was identified from the interview questions where the participants were asked about how the company managed the barriers faced during the implementation. Sub-themes emerged from the responses provided by the participants and were identified using Nvivo 12. Figure 5.20 below presents the theme and Sub-themes using Nvivo 12.

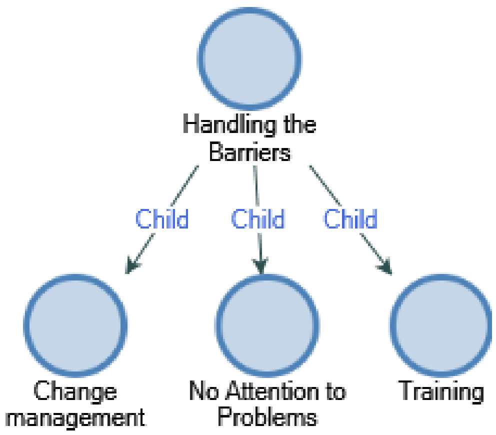


Figure 5. 20 Sub-themes of how the company handled the barriers in CS2

➢ **Change Management and Training**

Participants from the management and technical level commented that change management was critical for tackling the problems faced during the implementation. Responses shows that the company adopted new change strategies to ensure a successful implementation. Those strategies were based on training and educating employees on the new software and the processes involved within a BIM environment. According to TL3, training was effective for the building up of knowledge and expertise to handle the issues relating to the business. As per the words of TL3:

"The strategy adopted by the company included 3 weeks training to educate and train the employees on BIM and overcome the lack of knowledge and experience in the company".

Moreover, management offered bonuses and overtime to motivate and encourage employees to train and learn more about BIM. As commented by ML1:

"Offering bonuses and overtime was the strategy adopted by the company to motivate the staff members to learn more about BIM".

➢ **Benefits more important than costs**

Participants from management level commented that the high initial costs involved would be balanced out by the benefits to the company in the long term. As commented by ML1:

"Despite the high cost, we implemented BIM Level 2 as we believed that this will bring higher benefits to the company".

5.2.3 Critical Success Factors Influencing BIM level 2 Implementation in CS2

This section addressed the critical success factors for the implementation of BIM in CS2. In this section those factors were identified from the responses given and were ranked based on their experience and knowledge of the participants. The themes were based on the interview questions and the sub-themes were based on the the participant's responses as shown in Table 5.9 below.

Table 5. 9 Critical success factors Influencing BIM Level 2 in CS2.

Thmes	Sub-Themes
Human factors	• Staff • Training of Employees
Organisational Factors	• Change Management • BIM Awareness • Resources • Compatibility • Organisation Vision and Strategy • Top Management Support
Process Factors	• Collaboration and Communication • BIM Policy • Control of Performance
Extrernal Factors	• Government Support • Client Requirement • Consultant

5.2.3.1 Human Factors

From the analysis of the responses provided by the participants, human factors such as skilled people and training have been were identified as critical for BIM Level 2 implementation. Staff at both the management and technical levels stressed that training the employees and having qualified staff with the appropriate experience and skills would facilitate the adoption of BIM in the company. The two main factors identified in this category were categorised as sub-themes as shown in the Figure 5.21 below.

Figure 5. 21 Human factors influencing BIM Level 2 implementation in CS2.

Staff

Staff at both the management and terchnical levels commented that despite the previous experience in 3D modelling there was a lack of knowledge of BIM, its levels and the way to work according to BIM standards. Therefore, participants commented that experienced staff with this knowledge was vital to avoid failures during the implementation. As commented by ML2:

"To ensure the successful implementation of BIM Level 2, is critical to have staff with the right expertise and knowledge in the company".

- **Training of Employees**

Participants from management levels commented that it was important that staff had the right skills from the start and training was the key to this. Focusing on the theoretical as well as the practical aspect of BIM was critical and the training was organised to achieve this. As commented by ML1

"The three weeks training was critical for the success of the implementation, in the training knowledge, software, BIM standards were the main focus".

5.2.3.2 Organisational Factors

Organisational factors were crucial when implementing any new technology. Those factors were: BIM awareness; top management support; change management; and the vision, strategy and the resources of the company. Sub-themes were identified by the analysis of the responses of the participants as shown in Figure 5.22 below.

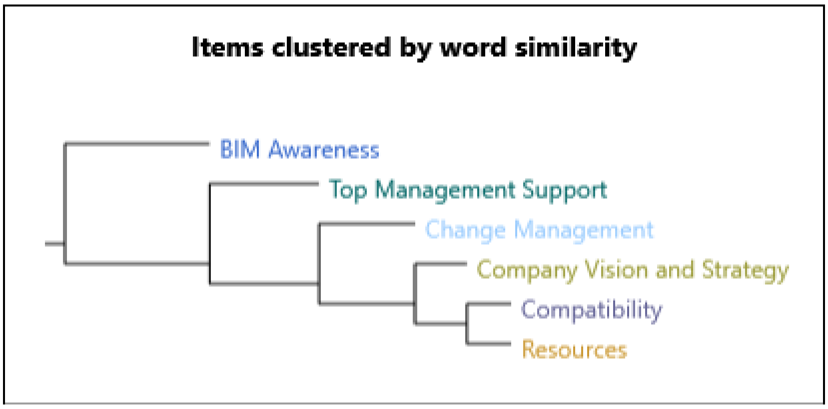


Figure 5. 22 Sub-themes of organisational factors presented by Nvivo 12 for CS2.

BIM awareness

From the responses, the awareness of BIM emerged as one of the factors which could significantly impact the implementation. Participants misunderstood the concept of BIM at the beginning as they thought it was just about learning the software rather than a new way of working. As commented by TL1:

"When the idea of implementing BIM was exposed, many participants thought they had to learn how to use a new software rather than a process, therefore BIM awareness is crucial within the company at the first stages of implementation".

- **Change Management**

As commented by both levels, the management and strategy of the company had to change in order to adapt to the new technology and achieve a successful implementation. These strategies focused on training and motivating employees to embrace BIM Level 2. As commented by ML1:

"Changing the company strategies and approaches was important to ensure a successful implementation, the strategies focused on the importance of employees to achieve the implementation".

- **Management Support**

The need for management support during the implementation emerged from the responses provided by the participants from the interviews, as they commented that, despite the high cost of software and training, the management were prepared to provide what was necessary. In addition, technical staff stated that support was also vital during the implementation as this inspired and encouraged them. As per the words of TL3:

"Management level supported the employees by providing all that was necessary to ensure a successful implementation".

➢ **Company Vision and Strategy**

As commented by ML1, the strategy and vison of the company was one of the factors that drove the company to adopt BIM Level 2. As the main strategy of the company focused on 3D modelling to plan and design projects, the vision and main goal was to embrace the new technology to improve and progress at the same rate as other companies in the industry. Also, the company wanted BIM because one of the main benefits of BIM level 2 was the improvements to make collaboration between all the parties in a construction project more effective. As per the words of ML1:

"Our previous strategy and vision were the reasons for implementing BIM Level 2, since we wanted to keep up with the industry and improve collaboration between our team".

➢ **Software Compatibility**

Technical staff stated that software compatibility can critically influence the BIM implementation. Software that was compatible with the other products would avoid the cost of modifications and would make information flow more effective throughout the company. As commented by TL2:

"Availability of compatible software will decrease the cost of implementation".

5.2.3.3 Process Factors

This theme emerged from the interview questions where participants gave their opinions regarding the factors that influenced the BIM Level 2 implementation. From their responses factors were identified and were categorised as sub-themes. A presented by Nvivo 12 pro, Figure 5.23 below shows the sub-themes that emerged from the process factors category.

Figure 5. 23 Sub-themes of process factors in CS2 presented using Nvivo 12.

➢ **Communication and Collaboration**

Both levels commented that the aim of implementing BIM was to create a collaborative environment to improve communication between the different parties involved. Therefore, they commented that in order to implement BIM successfully, communication and collaboration during the implementation were vital. Management mentioned that one way to overcome the lack of knowledge regarding BIM within the company, was by the collaboration and communication of employees with each other, as this would enable faster expansion and growth of BIM knowledge across the company. As commented by ML2:

"Collaboration and communication were crucial during the implementation since this helped in overcoming the lack of knowledge existing in the company".

- **BIM Policies**

Participants stated that policies were important during the implementation, however they commented that the only available sources were BIM standards which clarified the way to work with BIM, but there were no guidelines available for companies which showed how BIM could be implemented. Therefore, the implementation was based on the existing understanding of BIM Level 2 by the company. As commented by TL2:

"Policies are important during the implementation, however, due to the lack of available guidelines we had to implement BIM Level 2 based on our own understanding".

- **Control of Performance**

Participants stated that constant control of the performance was very important during the implementation. Moreover, incorporating evaluation measures which included the delivery time of projects, client satisfaction and the performance of employees was necessary to ensure that the best results were drawn out from the implementation. As per the words of TL1:

"Controlling the performance and allocating evaluation measurements is very important to make sure the performance is stable through the entire implementation's life-cycle".

5.2.3.4 External Factors

The analysis of the responses shows that there were external factors that affected the process of BIM Level 2 implementation. From the responses, three main sub-themes were recognised, which were: Governmental support, client demand and the use of an external consultant which are show in Figure 5.24 below.

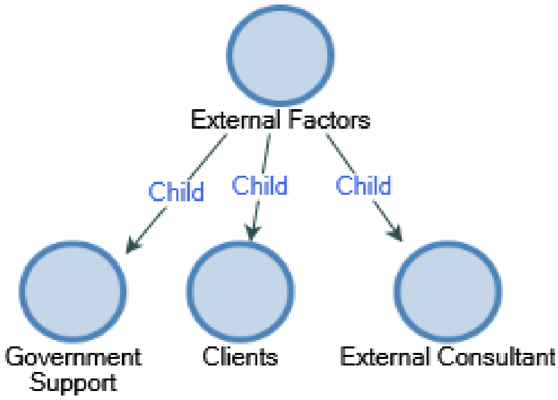


Figure 5. 24 Sub-themes of external factors in CS2 presented using Nvivo 12.

- **<u>Governmental Support and Client Demand</u>**

Both levels recognised these two factors were very important for every company to initiate the adoption stage. Participants commented that the pressure from government to use BIM Level 2 on all public projects from 2016 motivated the company to embrace this technology in order to not lose orders for future public projects. On the other hand, participants commented the clients will realise the benefits from saving of money and time which BIM can bring to them, so the demand to use this technology is likely to be very high. Also, The government mandate to make BIM compulsory on public projects make it necessary for consultancy to be familiar with the technology if they don't want to lose business. As commented by ML2:

"These two external factors can motivate every company to start the adoption stage for implementing BIM, since pressure from the government and high demand from the client will encourage company to embrace the technology in order to not lose projects in the future".

- **<u>External Consultant</u>**

Management level commented that the aid of a consultant with previous experience of BIM was critical for designing the implementation plan, which included setting the milestones for the implementation process and providing suitable training for employees. As commented by ML1:

"After the decision of adopting BIM was taken, we hired a consultant to help us design a plan which ensured the implementation of BIM Level 2 as requested by the government"

5.2.3.5 Ranking of Critical Successful Factors Based on their Importance

This section focusses on the importance of the critical success factors for implementing BIM level 2. The importance of the factors was based on the responses of the participants.

The scale of Miles and Huberman (1994) was used in order to rank the factors based on a scale of high (●), medium (□) and low (○). The researcher firstly studied the responses given from the participants, then with the help of Miles and Huberman scale the author was able to illustrate the importance of each factor as shown in Table 5.10. The cocept adopted by the researcher for identifying the importance of the factors is the same one adopted in Case Study 1.

Table 5. 10 Importance of the factors influencing BIM Level 2 implementation in CS2.

Factor Categories	*Factors Influencing BIM Level 2*	*Participants and their Responses*								*Average of Importance*
		ML1	**ML2**	**TL1**	**TL1**	**TL2**	**TL3**	**TL3**	**TL3**	
Human Factors	People	●	□	●	□	□	□	●	□	**M**
	Training of employees	●	●	●	●	□	●	●	□	**H**
Organisation Factors	Change management	●	●	□	□	□	□	●	□	**M**
	Top Management	●	●	●	●	●	□	●	□	**H**
	BIM awareness	●	●	●	●	●	●	●	●	**H**
	Resources	●	○	○	○	□	○	□	○	**L**
	Compatibility	□	○	○	○	□	○	○	○	**L**
	Company vision and strategy	●	□	□	□	○	□	○	○	**M**
Process Factors	Communication and Collaboration	●	●	●	●	●	□	□	●	**H**
	BIM policy	□	□	●	□	○	□	○	□	**M**
	Control of performance	●	●	●	●	□	□	●	□	**H**
External Factors	Governmental support	□	□	□	□	○	○	○	●	**M**
	Client demand	□	□	●	●	□	□	○	○	**M**
	External consultant	●	●	□	●	□	□	□	□	**M**

The Nvivo software was used to rank the factors from the most to the less important, based on their frequency during the interviews see Figure 5.25 below.

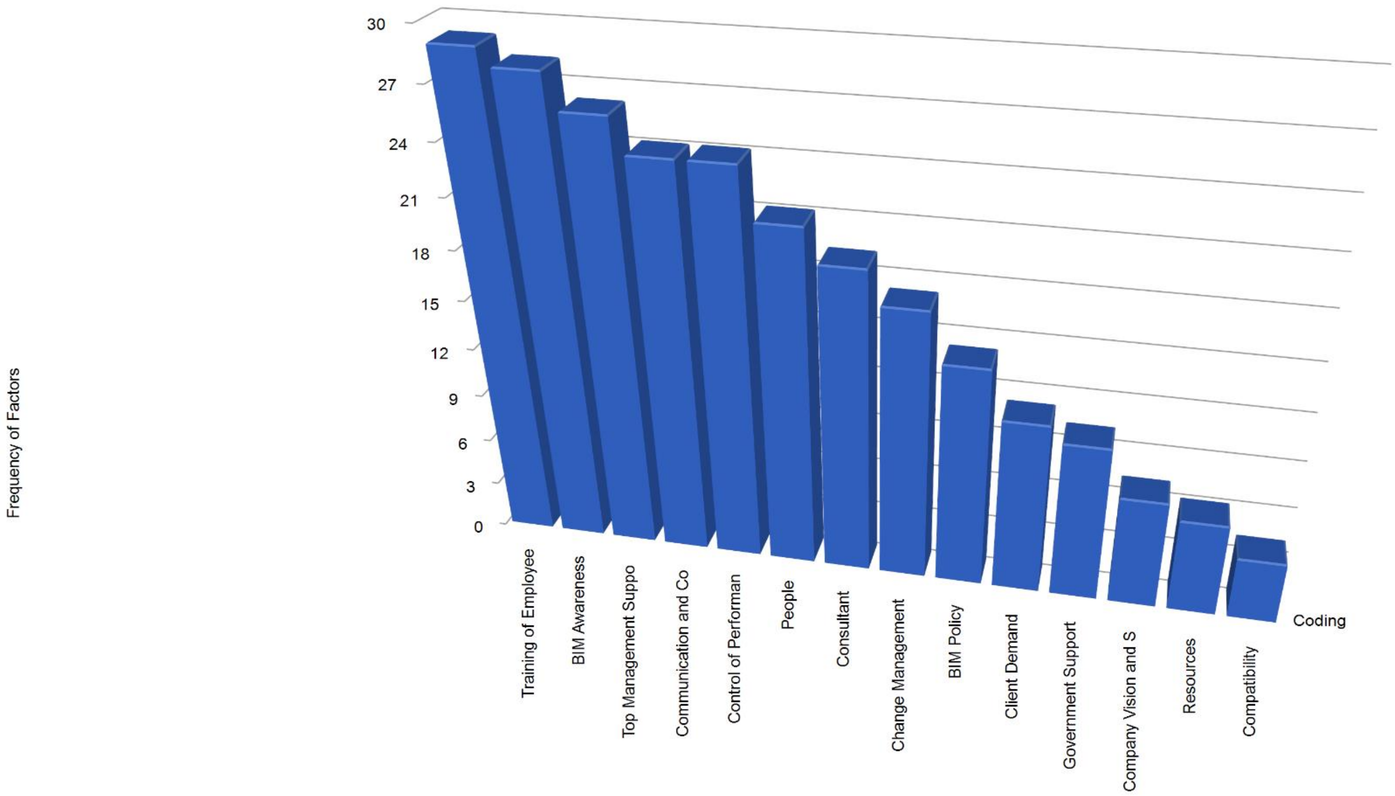


Figure 5. 25 Factors' frequency presented by Nvivo 12 for CS2.

5.2.4 Mapping Critical Success Factors Influencing BIM Level 2 across Lifecycle Implementation in CS2.

5.2.4.1 BIM Level 2 Lifecycle Implementation

In this section the participants were asked to identify the phases and stages which the company went thorough during the BIM Level 2 implementation. Based on the responses of the participants the implementation was divided into three main phases: pre-implementation, implementation and post-implementation phase. The phases were categorised as themes and there were coded as sub-themes as presented by Nvivo 12 pro and shown in Table 5.11 below.

Table 5. 11 Themes and sub-themes for this section CS2.

Themes	Sub-Themes
Pre-Implementation Phase	• Adoption • Planning
Implementation Phase	• Implementation
Post-Implementation Phase	• Evaluation • Update Implementation Plan

5.2.4.2 Pre-implementation Phase

Figure 5. 26 Pre-implementation phase and stages in CS2.

This phase identifies the planning and adoption stage as presented using Nvivo 12 pro and shown in Figure 5.26 above. Participants commented that CS2 gave a rating of highly important to top management support and resources availability in this phase, which was divided into adoption and planning stages. In the adoption stage the decision to implement BIM Level was taken by the management of the company. The strategy and vision of the company to improve collaboration motivated them to embrace the technology, since BIM Level 2 can create a collaborative environment. Available resources such as software and staff were analysed at this stage in order to identify which resources were already owned by the company and which were still needed to be acquired.

According to management, the planning stage was critical to ensure a successful implementation. Hiring a BIM expert was very important to overcome the existing gap of knowledge and experience in the company. Management and the BIM consultant were responsible for setting the implementation plan and identifying the areas on which employees should be trained. According to the technical staff, training in the technical and theoretical aspects of the implementation occurred at this stage. The technical aspects of the training included learning the new software, BIM standards and how to work in a Common Data Environment (CDE). The theoretical aspects of training included learning the concepts behind BIM and the differences between the functionality provided within each of the levels.

As per the words of ML1:

"In the Pre-implementation phase the decision to implement BIM level 2 was taken and the implementation plan was designed identifying the resources required and training needed to improve the skills of employees to meet the requirements of BIM Level 2"

On the other hand, ML2 stated:

"The BIM consultant was hired due to the lack of knowledge regarding BIM in the company at that time".

5.2.4.3 Implementation Phase

As commented by participants, the implementation phase started when the company began work on the first project to be delivered by BIM Level 2. In this phase the implementation plan was put into motion. All the participants commented that it was critical to maintain collaboration, communication and control during this phase. Performance and progress was monitored and controlled by the project manager and BIM Manager. As commented by ML2:

"It was very important to keep up control and communication during the implementation phase particularly in our first project to make sure we had a successful implementation".

