www.itcon.org - Journal of Information Technology in Construction - ISSN 1874-4753

CRITICAL SUCCESS COMPETENCIES FOR THE BIM IMPLEMENTATION PROCESS: UK CONSTRUCTION CLIENTS

SUBMITTED: May 2018
REVISED: November 2018
PUBLISHED: February 2019 at https://www.itcon.org/2019/5
EDITOR: Turk Ž.

Ammar Dakhil, PhD., Lecturer,
Civil engineering department, college of engineering, University of Basrah, Iraq,
ammarasha@yahoo.com

Jason Underwood, PhD.,
Professor, School of Built Environment, University of Salford, UK,
j.underwood@salford.ac.uk

Mustafa Al Shawi, PhD.,
Visiting Professor, School of Built Environment, University of Salford, UK,
M.A.Alshawi@salford.ac.uk

SUMMARY: *Construction clients'owners' demand is currently being recognised as a significant motivation and drive for the construction industry to begin to transform and adopt Building Information Modelling (BIM). In addition, clients can stimulate the innovation to achieve crucial benefits from BIM. However, the implementation of BIM is prevented from being more widely accepted across the construction industry by client fears and a lack of the full understanding of the benefits of BIM, as well as the requirements needed to realise these benefits. Therefore, it is important for client organisations to develop the required competencies that support the BIM implementation process and help to achieve the desired benefits of BIM. Accordingly, the purpose of this paper is to identify the critical success competencies that facilitate clients to fulfil their roles in the BIM implementation process. Multiple holistic case studies were used as the research strategy and semi-structured interviews were employed as the principal data collection technique. Code-based content analysis and cognitive mapping were used to analyse the verbatim interview transcripts. The data analysis process was facilitated by the computer-aided software, Nvivo. Several types of competencies are identified as critical success factors that enable client organisations to lead the BIM implementation process and increase the efficiency in BIM uses within the UK. In addition, it is concluded that by adopting these competencies, client organisations can enhance their Employer Information Requirements (EIR) and improve their ability to validate the outcome BIM models. These developments will increase client opportunities to meet their desired benefits. This paper provides a contribution to the body of knowledge by identifying BIM organisational maturity competencies for UK clients and their roles in the BIM implementation process, together with establishing the relationship between them. This will enhance the importance of the BIM maturity competencies within the BIM implementation from a clients' perspective. In addition, it will facilitate client organisations evaluating their ability to fulfil their roles through assessing the related competencies.*

KEYWORDS: *BIM, UK construction industry, client, organisation, BIM maturity, Competencies*

REFERENCE: *Ammar Dakhil, Jason Underwood, Mustafa Al Shawi (2019).Critical success competencies for the BIM implementation process: UK construction clients. Journal of Information Technology in Construction (ITcon), Vol. 24, pg. 80-94, http://www.itcon.org/2019/5*

1. INTRODUCTION

Since as far back as 1944, a series of government and industry initiatives/reports have called for significant improvements and change to the UK construction industry due to several factors; among the most concerned are poor productivity, reduce waste, and sustainability (Simon, 1944; Latham, 1994; Egan, 1998; National Audit Office, 2001; Wolstenholme, 2009, Farmer, 2016). The launch of the UK Government Construction Strategy in May 2011 brought about a real commitment from the UK Government to drive change and transformation within the industry; setting ambitious targets to be met by 2025 of cutting initial and operational costs by 33%, reducing the overall time from inception to completion by 50%, reducing carbon emissions by 50% and improvement in exports by 50%. As part of this commitment is the adoption of Building Information Modelling (BIM) (Department for Business, 2015). BIM is becoming increasingly adopted in the UK in recent years with a significant drive from the UK Government to mandate the use of collaborative 3D BIM from April 4th, 2016 for its centrally procured built environment assets (BIM Industry Working Group, 2011). The aim of mandating BIM is to improve the overall performance of the industry by introducing a step change in not just the project delivery process (i.e. Capital Expenditure, CAPEX), but to address the whole asset lifecycle. The process of digitising project information, from inception through to the operational phase of the built asset, requires a change in culture (Baskerville and Wood-Harper, 2016; Lalonde and Adler, 2015; Schwalbe, 2015). Furthermore, such a change cannot be achieved without the introduction of technology-based business processes; enabled by a new set of skills and competencies (Barnes and Davies, 2014; Ojo et al., 2015).

Generally, BIM can be utilised to improve the efficiency of the built asset lifecycle, provide a safer and more productive environment for its occupants and be more operationally competent for its owners throughout its lifecycle (Arayici and Aouad, 2010; Rodriguez, 2011; Vernikos, 2012). As such, BIM is slowly becoming embedded in various practices of key industry stakeholders, including consultants, contractors, suppliers and client organisations (National BIM Report, 2013;Cao et al., 2018). However, the degree by which BIM can be effectively implemented in order to maximise its benefits depends highly on the maturity of the organisation to apply and manage the adoption (Barlish and Sullivan, 2012; Ghaffarianhoseini et al., 2016; Liang et al., 2016).

Although some organisations across the supply chain may have been using BIM to improve efficiency and collaboration, its benefits will remain limited without a clear mandate from clients (Liao, L., & Ai Lin Teo, E., 2018; Mohammed et al., 2018; Mansson, D. W., Hampson, K. D., & Lindahl, G. A., 2017). According to recent surveys (Smart Market, 2014; RICS, 2011; NBS 2015), clients can play a vital role in accelerating the process of innovation and to drive the industry to embrace change. In addition, research also shows that clients can stimulate innovation to achieve crucial benefits from BIM adoption such as cost and time reduction, improve facility management and information management. (Gann and Salter, 2000; Harty, 2005; Kulatunga et al., 2011; Manley, 2006; Miller, 2009).

