BIM adoption and implementation: Focusing on SMEs

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Purpose - To reach its full potential, Building Information Modelling (BIM) should be implemented throughout the supply chain. This study explores BIM implementation and adoption among Small and Medium Enterprises (SMEs) in the UK Architecture, Engineering and Construction (AEC) sector. The paper addresses two key issues; the slow rate and lack of homogeneity of BIM adoption in the SME sector.

Design/methodology/approach - The study employs qualitative and quantitative methods to investigate BIM uptake and test for correlations between organisational features and BIM aspects. The sample includes data from SMEs, based in the South East of England, analysed by using descriptive and inferential statistics.

Findings - The results show that, although SMEs have some understanding of BIM related concepts, their familiarity with existing BIM software support systems is particularly low. Limited financial capacity is identified as the main barrier to BIM adoption while knowledge exchange initiatives as the most useful measure in facilitating further implementation. The variations of SMEs in the adoption and implementation of BIM are mostly affected by company size, professional discipline and offered services. The paper also demonstrates that a one-size-fits-all approach to BIM implementation in the AEC sector has limited potential.

Originality/value - The heterogeneity of SMEs in the AEC sector has been considered to a very limited extent. This paper considers the nature, characteristics and core business areas of SMEs as factors affecting BIM adoption and implementation.

Keywords Building information modelling (BIM); BIM software, IT surveys,
Small and medium enterprises (SMEs), IT implementation

Paper type Research paper

Introduction

The adoption of Building Information Modelling (BIM) has been identified as a key factor in the capacity of supply chains to manage project information, complexity and risk. Indeed, it is widely accepted that BIM can improve decision making and integration between supply chain partners by facilitating faster and more effective information sharing (Eastman et al., 2008; Azhar, 2011; Abanda et al., 2017; Mahamadu et al., 2017). Currently, BIM is considered by an important part of the UK construction sector as the long-awaited response to the call for a more collaborative project development and delivery approach suggested by Egan almost two decades ago (Egan, 1998). Although it would be too early to assess the validity of this view, one cannot ignore that BIM adoption campaigns are being intensified and BIM competence targets rolled out (BIS, 2011). Following the publication of the 2011 UK Construction Strategy which called for the Architecture, Engineering and Construction (AEC) supply chains to work collaboratively through BIM, the adoption of BIM was supported by a number of initiatives aiming to help businesses attain BIM level 2 compliance by 2016. BIM Level 2 is defined as a managed 3D environment held in separate discipline 'BIM' tools with attached data while commercial data is managed by an enterprise resource platform. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary). The approach may utilize 4D programme data and 5D cost elements as well as operational systems (Guillen et al., 2016). However, although the impact of the various initiatives and relevant legislation cannot be underestimated, the rate of BIM adoption in the UK AEC industry has been slow; perhaps due to various challenges associated with the implications of a BIM approach. Although the meaning of 'slow' in relation to BIM adoption is hardly defined by most communities, based on most literature it can be construed to mean speed at which an aspect or combination of aspects of the paradigm has been adopted. It is important to note that this approach is problematic because it requires baseline data for the speed of adoption to be meaningfully determined. Base line data about the adoption of certain BIM concepts are scarce. The most relevant instrument for measuring speed of adoption is the BIM maturity levels defined differently by different countries (Edirisinghe and London, 2015). For example, after the UK government mandate for BIM Level 2 to be adopted on all central government funded projects from 2016, in 2017, a survey large-scale survey suggests a third of the sector is still unclear about how to comply with BIM Level 2 (NBS, 2017). The problem is fundamental as according to Azhar (2011) the use of BIM technology requires managing the risks associated with different applications and importantly, covering the cost of its implementation. BIM diffusion among SMEs appears to be particularly low with recent studies revealing that at least 61% of SME contractors have never used basic BIM features (NFB, 2015). In 2016, a study conducted by Hosseini et al. (2016) revealed that currently around 42% of Australian SMEs use BIM in Level 1 and Level 2 with only around 5% demonstrating knowledge of Level 3. Given the high prevalence of SMEs in the AEC sector supply chains, this state of affairs hinders significantly the opportunity for capitalising on the benefits associated with the collaborative approach suggested by the implementation of BIM. This is also in line with the unequivocal view held by Dainty et al. (2017) who highlight that there is an acute need to explore BIM from the perspective of less powerful and influential actors in the industry, the SMEs.

Exploring the reasons underlying or hindering BIM adoption by SMEs involves mainly looking at practical implementation aspects including the adoption of BIM related technologies in accordance with the various needs of SMEs. Therefore, it could be suggested that the adoption of BIM by SMEs is affected by two fundamental factors. First, issues related to the capacity of adopting the technology underlying BIM implementation and second, aspects associated with the very nature of SMEs. To address the former the paper looks at the current rate of SMEs familiarity with key BIM concepts and tools associated with the technological aspect of BIM (Abdirad, 2017). To explore the latter the paper investigates how BIM adoption and implementation is affected by organisational features. BIM adoption and SMEs are the key themes explored in the literature review. This information is presented in the next section of the paper serving as a background to the study as well as an introduction to the methodological stance adopted. Then, the research methodology section presents key assumptions, sampling and analytical methods used to facilitate an in-depth understanding of the BIM phenomenon in relation to SMEs and the extent to which it can serve as a basis for stronger collaboration and integration in the AEC sector. Subsequently, the results are presented, mainly in the form of descriptive and inferential statistics aiming to provide a general overview of BIM adoption as well as a detailed analysis of how this relates to SME characteristics. The discussion focuses on key findings which demonstrate that a one-size-fits-all approach to BIM implementation in the AEC sector has limited potential. If the full potential of BIM is to be realised it is vital to consider information logistics and supply chain dynamics.