5.2.4.4 Post-implementation Phase

The Post-Implementation stage included the evaluation of the implementation and the updating of the plan for the next BIM level. These are presented using Nvivo 12 pro in figure 5.27.

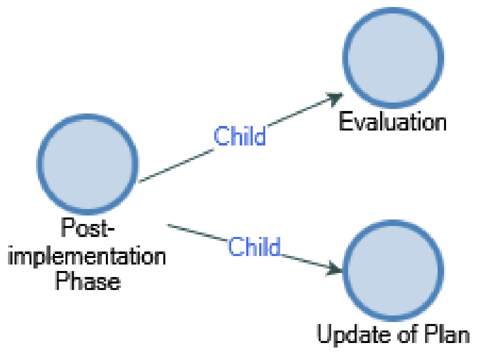


Figure 5. 27 Post-implementation phase and its stages presented by Nvivo in CS2.

After the first project was delivered, the evaluation stage was started in order to assess the implementation of BIM Level 2. The evaluation was completed based on the checklists created by management to assess the success of the project. These checklists included: client satisfaction, delivery time, final cost of the project and employee performance. According to the participants, the implementation of BIM was successful due to delivering the project within budget and on time as well as achieving a high level of satisfaction for the client. Participants also added, that at this stage, conflicts and clashes occurred, although there were less conflicts when compared with the traditional methods of construction. As commented by ML2:

"When the first project was evaluated, we decided that the implementation was successful, this decision was based on the specifications set by the management".

Moreover, TL1 commented:

"Designers, client and contractors worked efficiently together during the project and very few clashes were encountered, but with the help of BIM models these issues were solved easily".

An update stage was identified as needed by management, as an update for the plan would be required in order to meet the requirements of BIM Level 3, but overall it should require less effort and training because of the knowledge gained by implementing the previous levels of BIM. As per the words of ML1:

"Our plan will be updated when we will implement BIM Level 3 which will happen very soon".

In addition, ML1 stated:

"For BIM Level 3, less effort will be required as we already have the basics of BIM".

5.2.4.5 Mapping the Critical Factors into the BIM Level 2 Implementation Lifecycle in CS2.

This section addressed the last question of the interview protocol, where the participants were asked to identify the factors which affected each phase and stage of BIM Level 2 implementation. Participants from the management and technical levels answered this question based on their knowledge and previous experience with the BIM implementation. From the analysis it emerged that all the participants were of the same opinion with regards to mapping the factors across the life-cycle of the implementation. The factors recognised in each phase and stage, based on the responses of the participants, are shown in Table 5.12 below, marked with a symbol (✓) in any specific stage where they were considered to be critical.

Table 5. 12 Mapping the factors influencing BIM Level 2 lifecycle in CS2.

Factors Category	***Factors Influencing BIM Level 2***	***BIM Level 2 Lifecycle Implementation in CS2***				
		Pre-implementation Phase		*Implementation Phase*	*Post-implementation Phase*	
		Adoption Stage	Planning Stage	Implementation Stage	Evaluation Stage	Update Plan Stage
Human Factors	People	✓	✓	✓	✓	✓
	Training of employees		✓	✓		
Organisation Factors	Change management		✓	✓		
	Top Management	✓	✓	✓	✓	✓
	BIM awareness	✓	✓	✓		
	Resources		✓	✓		
	Compatibility		✓	✓		
	Company vision and strategy	✓	✓			
Process Factors	Communication and Collaboration		✓	✓	✓	✓
	BIM policy	✓	✓	✓		
	Control of performance		✓	✓	✓	✓
External Factors	Governmental support	✓	✓			
	Client demand	✓		✓		
	External consultant		✓	✓		

The factors affecting each stage in the life-cycle for the implementation of BIM Level 2 in CS2, according to the answers provided by the participants, where the themes were identified from the interview questions, and the sub-themes emerged from the responses, can be seen presented by Nvivo 12 pro in Figures 5.28, 5.29 and 5.30 below.

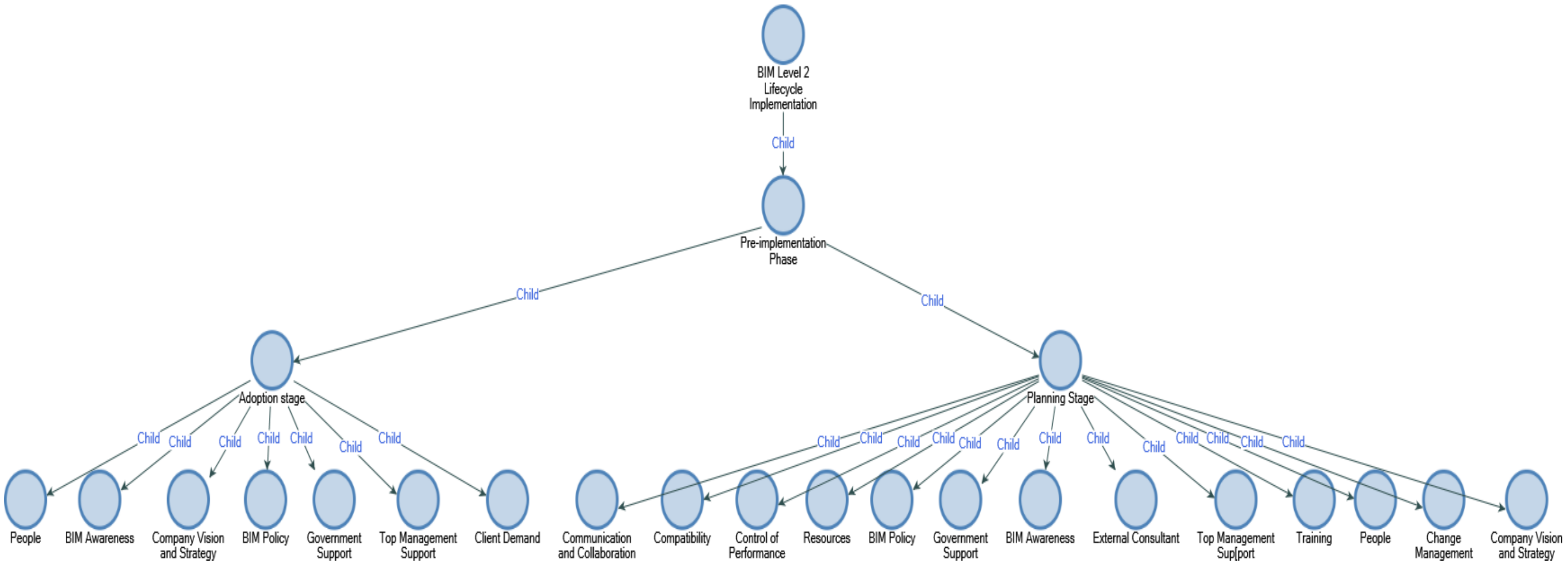


Figure 5. 28 Factors influencing the adoption and planning stages in CS2

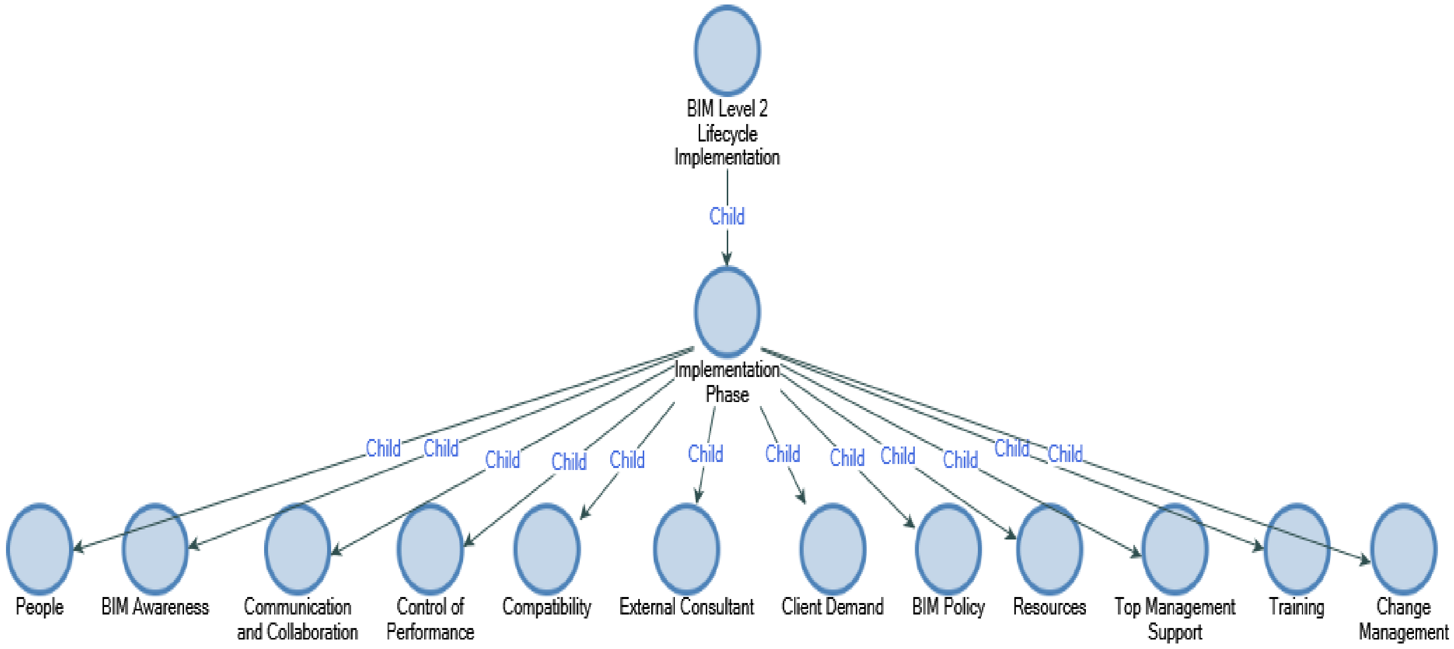


Figure 5. 29 Factors influencing the implementation stage in CS2.

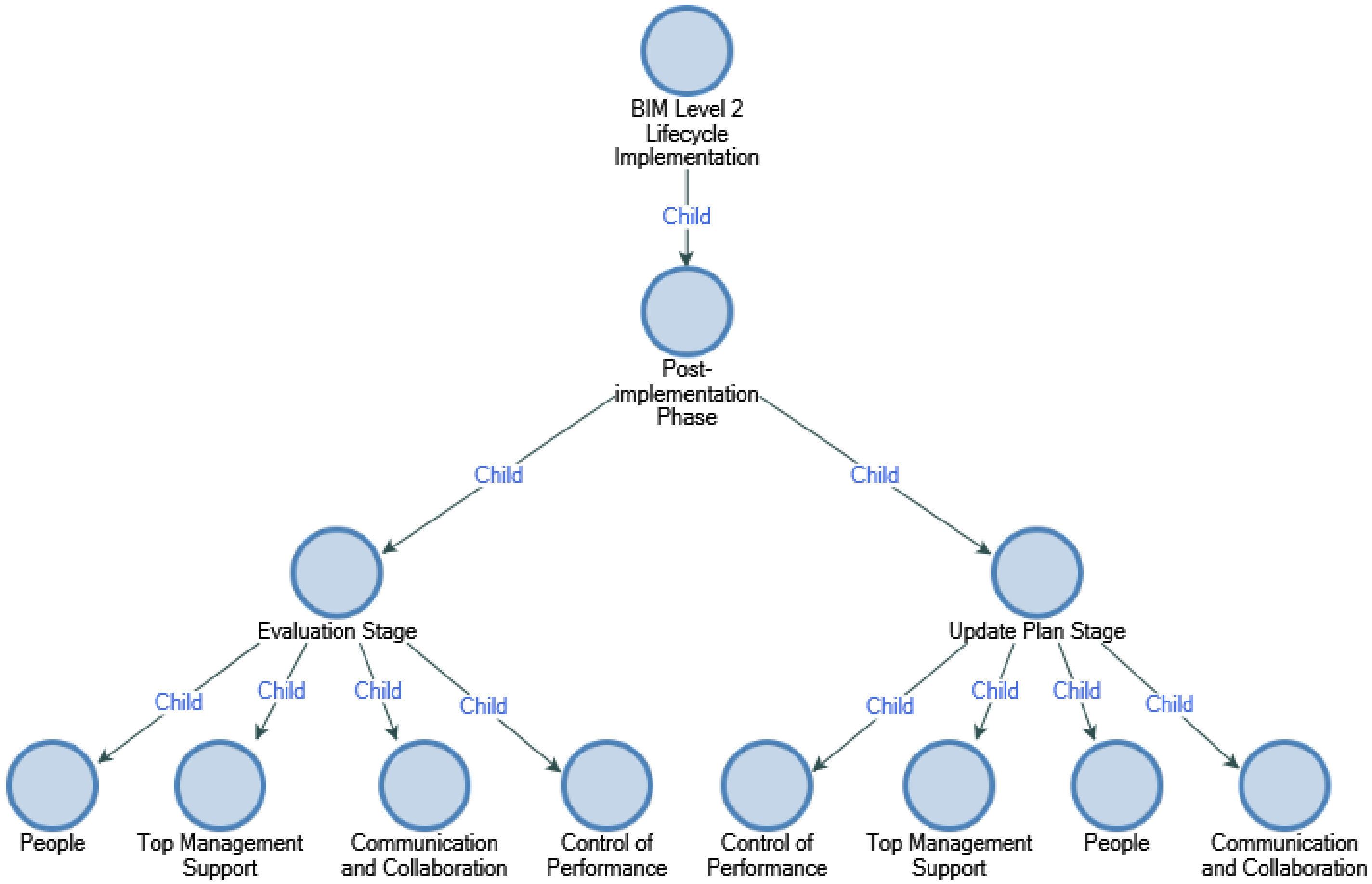


Figure 5. 30 Factors affecting the Evaluation and Update plan stages in CS2.

5.3 Introduction to Case Study 3 (CS3)

CS3 is a medium architecture company founded in 2009 with two main offices located in London and Edinburgh with a total number of 62 employees. The company had previous experience in many sectors which included: sport, masterpieces, transporting and housing. The main approach of the company was to encourage an early collaboration between clients, consultants and suppliers at the design stage of a building, in addition to working with engineering and construction management companies across the world. Some of the projects delivered by the company were situated in the UK and others in Qatar and AEU.

BIM Level 2 was adopted and implemented in the company in 2014 to embrace the benefits of collaboration, coordination and integration from the early design phase. Models such as 4D and 5D were used for time and cost estimating on projects. Moreover, BIM was used to simulate building performance to ensure the best sustainable design.

In this case study, 10 participants contributed to the study. Participants were from both management and technical levels including two Directors ML1, two project managers ML2, one BIM managerTL1, one design manager TL2, three architectural engineers TL3 and one IT engineer TL4.

5.3.1 BIM Implementation in CS3

This section demonstrated the level of understanding of the participants regarding BIM Level 2, the reason for the implementation, and the current usage of BIM in projects. It included three questions which were: "What is your definition of BIM Level 2?"; "What are the reasons behind the selection of BIM Level 2? "and "On how many projects have you used BIM Level 2?". These questions were put to the participants in order to address the first research question of the current study, which was: "What is the current situation regarding BIM level 2 implementation in SMEs?"

Nvivo 12 Pro was used as the data analysis software for the research. The semi-structured interviews helped to identify the main themes for this section known as parent nodes in the Nvivo software, while the answers from the interviews generated the sub-themes or child nodes. Table 5.13 below lists the themes and sub-themes.

Table 5. 13 Themes and sub-themes for section 1 in CS3

Themes	Sub-Themes
BIM Definition	• Process • Models • Method • Single environment
Reason of Implementing BIM Level 2	• Collaboration and communication • Integration • Risk avoidance • Cost and Time Estimation
Number of Projects Achieved by Using BIM	• 15 Projects

5.3.1.1 BIM Level 2 Definition

The interview questions aided the researcher to identify this first theme, while the four sub themes emerged from the responses of the participants as shown in Figure 5.31 below presented using Nvivo 12 pro.

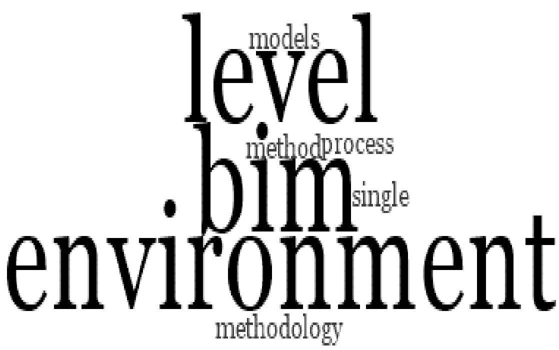


Figure 5. 31 Sub-themes which emerged from BIM Level 2 definition in CS2.

➢ **<u>Process and Method</u>**

Participants commented that BIM Level 2 was a new process and method to deliver construction projects. They stated that working with BIM was not only about software, but it was a whole process which helped to deliver projects efficiently. Moreover, it was commented that BIM was a methodology which was used to increase collaboration between the parties involved in the project. As commented by TL1:

"BIM is not just 3D modelling or some kind of software, but it is a process".

Moreover, TL2 commented:

"BIM is a methodology which allows the creation of a more collaborative environment".

- **Models**

The staff at management and technical levels stated that BIM used much more advanced models than other traditional approaches. These models were obtained by integrating time and cost information (Dimensions) to a 3D BIM model which resulted in 4D and 5D BIM models. As commented by technical staff, these models were very detailed and resulted in time and cost savings. As per the words of TL3:

"We merge cost and schedule data constantly to the models to help us generating more detailed models which offer clients more confidence in our cost and time estimates".

- **Single environment**

Participants commented that the core contribution of BIM Level 2 was producing a platform where all the models and data are attached. This was known as a Common Data Environment (CDE). In addition, by being attached to the CDE, these separate models provided a single source of information to designers, architects, contractors and clients. As commented by TL1:

"The core of BIM Level 2 is to create a digital place where all the information and models related to a certain project can be found".

TL4 commented:

"Creating CDE was our first priority since BIM Level 2 cannot be achieved without it".

5.3.1.2 Reason of Implementing BIM Level 2 in CS3

This theme was identified from the question 2 above (see 5.4.1), which was divided into sub-themes according to the responses from the participants on the reasons for Implementing BIM level 2. Figure 5.32 below shows the themes and sub-themes for this question as presented by Nvivo 12 pro.