However, clients are less optimistic than the rest of the industry that BIM will achieve the various targets set out in the Government Strategy (Eadie et al., 2015; ED Love et al., 2015; Lindblad and Vass, 2015; Mason and Knott, 2016). Clients' fear and a lack of a full understanding of the benefits of BIM, as well as the requirements needed to achieve these benefits, are preventing BIM from being widely accepted across the industry (Succar, 2012b; Walasek, D., & Barszcz, A.,2017; Ventura, S. M., & Ciribini, A. L.,2017). Hence, in order to drive the best value through the entire BIM process, clients need to become fully aware of the required organisational capabilities along with the supporting processes and competencies to better manage this new technology (Fejfarová, 2015; Koh, 2015).

In doing so, clients will be placed in a leading position to drive an effective BIM implementation process. However, this is not an easy task to achieve as client organisations need to have improvement plans that will allow them to gradually build capacity within their practices before being able to effectively work with their supply chain to meet their BIM requirements (Jackson 2002, Eastman 2011). Identifying relevant and critical competencies which client organisations need are a major challenge facing them to forward plan, maximise return on investment and allocate appropriate resources to achieve their objectives (Eadie et al., 2015; Lindblad and Vass, 2015; Mason and Knott, 2016). This paper presents the first phase of a research study that aims to identify the critical BIM competencies that client organisations must develop in order to effectively implement and manage the BIM implementation process.

2. BIM FOR CLIENT ORGANISATIONS

The significance of clients' lead is strongly recognised as essential to bringing about change through better collaboration between project stakeholders (Drew et al., 2001; Maradza et al., 2014; Robson et al., 2014). As achieving higher objectives from the implementation of BIM is based on collaboration, this certainly needs to be fully client-led. Without this support and push from clients, the end result may never reach its full potential (ED Love et al., 2015; Lindblad and Vass, 2015; Market, 2014). This is becoming more important with the adoption of the Level 2 BIM process and the need for knowledgeable and experienced representatives within the client organisations. The UK Government's Construction Strategy defines BIM in terms of a number of 'levels of maturity' in relation to progressively moving the construction industry to 'full' collaborative working; within a range from 0 to 3. Starting at Level 0, this describes unmanaged CAD (Computer Aided Design), whereby there is no collaboration and only 2D CAD drafting is utilised, mainly for Production Information. Level 1 represents managed CAD in 2D or 3D to BS1192:2007, with the electronic sharing of data being carried out through a common data environment (CDE); however models are not shared between project team members. Level 2 is distinguished by collaborative working and involves the development of built environment asset information in a collaborative 3D environment with data attached, but created in separate discipline models. Level 3 (Digital Built Britain) has been perceived as the 'holy grail' and a real game changer in representing 'full' collaboration between all disciplines whereby all parties can access and modify a single, shared project model, through a centralised repository (i.e. 'Open BIM'); removing the final layer of risk for conflicting information (NBS, 2014).

Clients, in particular, can significantly benefit by adopting BIM as a process and tool to guide their projects delivery process to a higher quality and performance over the whole asset lifecycle (Eastman, 2011). BIM changes the current design and builds practices (Yan and Damian, 2008), which can lead to higher benefits to clients, such as reducing projects cost and time (Love et al., 2013). BIM can facilitate the creation of a collaborative environment, where all project stakeholders can sit together and exchange information at the early stages of the project lifecycle (Arayici et al., 2011; Dado, 2011; Eastman, 2011; Laine et al., 2007; Reddy, 2012). Furthermore, based on the level of collaboration among stakeholders, this could expand the client's organisational boundaries (Arayici et al, 2011).

To ensure greater efficiencies and value for money in how assets are built and operated, the client's role is, more than ever, crucial in making sure the core requirements are maintained and communicated to the various parties involved (Wing et al., 2015). However, providing accurate requirements is not enough without the validation of the supply chain's deliverables. It can be a difficult and challenging situation when the project is finished and it becomes apparent that the objectives and outcomes are not aligned (Al-Harthi et al., 2014; Boyd and Chinyio, 2008; Doloi, 2012). Therefore, being the 'client' of a project is an important role, which can provide the necessary management and control procedures to projects to ensure projects meet their objectives.

Furthermore, it is crucial that clients understand their roles in the BIM implementation process so they can request and issue the right information, at the right time, and to the right level of quality. For example, without a detailed Asset Information Requirements (AIR) from the client, project delivery teams will be unable to provide relevant and adequate asset data that the client need; thereby leading to waste in time and fees (Lindblad and Vass, 2015; Underwood et al., 2016).

Based on the above, the clients' role to derive the BIM implementation process can be classified into three main categories:

2.1 The Development of the Employer Information Requirement (EIR)

According to PAS 1192-2 (2013), any project where BIM is to be implemented must start with an EIR. The EIR has to be developed by clients, which have to be met by the supply chain throughout projects lifecycle. According to the UK Government standards, clients must be able to develop their requirements under three main areas; technical, management, and commercial (Ashworth et al., 2016b; Dwairi et al., 2016). Developing an EIR is not an easy task and requires considerable knowledge and experience. However, the relationship between a client's ability to produce high-quality BIM requirements and the required level of BIM knowledge and experience within a client organisation is still not clear (Dwairi et al., 2016; M. A. Hafeez et al., 2015; Lindblad and Vass, 2015). Therefore, understanding such a relationship can help clients to identify what types of proficiency they need to have to enable them to build their own BIM requirements (Ashworth et al., 2016).