Literature review

BIM adoption

Collaboration has been described as a durable and persuasive relationship that requires greater commitment to a common goal with an attendant increase in risk (Mattessich and Monsey, 1992; Kvan, 2000). The acceptable degree of risk is inevitably linked to the associated benefits (Oti and Tizani, 2010). To increase the benefits from collaboration, the AEC sector is looking forward to advancing beyond traditional collaborative practices that are often based on non-intelligent/non-interoperable building data and 2D drawings. Mainly due to the nature of construction projects, synchronous distributed collaboration is usually the preferred model for real-time communication of project information including textual, geometrical and object manipulations. Examples of such communication include exchanging information among members of multi-disciplinary design teams, snagging of works during project commissioning activities and transferring field data/records during operations and maintenance activities. Undoubtedly, these tasks can be performed more efficiently by using BIM, realising its value as an information technology (IT) facility (Lee and Runge, 2001; Dibrell et al., 2008; Papadonikolaki et al., 2016).

Although the promotion of BIM implementation has recently been amongst the top government priorities worldwide, the reluctance by many professionals to adopt BIM is not uncommon while significant barriers still exist (Gu and London, 2010; McAdam, 2010; Alreshidi et al., 2018). This is also confirmed by Jensen and Jóhannesson (2013) in a study based in Denmark and Iceland which reports very limited take up of BIM in relation to the other Nordic countries. Similarly, in their very recent study, Badi and Diamantidou (2017) look at a BIM-enabled project which is suggested to be the first of its kind in Greece. Work by Abanda et al. (2015a) shows that the BIM adoption level in Cameroon is still very low, especially in comparison to developed countries. This is a suggestion also made by Jung and Lee (2015). Along the same lines, Ahuja et al. (2016) argue that countries such as India and China are late entrants in the BIM adoption journey and are seeing a slower adoption rate. An earlier joint survey report published in 2008 covering Denmark, Norway, Sweden and Finland, had already estimated the ratio of Computer-Aided Design (CAD) to BIM use among companies to be approximately 3:1 (Kiviniemi et al., 2008). Despite such studies being rare, in 2012, the UK National BIM Report confirmed that the majority of companies still used CAD in one way or another (NBS, 2012).

The slow adoption of BIM can be attributed to the associated risks which emanate from uncertainties accompanying any innovation. It has been argued that the 'push and pull' factors from the consequences of BIM adoption can significantly drive the industry towards the desired level of adoption of BIM. This is yielding positive results as, in the National BIM Survey Report 2017, the level of BIM adoption is reported to be on the rise (NBS, 2017). Although the study did not specifically target SMEs, the participants involved in this study the indicated the rise of this BIM adoption came from a range of professions and practice types. Specifically, it emerged that small practices (with 15 or fewer staff) were less likely to have adopted BIM than larger ones, though 48% had. For medium (16 to 50 staff) and larger practices (50+ staff), almost three quarters had adopted BIM.

Indeed, the report stipulates that respondents currently using BIM in the UK rose from 13% in 2011 to 62% in 2017.

A consideration of consistently published reports reveals that leading commercial organisations have taken the forefront in investigating BIM implementation at international and national levels. McGraw Hill Construction has conducted studies on the impact of BIM since 2007. The focus has been mainly on top companies operating in leading global construction markets such as Canada, France, Germany, UK, US, Brazil, Japan, Korea, Australia and New Zealand (McGraw-Hill Construction, 2014). In the UK, the National Building Specification (NBS) has conducted eight major BIM reports since 2010, with the last two published in 2018 and 2017 containing some significant results. The BIM report NBS (2017) stated that ‘BIM is not just for larger practices - but small practices are less likely to have adopted BIM’. Indeed, small practices are approximately 65% less likely to have adopted BIM than larger companies (NBS, 2017). This finding confirms the suggestion made in the National BIM Report 2016 (NBS, 2016) that small businesses are very worried about being able to afford BIM, mainly because of the costs associated with investment in software, training and changes in business process.

Given that SMEs comprise some 99.9% of UK construction contracting businesses (BIS, 2013) their role in the adoption of BIM within the AEC industry cannot be underestimated. With the recent UK government mandate on the Level 2 BIM to be adopted on all central government funded projects, main contractors expect SMEs to be BIM proficient in order to meet the BIM execution plan requirements. Thus, if BIM is about collaboration there is an absolute requirement to take a closer look at the needs and features of SMEs in order to lay the foundation for designing effective strategies for BIM adoption.

SMEs and technology adoption

SMEs are involved in every part of the AEC sector including off-site manufacturing, design, procurement, on-site production assembly and support services (Rezgui and Zarli, 2006). For SMEs the transition to BIM represents a series of incremental innovations to advance the organisation's BIM capabilities (Poirier et al., 2015). Generally, unlike larger businesses, research has shown that SMEs' take-up of IT innovations is highly influenced by the associated large amount of investment requirement and the risks associated with it (Acar et al., 2005; Benjaoran, 2009; Abanda and Tah, 2014). Indeed, a survey on BIM application throughout the project life cycle highlights that BIM implementation requires significant cost and training investments (Eadie et al., 2013). Furthermore, BIM adoption and application is influenced by uncertainties and risks associated with the lack of awareness and personnel training, reluctance to change, technology adoption, legal ambiguity, and lack of clarity on roles, responsibilities and distribution of benefits (Gu and London, 2010; Sun et al., 2017). A survey carried out by the National Federation of Builders reports that more than half of the SMEs accept that BIM might benefit their businesses with SMEs making the larger proportion of those who do not perceive any business benefits (NFB, 2012). The same report also suggests that SMEs in particular are lagging in developing concrete understanding and investing in BIM enabling tools.