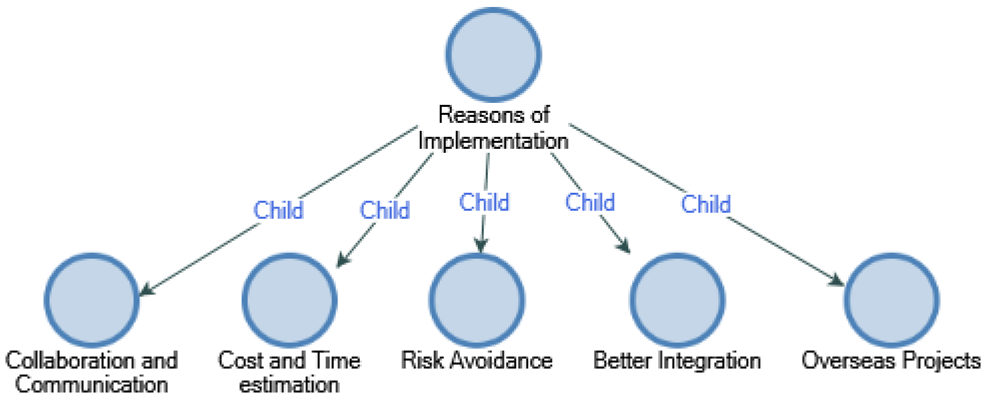


Figure 5. 32 Themes and sub-themes of the reasons of implementation in CS3.

Communication, Collaboration and Integration

All the participants commented that BIM was implemented to improve communication and collaboration in the company because of the nature of the construction environment which was fragmented due to all the different parties involved. In addition, the key for enhancing communication and collaboration was the efficient sharing of information. In addition, participants commented that improved communication and collaboration will result in a more integrated team, where there was less debates and clashes. As commented by ML1:

"We aimed to implement BIM Level 2 to enhance collaboration and communication within our team, as well as to improve integration".

Moreover, ML2 stated:

"The nature of construction projects is fragmented, so BIM was implemented with the aim of solving this issue."

- **Cost and Time Estimation**

According to participants from both levels, generating 4D and 5D models resulted in more accurate time and cost estimation. As stated by the participants, client satisfaction was critical in construction projects, and could be achieved by completing projects within the time and cost expected. Therefore, this motivated the company to implement BIM Level 2 since time and cost were modelled within this level. As per the words of TL3:

"Is important to deliver project within the expected time and cost, therefore BIM Level 2 was implemented as we believed this technology could help us achieve this".

- **Risk avoidance**

Participants stressed that as they were an architectural company, the design phase was critical as this was the foundation for any project. Therefore, it was important to remove the likelihood of risks occurring by the production of coordinated and accurate models as early as possible during the design phase. This will increase the client confidence through the remaining phases of the project. As commented by TL2:

"In our company the design phase is important, and it is vital that it is risk free so we can gain the client confidence".

- **Overseas projects**

Participants, particularly from the management level commented, that it was critical to work with other international companies which already used BIM to achieve a successful implementation. According to ML1:

"Our company works continuously on overseas projects with the help of other international large companies which already used BIM to deliver projects, therefore we had to adopt the same technology to work smoothly with them".

5.3.1.3 Number of Projects Achieved by Using BIM Level 2

From the responses provided by the participants, it was identified that the company was involved in 8 projects, where BIM level 2 was used from design to handover. Some of these were national projects located in the UK, and others were international located in Qatar and UAE. Figure 5.33 below shows the result for this sub-theme below presented using Nvivo 12 pro.

Figure 5. 33 Sub-theme for the number of projects where BIM Level 2 was used in CS3.

5.3.2 Barriers Faced during BIM Level 2 Implementation in CS3

This section addressed the interview questions aimed at understanding the barriers faced by CS3 when implementing BIM Level 2. Moreover, it shows the approaches used by the company to handle these barriers. Sub-themes emerged from the responses provided by the participants. Table 5.13 below shows the themes and sub-themes for this section presented using Nvivo 12 pro.

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Table 5.13: themes and sub-themes for the first section in CS3.

Themes	Sub-Themes
Barriers of Implementation	• Limited Knowledge • Resistance to Change • Cost • Lack of Guidance
Handling the Barriers	• Change management • No Attention to Problems • Previous Experience with BIM

5.3.2.1 Barriers of Implementation faced by CS3

The barriers which emerged from analysing the responses of staff at both management and technical levels were lack of guidance, limited knowledge, cost and resistance to change. The sub-themes are presented using Nvivo 12 pro and are shown in Figure 5.34 below.

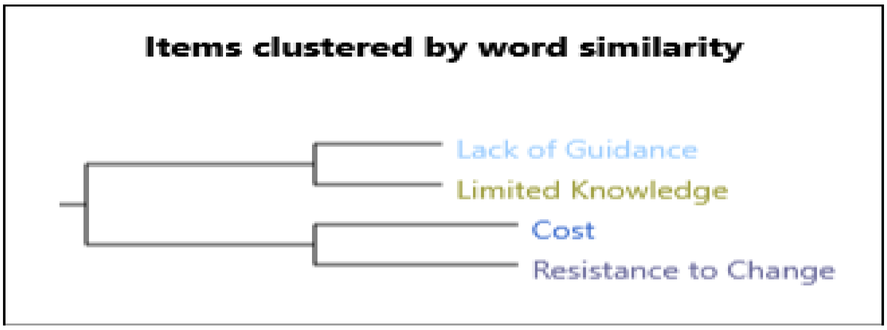

Figure 5. 34 Sub-theme for the barriers that were experienced when BIM Level 2 was implemented in CS2.

➢ **<u>Lack of Guidance</u>**

According to staff at the management and technical levels, when the company decided to implement BIM Level 2 they realised that there were no guide maps to be followed to ensure a successful implementation. Participants stated that although there were plenty of standards published online they were not helpful, since these standards show the way to work within a BIM environment but not how to implement it. Participants stressed that this guidance was necessary to assist companies in BIM Level 2 implementation, particularly for companies which lack knowledge and practice regarding BIM. As commented by TL1:

"The lack of guide maps was one of the problems faced in the first phases of the implementation, the online standards did not help us when we decided to implement BIM".

- **Limited Knowledge**

Technical staff stressed that there was a limited knowledge regarding the different dimensions used for models in BIM level 2. They commented that at the beginning it was not easy to create 4D and 5D models, since they did not understand the concepts involved with these more advanced models, therefore generating and managing them was a problems faced by some of the staff. Moreover, participants faced issues regarding understanding the way of working in a Common Data Environment (CDE) since this was a new approach for them. According to TL3:

"At the beginning of the implementation process, there was a clear limited knowledge regarding 4D and 5D, this included the way to generate and manage these models according to BIM Level 2 standards".

Moreover, TL4 commented:

"Creating a platform where all the models and data are shared, and then teaching employees how to use it, was one of the main concerns of the company".

- **Cost**

Management commented that at the beginning the cost was the main concern, because the new software was very expensive. Additionally, integrating a new process needed change intensive training to help the employees adapt to the ways of working, which was also expensive as well as being vital to ensure a successful implementation. As per the words of ML1:

"One of our first concerns was the high cost of implementation, as software and training were expensive".

- **Resistance to Change**

Management commented that resistance to the need to adapt to the new process was faced by the participants. Moreover, this resistance was noticed more from older people since the use of the new technology was an issue for them. On the other hand, it was easier for younger employees to adapt to the new technology. As mentioned by TL1:

"The adoption of a new technology was a problem for elder employees, this created some resistance at the beginning"

5.3.2.2 Handling the Barriers Faced during the Implementation in CS3

This theme was identified from the interview questions where the participants were asked about how the company managed the barriers faced during the implementation. Sub-themes emerged from the responses provided by the participants and are presented using Nvivo 12 pro In Figure 5.35 below.

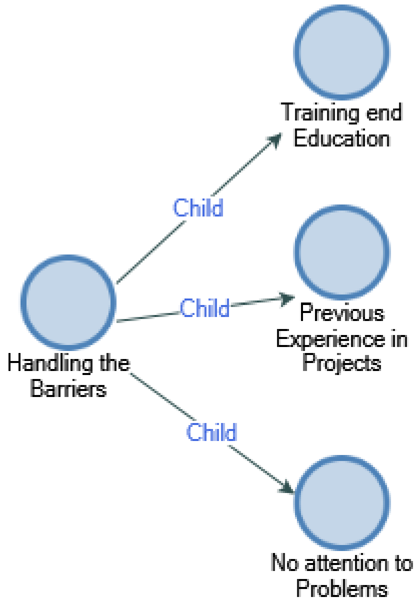

Figure 5. 35 Sub-theme for the barriers that were experienced when BIM Level 2 was implemented in CS2.

- **<u>Training and Education</u>**

Participants commented that the lack of knowledge and practice regarding the dimensions and the use of a CDE of BIM level 2 had been overcome by intensive training and education. Educating employees was fundamental to address the theoretical aspects and gaining the required knowledge within the company. On the other hand, training aimed to enhance skills, was essential to enable staff to use the new software efficiently and to be able to generate and manage the data and models within the CDE. As commented by ML2:

"Training and education were essential to minimise the issues related to limited knowledge, therefore seminars were designed to help employees with this regard"

- **<u>Little attention to cost and resistance to change</u>**

Management commented that they did not pay much attention to the high cost of BIM level 2 as they were aware of the significant Return on Investment (ROI) and other benefits which the technology would bring to the company and its clients. Also, little attention was given to issues of resistance to the implementation, as management realised that eventually the staff would adapt to the changes. As stated by ML1:

The strategy adopted by the company was based on not giving attention to issues we knew that with time will be solved, for instance cost and resistance to change".

➢ **Previous Experience from Overseas Projects**

Participants commented that despite the lack of guidance needed to implement BIM Level 2, the limited experience they gained from working on overseas projects with International companies helped them to quickly understand the core functions of BIM which were: information sharing, collaboration and communication, and based on this understanding, the implementation plan was designed. As commented by ML2:

"The limited experience we gained by working with international companies in Qatar and UAE gave us a general understanding of BIM which therefore helped us to design a proper implementation plan".

5.3.3 Critical Success Factors Influencing BIM level 2 Implementation in CS3

In this section the critical success factors influencing the implementation of BIM Level 2 in CS3 were identified. These factors emerged from the interview responses given by the participants and were ranked based on their experience and knowledge. Table 5.14 below shows the themes and sub-themes of this section.

Table 5. 14 Critical success factors Influencing BIM Level 2 implementation in CS3.

Themes	Sub-Themes
Human factors	• Staff • Training of Employees
Organisational Factors	• Change Management • BIM Knowledge • Resources • Compatibility • Organisation Vision and Strategy • Top Management Support
Process Factors	• Collaboration and Communication • BIM Policy

	• Control of Performance
Extrernal Factors	• Government Support • Client Requirement • Knowledge Transfer

5.3.3.1 Human Factors

From the responses provided by the participants, staff and training were identified as critical factors influencing the implementation of BIM Level 2 in CS3. Staff at both management and technical levels commented that training the employees and having qualified and skilled staff would ensure a successful implementation of BIM in the companies. The two main factors identified in this category, were categorised as sub-themes presented in Nvivo 12 pro as shown in Figure 5.36 below.

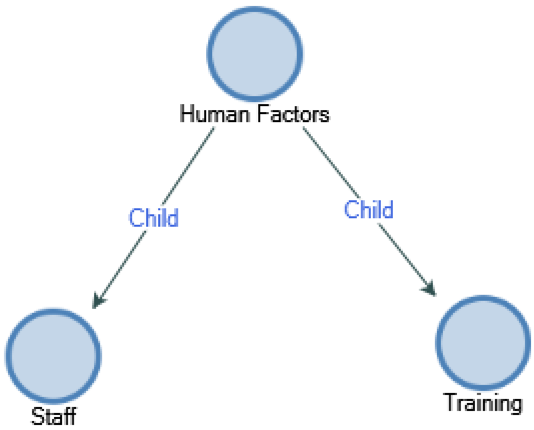

Figure 5. 36 Human factors influencing BIM Level 2 implementation in CS3.

➢ **Staff**

Staff at both management and technical levels commented that the availability of skilled staff was crucial in order to implement BIM level 2 successfully. Moreover, they commented that the right mind set of staff, to be ready to improve their own skills and abilities and learn new technologies, was important in order to adapt to change. As commented by ML2:

"Skilled employees are able to learn new software and new process, which is important for the success of the implementation".

➢ **Training of Employees**

The participants commented that implementing BIM Level 2 required new software and changing the way projects were delivered, so training employees on the new processes and software was essential to deliver BIM projects successfully. Seminars were organised to teach the new software, as well as to educate the employees about BIM in order to gain more knowledge about the technology. As mentioned by TL2:

"Seminars organised by the company were used by the company to teach employees the new software and change their mind set about BIM",

5.3.3.2 Organisational Factors

The analysis of the responses showed that there were external factors which affected the success of the BIM Level 2 implementation. These were identified as top management support, change management, resources and vision and strategy of the company, which became the sub-themes for Nvivo 12 pro as shown in Figure 5.37 below.

Figure 5. 37 Sub-themes of organisational factors for CS3.

➢ **<u>BIM Knowledge</u>**

Participants commented that having knowledge of the software and processes of BIM would result in an easier implementation, saving money and the time needed for training. Management also commented that having this knowledge would be very important in the pre-implementation and implementation phases of the system. As commented by ML2:

"Knowledge about BIM is very important as it could save money and time which would be spent on seminars and training".

➢ **<u>Change Management</u>**

Participants commented that change management was very important to enable the company to adapt to the new processes. Management stated that change management process required a significant amount of money, since training and acquiring the new software were part of this process. However, in order to ensure a successful implementation this investment was important. The process of change management focused on training and applying new strategies to motivate employees to embrace the technology, which minimised the resistance to the implementation. As commented by ML1:

"Despite the elevated cost of the change management process, we knew that it was critical to ensure a successful implementation".

- **Top Management Support**

Management support was considered to be important in the responses provided by the participants. It was necessary to provide the required finance for training as well as moral support through the critical stages of the implementation, to motivate and encourage them when adapting to the new processes. As per the words of TL2:

"The financial and moral support provided by the management level was very important throughout the implementation".

- **Company Vision and Strategy**

Participants commented that the company vision and objectives were important factors during the decision making for the adoption of BIM Level 2. As commented on by management, the main objectives were to increase collaboration, communication and integration between the parties involved in projects since the nature of construction was fragmented. As per the words of ML2:

"Our objectives and strategy were the reasons for implementing BIM Level 2, since we wanted to solve issues of miscommunication and lack of collaboration".

- **Resources and Compatibility**

Participants stressed that it was important to purchase new software in order to address BIM Level 2 requirements and it was critical to ensure that the software was compatible with the other products in the organisation to enable a smooth flow of information across the organisation. As commented by TL4:

"Purchasing new software which are compatible with each other was important for appropriate information sharing".

5.3.3.3 Process Factors

This theme was identified from the interview questions where participants gave their point of view regarding the factors affecting the BIM Level 2 implementation process. From the responses, factors were identified with the help of Nvivo 12 pro and were categorised as sub-themes, which are presented in Figure 5.38 below.

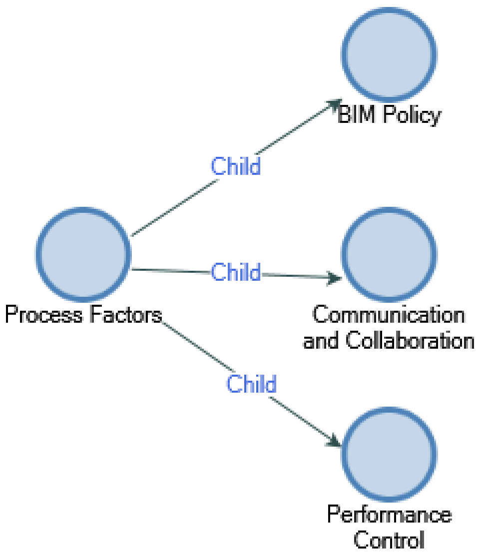

Figure 5. 38 Sub-themes of process factors in CS3.

- **BIM Policy**

Participants from both levels commented that a clear policy for implementing BIM Level 2 was very important to achieve a successful implementation, since BIM was divided into three levels, and each level had its own requirements. The project managers and BIM manager commented that these policies were particularly important for a company which was implementing BIM Level 2 for the first time, since failure in the implementation would result in a loss of time and money. As commented by TL1:

"Policies and guidelines are important to show the way to implement the new process in an efficient way, these would help companies in saving money and time".

- **Communication and Collaboration**

Participants commented that encouraging good communication and collaboration of the staff throughout the implementation process could help to minimise risks. Moreover, if staff shared their experiences and opinions it will help to increase the spread of knowledge across the organisation. As per the words of TL3:

"Communication and collaboration were the keys to spread BIM knowledge faster within the company".

- **Control of Performance**

Participants from both the technical and management levels agreed to achieve a successful implementation there needs to be proper control of performance throughout the whole life-cycle. By controlling the time, and budget was important to ensure that the final outcomes match with the expected results. As commented by ML2:

"Controlling of employees performance, time and budget is critical to ensure successful implementation in all the stages".

5.3.3.4 External Factors

From the analysis of the responses given by the participants in CS3, issues which were outside the control of the company emerged as factors which influenced the BIM Level 2 implementation. These external factors were government support, client demand and knowledge transfer which emerged as the sub-themes identified in Figure 5.39 below.

Figure 5. 39 Sub-themes of external factors in CS3.

- **<u>Government Support and Client Demand</u>**

Participants recognised that government support were the main drivers of the BIM Level 2 implementation. It was commented that the setting of policies and standards by the government and the mandate that made the use of BIM compulsory in all public projects accelerated the adoption by many companies. Moreover, the increase in client demand that resulted from this mandate would also increase the adoption throughout the whole industry. As commented by ML1:

"The adoption of BIM by the entire construction industry can be influenced by high client demand and support offered by the government".

- **<u>Knowledge Transfer</u>**

This factor was mentioned by all the participants, due to its importance during the pre-implementation and implementation phase. Participants commented that the knowledge gained when working on overseas projects was a significant driver for implementing BIM, so that companies could compete with their international counterparts. As commented by ML1:

"As I mentioned before, there are limited policies and guidelines which show the right way of implementing BIM. However, in our case, the knowledge transferred from working with other international companies helped us to set the foundation for BIM".

5.3.3.5 Ranking of Critical Successful Factors Based on their Importance

This section focusses on the importance of the critical success factors for implementing BIM level 2. The importance of the factors was based on the responses of the participants. The ranking of these factors according to their importance in BIM implementation is shown in Table 5.15 below. The same concept used in Case Study 1 and 2 was used for this case study.

Table 5. 15 Importance of the factors influencing BIM Level 2 implementation in CS3.

Factor Categories	***Factors Influencing BIM Level 2***	***Participants and their Responses***										***Average of Importance***
		ML1	**ML1**	**ML2**	**ML2**	**TL1**	**TL2**	**TL3**	**TL3**	**TL3**	**TL4**	
Human Factors	People	□	●	□	□	□	□	○	○	○	□	**M**
	Training of employees	●	●	●	□	●	●	●	●	●	●	**H**
Organisation Factors	Change management	□	●	●	□	□	□	□	□	□	●	**M**
	Top Management	●	●	□	□	●	●	●	□	●	●	**H**
	BIM Knowledge	□	●	●	□	●	●	●	●	□	●	**H**
	Resources	○	○	□	○	○	○	○	□	○	●	**L**
	Compatibility	□	○	○	○	□	○	○	○	□	●	**L**
	Company vision and strategy	●	●	□	□	○	□	□	□	□	○	**M**
Process Factors	Communication and Collaboration	●	●	●	●	●	●	□	●	□	●	**H**
	BIM policy	□	□	□	○	□	○	□	□	○	□	**M**
	Control of performance	□	□	●	□	□	□	●	□	□	□	**M**
External Factors	Governmental support	□	□	□	□	○	●	□	□	□	□	**M**
	Client demand	●	□	●	□	□	□	○	○	□	□	**M**
	Knowledge Transfer	●	●	●	●	●	□	□	□	●	●	**H**

The Nvivo software was used to rank the factors from the most to the less important, based on their frequency during the interviews see Figure 5.40 below.