2.2 Validation of the Outcomes

In addition to clients possessing the ability to develop their requirements, clients also need to validate the outcomes of the BIM implementation process to ensure that the supply chain meet their requirements. PAS 1192-2 and 3 provide guidelines to facilitate the validation process, e.g. the definition and agreement of the data drop located throughout the project lifecycle. It is important to mention here that clients should have the ability to effectively manage and control the validation process. This role demands a certain level of BIM knowledge and experience to enable clients to efficiently communicate with the supply chain and to be able to streamline the approval process of the expected outcomes. However, the relationship between a client's ability to validate the outcomes of a BIM implementation process and the required level of BIM knowledge and experience within a client's organisation is still not described clearly and explicitly in the literature. However, by establishing such a relationship, this will help clients to identify the type of proficiencies they need to have in order to enable them to achieve the required BIM outcomes (Chong et al., 2016; Ciribini et al., 2015; Getuli et al., 2016).

2.3 Leadership

The capability of clients to fulfil the above two roles highlights the extent of their readiness to lead a BIM implementation process, which is considered essential in optimising the desired benefits of BIM (Figure 1). The higher the capability of a client organisation to command these two roles, the higher its capability to lead the entire BIM process. The latter leadership becomes critical in getting project stakeholders together to efficiently collaborate to achieve the project requirements. However, despite several studies, which focus on the importance of client leadership, there is a lack of research into BIM leadership characteristics in terms of the particular competencies and proficiencies that clients need to possess in order to lead a BIM implementation process throughout the project lifecycle (Loosemore and Richard, 2015; Senaratne and Samaraweera, 2015; Wing et al., 2015).

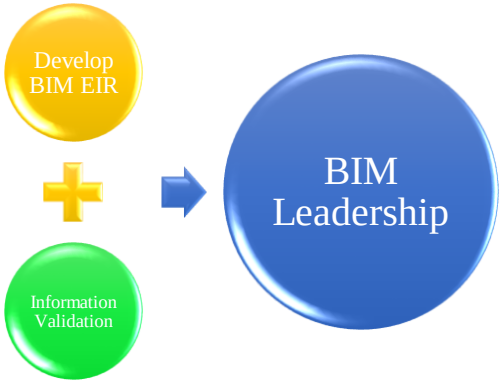

Fig. 1. Clients' roles in the BIM implementation process

3. BIM COMPETENCIES

Strebler (1997) suggested that two different meanings of the term competency have been established. Competencies may be expressed as "behaviours that an individual needs to demonstrate", or they may be expressed as "minimum standards of performance". As such, there has been growing opinion across the BIM literature that there has been scant regarding the importance of stakeholder competency in implementing BIM together with how further exploration of this area may produce some valuable insights (Arayici et al., 2011; Lindblad and Vass, 2015; Tse et al., 2005). Moreover, Linderoth (2010) confirms that the adoption and use of BIM could be shaped by the interplay between the technology and the social context in which it is adopted and used. Such studies indicate that a significant reason for the poor adoption and implementation of BIM is the failure to recognise the user competencies required to manage BIM (Succar, 2015).

BIM competency represents the ability of users to fulfil all the important areas of an effective BIM implementation to deliver value and achieve the expected BIM product/service. Before identifying the core organisational competencies for BIM implementation within an organisation, it is necessary to understand the term maturity, which represents the proficiency level of competency. Adopting maturity models to assess the capability of an organisation to effectively manage the BIM implementation process can produce valuable benefits to BIM users

by having the ability to introduce and implement changes effectively (Giel and Issa, 2013c; Nepal et al., 2014; Succar, 2010a). This process can be simplified into levels that can be followed to achieve the desired BIM benefits (Giel and Issa, 2013c; Nepal et al., 2014). The range of levels that this form of BIM implementation (including modelling) can take in terms of excellence is described as maturity (Cooke-Davies and FAPM, 2004b; Khoshgoftar and Osman, 2009; WIKI, 2014). Therefore, BIM maturity reflects the degrees of excellence in delivering value to organisations through BIM.

Industry practitioners and academics have developed several maturity models for evaluating BIM implementation and performance for the industry (Giel and Issa, 2013; Nepal et al., 2014; Succar, 2010). These models can be classified into three main categories, according to their target in the evaluation process; individuals, projects and organisations, (Giel and Issa, 2013). While some of these research efforts may be used to assess the maturity of client organisations against their BIM implementation, few address the specific needs and information requirements of a client as a separate entity, such as Succar's BIM Maturity Index (Succar, 2010), CIC Research Program's Owner Matrix (State, 2012), and Owner's BIMCAT(Giel and Issa, 2014).

As the focus of this paper is to establish the required competencies for client organisations, those models that have been designed to assess client organisations have been investigated further (Tse et al., 2005; Arayici et al., 2009; Linderoth, 2010). They have been evaluated through two main steps in order to examine their suitability to assess UK construction clients. Firstly, a comparison analysis has been conducted, which helped to explore the similarities and differences among all models in term of BIM maturity competencies. Through the analysis each model has been examined to establish its strengths, scope and limitation in terms of its suitability to assess UK construction clients in relation to the previously outlined client roles, i.e. EIR, Validation, and Leadership.