As emphatically suggested by Sexton et al. (1999) 'SMEs and large construction companies are different animals… which need different sources and types of knowledge and technology to remain nourished and healthy'. The literature confirms this vulnerability of SMEs in the emerging market scenarios of innovative IT applications and the need to develop a defined collaborative working approach (Abanda et al., 2015b). To deal with this challenge and sufficiently explore the latest advances in IT, Rezgui and Miles (2009) put forward the concept of SME alliances as a mode of collaboration entailing groupings of partners as virtual networked organisations defined by customisable roles with added value across supply chains. Although similar initiatives should be expected to attract limited support (Dick and Payne, 2005); still, it has been suggested that SMEs should be considered as leaders of government initiatives to drive the industry, not simply the recipients (Powell, 1999; Davey et al., 2001; Davey et al., 2004). In addition to the high number of SMEs in the sector, the above considerations add to the need for looking at the role of SMEs as success determinants of initiatives promoting and supporting the adoption and implementation of BIM.

Methodology

Conceptual framework

The study is aimed at exploring BIM implementation and adoption among SMEs in the UK AEC sector by focusing on the South East of England. Although there is no universal definition of SMEs, in the context of this paper, SME refers to companies employing less than 250 staff with an annual turnover of no more than a £11.2 million or a balance sheet total of no more £5.6 million (DTI, 2001). The principal objectives addressed in this study are to identify SMEs:

- Level of knowledge/expertise in BIM technology tools
- Level of familiarity with BIM implementation support systems, concepts and literature
- Perceptions on BIM adoption barriers
- Perceptions on BIM adoption enabling factors

The literature reveals that previous research work in the area of BIM has adopted a variety of approaches. Some examples include case studies (Arayici et al., 2011b; Sebastian, 2011; Barlish and Sullivan, 2012; Papadonikolaki, 2018), action research (Arayici et al., 2011b), focus groups (Khosrowshahi and Arayici, 2012) and questionnaire surveys (Bynum et al., 2013; Eadie et al., 2013; Abanda et al., 2015a). The preceding works informed the design of a questionnaire and focus group questions. In this study, a combination of qualitative and quantitative methods is employed in order to identify and explore the parameters defining the central function of the conceptual framework illustrated in the form of a functional flow block diagram in

Figure 1.

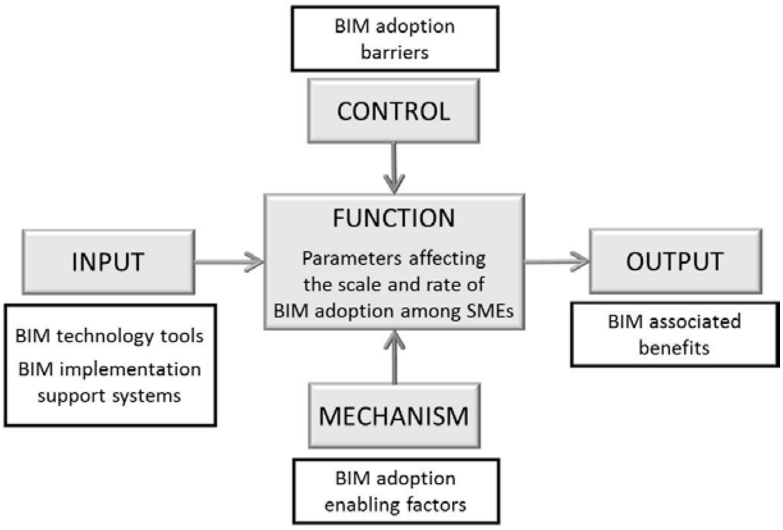

Figure 1. Conceptual framework

Issues affecting the extent of BIM adoption have been considered to have dimensions of social construct (Myers and Avison, 1997; Ahuja et al., 2016) and thus, a focus group approach was utilised as a means of gathering preliminary information and formulating questions and variables to be used in a questionnaire survey. Three focus groups, attended by a total of 27 SMEs, were conducted over a 3 week period enabling accumulation of information and knowledge. The questionnaire survey was web-hosted and distributed by the South East Centre for the Built Environment (SECBE), managing Constructing Excellence in London and the South East. The results from the questionnaire were analysed by using descriptive and inferential statistics. The analytical framework departs from the traditional approach which considers AEC SMEs as a single entity and looks into variations of SMEs operating in the sector. This is mainly a response to the requirement for a detailed investigation of the needs and features of SMEs which might result in disparate attitudes towards BIM adoption.

Analytical framework

The heterogeneity of SMEs in the AEC sector has been generally considered to a very limited extent by mainstream research in the Architectural Engineering and Construction Management field. Notable exceptions include works carried out by Forcada et al. (2007) who identified client, designer and contractor groups; London

(2010) who identified differences in SMEs approaches to enter international markets and Arayici et al. (2011a) who proposed a guideline for BIM adoption specifically for SME companies of architectural practices. Paradoxically, although SME variations have not been considered by many, the approach has been strongly suggested in previous research. Rezgui and Miles (2009) suggested that although the technological infrastructure necessary to support virtual business operations is available, there is still a need for dedicated software applications depending on the core business areas of SMEs. In the same vein, Egbu (2000) highlighted that the nature of the businesses in which SMEs find themselves impacts heavily upon their choice of technology for managing knowledge. Capturing these views, London (2006) recommended that research needs to focus on the identification of the characteristics of the different types of construction SMEs in relation to the differential levels, modes and rates of adoption of new technologies.

Research limitations

The companies participating in the study are based in the South East of England, one of the foremost commercial and business districts in the UK. Still, the geographical location of the sample is not expected to have a major impact on the general features of SMEs or the BIM-related challenges they face. SMEs across the UK share similar characteristics, especially in relation to ICT-based challenges. As argued by Lu et al. (2008) there is a dearth of reliable statistics of ICT investment or the value-add of ICT in UK construction SMEs. Also, SMEs in the UK tend to collaborate less in comparison to many European countries and are the least likely to adopt innovation compared with other sectors (BSI, 2014). At the same time, it can be assumed that companies operating in the selected region have ample access to initiatives, programmes and other support aiming at promoting BIM adoption.