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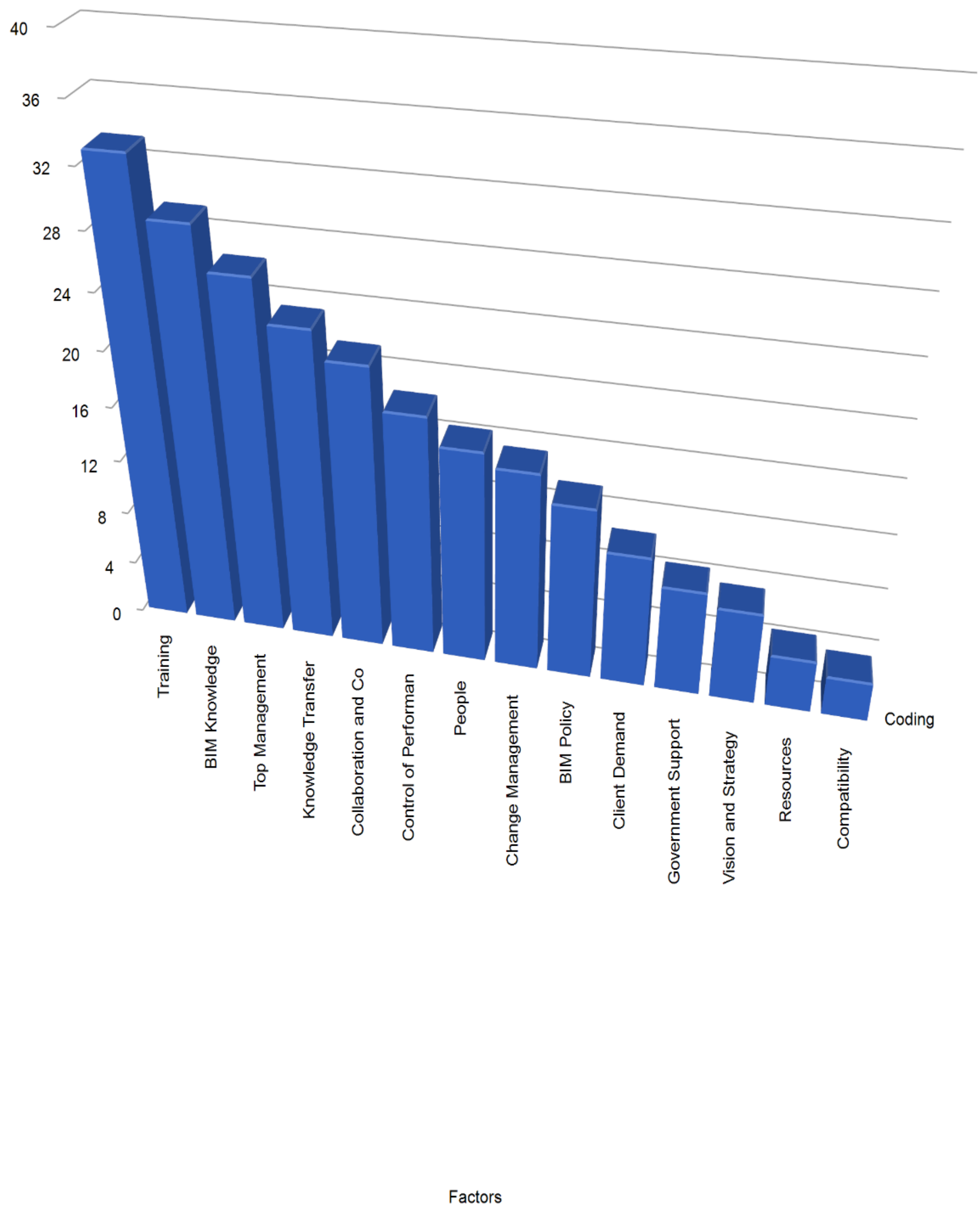

Figure 5. 40 Frequency of success factors for CS3

5.3.4 Mapping Critical Success Factors Influencing BIM Level 2 across Lifecycle Implementation in CS3.

5.3.4.1 BIM Level 2 Lifecycle Implementation

This section identifies the main phases for the implementation of BIM Level 2 in CS3. The implementation lifecycle can be divided in three main phases, which are: pre-implementation, implementation and post-implementation phase. Each phase contains two more stages. The phases were coded as themes and the stages emerged as sub-themes. Table 5.16 below shows the themes and sub-themes of this section presented in Nvivo 12.

Table 5. 16 Themes and sub-themes for implementation phases in CS3.

Themes	Sub-Themes
Pre-Implementation Phase	• Adoption • Planning
Implementation Phase	• Implementation
Post-Implementation Phase	• Evaluation • Update Implementation Plan

5.3.4.2 Pre-implementation Phase

Figure 5. 41 Pre-implementation phase and stages in CS3.

Participants commented that this phase was divided into two stages, as shown in Figure 5.41 above, which were the planning and adoption stages. They commented that in this phase, the knowledge transfer factor was critical for helping the company to adopt BIM Level 2. In the adoption stage, the company decided to embrace the new technology, and from then on, management support was very important through the whole implementation life-cycle. After the decision was made, the planning stage started and the implementation plan and strategy were set in order to meet BIM Level 2 requirements. The plan emphasised the importance of change management and staff training. Participants also commented that at this stage a significant amount of money was needed to purchase software and training. As commented by ML2:

"The implementation plan was set in this phase, where we designed the plan which focused on training of employees to obtain skilled and qualified people able to use BIM Level 2".

In addition, ML1 commented:

"Knowledge transfer obtained from working on overseas projects led us to start the adoption stage".

5.3.4.3 Implementation Phase

Participants commented that it was important in the first project where BIM Level 2 was used, to maintain good communication and encourage collaboration among the parties involved. Moreover, participants stated that what they have learnt in previous projects through the collaboration with large international companies, served as a road map to achieve a successful implementation. The performance of employees was monitored during all the stages of the project to ensure the success of the BIM project. As commented by ML2:

"Knowledge acquired from previous projects and continuous control were critical during the first project after the implementation".

5.3.4.4 Post-implementation Phase

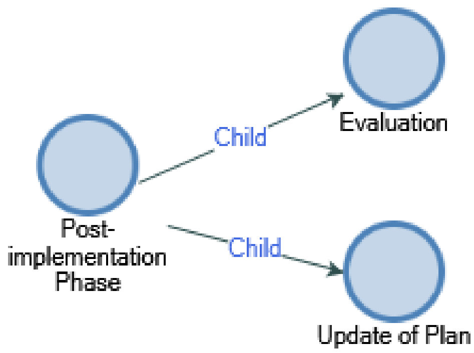

Figure 5. 42 Post-implementation phase and stages in CS3.

After the first project was delivered, the evaluation stage started in order to assess the success of the implementation of BIM Level 2. The sub-phases are presented through Nvivo 12 as shown in Figure 5.42 above. Management commented that the first project was successful because it was delivered within the estimated budget and on time. However, communication needed to be improved and collaboration encouraged when using the digital CDE platform. Therefore, a number of additional seminars were established. As per the words of TL1:

"The first project was assessed as successful, however more training was needed to improve collaboration within the CDE".

On the other hand, management commented that updating the implementation plan needed to happen before moving to the final level of BIM. The new plan will focus on the theoretical aspects of BIM Level 3, since employees will be more skilled in the use of the software by that time. As commented by TL1:

"When the plan will be updated the main focus will be the theoretical aspect in order to gain the appropriate knowledge to meet BIM Level 3 requirements".

5.3.4.5 Mapping the Critical Factors into the BIM Level 2 Implementation Lifecycle in CS3.

This section addressed the last question of the interview protocol, where the participants were asked to identify the factors which affected each phase and stage of the BIM Level 2 implementation. From this analysis, it emerged that all the participants agreed that there was a need to map the success factors across the life-cycle of the BIM implementation. The factors recognised in each phase and stage, based on the responses of the participants, are presented by Nvivo 12 pro and shown in Table 5.17 below, marked with a symbol (✓) in any specific stage where they were considered to be critical.

Factors Category	Factors Influencing BIM Level 2	BIM Level 2 Lifecycle Implementation in CS3				
		Pre-implementation Phase		*Implementation Phase*	*Post-implementation Phase*	
		Adoption Stage	Planning Stage	Implementation Stage	Evaluation Stage	Update Plan Stage
Human Factors	People	✓	✓	✓	✓	✓
	Training of employees		✓	✓		
Organisation Factors	Change management		✓	✓		
	Top Management	✓	✓	✓	✓	✓
	BIM Knowledge	✓	✓	✓		
	Resources		✓	✓		
	Compatibility		✓	✓		
	Company vision and strategy	✓	✓			
Process Factors	Communication and Collaboration		✓	✓	✓	✓
	BIM policy	✓	✓	✓		
	Control of performance		✓	✓	✓	✓
External Factors	Governmental support	✓	✓			
	Client demand	✓		✓		
	Knowledge Transfer	✓	✓	✓		

Table 5. 17 Mapping the factors influencing BIM Level 2 lifecycle in CS3.

The figures 5.43, 5.44, and 5.45 in the following pages show the factors affecting each stage in the lifecycle according to the answers provided by the participants. The themes were identified from the interview questions and the sub-themes emerged from the responses.

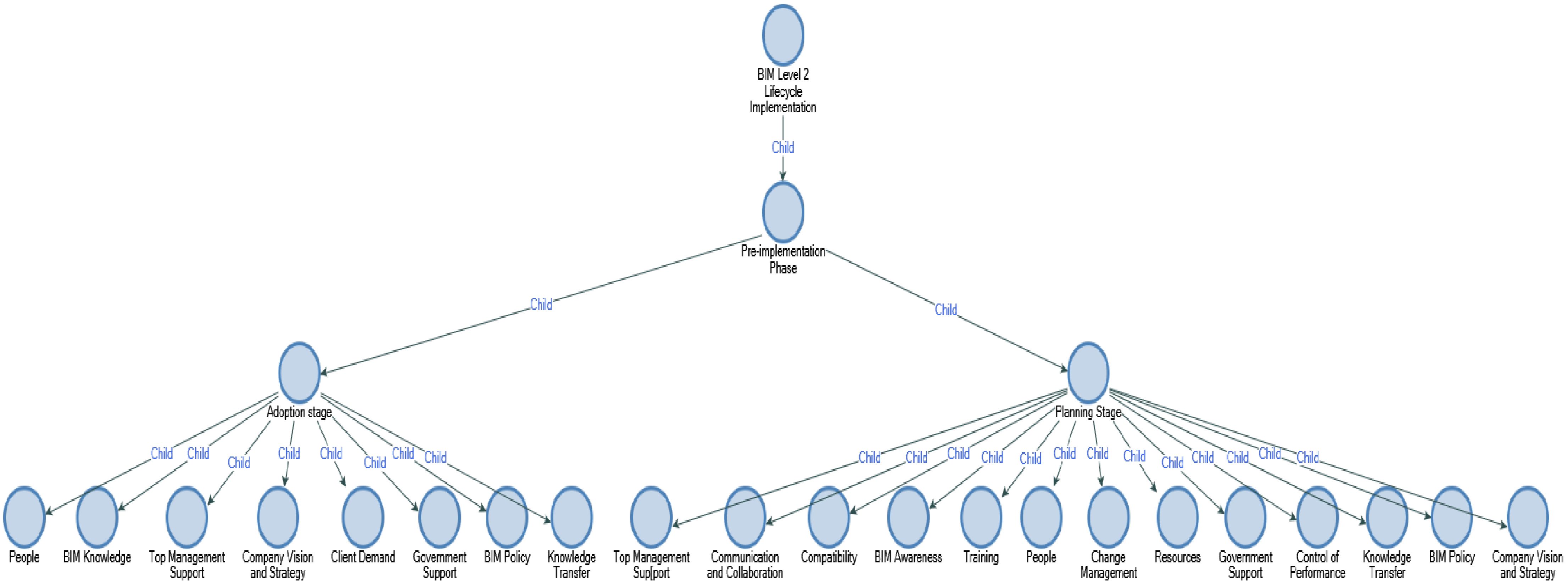

Figure 5. 43 Factors influencing adoption and planning stages in CS3

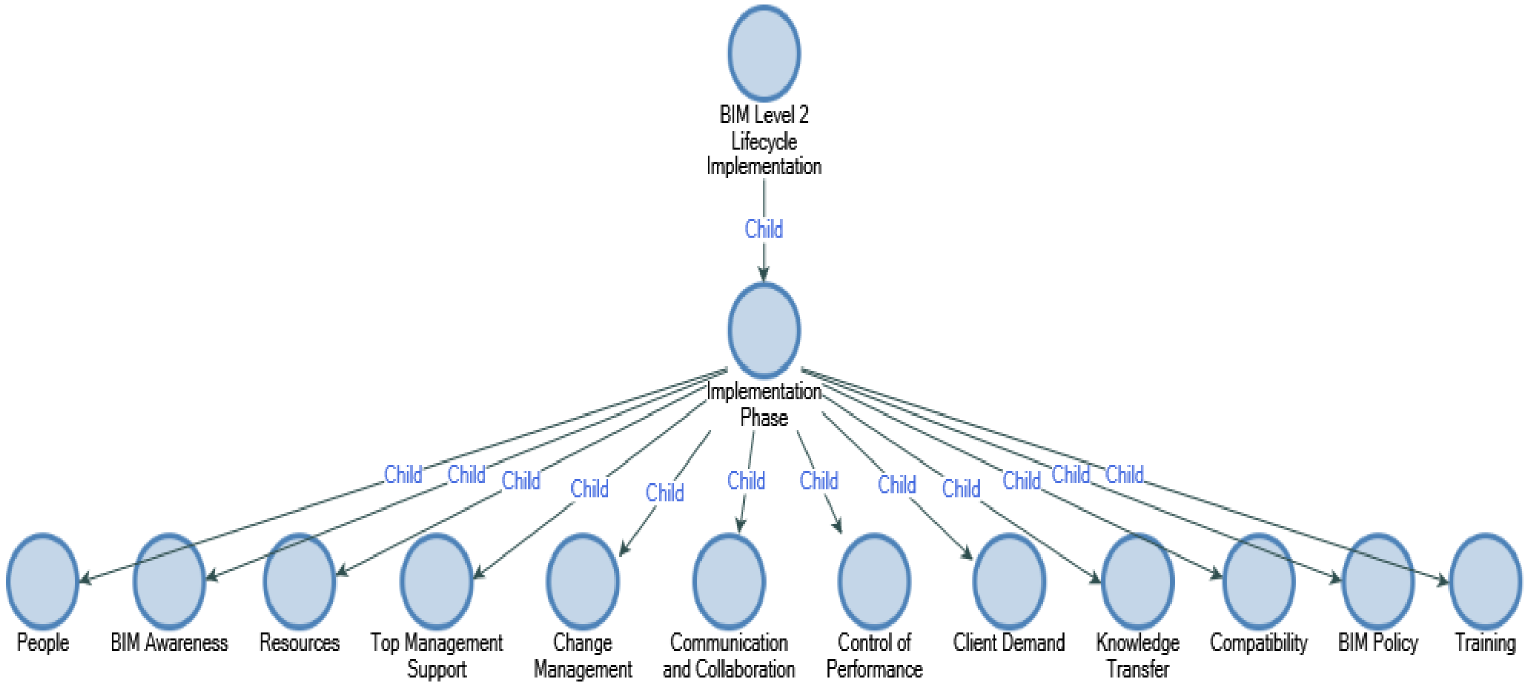

Figure 5. 44 Factors influencing implementation stage in CS3.

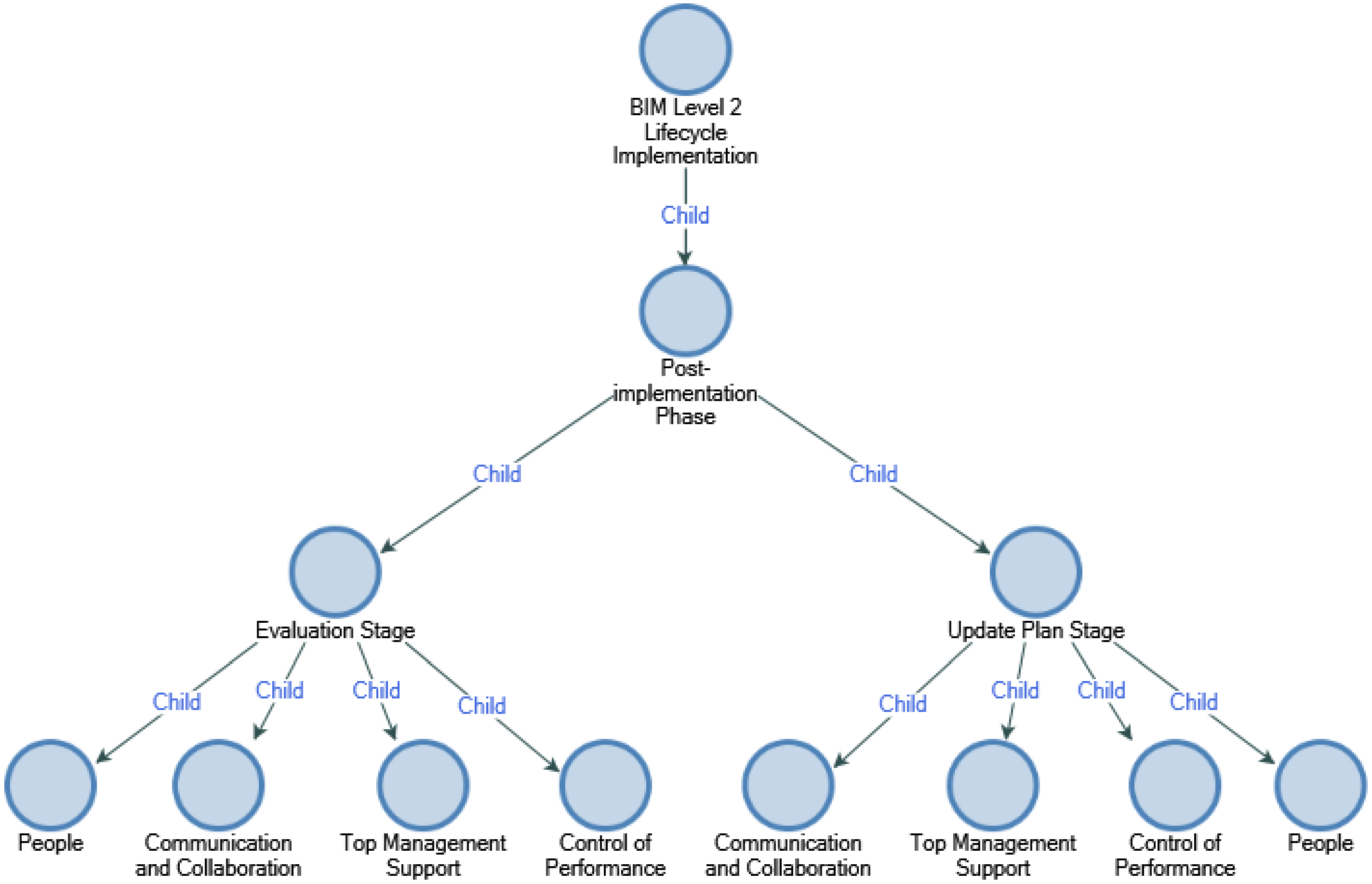

Figure 5. 45 Factors affecting the Evaluation and Update plan stages in CS3.