Table 1 represents the characteristics of the existing BIM maturity models that have the ability to assess client organisations against their BIM implementation. As shown, each model has different criteria for assessment along with different levels of maturity. Firstly, each model has its own methodology for evaluation regarding their key assessment categories. Furthermore, Succar adopts the traditional 5 levels of maturity, while the other two expand their models to have six levels. Secondly, Table 2 highlights the strengths and limitations of each of these models. It can be seen that individual models have certain limitations that prevent them being used in the UK construction industry. In addition, these models treat all their competencies with equal importance, which is contrary to reality as each client has their own unique needs. While different types of weaknesses are found in each of the models, these can be compensated for and improved from the strengths identified from the other models. For example, a lack of competencies related to the client organisation within the Succar model can be addressed by adding the competencies from the CIC model, which is designed specifically for the client organisation. However, there are common weaknesses across the existing models that also need to be addressed to increase the efficiency of these models for the client organisation. Therefore, this paper identifies the BIM competencies that currently have been implemented by UK client organisations to support them in their BIM journey. Based on the aforementioned evaluation, 19 competencies have been identified from the Succar and CIC BIM maturity models, which are considered to be essential for client organisations to develop in order to implement BIM efficiently. To further enhance the understanding of these competencies at an organisational level, they have been classified under the main four elements of organisational maturity, (Figure 2) (Chen et al., 2012; Giel and Issa, 2012; Mom and Hsieh, 2012; Succar, 2010). Such classification serves to add further clarification on where a particular competency has its main effects.

Table 1. Summary of BIM maturity evaluation models

Model Characteristics	The beneficiary	Number of maturity levels	Key assessment categories	Evaluation Method	Source
Succar's BIMMI	Designers, Contractors, and Clients	5	Technology Process Policy	Multi-method	(Succar,2012)
CIC Research Program's and Penn State Owner Matrix	Clients	6	Strategy Uses Process Information Infrastructure Personal	Self-evaluation	(Penn state, 2012).
Owner's BIMCAT	Clients	6 (Competence levels)	Operational Strategic Administrative	Self-evaluation	(Giel, 2013)

Table 2. The strengths and limitations of the selected BIM maturity models

No	BIM maturity model name	Strengths	Scope/Limitation
1	Succar's BIMMI	• Clear evaluation methodology. • Covering most of organisation BIM competencies. • Covers different types of organisations.	• Not client specific. • No specific clients' assessment competencies. • Does not clearly cover Maturity-benefits relationship.
2	CIC Research Program's Owner Matrix	• Clear evaluation methodology. • Covering most of organisation BIM competencies. • Client focused	• Mainly designed for USA-based organisations. • Does not clearly cover Maturity-benefits relationship. • Does not clearly cover maturity-client role relationship
3	Owner's BIMCAT	• Covering most of organisation BIM competencies. • Client focused	Evaluation methodology is clearly specified. • Does not clearly cover Maturity-benefits relationship. Does not clearly cover maturity-client role relationship

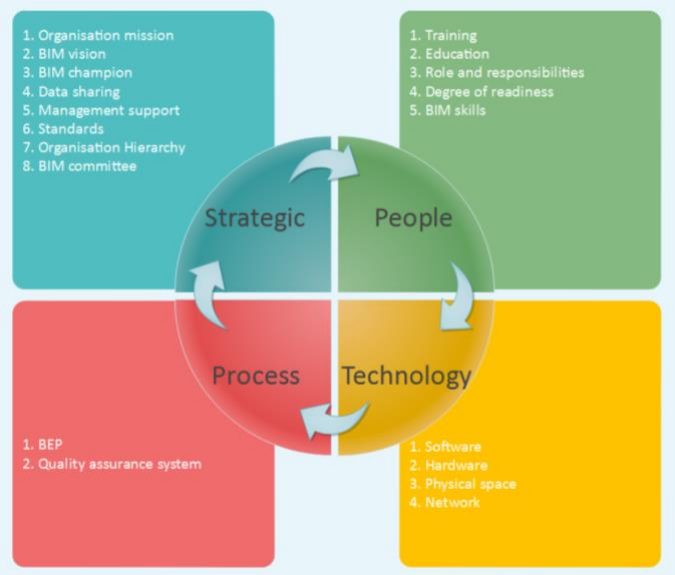

Fig. 2. Clients' roles in the BIM implementation process

4. RESEARCH METHODOLOGY

As outlined, the research problem is focused on the relationship between client's roles and the BIM competencies, which is currently blurry and unclear considering the UK is the main research context. Having this cogent focus in mind, this study aims to identify and understand the different views of client organisations in relation to the identified BIM competencies and their relationship with client roles in the BIM implementation process. A case study research approach was adopted, which according to Yin (2009) are appropriate when the research problem requires a deep understanding of a complex phenomenon that is not controlled by the researcher and when the research questions include a how and why queries. Six case studies were selected in an attempt to incorporate all clients' types, including two national public clients, one local public client, two private clients (retailer and real estate) and finally one mix client (university). The client BIM competencies were selected as the unit of analysis.

Semi-structured interviews have been used as data collection technique to help the researchers to gain an in-depth understanding of underlying reasons and motivations to use certain BIM competencies, which will be difficult to achieve via quantitative technique. They have been conducted with a total of 15 employees from the six client organisations; selected through purposive sampling based on participants that have previous knowledge and experience related to BIM implementation (Table 4). Interview durations ranged from 1 to 2 hours, which were digitally audio-recorded and then subsequently transcribed verbatim.

Two data analysis techniques, code-based content analysis and cognitive mapping, were adopted. The code-based analysis is a process for recognising concepts/themes from the set of data (verbatim transcripts) and categorising them under different names or labels (Bernard, 2000). Cognitive mapping is used for structuring and analysing ideas and causal relationships between themes and enabled a hierarchical network of ideas to be developed; helping to discover the relationships between these ideas in a more explicit way (Brightman, 2004, 2003; Eden, 1992). The reliability of the study was guaranteed by reducing participant error and bias, and observer error and bias by the selection of participants from different departments and thereby providing perspectives from different points of view.

In addition, the validity of the study was sustained by using a pilot study to assist in the development of research before carrying out the full case studies along with a cross-sectional analysis to perform a comparison between the case studies, which helps to produce one view across different themes that represent the UK construction clients.