The data collection concluded just prior to the introduction of UK legislation in 2016 requiring BIM level 2 compliance on all new government construction activity. Therefore, although Dainty et al. (2017) suggest that despite the BIM mandate the reform policies have failed to engage SMEs with BIM, it has to be highlighted that the study does not consider the impact of this significant development. The questionnaire was distributed to a purposive sample of 180 senior project professionals who attended events associated with the BIM FutureFit programme from June 2014 to April 2016. The survey returned 56 usable responses representing a 31% response rate. Although there is no agreed-upon standard for a minimum acceptable response rate (Fowler, 2002), 31% is significant as it is slightly higher than 20-30%, which is common with most questionnaire surveys conducted in a built environment setting (Akintoye, 2000). Still, although each respondent represents one SME, the obtained sample can be deemed small for a quantitative study. However, the adequacy of the sample size depends principally on the aim of the study, as confirmed by works carried out by Kassem and Succar (2017) who used samples of two to 16 respondents per country to identify and classify national BIM adoption policies implemented across 21 countries and Olawumi and Chan (2018) who employed a two-round Delphi quantitative survey approach involving 14 participants to rank benefits of integrating BIM and sustainability. In this study the volume of received responses was considered sufficient, given the exploratory nature of the research (Rubin and Babbie, 2009; Creswell and Plano Clark, 2010). Indeed, the study adopts an exploratory sequential mixed methods design (Creswell and Creswell, 2017) where the combination of qualitative and quantitative methods aims to provide an in depth exploration of practices and perspectives associated with BIM adoption by SMEs. As a result, the questionnaire survey does not aim to generalise on but to probe further into the qualitative result. Therefore, although the size of the sample is taken into account in the selection of the analytical methods employed and the discussion of the results, it is a limitation for the generalisation of the findings.

Data analysis methods

The survey results are analysed by using both descriptive and inferential statistics. The importance of descriptive statistics lies in understanding apparent attributes and perception of respondents, as well as facilitating further analysis to aid conclusions (Doloi et al., 2012). Further analysis is carried out by employing inferential statistics. To determine which correlation coefficient would be more appropriate to use with the dataset, there is a need to check if the data is parametric. This is achieved by carrying out tests of Normality, namely the Shapiro-Wilk (S-W) and Kolmogorov-Smirnov (K-S) tests. Although the S-W test is more appropriate for small sample sizes (< 50 samples), it can also handle large sample sizes up to 2000. On the other hand, the K-S test requires a much larger sample to achieve comparable power with the S-W test (Razali and Wah, 2011). For this reason, the S-W test has been used as the numerical means of assessing normality. The tests have been performed in SPSS. The result of the Shapiro-Wilk test produced significant value (0.00) less than 0.05 which appreciably deviates from a normal distribution. There are three correlation coefficients that can be used, namely Pearson correlation coefficient, Spearman's rho and Kendall Tau b. The former requires parametric data and thus, it would not be appropriate to use for this dataset. Kendall tau b performs better when the sample size is small but is more appropriate for a large number of tied ranks. Spearman's rho can be used when the data have violated parametric assumptions and does not require the same number of ranks. Therefore, the nature of the dataset in this paper indicates that the Spearman's rho should be used. Furthermore, since an association is expected but the direction of the relationship is not predicted a priori, the two tailed tests are used (Field, 2000).

Results and discussion

Data demographics

The demographics of the survey reveal a relatively general representation of the AEC sector, subject to sample limitations. Indeed, as Figure 2 illustrates, each one of the four identified dominant professional domains covers a high percentage, at least 15%, of the sample population.

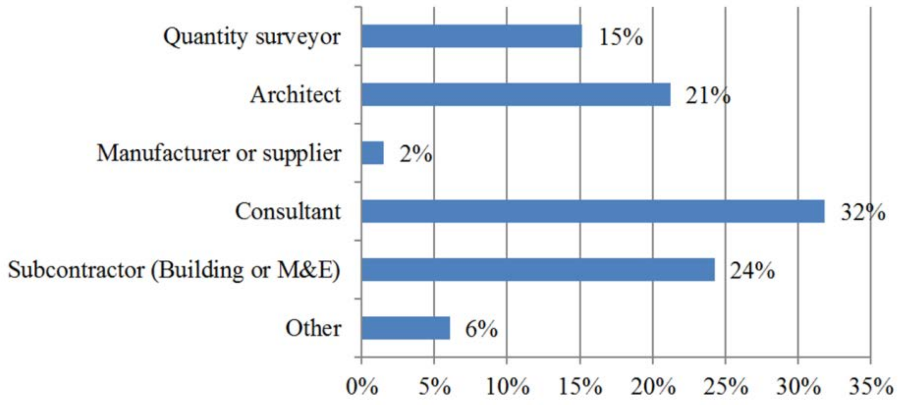

Figure 2. Data demographics: Professional domain

BIM implementation across the sector

The BIM software packages currently available for the AEC sector are numerous and with advances in technology, are likely to continue increasing in number. This is mainly due to the fragmented nature of the industry and the need for specialty applications for the various professional domains. Indeed, many applications are tailored towards the specific needs of the professional domain for which they have been developed. For example Quantity Surveyors are not expected to be proficient in structural engineering BIM software packages. Still, having some knowledge of some BIM applications is important. Knowledge means ability to use a particular software in performing a construction task or an application. For example, using Navisworks of quantity take-offs and project programmes. Packages such as for example Navisworks, are mainly used for coordination purposes by cutting across disciplines and familiarity with them, at least at a basic level, would be particularly useful. To assess the level of knowledge and competence in BIM applications the respondents were presented with a list of key BIM software packages including DesignBuilder, Vectorworks, Revit suite, CADmep, Digital Project, Navisworks, Bentley systems, ONUMA System, Green Building, Ecotect, Tekla, Vico, Synchro, Graitec, ArchiCAD, Robot and 3ds-MAX. Although it has to be noted that the list is not exhaustive, the overall results presented in Figure 3 suggest that on average more than 85% of the respondents have no expertise in the BIM packages featured in the survey.