5.4 Chapter Summary

This chapter presented the analysis of the three case studies. Each case study was analysed separately in order to explore in details each construct, theme and sub-themes to drive most benefits from the responses provided by the participants. All case studies explored the state of BIM in terms of participants' understanding of BIM Level 2, the reason behind embracing the technology and the number of projects delivered using BIM. Afterwards, the barriers faced by each company were analysed to comprehend the obstacles faced by SMEs when implementing BIM.

Eventually, the third construct were explored in each company, which addressed the critical success factors influencing BIM Level 2 implementation. Finally, the fourth and last construct explored BIM Level 2 lifecycle and the identified factors were mapped into each phase and stage of the implementation lifecycle based on the participants' responses.

During the analysis process, new factors were identified from the three case studies, which have not been cited in the literature reviews. In the first case study, hiring an external consultant with previous experience and prosperous knowledge in BIM was critical to ensure a successful implementation of BIM Level 2. On the other hand, control of performance through the implementation lifecycle has been recognised as critical factor from participants in CS2. Finally, in the third case study, knowledge transfer was a critical factor for adopting and implementing BIM Level 2.

CHAPTER SIX: Data Discussion

6.0 Chapter Overview

The previous chapters have justified the rationale of this research, and data collection and analysis procedures have been explained. In chapter five the three case studies were analysed in order to draw out the findings which have helped the researcher to achieve the objectives of this study. This chapter presents the findings which emerged from the analysis of the data obtained from the semi-structured interviews conducted in the three case studies. The findings from both this chapter and the literature will help to achieve the fourth objective of the study which was to propose a framework for the successful implementation of BIM Level 2 in SMEs. This chapter highlights the current understanding of BIM Level 2 by participants and the barriers to the implementation of BIM Level 2 that was faced by SMEs. In addition, a special focus is given to the critical success factors influencing the implementation throughout the life-cycle. The critical success factors influencing BIM Level 2, based on their importance in each phase and stage of the implementation lifecycle, form the main pillar for the framework.

6.1 The State of BIM level 2 in the Three Case Studies.

This first section identified the current understanding of BIM Level 2 in the company based on the results from the interviews. In this section, different themes were identified for both the definition of BIM Level 2 and the reasons for implementing this technology. The motive behind these questions was to determine the level of awareness and the depth of knowledge of the technique within the company and the reasons behind the decision to implement it.

6.1.1 Definition of BIM Level 2

Participants from each company were asked to provide a definition in order to understand the existing knowledge within each company regarding BIM level 2. From the answers provided, sub-themes emerged which were identified with the help of Nvivo 12 pro and are presented below in Figure 6.1 below.

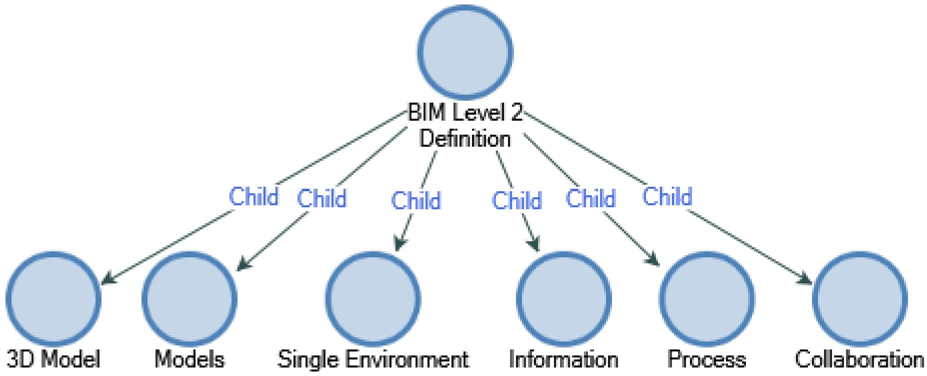

Figure 6. 1 Definition of BIM Level 2 derived from the three case studies.

When asked to define BIM level 2 a number of different elements of the definition emerged from the three case studies which were: a **modelling** technique (most of the participants had this as part of their definition); a process; an information system; a means for sharing 3D models within a **single environment** to improve **collaboration** between stakeholders; and an extension of 3D modelling to include 4D and 5D.

These different responses from the participants show that there was no single definition for BIM Level 2, as each participant had a different understanding, a view which was supported by other researchers as Race (2012); Miettinen and Paavola, (2014) as they suggest in their study that there is a debate on the definition of each level. However, most of the participants agreed that BIM level 2 was a **process** based on **information** sharing, and according to Hardin (2009) these are the two fundamentals of BIM definition, since is vital for BIM to be recognized as a process which aid in information exchange rather than just a software.

6.1.2 Reasons for Implementing BIM Level 2

Participants from each company were asked to provide the reasons for the implementation of BIM Level 2. These reasons could be perceived as the benefits which the companies expected to gain from the implementation. Various reasons emerged across the three case studies which are shown in Figure 6.2 below.

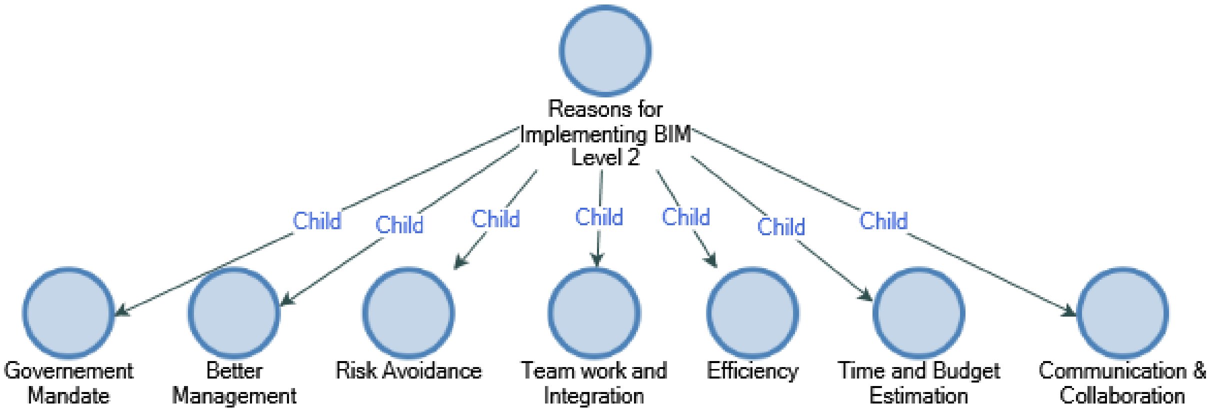

Figure 6. 2 Reasons of Implementing BIM Level 2 in the three case studies.

Collaboration was identified as one of the reasons given to adopt BIM Level 2 which was supported by Zuppa et al. (2009) when they stated that BIM Level 2 was a process which could improve **collaboration**, **communication** and coordination among the stakeholders involved in a project. In CS1 improving the overall **efficiency** was mentioned as one the reasons behind the implementation. According to Ahuja et al. (2018), BIM has the potential to improve **efficiency** throughout the project life-cycle, which could result in better **cost and time estimation** as was also stated by (Aibinu & Ventkatesh, 2014).

One more reason which resulted from both Case Study two (CS2) and Case Study three (CS3) was better **team work** and **integration**. Integration was also highlighted by Bradinath et al. (2016), who expressed that BIM can bring people, system and business together into a more collaborative environment, which could consequently improve efficiency.

Participants from the second case study (CS2) stated that improving the **management** of construction projects was one of the reasons for implementing BIM level 2. Based on the results of a survey conducted by Kunz and Gilligan (2007), it can also be seen that the use of BIM will increase productivity and aid management operations through the lifecycle of a project. Moreover, in addition, from the results of this study also emerged that BIM can help to **reduce risks** faced during project by the improved visualisation which could reduce the level of clashes in the design phase. A study by (Chileshe & Kikwasi 2014) also mentioned risk avoidance and assessment as one of the main reasons for the implementation of BIM.

The government mandate to use BIM level 2 in all public projects from 2016, as stated by both case study one (CS1) and case study two (CS2), was another motive for implementing the technology. This was considered by the majority of participants as the main motive for the implementation, since not using this technology could result in the loss of future public projects as also mentioned by Blackwell (2012) and Gurevich et al. 2017.

To sum up then, it can be stated that the benefits offered from BIM Level 2 were the drivers which led the companies to adopt and implement this technology.

6.2 Barriers Faced During the Implementation

During the semi-structured interviews, the participants from each company were asked to identify the barriers to the implementation of BIM Level 2. The findings which emerged from analysing the case studies, showed that the same barriers were mostly faced by all three companies. These barriers were identified as: lack of client demand, lack of knowledge and expertise, high cost of implementation and resistance to adapt to the new system.

Participants commented that overcoming the unwillingness of clients to use BIM level 2, because they did not see the need for it, was critical to initiate the adoption and implementation stages of a construction project. This agrees with the NBS Report (2015) and Ahmed (2018), as both identified that the majority of clients of smaller companies do not demand the use of BIM Level 2 in their projects.

Lack of knowledge and expertise were mentioned by all three case studies as barriers to implementation, which was also supported by other studies (Liu et al., 2015; Turpin 2016; NBS 2014). In addition, in a study conducted by Ahmed (2018) which identified all the critical barriers faced by a company when implementing BIM found that the lack of expert knowledge had a high impact on the success of a BIM implementation.

The high cost of implementation was identified in various literature. For instance, Liu et al, (2015) stated that the implementation of any new technology will incur high costs. These costs include the cost of training, education and purchasing new software. According to Ganah and John (2014), BIM was more affordable for large companies with greater access to financial resources, a finding which was also supported by other studies (Alreshidi et al., 2017; NBS 2015).

Participants mentioned resistance to change was a barrier because it was not easy to motivate and encourage employees to adapt from the traditional ways of working to the new advanced processes required by BIM level 2. This was in spite of management insisting that BIM must be used. Ahmed (2018) stressed that the social and habitual resistance to change was a natural factor in every human being.

6.3 Factors Influencing BIM Level 2 Implementation in SMEs.

Table 6.1 below identifies the success factors which have been derived from both the literature and the results of the interviews of participants from the three case studies. These are discussed further in the paragraphs following.

Table 6. 1 CSFs identified for BIM Level 2

Factors	***Factor's Influence***
People	Qualified and skilled employees with the right mind set to embrace a new technology in the company will help in a successful implementation.
Training of Employees	Training on both theoretical and technical levels is important to prepare the staff for the integration of a new process.
BIM Awareness	BIM awareness and knowledge about its concept, different levels and dimension will facilitate its implementation.
Resources	Resources as software, hardware and skilled staff are needed to ensure a successful implementation.
Compatibility	Compatibility of software is critical to ensure collaboration and communication which is the core of BIM Level 2.
Top Management Support	Support provided by the management level from the early stage of implementation is very important. Management level should support the implementation by providing training, software and all the needs to ensure a successful implementation.
Company Vision and Strategy	The pre-defined strategy and objectives is a critical factor to motivate company to embrace BIM Level 2.
Collaboration and Communication	Communication and collaboration between staff within the company and all the parties involved in a project is essential to obtain a successful implementation and ensure a proper exchange of information.

BIM Policy	Policies and guidelines available which describes how to achieve a successful implementation are very important through the lifecycle.
Control of Performance	Controlling the performance of employees and setting evaluation measurements is needed to secure that the implementation proceeds as planned.
Government Support	The support from government and the initiative which required the use of BIM Level 2 in all public projects from 2016 was very important to force companies to adopt and implement the new technology.
Client Demand	Client awareness of the benefits offered by BIM will result in more demand for using this technology which consequently will influence companies of all sizes to adopt it.
Consultant	Hiring an expert with previous knowledge and experience in BIM by companies which have limited awareness related to BIM, will aid in the implementation process for designing the implementation plan, training and controlling the performance.
Knowledge Transfer	Knowledge transferred from partnering with other companies or working on projects where BIM is used, will help to obtain knowledge and experience related to this technology to aid the implementation process.
Change Management	Change management is required when implementing a new process. Planning and managing this change is critical to meet BIM Level 2 requirements.

6.3.1 Revised BIM Level 2 Factors

From the literature certain factors were identified and classified into categories which were: human, organisational, process and external.

The findings which emerged from the analysis of case studies, showed that participants had mentioned the same critical factors as the factors mentioned in the literature. Moreover, from the analysis new factors were also identified.

For each of the categories the following factors were identified both from the literature and the case studies:

a. Human: people and training.

b. Organisational: change management; top management support; resources; compatibility; company vision and strategy; and BIM awareness.
c. Process: BIM policy; and, communication and collaboration. Moreover, participants identified a new factor which was the control of performance during the implementation process. From the analysis of case study one and two is was observed that participants from both the management and technical level stated control of performance as a factor,
d. External: government support and client demand. In addition, two more factors were recognised from the analysis, which were the need for an external consultant and knowledge transfer. Hiring a consultant was identified by participants from case studies one and two to be critical, due to the limited knowledge and experience of BIM and the different levels. On the other hand, participants from case study 3, knowledge transfer was stated to be critical.

The participants from the three case studies were asked to examine the factors in each category and identify those that they considered were important to the implementation, and to add any other factors they thought were important. (Each participant was also asked to determine the level of importance, broken down into low, medium and high, the results of this are discussed in section 6.3.3).

Twelve critical success factors identified from the literature were confirmed to be important from the analysis of the three case studies. These were human factors (people and training of employees), organisational factors (change management, top management support, resources, compatibility, BIM awareness and organisation vision and strategy), process factors (BIM policy, communication and collaboration), and external factors (government support and client demand).

The analysis indicated that the participants viewed training as important in order to improve their own skills, this has been identified also in other studies as the one conducted by Crowther and Ajayi (2019) and Ahn et al. (2016). Moreover, communication and collaboration were also acknowledged by the participants to be important since BIM Level 2 required appropriate communication and exchange of information, since this is the main core of BIM Level 2 were this particular level focuses on creating a more collaborative environment, this was also supported in the study by Eadie et al. (2016) and Havenvid et al. (2016)

The findings of the research confirmed that BIM awareness and training of employees were important, since previous knowledge of BIM was essential and giving appropriate training before starting would ensure that the implementation was successful. Moreover, assessing and evaluating people's skills, competencies and awareness within the company was identified important in order to define the level of training they require. These findings were also supported by other studies (Gu and London 2010; Arayici et al. 2011; Eadie et al 2016; Yaakob et al. 2016; and Latiffi et al. 2016).

On the other hand, the barriers faced by the companies when implementing BIM Level 2 were highlighted as important, these barriers were: the high cost of software and training, limited knowledge about BIM and its levels, no client demand to use BIM, resistance to change, lack of expertise and lack of guidance to aid the implementation. Despite the high cost of purchasing new software and training of employees, the change management process required for implementing BIM was identified to be a critical factor which confirmed the work of previous studies (Arayici et al. 2011; Azhar et al. 2014; Ahuja et al. 2018).

Top management support together with company vision and strategy were recognised by participants as being important which was supported by a number of other studies (Ahn et al. 2016; Zakaria et al. 2016; Gilligan and Kunz, 2007; Latiffi et al. 2016; and Waterhouse and Philp 2016). The organisational category to which all these factors belonged was suggested by Ahn et al. (2016).

Government support and client demand were considered important by the participants. These factors were also stated in previous studies (NBS 2016; Ahmed 2018). They were categorised as external factors by Enegbuna *et al. (*2015), because they influence from outside the organisation.

6.3.2 Proposed New Critical Success Factors Influencing BIM Level 2 Implementation from the Case Studies

From the analysis in the previous chapter, three proposed new critical factors were identified. These factors were: 1. hiring an external consultant 2. Control of Performance 3. Knowledge transfer.

1. ***Hiring an external consultant:***

This critical success factor was recognised in the results of case study 1 and 2. It has been categorised as an external factor since the consultant was hired from outside the company. This factor was identified by both case studies to be very important in the planning stage and the implementation stage. Regarding Case Study 1 (CS1), this factor was identified to be extremely important. CS1 was a company which implemented BIM Level 2 in 2015, however before that time they had a shortage of knowledge and experience in BIM technology. Consequently, the company had to hire a consultant with the appropriate knowledge and experience in BIM to ensure that the implementation process would be accomplished successfully. According to the responses provided by the participants, this factor was important for CS1, since the main duties of the consultant were: designing the implementation plan; controlling and supervising the implementation phase; training the employees and evaluating the final results of the implementation. Therefore, due to the extremely limited knowledge and experience regarding BIM, this factor was given a ranking of *very high* importance by the participants regarding its influence on the successful implementation of BIM Level 2. Moreover, after the implementation process was completed, the external consultant was hired by the company as a BIM manager.

This factor was identified in Case Study 2 (CS2) when the researcher went for a “second round” to validate the factor identified in CS1. Consultancy was stated by the participants to be a factor which aided the successful implementation of BIM. However, it should be noticed from the analysis that this factor was ranked as a factor of *medium* importance. The reason for this ranking was the employees in CS2 had previous knowledge of 3D modelling and some level of knowledge of BIM. However, the participants commented that this factor was critical for the design of the implementation plan, training the employees on the new software and changing their mind-set to accept the new technology, which was achieved by the help of the consultant.

When the researcher asked participants in Case Study 3 (CS3) if they required the help of an external consultant, they stated that there was no need since they had some experience and knowledge of BIM from working on projects where BIM was used. Consequently, they implemented BIM based on their own experience and understanding.

2. ***Control of performance:***

This factor was first identified by the researcher in CS2, then it was validated in both CS1 and CS3. It was classified under the process category, due to its influence on the overall performance of the process. For CS2 this factor was recognised as a factor of *high* importance to ensure a successful implementation. Participants commented that management, with the help of the consultant, were responsible for controlling the performance of employees during the implementation stage to ensure that every task was delivered as planned. Moreover, the performance was evaluated based on measurements set by management and the consultant. The evaluation criteria were the time and cost needed to deliver the project and the level of client satisfaction for the final product.