Table 4. The case studies background and participant's current position and experience.

No	Case Type	Participant	Position	Experience (years)
1	Public National (PN1)	PN1-1	BIM Champion	30
		PN1-2	Technical Standards	16
		PN1-3	BIM Support Officer	13
2	Public National (PN2)	PN2-1	BIM and GSL Programme Manager	24
		PN2-2	Regional MEICA Engineer	20
		PN2-3	Senior Project Manager	17
		PN2-4	Flood and Coastal Risk Management Advisor	15
3	Public Local (PL1)	PL1-1	Capital Programme Manager	20
		PL1-2	C-Pad Team Leader	15
4	Private Retailer (PR1)	PR1-1	Small Formats Construction Model Development	20
		PR1-2	External BIM Consultant	18
5	Private Real Estate (PRE1)	PRE1-1	Head of Projects	30
		PRE1-2	External BIM Consultant	25
6	Mix Client University (MU1)	MU1-1	Professor	30
		MU1-2	Visiting Lecturer	15

4.1 Pilot Study

This research used a pilot study to gain a greater understanding of the BIM competencies that were established from the review of the literature and to assist in the development of the interview questions and process. This validation process has been conducted through sending the proposed research approach to two experts from public client organisation via email with a brief explanation about each component and then asking them whether the proposed approach is suitable for identifying current BIM maturity competencies in client organisations. After receiving their feedback via email, the modified competencies have been further discussed with them via a workshop held in their offices in order to ensure that their feedback was addressed appropriately. While this study covers different types of clients, a public client was selected for the pilot study due to their level of BIM

implementation being more advanced in contrast to other clients; therefore qualifying them to review the proposed research approach.

From the pilot study, several comments have been noted. Firstly, the UK construction industry is focusing on BIM level 2, which is a BIM maturity project-based evaluation model cannot be used to assess organisation progress regarding BIM implementation. Secondly, there is a need to establish an organisation BIM maturity model that can be used within the UK. Finally, UK clients are in dire need of any kind of support in term of BIM implementation. These comments in addition to the review of literature serve to establish the current situation of BIM implementation inside the UK which basically there is a gap in term of any organisation assessment method that can help the client to achieve the desired benefits from BIM implementation.

5. FINDINGS AND ANALYSIS

A cross-sectional analysis was conducted of the six case studies to identify the required competencies to enable a client organisation to fulfil their roles in developing their EIR, validating BIM targets and outcomes over the projects life cycle, and providing effective leadership to successfully lead the entire BIM implementation. The following sections discuss the outcomes of the study under the three defined clients' roles.

5.1 Employer Information Requirements (EIR)

Each of the six case studies has identified a number of competencies that enable the interviewed organisations to develop their EIR. Figure 3 shows the word-cloud constructed from the word frequency analysis as applied to the content analysis. This analysis shows that "understanding BIM", i.e. concept, implementation, value, etc., is the main challenge facing almost all of them. Each client organisation has identified different types of competencies that enable them to "understand BIM" effectively such as BIM skills, BIM vision, and data sharing.

In addition, BIM 'Standards' has been identified as the most frequent word which reflects that all clients suggested that understanding the scope, limitation and implementation of BIM "Standard" as a competency can help them to better "understand BIM". This clearly shows that if client organisations do not have a deep understanding of BIM in terms of a) the required work environment and processes, b) the standards required to achieve their BIM targets and deliverables and c) the required skills to achieve that, then it becomes extremely difficult for them to create and lead a high-quality EIR.

In this context, it will be important to establish the relationship between the benefits that a client organisation can achieve from the BIM implementation and the necessary competencies to achieve them. Therefore, this will enable organisations to select the most appropriate competencies to match their business needs.

Fig. 3. Word frequency analysis of EIR competencies requirements

Table 5 presents the competencies that have been identified to improve clients' ability to develop their EIR. It can be seen that different clients have identified different types of competencies. This could either be related to their level of understanding of BIM implementation (as highlighted by the word-cloud analysis), and/or their different business needs from the BIM implementation. It is therefore not realistic to simply propose a list of competencies and apply them to all clients without considering the business benefits that could be achieved through BIM.

However, there are common competencies which have been identified by more than half of the client organisations in order to efficiently meet the EIR. These are "Standards", "Data Sharing", "BIM Vision", and "BIM Skills". "BIM Standards" helps to structure the required information and specify data format, while understanding "Data Sharing" scope, methods and benefits help in defining higher level of requirements, and "BIM vision" helps to facilitate the required work environment to implement BIM efficiently across the organisations, and the availability of relevant and adequate "BIM skills" (managerial and technical) can significantly improve "understanding BIM", its potential added value and improvement across the organisations.

It can be suggested that there is a general understanding among UK construction clients in relation to the essential competencies for the BIM implementation. Therefore, for the purpose of this study, the commonly agreed competencies can be treated as essential generic competencies for this role, whilst the others should be considered depending on clients' needs and their expected BIM benefits.

Table 5. Required competencies for the development of the EIR

No	Competencies	Public Client			Private		Mix Client	Frequency Ratio
		National		Local	Retailer	Real Estate	University	
		PN1	PN2	PL1	PR1	PRE1	MU1	
1	Standards	√	√	√	√	√	√	100.0%
2	Data Protection and security	√			√	√		50.0%
3	Physical space	√						16.7%
4	Training	√					√	33.3%
5	Data Sharing method	√	√	√	√	√	√	100.0%
6	BIM Vision	√	√	√		√		66.7%
7	BIM skills		√	√	√	√	√	83.3%
8	Education				√		√	33.3%
9	Organisation mission					√	√	33.3%

5.2 Validation of the BIM Implementation

The case studies have identified a number of competencies which could enhance the ability of clients to validate the BIM implementation process as delivered by the supply chain, i.e. to ensure that they meet the clients' requirements. Figure 4 presents the word-cloud for the word frequency analysis of this role. It shows that the availability of BIM "Standards" and getting and verifying the right "Information" are the main challenges facing client organisations. In addition, having the appropriate "BIM Skills" has been identified by the most frequent words, which reflects the importance of this competence to the validation role of clients.