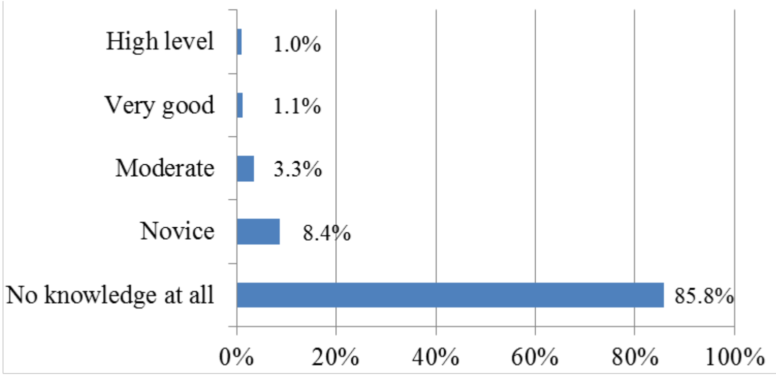

Figure 3. General knowledge of BIM software packages

A more detailed look at the results reveals just slightly over 50% of respondents had knowledge of the Revit suit, a combination of Revit Architecture, Structures and MEP, Naviswork, ArchiCAD and 3ds-Max. These BIM tools have been mostly used by the respondents for the purposes of drafting, visualisation and clash detection, as shown in Figure 4. However, activities involving building code verification, soft landings, embodied energy and carbon analysis receive very little support by BIM applications.

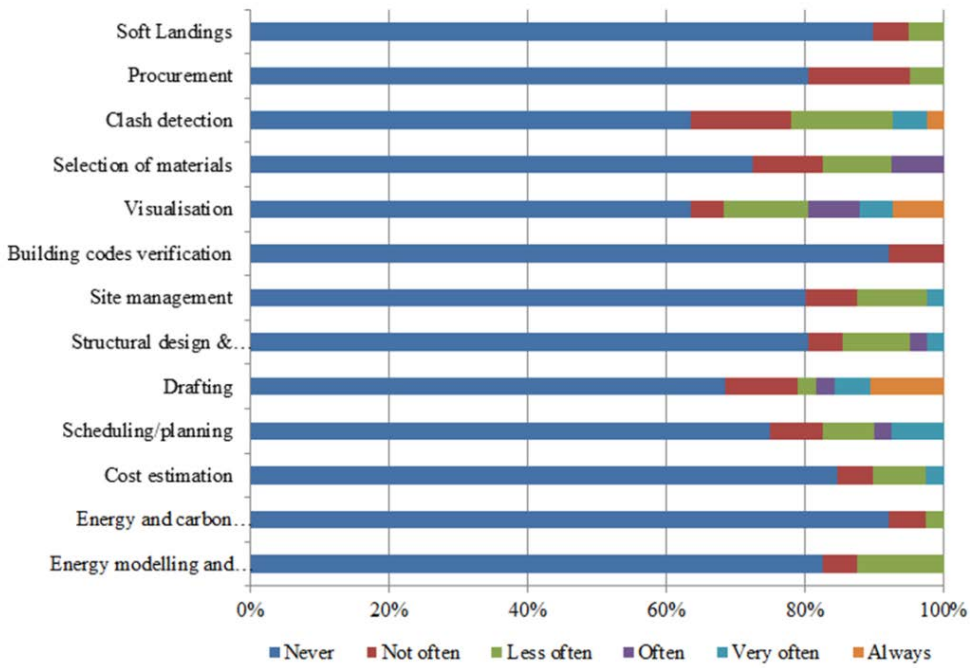

Figure 4. Activities supported by BIM software

Given that these areas are supported by publications, processes and campaigns put in place by the UK government and professional bodies to encourage BIM adoption, one can ponder over the extent to which SMEs are able or receive adequate support in developing such capacities. On the contrary, the results illustrated in Figure 5 indicate that SMEs are relatively familiar with BIM related concepts (also known as soft BIM) and relevant literature. Although approximately half of the respondents demonstrate no knowledge of the listed items (see the vertical axis in Figure 5), or soft BIM; the figures appear more encouraging than those related to software expertise.

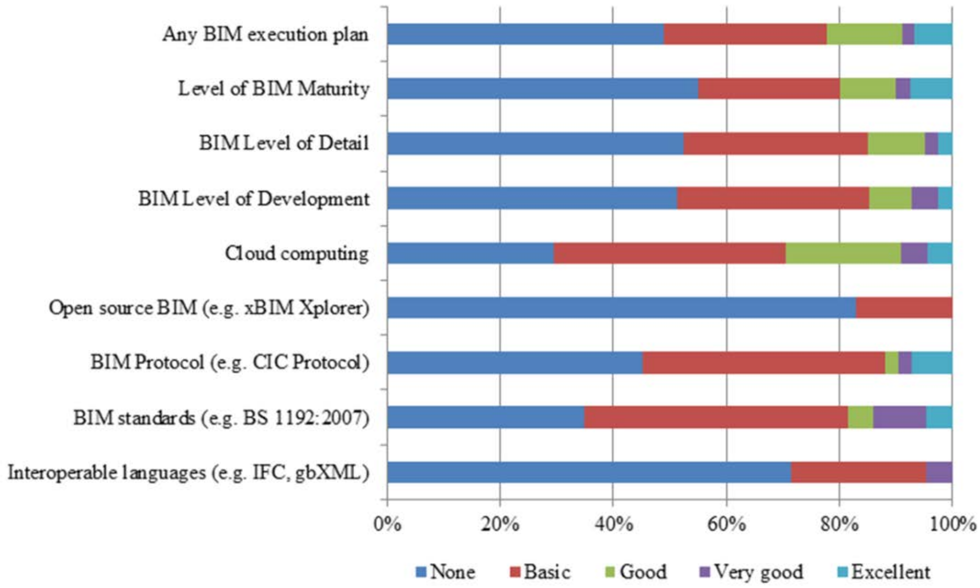

Figure 5. Knowledge of BIM concepts and literature

This might be due to the various efforts and initiatives aiming at promoting the business case for BIM and in the future might lead to an increase in the level of knowledge and frequency of use of BIM software packages. To a certain extent, this assumption is confirmed by a trend already evident in the literature. While previous studies such as Khosrowshahi and Arayici (2012) and Rodgers et al. (2015) identified the lack of knowledge and expertise on BIM as major barriers towards BIM adoption; research carried out more recently by Hosseini et al. (2016) reveals that these factors are currently not considered to be major barriers for supply chains and SMEs.