For CS1 and CS3, controlling the performance of the implementation process was identified as important. When the participants of both companies were asked about its importance, they ranked it to be of *medium* importance. However, since the factor was ranked in all three case studies to be either *high* or *medium* importance, this leads to the conclusion that continuous control during the implementation of BIM Level 2 was critical to avoid failure during the process.

3. ***Knowledge transfer:***

This factor was identified from the analysis of CS3 and was categorised as an external factor. According to the participants of CS3, working on overseas projects in Qatar and Dubai, and collaborating with international companies which used BIM, resulted in the transfer of this technology to CS3. Therefore, because of this, when the participants were asked about how the implementation was performed, or if they had the help of any external stakeholder, they commented that the implementation was achieved based on their own knowledge and experience which was gained from other companies.

On the other hand, when CS1 and Cs2 were approached to verify this factor, none of the participants stated knowledge transfer to be an influential factor. The reason behind this was because neither CS1 nor CS2 had worked with another company that used BIM. Moreover, this could be one of the reasons for the limited knowledge of BIM in these two companies which led them to hire a consultant who had this knowledge.

Figure 6.3 illustrates the revised factors influencing BIM Level 2 adoption and implementation in SMEs and categorises the factors into: (a) human, (b) process, (c) external and (d) organisational.

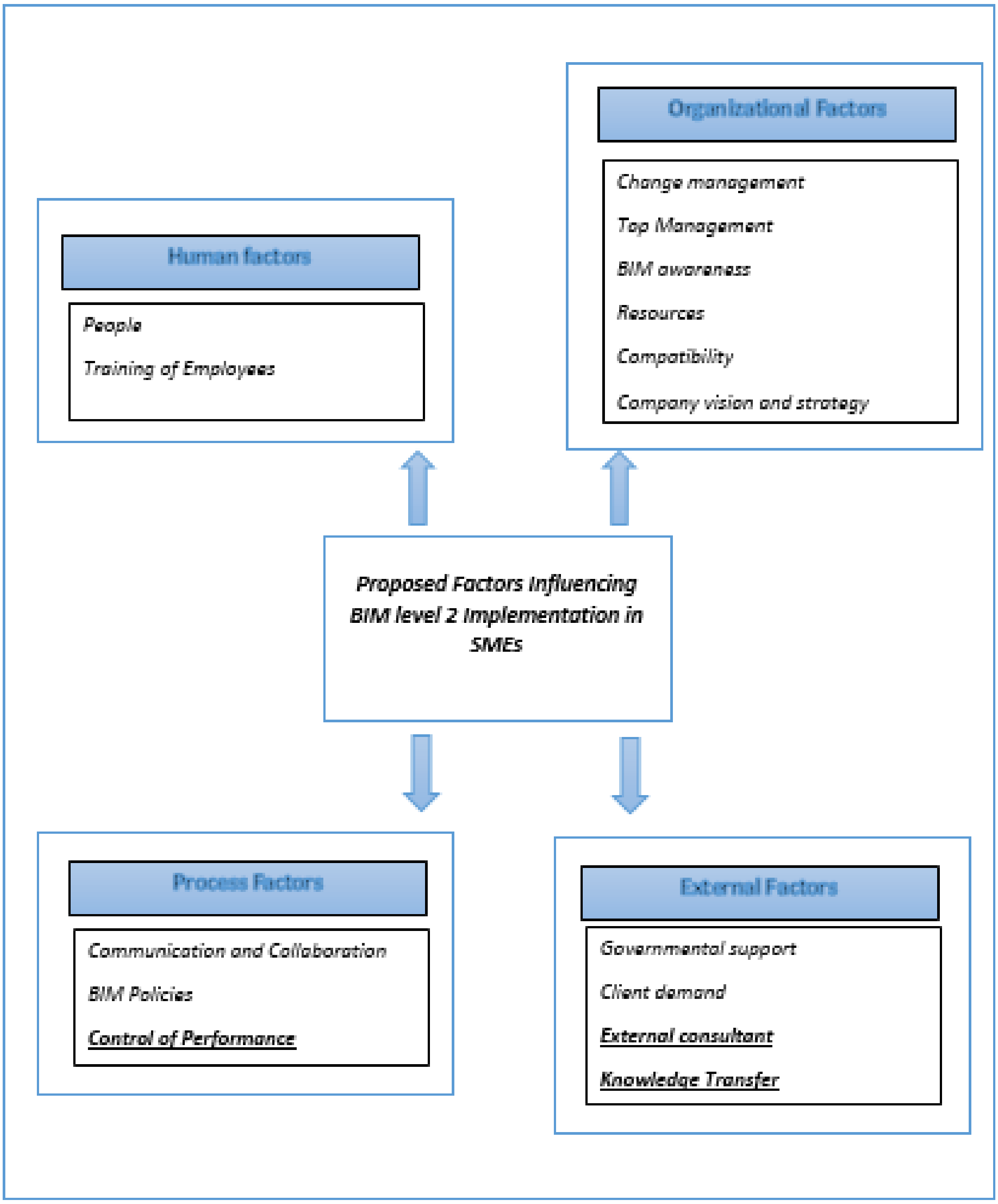

Figure 6. 3 Revised Factors for BIM Level 2 Implementation in SMEs.

6.3.3 Proposed Critical Success Factors Influencing BIM Level 2 Implementation

In the previous chapter the importance of each Critical Success Factor (CSF), for each case study was discussed. This importance was based on the responses of the participants from the semi-structured interviews. It should be noticed that the level of importance for some of the factors was similar for each of the three case studies. On the other hand, there were factors which differed in levels of importance from one case study to another. Therefore, Table 6.2 shows the overall interpretation of CSF importance from the three case studies. This interpretation was based on the level of importance given most frequently by the participants. For instance, if a factor was stated as *medium* importance by most of the 25 participants, then the overall ranking was taken as **medium.** In this way, the researcher was able to interpret the overall ranking as shown in the table below. If a factor was not mentioned in one of the case studies, the symbol (-) was used to denote this. The judgment of the researcher helped to identify the average importance for each factor. This interpretation by the researcher should not be considered as researcher's bias but was derived from the evidence in the literature and the responses from the interviews.

Table 6. 2 Overall Importance of the factors influencing BIM Level 2 implementation from the three case studies.

Factor Categories	***Factors Influencing BIM Level 2***	***CS1=7 Participants***			***CS2= 8 Participants***			***CS3= 10 Participants***			***Overall/ 25 Participants***			***Average of Importance***
		H	**M**	**L**	**H**	**M**	**L**	**H**	**M**	**L**	**H**	**M**	**L**	
Human Factors	People	2	1	4	3	5	0	1	6	3	6	12	7	**M**
	Training of employees	6	1	0	6	2	0	9	1	0	21	4	0	**H**
Organisation Factors	Change management	2	4	1	3	5	0	3	7	0	8	16	1	**M**
	Top Management	6	1	0	6	2	0	7	3	0	19	6	0	**H**
	BIM awareness	6	1	0	8	0	0	7	3	0	21	4	0	**H**
	Resources	2	2	3	1	2	5	1	2	7	4	6	15	**L**
	Compatibility	2	2	3	0	2	6	1	3	6	3	7	15	**L**
	Company vision and strategy	2	4	1	1	4	3	2	6	2	5	14	6	**M**
Process Factors	Communication and Collaboration	5	2	0	6	2	0	8	2	0	19	6	0	**H**
	BIM policy	2	4	1	1	5	2	0	7	3	3	16	6	**M**
	Control of performance	2	1	4	5	3	0	2	8	0	9	12	4	**M**
External Factors	Governmental support	2	4	1	1	4	3	1	8	1	4	16	5	**M**
	Client demand	2	3	2	2	4	2	2	6	2	6	13	6	**M**
	External consultant	6	1	0	3	5	0	-	-	-	9	6	0	**H**
	Knowledge Transfer	-	-	-	-	-	-	7	3	0	7	3	0	**H**

Table 6.2 shows the importance of each of the critical success factors as stated in the interviews with the 25 participants. From the table it can be seen that BIM awareness and training have been ranked as *highly* important during the whole process of implementing BIM Level 2. These two factors influence the capability, skills and mind-set of employees who use the new technology. It was found that it was easier to implement BIM if companies had previous knowledge of BIM and some experience in using this technology. For instance, in this study it emerged that due to the previous knowledge and experience acquired, the company in Case Study 3 did not need to hire an external consultant since the implementation was based on their own knowledge. On the contrary though, in case study 1 and 2, employees lacked the necessary knowledge and experience, therefore hiring an external consultant was necessary in order to achieve a successful implementation.

On the other hand, some factors were identified in the table as *medium* importance, which were: available BIM policies, continuous control of performance, client demand to use BIM Level 2 and the government support. It can be argued from the responses of the participants that more the factors influence the implementation lifecycle more it become important. Therefore, these factors were identified as *medium* importance since they affected only a part of the whole lifecycle of implementation. On the contrary, some factors were identified as *high* importance, because they influenced most of the stages of the implementation life-cycle as Top management support and BIM knowledge and awareness.

Table 6.2 shows the importance of the factors based on high, medium and low rankings. However, there was a need to rank the factors and sort them from the most influential to the least influential in order to meet the objectives of this study. The ranking was identified with the aid of Nvivo 12 pro, based on the responses of the participants and the frequency of the factors during the interviews. The ranking from the most to the least influential is shown in Figure 6.4.

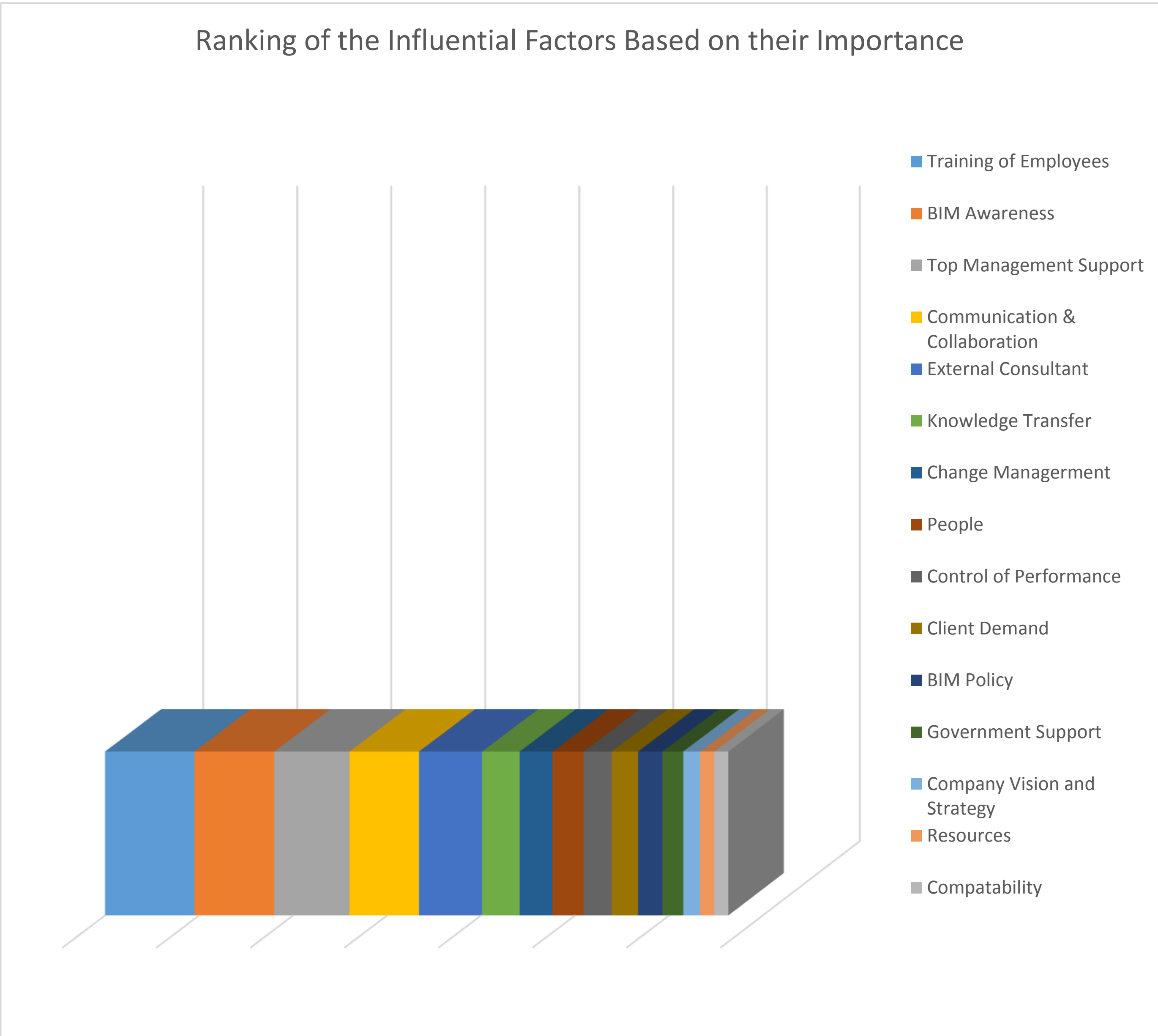

Figure 6. 4 Ranking of the Influential Factors based on their Importance

6.4 Proposed BIM Level 2 Implementation Lifecycle Model

From the literature review and the responses provided by the participants, three main phases were identified for BIM Level 2 implementation within an organisation. These phases were pre-implementation, implementation and post-implementation. The three case studies followed a similar lifecycle for the implementation, consequently no new phases or stages were recognised from the analysis. According to the results, the highest level of importance for the implementation lifecycle was given to both the planning and implementation stages. In the following section the five stages identified from the analysis are described.

6.4.1 Pre-implementation Phase

- ***Adoption stage***

In this stage the decision for embracing BIM level 2 technology was taken. This stage included the analysis and assessment of resource allocations, the selection of the project team and the approval by management to give financial support for the whole process. At this stage, the consultant needed to design the implementation plan as well as the vendors of the required software are selected by management (Kumar 2015).

Participants from the three case studies stated that the need for qualified staff, the financial support of the management level, availability of resources and the demand by the client to use BIM Level 2 in their project, are all important factors for influencing the organisation to adopt BIM. Moreover, participants from CS3 commented that the knowledge transfer factor was important at this stage for BIM level 2 adoption.

- ***Planning stage***

In this stage the organisation worked to the implementation plan which comprised: the change management process for implementing BIM, the theoretical and technical training of employees to help them to adapt to the new system. In addition, checklists were designed at this stage to be used for the post-implementation evaluation stage. Moreover, the integration of the Common Data Environment (CDE) as a platform to share data, information and models took place at this stage (Arayici et al. 2011; Dell 2011)

Participants in all three case studies emphasised the importance of this stage, since the success or failure of the implementation of the new process depends on proper planning.

This high importance given to this stage can be seen since most the factors were identified to be critical at this particular stage.

6.4.2 Implementation Phase

The findings show that this phase includes only one stage, the participants of all three case studies, recognised to be the implementation stage.

- ***Implementation stage***

At this stage of the implementation, BIM Level 2 was used for the first time. At this stage some issues were observed by management and the consultants. For example, resistance to adapt to the new process was evident at this stage. This issue was clear in CS1, therefore, according to the participants more training was needed (Arayici and Aouad 2011). In CS2 the implementation stage was managed properly, due to the appropriate collaboration between the parties involved in the project, which, according to the participants, resulted in a successful implementation.

In all the three case studies, staff from the management and technical level participated in the implementation of BIM Level 2 on their first project. Moreover, in all the case studies, maintaining communication and collaboration was critical to ensure the success of the implementation. Regarding CS1 and CS2, both management and the consultant were responsible for controlling the performance of employees and ensuring the tasks were delivered according to the pre-defined implementation plan.

6.4.3 Post-implementation Phase

- ***Evaluation stage***

In this stage the performance during the implementation stage was be evaluated. This evaluation was based on checklists designed by management with the help of the consultant in CS1 and CS2. These checklists evaluated the overall performance of employees during the implementation. The performance was based on: the effectiveness of communication and collaboration, the extent of conflict between parties involved, and the data exchange using the CDE. Moreover, the checklists included: the assessment of the quality of the final product, whether it was delivered on time, and within budget, and the level of client satisfaction (Arayici et al. 2011; Hardin 2009).

In CS1 and CS3 the participants from the management level commented that the evaluation process resulted in some deficiencies in exchanging data appropriately on the CDE and resistance to the adoption of the new process which led to the need for the additional training of employees. Regarding CS2, the evaluation process resulted in a successful implementation since the checklists were all completed and the implementation plan was achieved successfully.

- ***Update plan stage***

At this stage of BIM life-cycle, the implementation plan was updated in case any deficiency was detected during the implementation stage or any issues emerged from the evaluation. At this stage management made the decision to improve the process by delivering more training for employees and optimising the overall performance.

In CS1, the plan was optimised by delivering more training for employees since resistance to the adoption of the new process was detected at the evaluation stage.

Participants in CS2 commented that there was no need for updating the plan since the implementation was evaluated as successful. However, it was commented that an update would be needed when BIM Level 3 will be implemented.

For CS3, improving the implementation plan was needed. This focused on delivering additional seminars for employees to improve their skills and abilities to use BIM Level 2. Moreover, updating the plan would be needed when implementing the next BIM Level.

To sum up, it can be noticed that in CS1, there was a need for more training which resulted from the evaluation stage. While in CS2, the implementation was defined as successful by the participants, since all the checklists were completed, therefore there was no need for updating the plan. However, the plan will need to be updated when the company implements BIM Level 3. Regarding Case Study 3 (CS3), during the implementation it emerged there was some resistance to adapt to the new process and the use of CDE, therefore more training and forcing the use of BIM Level 2 was the approach used by management to solve these issues. Based on the lifecycle which emerged from the three case studies, BIM Level 2 implementation was comprised of three phases and five stages which were:

- Pre-Implementation phase - adoption stage and planning stage
- Implementation phase - Implementation stage.
- Post-Implementation phase – evaluation stage and update plan stage

The proposed BIM Level 2 implementation lifecycle is presented in figure 6.5.