Fig. 4. Word frequency analysis for the validation role

Similarly, with the EIR, the outcome of the interviews has shown that different clients have identified different competencies to improve their ability to validate the BIM implementation (Table 6). Therefore, again, it is not realistic to propose a list of competencies and apply them to all clients without aligning them with the business benefits that could be achieved through BIM. Thus, in order to avoid investing in the development of non-essential competencies, it is crucial to establish a relationship between what competencies an organisation needs and the business value (benefits) that they can achieve from the BIM implementation.

The analysis shows that all participating clients agreed that "BIM Skills", "Standards", and

"BIM Champion" is the main competencies that will support clients in the validation role. Other competencies like "Data Sharing", "Roles and Responsibilities", "Data Protection", "BIM Technology", and the "Validation Process" have been highlighted by more than half of the clients as essential competencies to enable them with validating the BIM implementation.

As collaboration is the underpinning process for providing accurate and timely information throughout the BIM implementation process, all the above-mentioned competencies clearly become important to achieve a high level of collaboration. In addition, the identified "Validation Process", as a competency, helps client organisations to establish documentary evidence for current and/or future validation processes, which will increase clients' ability to ensure that projects requirements have been met.

In addition, it can be seen that the participants selected some of the same competencies for developing the EIR role, i.e. "Standards", "Data Sharing" and "BIM Skills"; suggesting that improving some competencies can improve a client's ability to perform different kinds of roles, which can consequently improve the efficiency of their BIM uses.

Table 6. Required competencies to the BIM validation process

NO	Competencies	Public Client			Private		Mix Client	Frequencies Ratio
		National		Local	Retailer	Real Estate	University	
		PN1	PN2	PL1	PR1	PRE1	MU1	
1	BIM Skills	√	√	√	√	√	√	100.0%
2	Data sharing method	√	√	√	√		√	83.3%
3	Standards	√	√	√	√	√	√	100.0%
4	BIM technology	√	√		√	√	√	83.3%
5	Data protection	√	√	√			√	66.7%
6	Role and responsibilities		√			√	√	50.0%
7	Network			√		√		33.3%
8	Quality assurance system				√			16.7%
9	BIM champion	√	√	√	√	√	√	100.0%
10	Validation Process	√	√				√	50.0%

5.3 Client leadership

As with regard to the Client Leadership role, the case studies have identified a number of competencies that enable clients to lead a BIM implementation process. A word frequency analysis showed that "understanding BIM" in terms of concept, implementation, value, etc. has been the most frequently used word (Figure 5). Other competencies such as developing an organisation's needs or requirements have also been highlighted as important. As similarly highlighted through the analysis of the two previous roles, this finding stresses the fact that better understanding of clients' business needs and requirements can lead to stronger client BIM leadership.

Fig. 5. Word frequency analysis of leadership competencies

Table 7 presents the identified competencies that the six client organisations proposed as essential for enabling them to lead the BIM implementation process. The "OIR", "BIM Skills", "BIM Technology", "Data Sharing" and "Standards" have been identified as critical by more than half of the cases. Being able to adequately and efficiently define the Organisation Information Requirement (OIR) can be considered as an essential competency that client organisations should have in order to better define and exercise the leadership role. To achieve this competency and to ensure that the "OIR" is clearly defined in line with the concepts and business values that can be achieved from BIM, it is highly important that the organisation have the necessary "BIM Skills", understand what the "BIM Technology" can deliver, what possible "Data Sharing" methods can be used, and how "BIM Standards" can be utilised for this purpose.

Again, it can be seen that the participants selected some of the same competencies for developing the EIR role and the Validation process, i.e. "Standards", "Data Sharing" and "BIM Skills"; again suggesting that improving some competencies can improve a client's ability to perform different kinds of roles.

Table 7. Required competencies to enable the client to lead BIM implementation

NO	Competencies	Public Client			Private		Mix Client	Frequency Ratio
		National		Local	Retailer	Real Estate	University	
		PN1	PN2	PL1	PR1	PRE1	MU1	
1	BIM Champion				√	√		33.3%
2	BIM manager				√		√	33.3%
3	BIM committee				√			16.7%
4	BIM Skills		√	√	√	√		66.7%
5	Training				√		√	33.3%
6	BIM technology		√	√	√	√		66.7%
7	Management support.			√	√			33.3%
8	Organisation Information Requirements	√	√	√		√		66.7%
9	Data Sharing	√	√	√			√	66.7%
10	Standards	√	√	√		√		66.7%
11	Quality assurance		√					16.7%
12	BIM Vision			√		√		33.3%
13	Change readiness					√	√	33.3%

6. DISCUSSION AND CONCLUSIONS

This study shows that client organisations could select different types of BIM competencies to fulfil their expected roles, i.e. developing their EIR, then moving to the validation process and finally leading BIM implementation. The findings have not only identified the BIM competencies as critical competencies to fulfil these three roles, but has also categorised them according to each role. This, therefore, serves to provide a better understanding of the required competencies which can help managers to focus their efforts and resources to develop them.