Given the low level of SMEs familiarity and knowledge of BIM it is important to look at how SMEs can access and develop BIM expertise. As shown in Figure 6, sharing experiences with other professionals is perceived by most of the respondents (33%) to be the most effective and useful approach. The overall response might be a result of the limited resources that SMEs can commit to, a common observation in the relevant literature. However, the responses also indicate that all means suggested to improve BIM skills are considered as important by the majority of the participants. Therefore, it can be suggested that SMEs might need a combination of these options depending on the availability of in-house skills, scope of offered services or indeed their BIM adoption approach.

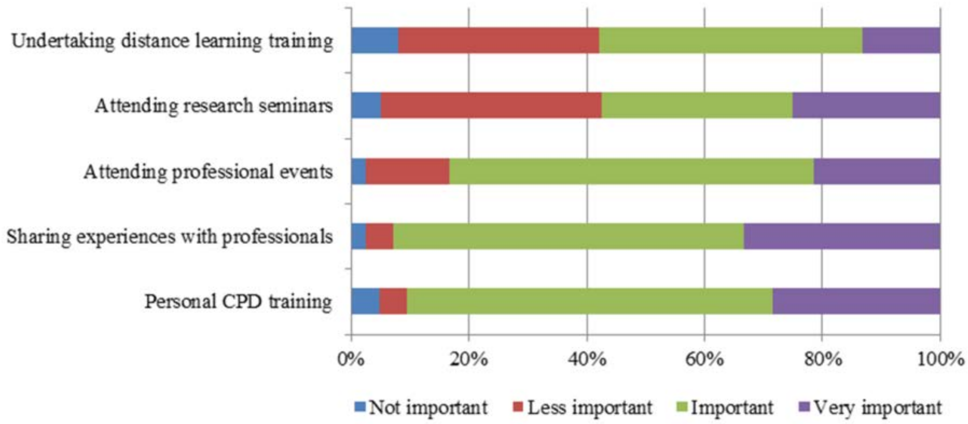

Figure 6. Importance of approaches enhancing BIM skills

The importance of factors impeding or encouraging adoption and further implementation of BIM is illustrated in Figures 7 and 8 respectively.

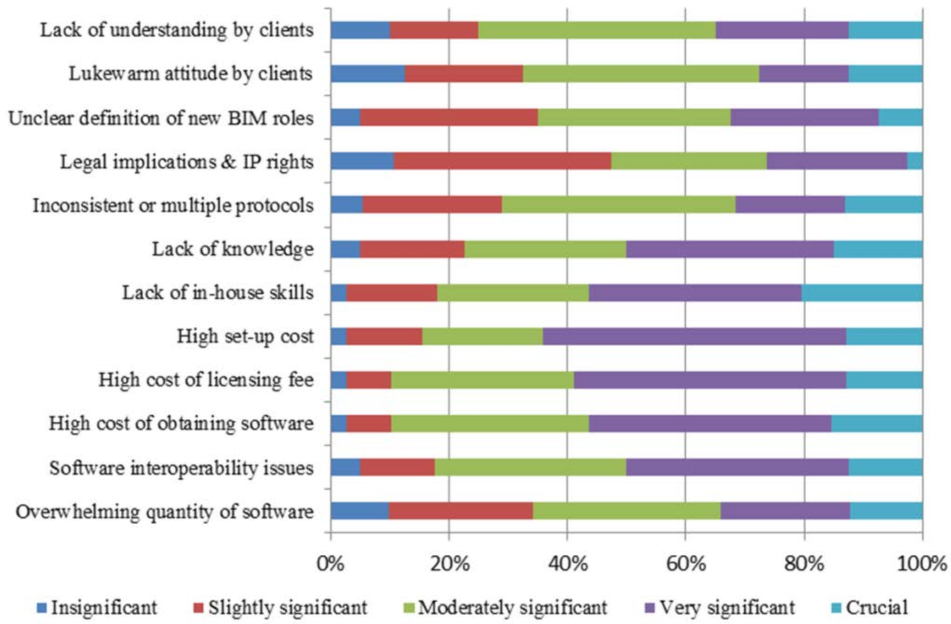

Figure 7. Importance of factors impeding adoption of BIM by SMEs

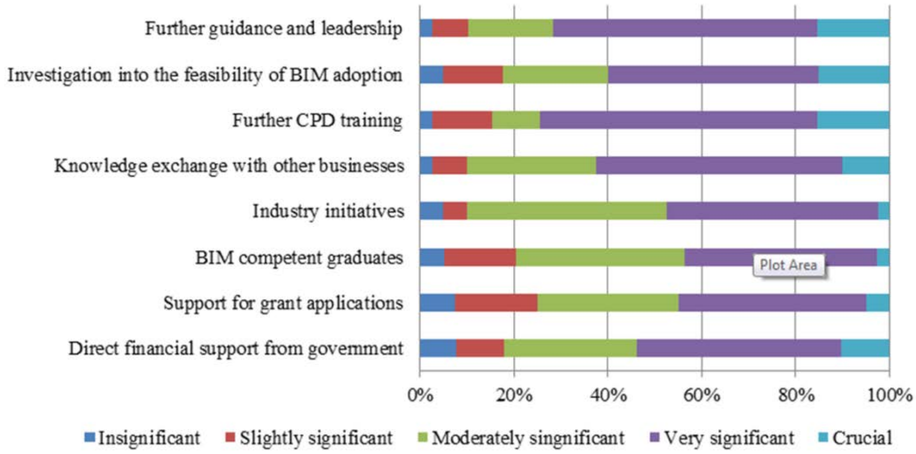

Figure 8. Importance of factors encouraging adoption of BIM by SMEs

The five factors identified to be the major barriers in BIM adoption or further implementation are ranked as illustrated in Figure 9.