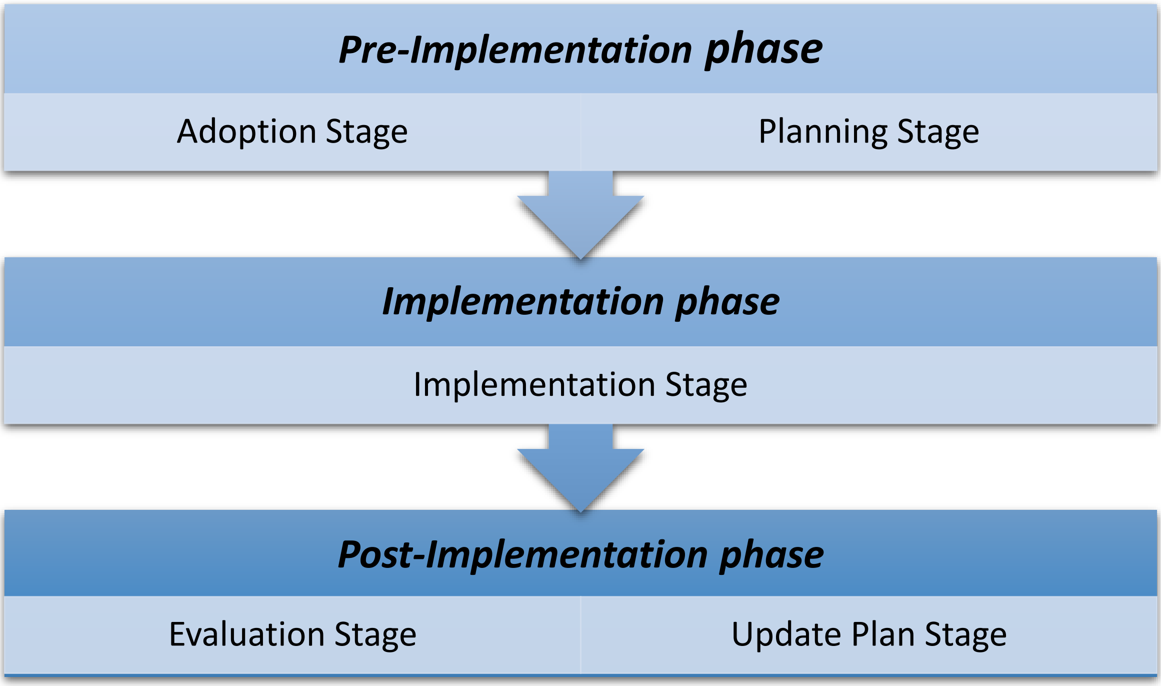

Figure 6. 5 Proposed BIM level 2 lifecycle implementation.

6.4.4 Mapping the Critical Success Factors on BIM Level 2 Implementation Lifecycle.

In the previous sections the factors influencing BIM Level 2 and the phases and stages of the implementation lifecycle have been identified. However, in order to meet all the objectives of the study, there is a need to map the factors on to the implementation lifecycle. In chapter five the factors were mapped on to the lifecycle for each case study. The mapping was achieved by analysing the responses of the participants, since one of the interview questions was to identify the factors which were most influential in each stage of the implementation lifecycle.

However, there was a need for the overall mapping of the factors from all three case studies. This final mapping was identified from the responses given by all participants which will be used for the framework proposed by this study. Moreover, the judgment and understanding of the researcher helped in the mapping of the factors on to the BIM Level 2 implementation lifecycle. This interpretation of the researcher should not be considered as researcher's bias but was derived from reviewing the literature and the indications of previous studies, as well as observation during all the semi-structured interviews. Table 6.3 shows the overall mapping of the influential factors identified by the participants, on to the BIM Level 2 implementation lifecycle.

Table 6. 3 Overall Mapping of the factors on BIM Level 2 implementation lifecycle.

Factors Category	***Factors Influencing BIM Level 2***	***BIM Level 2 Lifecycle Implementation*** — *Pre-implementation Phase*		*Implementation Phase*	*Post-implementation Phase*	
		Adoption Stage	Planning Stage	Implementation Stage	Evaluation Stage	Update Plan Stage
Human Factors	People	✓	✓	✓	✓	✓
	Training of employees		✓	✓		✓
Organisation Factors	Change management		✓	✓		
	Top Management	✓	✓	✓	✓	✓
	BIM Knowledge	✓	✓	✓	✓	
	Resources		✓	✓		
	Compatibility		✓	✓		
	Company vision and strategy	✓	✓			
Process Factors	Communication and Collaboration		✓	✓	✓	✓
	BIM policy	✓	✓	✓		
	Control of performance		✓	✓	✓	✓
External Factors	Governmental support	✓	✓			
	Client demand	✓		✓		
	Knowledge Transfer	✓	✓	✓		
	External Consultant		✓	✓	✓	✓

6.5 Chapter Summary

The 25 semi-structured interviews contributed by providing a deep understanding of BIM Level 2 in SMEs. The discussion focused mainly on four sections. The first section concentrated on understanding the current situation of BIM Level 2 within the companies, in terms of their knowledge of BIM and the reasons which drove them to implement it. The second section discussed the barriers faced by SMEs while implementing BIM level 2, which included the high cost of implementation, limited knowledge and expertise, limited demand from the clients to use BIM Level 2 and limited guidance on how the implementation can be achieved.

The third section discussed the critical success factors (CSFs) influencing the implementation of BIM in SMEs. Twelve factors from the literature were identified as important from the responses to the interviews. In addition, three more factors emerged from the analysis to be recognised as new factors. These factors were: hiring an external consultant, control of performance and knowledge transfer. A validation process was undertaken to ensure the validity and reliability of each new factor. The validation process was based on asking the participants in CS2 and CS3 about the new factor identified in CS1. The same process was used for the new factors identified in CS2 and CS3 to ensure validity of the new factors.

From the comments of the participants from the three case studies, the influential factors were classified under four main categories which were: 1) human; 2) organisational; 3) process; and 4) external. The factors classified under each category are as following:

- Human factors: people and training of employees.
- Organisational factors: change management, BIM awareness (Knowledge), top management support, company vision and strategy, resources and compatibility.
- Process factors: control of performance, communication and collaboration and BIM policies.
- External factors: client demand, government support, external consultant and knowledge transfer.

Then the discussion moved to identifying the implementation phases and stages of BIM Level 2. The identified stages were: adoption, planning, implementation, evaluation and update plan. Furthermore, in this chapter, from the comments of the participants, the CSFs were prioritised based on their importance presented by Nvivo 12 pro as shown in figure 6.2. Then, these factors were mapped on to the implementation lifecycle of BIM Level 2 as shown in table 6.3 in order to meet objectives 3 and 4 of this study. Finally, the prioritisation and mapping of factors will be used to construct the conceptual framework in the following chapter in order to achieve the last objective of this study.

CHAPTER SEVEN: Proposed Framework and Validation

7.0 Chapter Overview

The current research aims to explore the implementation of BIM Level 2 in Small and Medium enterprises (SMEs) in the UK construction industry.

In this chapter a framework will be proposed for the successful implementation of BIM level 2 in SMEs. The supporting outline for this framework was addressed in the previous chapter.

The following objectives were addressed in order to propose the framework:

1. To identify the barriers to the adoption and implementation of BIM Level 2.
2. To explore the current situation of BIM Level 2 in the SMEs in the UK construction industry.
3. To investigate and analyse critical success factors influencing BIM Level 2 implementation.
4. To map the critical success factors on to the BIM level 2 implementation lifecycle base on their importance.
5. To propose and validate a framework for implementing BIM level 2.

In the prior chapter the results from three case studies were analysed to identify the critical success factors which influenced the successful implementation of BIM Level 2. The conceptual framework suggested in Chapter 3 was modified based on the results that emerged in the previous chapter. Therefore, a synthesised framework has been proposed in this chapter for BIM Level 2 implementation. Moreover, the last section of this chapter will demonstrate the validation process for the proposed framework and present the findings.

7.1 Rationality for Proposing the Framework

One of the propositions of this research was to develop a model which can be used by SMEs within the UK construction industry to implement BIM Level 2 successfully. In chapter one the research questions and objectives of the study were stated. Moreover, to comprehend the necessity for implementing BIM Level 2, the associated literature was reviewed in chapter two. From the review, the subsequent issues were identified:

1. There are limited guidelines to assist SMEs on how to implement BIM. This is reflected by the low adoption rate (Eastman *et al.*, 2011; Migilinskas *et al.*, 2013; Fox 2014; Poirer at al. 2016; Daynti at al. 2017; Dowsett and Harty 2018; Vidalakis et al. 2019). Therefore, the proposed framework has been designed to fill that gap in knowledge.
2. There is a lack of understanding of BIM Level 2, according to NBS (2014) and Turpin (2016) argued that although the construction industry sector was aware of the different levels of BIM implementation, there was debate regarding the functions within each level and how they can be implemented. Moreover, one of the main issues related to the limited implementation of BIM Level 2 in SMEs was the lack of knowledge (ahankoob 2019). Hence, this research looks specifically at BIM Level 2 in order to address this issue.
3. According to Bradinath *et al.* (2016), there were few studies which focussed on BIM adoption, and only 6% of publications focused on adoption by SMEs. This result confirms the findings from a study by Dainty et al., (2017), which stated that small and medium sized companies did not feel that BIM was appropriate for them since they were ignored by policies initiatives. Moreover, there were only a few studies which provided explored the CSFs for BIM adoption and implementation in the UK (Mohammad et al, 2018). Also, according to Koucha et al., (2018) SMEs are unaware of how to implement BIM, and how it could increase their competitiveness. Consequently, this research, by exploring the critical factors influencing BIM Level 2 adoption and implementation, has aimed to propose a framework to assist SMEs in the adoption and implementation process.

The following stages were completed in order to develop the proposed framework:

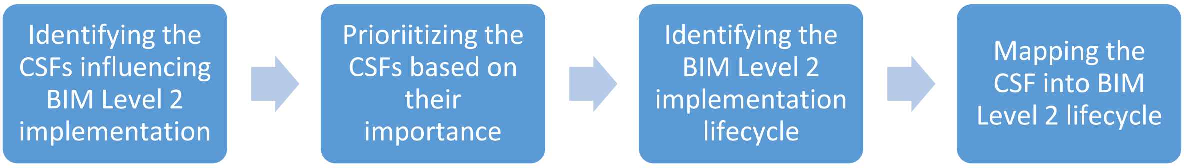

Figure 7. 1 The steps for developing the proposed framework.

The research methodology adopted for this research was explained in chapter four and a proper justification for the use of the chosen methods was provided in this chapter. In order to address the research questions, a qualitative case studies approach was adopted. Three companies, one small and the other two medium-sized, which had implemented BIM Level 2 were chosen as case studies to provide the empirical findings for the research which were presented in chapter 5.

From the analysis of the three case studies, 15 critical success factors were identified which have been prioritised according to the amount of influence they had on the implementation process of BIM Level 2.

The BIM Level 2 implementation lifecycle was revised based on the findings that emerged from the analysis. The Phases and stages that were identified were the same for the three case studies.

The proposed framework was derived from an analysis of the results from the three case studies and designed to be used by SMEs as a guide map for implementing BIM Level 2.

7.2 The Proposed Framework

The proposed conceptual framework was built on a foundation of two main pillars which were identified in the previous chapters. These two pillars were the critical success factors that influenced the BIM level 2 implementation lifecycle as well as the lifecycle itself. The framework is shown in Figure 7.2 below and further explained in the following sections:

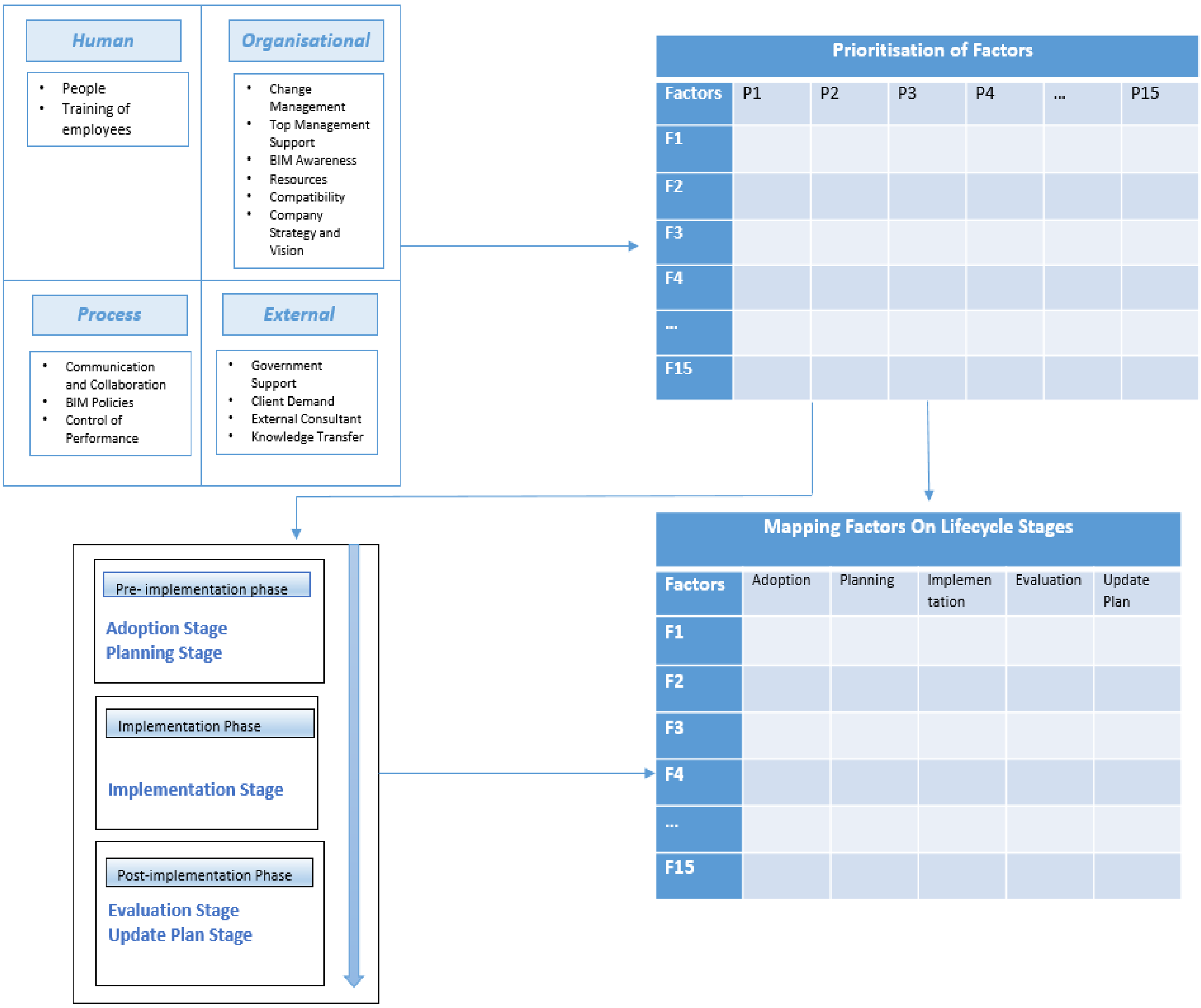

Figure 7. 2 Proposed Conceptual Framework for BIM Level 2 Implementation across Lifecycle.

7.2.1 Development and Understanding the Framework

The justification for proposing this framework was to support small and medium companies in the implementation of BIM Level 2. The literature review (Chapters 2 and 3) and the findings identified in Chapter 6 aided in the identification of twelve critical success factors (CSFs). Three new factors also emerged under the category of external and process factors as shown in the framework in figure 7.2. Each factor was then given an importance based on a scale of *high, medium and low*, according to the data provided by the participants who contributed to the study. Consequently, based on both the responses of the participants and the understanding of the researcher, acquired from reviewing the literature, these factors were ranked from the most to the least important. The importance and ranking given to each factor, identified in chapter six in table 6.2 and figure 6.4, is represented by the "Prioritisation of Factors" box shown in the framework.

The framework shows the five stages for implementing BIM Level 2 in SMEs which are classified under the three main phases. These stages and phases were identified from the literature and the findings of the case studies. In chapter six, the CSFs were mapped on to the implementation lifecycle as shown in table 6.3. The mapping shows the factors which were influential at each stage and phase during the implementation, which is represented by the "Mapping factors in lifecycle stages" box in the proposed framework.

It can be seen from figure 7.2 that all the tables are linked between each other with arrows. This is to show that the framework was built on procedures as shown previously in figure 7.1, which means that the final output cannot be achieved without going through each step of the framework. For instance, the mapping cannot be achieved without firstly prioritising the factors, then integrating them into the stages of the implementation lifecycle.

This framework was proposed based on the issues identified in the literature which stressed that there was limited research and guidance to aid SMEs for the implementation of BIM Level 2. Therefore, this framework, which can be used by small and medium sized companies as a guide to achieve a successful implementation was designed to address this gap in knowledge.

However, in order to meet the fifth and last objective of this research there was a need to validate the framework. This validation will be presented in the next section.

7.3 Framework Validation

In order to achieve the fifth objective of the study, validation of the framework was needed. According to Rossman and Rallis (2017) it is crucial for the right participants to take part into the validation process as their understanding and awareness could be reflected on the validation results. On the other hand, Morgan (1997), asserted that recruiting participants with previous knowledge about the research could facilitate the interaction between the researcher and the participants during the validation process. Therefore, in order to guarantee understanding and awareness of participants throughout the validation process, the researcher approached five participants who previously contributed in the semi-structured interviews which made them aware and familiar of the aim and objectives of the study. The benefits of familiarity being seen to be more important to this study, than any bias that might occur, as a result of their involvement.

The researcher, at first, contacted seven participants by sending emails to invite them to take part into the validation. However, only five replied and agreed to participate Three of the participants were given face to face interviews, while the other two, to fit in with their work commitments, preferred to be interviewed using Skype. All the interviews and meetings were recorded and transcribed. Table 7.1 shows, for each case study, the participants who contributed in the validation of the framework, and the type of interview.

Table 7. 1 Participants who contributed in the validation process.

Case Study	***Participants***	***Type of Interview***
Case Study 1 (CS1)	Project Manager	Face to Face
	BIM Manager	Face to Face
Case Study 2 (CS2)	BIM Manager	Skype
	Architecture Manager	Face to Face
Case Study 3 (CS3)	Architecture Manager	Skype

The proposed framework illustrated in figure 7.2 was sent by email to the participants 3 days before the interviews in order for them to study the details of the framework and for the researcher to be able to answer any questions they had before the interviews took place. Once the interviews and meetings were undertaken, the framework was presented orally. The presentation showed how the components of the framework were developed, and how the findings obtained from the interviews would be integrated into the framework, to be used as a guide map to obtain a successful implementation. The duration of each presentation was 10-15 minutes and the components of the framework, including the CSFs and the stages of the implementation lifecycle were presented and discussed. After the presentation, the participants were asked a set of questions which were designed by the researcher to validate the components and the framework as a whole. The questions were as follows:

- What do you think about the validity of the components?
- What do you think about the entire validity of the framework?
- What is your opinion about the practical use of the framework?
- What are your recommendations before using this framework?

In general, the feedback was positive and the participants gave their approval for the framework. The feedback provided by the participants is highlighted in the next section.