Table 8 shows all the competencies identified from the literature. They are classified under the four categories; strategic, people, process, and technology. The Organisation hierarchy is the only competency that has not been identified by the participating client organisations as a critical competency. This may be due to client organisations still being unaware of the importance of organisational hierarchy in facilitating the BIM implementation process. In addition, both of the "BIM Committee" and "Quality Assurance" competencies have been only identified by one client organisation as critical. Again, this may be due to the fact that not all client organisations have exercised a full-scale BIM implementation across their organisations over a long period of time, which necessitates the need and implementation for QA procedures across the organisation.

Table 8. Critical success competencies for UK construction client

Maturity Element (from literature) /Client Type	PN1	PN2	PL1	PR1	PR2	M1	Frequency Ratio
STRATEGY							
Organisation Mission					√	√	33.3%
BIM Vision	√	√	√		√		66.7%
BIM Champion	√	√	√	√	√	√	100.0%
Data Sharing	√	√	√	√	√	√	100.0%
Management Support			√	√			33.3%
BIM Committee				√			16.7%
Standards	√	√	√	√	√	√	100.0%
PEOPLE							
Training	√			√		√	50.0%
Education				√		√	33.3%
Role and responsibilities		√			√	√	50.0%
Change readiness					√	√	33.3%
BIM Skills	√	√	√	√	√	√	100.0%
PROCESS							
OIR	√	√	√		√		66.7%
Validation Process	√	√				√	50.0%
Quality assurance system	√	√		√		√	66.7%
TECHNOLOGY							
Software	√	√	√	√	√	√	100.0%
Hardware	√	√	√	√	√	√	100.0%
Physical space	√						16.7%
Network			√		√		33.3%

It has been previously stated that each of the interviewed client organisations might have a unique business case that reflects different needs and requirements (even among the same type of clients). The uniqueness of the business case could lead to the selection of different BIM uses and therefore place emphasis on different competencies to achieve them. This reflects that each BIM competency needs to be treated individually, rather

than trying to apply one competency model for all client organisations. Furthermore, this highlights the importance of developing a relationship between BIM competencies and BIM benefits in order to help clients in only investing in valuable competencies which are more relevant to the selected BIM benefits.

The level of BIM understanding and knowledge within client organisations can also affect clients' ability to identify appropriate competencies. Without a good level of BIM understanding, it is difficult to establish a high-quality EIR in line with their business needs, let alone have the capability to provide the required BIM leadership. Therefore, low maturity client organisations cannot be expected to gain high business benefits from the BIM implementation process in that they are unable to effectively perform the BIM roles as client organisations, compared to that of a high maturity level organisation. Thus, there is a need for a maturity model to assess the BIM maturity of client organisations to enable them to identify their strengths and weaknesses and then subsequently being able to plan for effective competency development and thereby leading to continuous improvements. Furthermore, by utilising such a model, clients can carefully invest in developing their internal BIM competencies in line with a) their level of maturity and b) the benefits that they can achieve from BIM. In addition to leading to efficient use of resources, organisations can better plan for their BIM implementation in line with their business strategy.

Therefore, in order for clients to achieve their BIM objectives, they do not necessarily need to focus on developing and improving all BIM competencies, as proposed by the existing maturity models. Rather, a client's business needs will assist in the identification of the required competencies and the level of improvement needed to help them achieve their desired benefits. In conclusion, there are certain BIM competencies that client organisations need to develop in order to fulfil certain roles (Figure 6|):

- Developing an effective EIR requires competencies such as "BIM Vision", "Standards", "BIM Skills" and "Data Sharing"
- The validation role requires competencies such as "Standards", "BIM Skills" and "Data Sharing", "Data Protection", "Data Sharing", "Roles and Responsibilities", and "BIM Technology".
- Finally, improving the ability of client organisations' to lead the BIM implementation process requires competencies such as "Standards", "BIM Skills", "Data Sharing", "OIR" and "BIM Technology". Only the competency of OIR development is required when the client aims to lead BIM implementation process because client in this stage will be able to set up his organisation requirement independently. At the same time, client need to be more mature in the other competencies that identified for this role.

However, while connecting clients' roles with certain competencies do not necessarily mean that the other competencies are not important, it will assist client organisations with setting up their development priorities with limited resources.