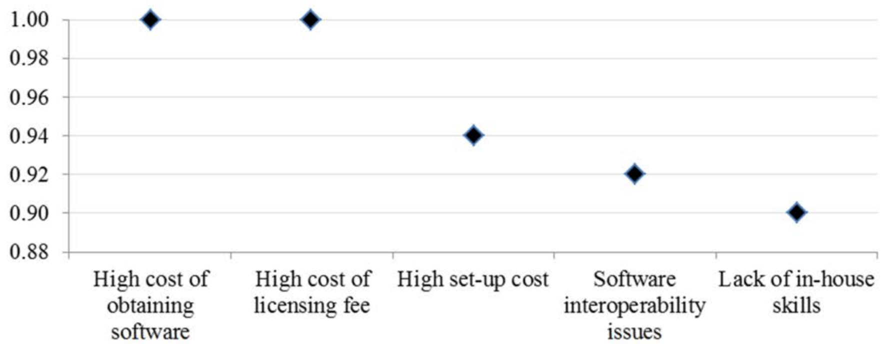

Figure 9. Ranking of BIM adoption barriers

This result demonstrates that BIM adoption by SMEs is highly dependent on cost considerations and confirms suggestions made by Azhar (2011), Eadie et al. (2013) and NBS (2016). Still, the SMEs also appear to be concerned about the inefficiencies and interoperability issues of existing software packages. As shown in Figure 9, other factors including potential lack of understanding or the lukewarm attitude by clients ranked lower; suggesting that SMEs feel the pressure and perhaps recognise that making the most of BIM relies predominantly on themselves. This finding is in accordance with the view expressed by many authors that SMEs should be seen as leaders of government initiatives (Davey et al., 2004). Perhaps for similar reasons, knowledge exchange with other businesses as well as industry initiatives are seen as the main enablers for the wider adoption of BIM. Indeed, as shown in Figure 10, these two factors were ranked by SMEs as the first and second most effective enablers of BIM adoption and further implementation.

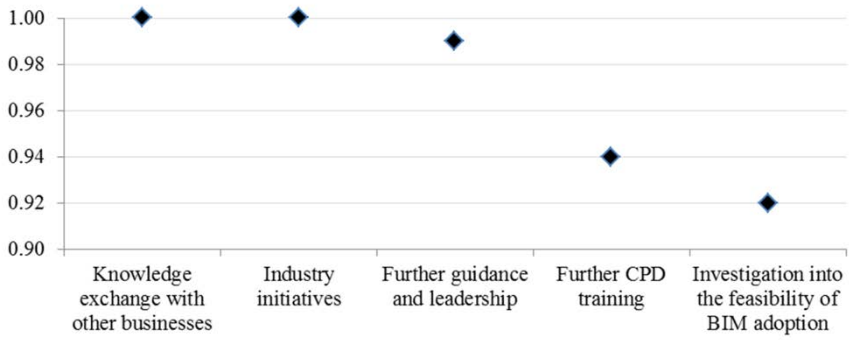

Figure 10. Ranking of BIM adoption enablers

As one would expect, the importance of BIM adoption enablers is relevant to the impact of the identified barriers. However, it is important to highlight that the factors ranked third and fifth imply a requirement, mostly for the Government, to review leadership arrangements and strengthen the business case for BIM, notwithstanding the introduction of relevant legislation. It is also interesting to note that, as shown in Figure 8, more than 50% of the respondents do not think that BIM competent graduates can have a very significant impact on BIM adoption. Although this seems not to align with the recent development of BIM-related programmes by several Higher Education Institutions in the UK (Kouider et al., 2018), the explanation might be that these developments are relatively recent and the impact has not yet seen by the sector.

BIM implementation within the sector

The inferential analysis is performed by using six proxy variables, as defined in Table I. For each of the variables representing level of expertise in BIM software or level of familiarity with BIM concepts, a Spearman correlation was performed.

- Insert Table I here -

However, none of the correlations showed a statistically significant relationship. This might well be due to the sample size which affects skewness and outliers which in turn impact on p-values. As no concrete conclusions can be reached through correlations, a contingency table analytical approach (Rayner and Best, 2001; Elliott and Woodward, 2007) was employed. Figure 11 (a) and (b) illustrates how the company size impacts on each of the parameters 1 to 6 identified in Table I. The finding provides strong evidence that the smaller the size of the SMEs, the more limited its BIM capacity is. Previous research has already established that SMEs capacity in implementing BIM differs from this of large companies (Arayici et al., 2011b; NBS, 2016). This finding; however, extends this view by suggesting that the size of the SME is also a significant factor affecting BIM competence. Indeed, this suggestion is in line with the principles of the framework put forward by Succar et al. (2012) which identifies company size as one of the factors to be considered if BIM performance is to be understood and assessed.