7.3.1 Validation of the Components

- **Critical Success Factors:**

All participants agreed that the critical factors presented, influenced the adoption and implementation of BIM Level 2 within any company and had been clearly classified into the four main categories. The project manager in case study 2 commented:

"*When BIM Level 2 is implemented, there are factors which influence the process, from both inside and outside the organisation"*

- **Prioritisation of the Factors:**

The participants stated that the importance given to each factor was clear and well explained. In addition, they commented that the prioritisation of the factors was coherent, their judgement being based on their own experience in implementing BIM Level 2. As the BIM manager in case study 1 commented:

"*All the presented factors are clear and the ranking from the most to the less influential factor is well explained*"

- **Implementation Lifecycle (Phases and Stages):**

The participants agreed that the phases and stages of the implementation of BIM Level 2 identified by the research were correctly identified. As commented by the architecture in case study 3:

"*These stages, from the adoption to the update stage, were embraced in our company in order to implement the new technology"*

- **Mapping the Factors into the Implementation Lifecycle:**

The participants agreed with the mapping presented by the researcher. They commented that the identification of the factors which influenced each stage of the implementation was logical and clear. The project manager in case study 2 commented:

"It is clear which factor affects each stage and phase of the implementation, and the logic of the mapping is clear and could be understood"

7.3.2 Feedback of Participants on the Practical use of the Framework

After questioning the participants about the components of the framework, they were asked the third question shown in Appendix B, which addressed how it could be applied in practice. All participants commented that the framework was easy to use, because it showed the influential factors affecting each stage of the implementation. Moreover, the participants stated that the framework will help to achieve a successful implementation. All the participants approved on the critical success factors, except the architecture manager in case study 2 who commented that the **knowledge transfer** factor, identified originally in case study 3, was not considered in their company. Despite that, the architecture manager said that this factor could apply for companies which partnered with other companies that used BIM previously.

On the other hand, the BIM manager commented that the framework will shed light on the factors which should be considered in each stage, and as a result, special attention would be given to them. Furthermore, all the participants commented that the framework will help organisations in building of a plan which will support them through the implementation of BIM Level 2, and set the foundations for BIM Level 3 in the future. The consensus of those interviewed was that the framework would assist small and medium companies to adopt and implement BIM Level 2 since it was recognised as a step toward achieving the required level of BIM as mandated by the UK government in 2016.

7.4 Recommendations for the Use of the Framework.

These recommendations have been derived from the answers provided by the participants, who mentioned that the following points should be considered before using the framework for implementing BIM Level 2:

- **BIM Awareness:** ensure that there was a proper awareness of BIM within the company in terms of its content and the resulting benefits.
- **BIM Level 2 Knowledge:** understand the core deliverables from BIM Level 2, especially support for collaboration, how it aids information sharing, its processes and the use of a single environment (i.e. CDE). This will help employees to differentiate

between the different levels and understand when a full implementation of BIM Level 2 is achieved.

- **BIM Barriers:** understand the barriers which could be faced during the implementation of BIM Level 2, which will result in better handling of the issues and avoiding the risks.
- **Organisation Features:** understand the characteristics of the organisation in terms of structure, resources and flexibility to adapt to innovation. In addition, an internal analysis is required to comprehend the strength and weaknesses of the organisation, as well as its vision and objectives during the pre-implementation phase.
- **Management Support:** ensure the support of management is given through the whole implementation lifecycle to help solve issues relating to the high cost of software and training and to adopt the right approach to handle possible resistance to change. Moreover, management support is critical to ensure the employees will receive the appropriate training to be able to work within a BIM environment.
- **BIM Adoption and Implementation:** recognise the adoption and implementation factors which influence the process based on their importance, and design an appropriate plan for the implementation.

7.5 Chapter Summary

In this chapter, a framework for adopting and implementing BIM Level 2 in small and medium-sized companies has been presented. The empirical findings of the semi-structured interviews presented in chapter five and six, and the literature in chapter two and three have helped in the development of this framework. The framework is composed of four main components which are: the identification of critical success factors, the prioritisation of the factors according to their influence on the implementation lifecycle and the mapping of those factors to the phases and stages of that lifecycle.

The framework was proposed in order to address the fifth objective of this study and was validated by both face-to-face and Skype interviews. The validation demonstrated that the framework was suitable for practical use and recommendations were provided in order to use the framework effectively.

CHAPTER EIGHT: Conclusion and Recommendations

8.0 Chapter Overview

In the preceding chapters, the rationale for carrying out this research was addressed in chapter two, then the proposed conceptual framework was presented in chapter three for the implementation of BIM Level 2 in SMEs. Moving forward to chapter four, the methodology adopted by this research was explained with the justification for the approach taken, then chapter five and six presented and discussed the empirical data obtained from the three different case studies. Chapter seven presented the framework for the implementation of BIM Level 2 in SMEs, which focused on the critical success factors and the implementation lifecycle.

In the former chapter, the critical success factors influencing the implementation of BIM Level 2 in SMES were presented and revised based on the findings obtained from the three case studies, and, the phases and stages of the implementation lifecycle were identified. This chapter aims to summarise the findings of this research according to the results obtained from the case studies. Moreover, this chapter will identify the contributions made to knowledge and practice, the limitations of the study and the recommendations for future research.

8.1 Revision of the Research Objectives

The main aim of this research was to explore the implementation of Level 2 Building Information Modelling (BIM) in Small and Medium-sized Enterprises (SMEs) in the UK construction industry. During the literature review process, it was highlighted that the implementations of BIM Level 2, within large companies in the UK, were increasing. On the other hand, it was identified that small and medium sized companies were different, since the implementation process was slow compared to large companies. The literature identified various issues which explained this situation. Those issues were related to the high cost of implementation, the readiness to use ICT innovation, a lack of client demand to use the technology, limited knowledge and expertise of BIM, and a lack of guidelines for implementation in SMEs. Because of the lack of BIM frameworks in the literature specifically designed to meet the needs of SMEs, the technology was considered to be unsuitable for that purpose, hence the main focus of this research was to fill that gap in knowledge.

Therefore, the first chapter of this research presented the objectives which needed to be achieved in order to address the aims of this study, which were as follows.

Objective one: To identify the barriers to the adoption and implementation of BIM Level 2.

A wider perception was needed of the issues faced when adopting and implementing BIM Level 2 in the UK construction sector. This objective was achieved following the review of the literature, where the barriers were identified as the high costs of software and training, a lack of expertise and knowledge of the technology, a lack of client demand to use BIM, limited readiness to adopt new ICT innovation, and cultural issues within organisations.

Objective two: To explore the current situation regarding BIM Level 2 for SMEs in the UK construction industry.

The first objective that needed to be addressed in this study was exploring and investigating the existing situation for BIM Level 2 within small and medium sized companies. This was presented in chapter two, where the topics of BIM Level 2 and SMEs were discussed, by referring to the existing studies related to the topics. The importance of SMEs in the UK construction sector, who make up 99% of organisations in the UK, and the significant impact that they have on the sector, was identified by the review of the literature. Then, BIM Level 2 was studied, discussing the level of maturity by reference to the different levels of the technology. The combination of these two investigations led to a more complete understanding of BIM Level 2 implementation within SMEs.

Objective three: To investigate and analyse critical success factors influencing BIM Level 2 implementation in SMEs

It was concluded in chapter two that there were few guidelines and frameworks to assist SMEs in the implementation of BIM level 2 (Liu *et al.*, 2010; Eastman *et al.*, 2011; Migilinskas *et al.*, 2013; Kouider, 2013; Arayici et al 2011 and Daynti et al 2017). Moreover, other than the work by Mohammad et al. (2018), little research has been done to recognise the critical CSFs which influenced BIM Level 2 implementation in SMEs.

Hence, this study focussed specifically on SMEs, to understand the factors involved and then ranking them according to their influence on the process. This objective was achieved by gathering and analysing the results from both the literature review, and the semi-structured interviews of management and technical staff, from the three case study companies. The identification and ranking of the CSFs made up the first of the two components which provided the foundation of the conceptual framework produced by this research.

Objective four: To map the critical success factors on to the BIM level 2 implementation lifecycle.

This objective was achieved, firstly, by identifying the phases and stages followed by the case study companies in their implementation of BIM level 2. Then the interviews of the management and technical staff involved in the implementation of BIM in the three case study companies, provided the information as to which phases and stages of the BIM implementation lifecycle, were impacted by the CSFs. The mapping of the CSFs onto the phases and stages of the implementation was the second of the two components of the conceptual framework produced by this research.

Objective five: To propose and validate a framework for implementing BIM Level 2 in SMEs.

This objective was achieved by the presentation in chapter seven of the theoretical framework shown in Figure 7.2. The framework was based on the empirical findings obtained from the three case studies. The framework was tested by key participants of each of the case studies and the results of the testing confirmed it to be suitable for practical use, and demonstrated that the identification of the CSFs which affected each phase and stage of the process, will help SMEs in the implementation of BIM level 2.

The researcher needs to highlight the fact that although the framework was declared to be suitable for the three case study companies, it could not be generally applied to all companies without due consideration being given to the background of those particular organisations.

However, where the context is similar the framework should provide a useful aid to implementation.

8.2 Conclusion of the research

The following conclusions can be deducted from this research

- Currently, as stated in the literature, the BIM maturity of SMEs is inferior the government mandate, with the results referring that SMEs are lagging behind in the adoption and implementation of BIM Level 2. According to NBS (2017), 52% of small companies have not used BIM in any project.
- The findings indicate that there is a lack of understanding and knowledge about BIM Level 2 itself. As stated in the literature, the construction sector is aware about the different levels of BIM implementation, however they argued that there is debate related on the meaning of each level and how it can be implemented, especially Level 2 because this is the first level required to be implemented by 2016.
- From the findings of this research, 15 CSFs were identified to be influential for the adoption and implementation of BIM Level 2 into SMEs. These factors enabled the development of a framework for BIM level 2 implementation.
- The fifteen CSFs identified from this study comprises twelve factors mentioned previously in the literature which included: people, training, change management, top management support, BIM awareness, resources, compatibility, vision and strategy of the company, communication and collaboration, BIM policies government support, client demand. In addition to three new CSFs identified from this study which included: control of performance, external consultant and knowledge transfer.
- Finally, SMEs have to adopt and implement BIM as mandated by the government if they do not want to lose potential public projects and to embrace the benefits offered by this technology which will result in a total improvement in the entire construction sector.

8.3 Contributions

The researcher has shown that this research will make an original and important contribution to BIM level 2 implementation in SMEs, particularly in the UK construction industry. Moreover, the findings obtained from the three case studies should be able to be generalised to cover most of SMEs in the UK. The generality of the findings provides a detailed understanding of the reasons for the adoption of BIM Level 2 implementation, the barriers faced during the implementation, and the factors influencing the adoption and implementation process. The researcher focused on the novelty and originality of the research without altering the validity and reliability of the study. From the point of view of the researcher this study will contribute to knowledge and practice as shown in the following sections.

8.3.1 Contribution to theory

The theoretical contributions of this PhD research for the implementation of BIM level 2 are evidenced by:

- The identification of critical success factors (CSFs) which influence the adoption and implementation of BIM Level 2 in the UK and the prioritisation of these factors based on their importance, this has addressed the gap identified in the study conducted by Mohammad et al. (2018), where it has been stated that the UK has the lowest number of studies investigating the CSFs influencing BIM adoption and implementation.
- The provision of a theoretical framework mapping the CSFs on to the phases and stages of a BIM Level 2 implementation, this has aided in providing an in-depth understanding of BIM Level 2 implementation process in response to the argument raised by Ganah and John (2014) as they stated that the government has not defined how the implementation of BIM Level 2 will be achieved. Moreover, an in-depth understanding was needed as most of the studies concerning BIM implementation provides a basic and simple plan which lack of information and details on how to achieve a successful implementation (Fox 2014; Ahmed 2018).
- The identification of three new CSFs which were the control of performance, the use of an external consultant and knowledge transfer from other organisations.
- This study uniquely explores BIM Level 2 specifically, which contains many extensions to the original technology requiring a more comprehensive understanding of its concepts, whereas previous studies have only concentrated on BIM in its general forms. The need to understand level 2 has become more pressing since 2016 as its use for construction projects has been mandated by the UK government. This study was needed since it has been argued that a one-size-fits all approach to BIM implementation has restricted the potential of SMEs in embracing tis technology (Vidalkis et al. 2019)

8.3.2 Contribution to Practice

This PhD research also contributes to practice by offering an in-depth understanding of the CSFs influencing BIM Level 2 in SMEs because as stated by Fox (2014) the implementation plans available in the literature are simplistic which will lead decision-makers to substandard decisions based on limited information available. Moreover, the implementation lifecycle for BIM Level 2 has been provided, consisting of three main phases identifying the different stages within each phase. In addition, a more in-depth understanding was then provided by mapping the identified factors on to the BIM Level 2 implementation lifecycle.

On the other hand, by providing guidelines specifically for SMEs, where none existed before, will encourage them to adopt and implement BIM Level 2, since the limited frameworks have been identified as a main reason behind the limited adoption of BIM Level 2 by SMEs (Mellon and Kouider 2016; Kokkonen and Alin 2016).

8.4 Limitations of the Research

The amount of literature relating to BIM in general, and BIM level 2 in particular, was extensive, and it was not possible to examine all the publications on the topics. However, the author of this thesis has reviewed the most relevant literature, and the critical examination of the theories and information, provided one of the sources of information for the framework proposed.

BIM is a large topic and this study has focused specifically on level 2 of BIM and the benefits that it could bring to companies driven by the importance of the level as a mandatory requirement for construction companies in the UK. The other levels of the technology would also bring benefits, but these have not been considered in this study.

The following limitations applied to this research:

- This research has been based on the results of only three case studies and the conclusions and recommendations cannot be generalised without consideration been given to the specific context of the companies to which they are applied.
- Only three case studies were considered, with a limited number of participants, whose time was restricted due to their other commitments. However, the findings were generalised based on the three case studies, which was justified according to the work of Chang and Fang (2007), who stated that with a sample of only two case studies, the findings will be theoretically correct and can be generalised in their restricted aim.

- The answers provided from the interviews were affected by the limited knowledge of the participants relating to BIM Level 2, particularly the technical staff.
- Finally, this research focused only on the UK and no comparison was made with other countries in order to gain a global understanding of BIM Level 2 implementation.

8.5 Recommendations

Based on the research findings, the following recommendations are proposed:

1. Is crucial that SMEs adopt and implement BIM Level 2 in order to see a development in the UK construction industry as they make 99% of the total number of construction companies in the UK. Moreover, as long as SMEs are not embracing BIM this will slow down the adoption of BIM final level (Level 3).
2. In order to benefit from the proposed framework is crucial to have a proper awareness of BIM technology in the organization and within the stakeholders as they are the primary users of this technology. In addition, is important to have the correct knowledge about the different levels of BIM and comprehend the outcomes of each level.
3. Understand the features of the organisation in terms of structure, resources and flexibility to adapt to innovation. In addition, internal analysis, as SWOT and PESTEL, are recommended to comprehend the strength and weaknesses of the organisation, as well as to match the vision of the company with the benefits obtained from implementing BIM Level 2. In addition, to comprehend how the implementation will affect them from environmental, legal and technological perspectives.
4. Recognize the adoption and implementation factors which influence the process based on their importance, and design an appropriate plan for the implementation. Moreover, is critical to ensure the management support throughout the implantation process in order to solve issues as high cost of software and training of employees and handle problem may be faced during the implementation as resistance to change.

8.6 Future Research

The UK government is encouraging the construction industry to adopt BIM Level 2 as the first mandatory level in order to improve efficiency and performance. Recently, the Farmers Report in 2016 highlighted that the construction industry will be unsuccessful if it fails to adopt and implement this technology more widely in the UK. Moreover, in the available literature it was stated that the rate of adoption and implementation of BIM Level 2 by SMEs has been slow when compared to larger companies. Therefore, this research has investigated the implementation of BIM Level 2 in SMEs.

The case studies presented in this research have provided an in-depth analysis of the Implementation of BIM Level 2, and in more detail than previous studies, and has introduced new directions for future work. In addition, the findings and recommendations provided by this study have opened up new opportunities for researchers and SMEs to further study and investigate BIM level 2 to embrace its benefits.

The development of the current research can be achieved by duplicating the research with a wider scope and avoiding the limitations mentioned previously, or by investigating the research questions of this study using different approaches.

As mentioned previously, this research investigated only three case studies due to the limited time and number of participants, hence future research could consider larger samples which would give more representative results.

Also, the investigation BIM level 2 implementations in other countries would encourage the adoption of the technique globally and bring efficiencies to the construction industry worldwide.

On the other hand, the research purpose was to investigate the implementation of BIM Level 2 in SMEs. Due to the limited time and difficult access to companies, the research was able to approach only two medium organizations and one small organization. Therefore, it would be recommended for future studies to expand the sample to cover more small companies.

It is critical for other researchers to use the findings of this research as a foundation to investigate further the adoption and implementation of BIM level 2 in SMEs, by using other methods of data collection.

8.7 Chapter Summary

This chapter has summarised this research thesis and provided an outline of the accomplishment of its objectives, the contribution to both knowledge and practice, the limitations of the findings and future research. This thesis has achieved the aim of the study, recognised 15 critical success factors, identified the implementation lifecycle phases and stages, mapped the factors to those phases and stages and proposed a framework for the implementation of BIM Level 2 in SMEs. Moreover, this thesis has contributed to knowledge by bridging the gap identified in the literature, which was recognized to be the limited research concerning SMEs within BIM context. Moreover, this study has contributed to practice by providing SMEs a framework and a set of recommendations to assist them throughout the implementation process.

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APPENDIX:

Interview Protocol

Targeted Participants	Stages	Questions	Rational
Project Managers/ Engineers	Introduction (2 min)	Nature of research and how will be used Research study aims to explore Level 2 implementation for SMEs construction companies. Will be used in PhD thesis and for academic publications and conference papers. Recording for recollection purposes / quotes. Anything said will be treated as confidential and anonymous/ your personal data will not be passed on to anyone else. I'll nod a lot because e I want to hear you, not me… Think of this as an informal chat. There are no right or wrong answers and I'm interested in your honest views and opinions about the topic. So, before we start, please fill in the consent form.	To provide a clear set of instructions for interviewers and interviewees. To get consent from interviewees.
	Warming up (3 min)	Now tell me a little bit about yourself, • Your current position at this organisation? How long? • What do you do for your current role?	To help the participant feel comfortable

	about Level 2 in your organisation (10 mins)	• What are the reasons of implementing BIM Level 2? • In how many projects have you used Level 2?	information about the Level 2
	Barriers when implementing Level 2 in organisation (10 mins – or more if they are willing to talk!!)	• What are the barriers faced by your organisation when implementing Level 2? • Was there any resistance to change? • How did your organisation handle this resistance to change and manage to implement/use Level 2?	To understand the barriers faced by the organisation when implementing this BIM level 2.
	Critical factors influencing Level 2 implementation (15 mins)	Let's move on to CSFs for Level 2 implementation. My research is particularly interested in investigating this: • Please identify any factors that may affect the Level 2 implementation? • Can you rank the CSFs which influence Level 2 implementation based on their importance? • Can you explain how these factors may help or hinder the implementation?	To identify the factors that may influence Level 2 implementation
	Identifying the main phases and stages when implementing Level 2 (10 minutes)	• What are the main phases and stages when implementing Level 2? • Can you please prioritize the identified CSFs in their relative position in the lifecycle implementation?	To identify the phases and stages of implementing Level 2 and recognize which factor affect in each phase and stage.
	Any other relevant aspects not discussed (2 min)	The discussion is coming to an end now, so: • Is there anything we haven't talked about that you think we should discuss?	
	Finalise the interview (2 min)	• Is it possible to have additional interview in the near future?	This will help me to see the progress and how things change from time to time