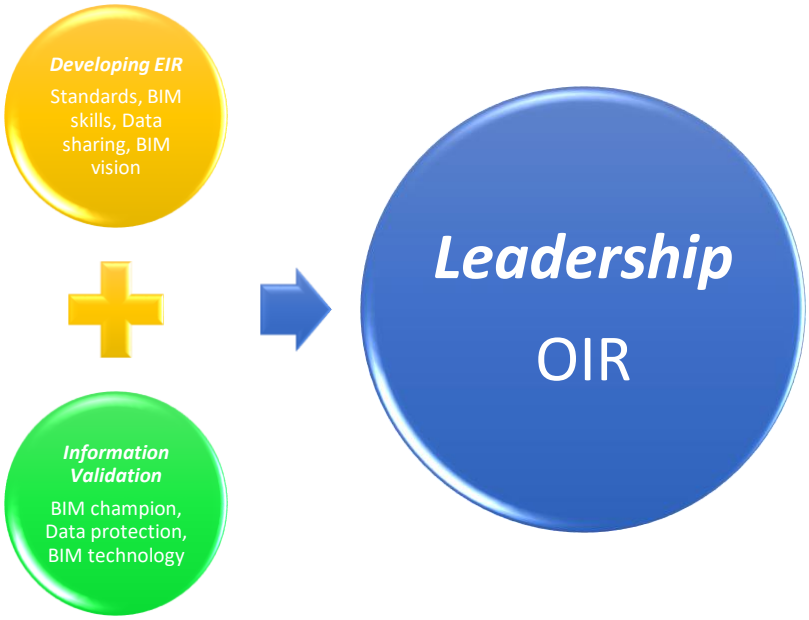

Fig. 6. Critical success competencies for client main roles

7. CONCLUSION

The identification of clients' roles in the BIM implementation process and their relationship with BIM competencies has provided a crucial guideline for BIM implementation from a client perspective. This will increase clients' BIM understanding and their ability to achieve the desired benefits of BIM. Furthermore, it will assist them in developing and improving the required competencies, rather than investing in the development of those competencies that have little or no impact. By conducting multi-case studies of different types of construction clients, valuable knowledge has been captured regarding clients' BIM implementation requirements. The findings serve to provide a better understanding of the logic and rationale behind each of the identified clients' BIM implementation roles, and the associated competencies that support them. This paper presents the findings from the first phase of research that focused on the BIM competencies which are required over the BIM lifecycle. Having identified the different types of competencies that can be used to assess client organisations against their BIM implementation process, the next phase of the research focuses on establishing the relationship between the identified competencies and the related BIM benefits. This will help client organisations to better plan for continuous improvement and to effectively invest in developing appropriate competencies to achieve their strategic business objectives through the successful implementation of BIM.

REFERENCES

Arayici, Y., & Aouad, G. (2010). Building information modelling (BIM) for construction lifecycle management.

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM—A case study approach. *Automation in Construction, 24*, 149-159.

Cao, D., Li, H., Wang, G., Luo, X., & Tan, D. (2018). Relationship Network Structure and Organizational Competitiveness: Evidence from BIM Implementation Practices in the Construction Industry. *Journal of Management in Engineering, 34*(3), 04018005.

Department for Business, I. S., The Rt Hon Dr Vince Cable and Technology Strategy Board. (2015). *£150 million investment will help transform UK construction sector*. Retrieved from https://www.gov.uk/government/news/150-million-investment-will-help-transform-uk-construction-sector.

Dwairi, S., Mahdjoubi, L., Odeh, M. and Kossmann, M. (2016). Development of OntEIR framework to support BIM clients in construction. *International Journal of 3-D Information Modeling (IJ3DIM)*, 5(1), 45-66.

Farmer, M. (2016). The Farmer Review of the UK Construction Labour Model. Construction Leadership Council.

Gann, D. M., & Salter, A. J. (2000). Innovation in project-based, service-enhanced firms: the construction of complex products and systems. *Research Policy, 29*(7), 955-972.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2016). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews*.

Giel, B., & Issa, R. (2014). Framework for evaluating the BIM competencies of building owners *Computing in Civil and Building Engineering (2014)* (pp. 552-559).

Giel, B., & Issa, R. R. (2013). *Synthesis of Existing BIM Maturity Toolsets to Evaluate Building Owners.* Paper presented at the Computing in Civil Engineering (2013).

Harty, C. (2005). Innovation in construction: a sociology of technology approach. *Building Research & Information, 33*(6), 512-522.

Kulatunga, K., Kulatunga, U., Amaratunga, D., & Haigh, R. (2011). Client's championing characteristics that promote construction innovation. *Construction Innovation: Information, Process, Management, 11*(4), 380-398.

Liang, C., Lu, W., Rowlinson, S., & Zhang, X. (2016). Development of a Multifunctional BIM Maturity Model. *Journal of construction engineering and management, 142*(11), 06016003.

Liao, L., & Ai Lin Teo, E. (2018). Organizational Change Perspective on People Management in BIM Implementation in Building Projects. *Journal of Management in Engineering, 34*(3), 04018008.

Manley, K. (2006). The innovation competence of repeat public sector clients in the Australian construction industry. *Construction Management and Economics, 24*(12), 1295-1304.

Mansson, D. W., Hampson, K. D., & Lindahl, G. A. (2017). Assessing BIM performance in building management organisations.

Miller, R. (2009). 10 Clients as innovation drivers in large engineering projects. *Clients Driving Innovation*, 88.

Mohammad, W. W., Abdullah, M. R., Ismail, S., & Takim, R. (2018, April). Overview of Building Information Modelling (BIM) adoption factors for construction organisations. In *IOP Conference Series: Earth and Environmental Science* (Vol. 140, No. 1, p. 012107). IOP Publishing.

National Building Specification. (2014). BIM levels explained. Retrieved on 22 April 2017, from: https://www.thenbs.com/knowledge/bim-levels-explained.

Nepal, M. P., Jupp, J. R., & Aibinu, A. A. (2014). Evaluations of BIM: frameworks and perspectives. *Computing in Civil and Building Engineering (2014)*, 769-776.

Rodriguez, J. (2011). Building Information Modeling (BIM) Benefits. *About.com Construction*. Retrieved from http://construction.about.com/od/Technology/a/Building-Information-Modeling-Benefits.htm

State, P. (2012). BIM Planning Guide for Facility Owners. Retrieved from http://bim.psu.edu/Owner/default.aspx

Succar, B. (2010). Building information modelling maturity matrix. *Handbook of research on building information modelling and construction informatics: Concepts and technologies, J. Underwood and U. Isikdag, eds., IGI Publishing*, 65-103.

Ventura, S. M., & Ciribini, A. L. (2017). Client and User Involvement Through BIM-Related Technologies. *International Journal of 3-D Information Modeling (IJ3DIM)*, *6*(1), 19-34.

Vernikos, V. (2012). *Optimising building information modelling and off-site construction for civil engineering.* Paper presented at the Proceedings of the ICE-Civil Engineering.

Walasek, D., & Barszcz, A. (2017). Analysis of the Adoption Rate of Building Information Modeling [BIM] and its Return on Investment [ROI]. *Procedia Engineering*, *172*, 1227-1234.