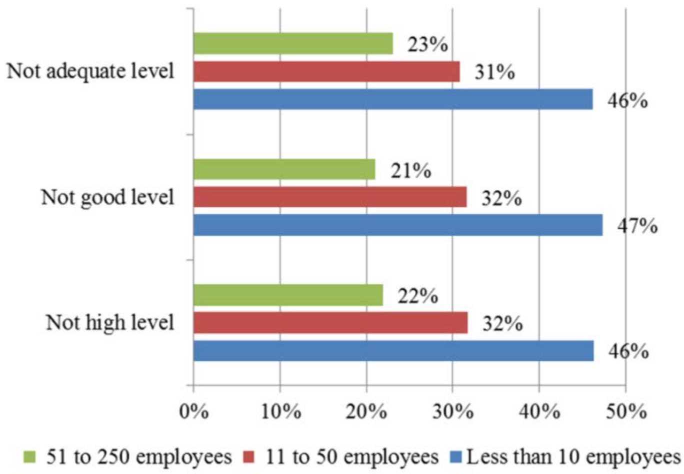

Figure 11a. Impact of SME size on levels of expertise in BIM software

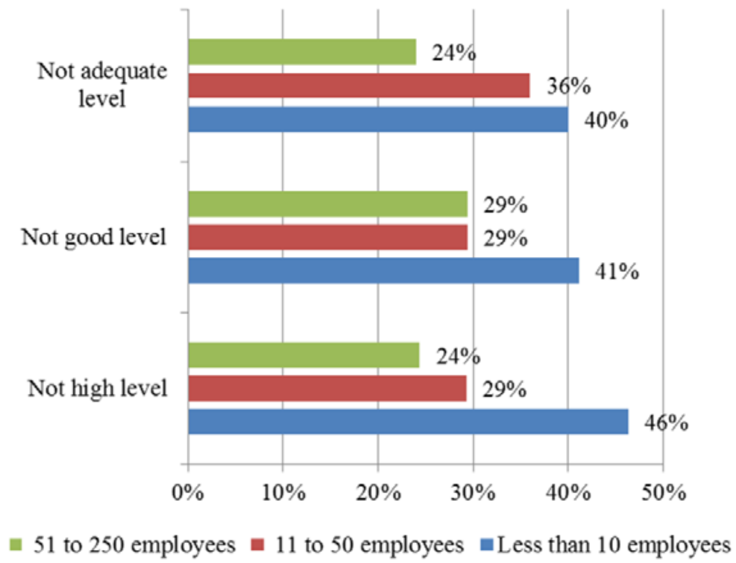

Figure 11b. Impact of SME size on levels of familiarity with BIM concepts

The results of the correlation performed between Proxy2 and Proxy5 are presented in Table II. The correlation is statistically significant at the 0.05 level and positive and, although not particularly strong, suggests that good levels of BIM software expertise are linked to good levels of familiarity with soft BIM related concepts. This result is quite important as previous studies (see Davies et al., 2015; Papadonikolaki and van Oel, 2016) have identified and distinguished between BIM soft and technical skills but have not established any link between them. Given the concepts examined in this study and taking into consideration that the core aspects of BIM include people, process, technology and policy (Leite et al., 2011), the correlation confirms the interdependence among, at least, the latter three.

- Insert Table II here -

As correlation does not prove any causation, the relationship between good knowledge of BIM software and concepts was investigated in more detail. However, it was found that the direction of causality is either way with 50% of respondents with good knowledge of BIM software having good familiarity with BIM concepts and 58% of respondents with good familiarity with BIM concepts having good knowledge of BIM software.

The next step of the analysis focused on the competencies of the various professional disciplines represented in the study. To determine whether the differences between professional groups are significant the Kruskal-Wallis (KW) test was used. Essentially, the KW test is the non-parametric version of ANOVA and, in contrast with the Mann-Whitney test, allows for comparing between more than two groups. The results of the KW test are shown in Table III and demonstrate that there are statistically significant differences between the various groups in terms of high or good levels of expertise in BIM software (proxy1 and proxy2).

- Insert Table III here -

Subsequent comparisons for each pair of groups showed that the BIM software competence between Architects and the rest of the professionals differ significantly. Indeed, in contrast to the very low expertise across the sector, 71% of the Architects appear to have good or high level of expertise in BIM software. However, the KW results also demonstrated that differences are not significant in relation to SMEs familiarity with BIM concepts. In fact, descriptive statistics show that consultants are more familiar with BIM concepts than Architects. Therefore, it would be appropriate to suggest that different professional domains have different levels of BIM capacity and also that they focus on different aspects of BIM. As a result, they would require different approaches to BIM implementation support which are not covered by a one-size-fits-all strategy. This finding also confirms London's (2006) view that research needs to differentiate among types of construction SMEs in order to provide more pragmatic suggestions for policy makers regarding approaches that promote BIM adoption.

The collected data also showed that more than 70% of the Architects offer Project Management services. However, it was not proven that this was facilitated by higher expertise in BIM software. Still, given the correlation between BIM software expertise and familiarity with BIM related concepts one can safely assume that Architects, more than any other professional group, have the potential to realise the BIM-related benefits faster. In fact, this belief was first expressed in 2008 by Hartmann and Fischer (2008) who suggested that Architects could use BIM profitably without even collaborating with others. However, the benefits could be spread to the whole supply chain by releasing the power of collaboration through the changing roles clients, architects, engineers, and builders within a process using BIM (Sebastian, 2011; Papadonikolaki et al., 2016).

Conclusion

The current eagerness to support wide implementation of BIM in the AEC sector has been accompanied by high expectations of the benefits it will bring. Although this is certainly justified and understandable one cannot underestimate the scepticism about the sector's recorded struggle to realise expected benefits from IT investments (Willcocks, 1992; Love and Irani, 2004). A major strength and benefit of BIM is in facilitating information management, communication and collaboration between supply chain actors. However, in order to maximise the aforementioned benefit, all supply chain actors should participate in the BIM process during project delivery. Given the amount of SMEs in the AEC sector, the adoption and implementation of BIM by SMEs becomes a fundamental requirement. The wider implications of the preceding statement vis-à-vis the findings of this research are theoretical as well as practical.

From a theoretical perspective, the research presented in this paper confirmed a growing concern expressed in previous literature. The findings indicated that SMEs knowledge in existing BIM support systems is at a particularly low level with monetary related issues identified as the main barrier. At the same time, non-financial factors such as peer education, industry initiatives and effective leadership were highlighted as being the most useful in facilitating further adoption. The outcome is a strong indication that more needs to be done to encourage SMEs to explore, adopt and implement BIM. This is also a clear call for the sector to come together in order to exchange ideas and work together in order to build BIM capacity across the supply chain.

BIM adoption, as an on-going process, requires continuous monitoring, planning and execution. This would allow for benchmarking progress, developing appropriate solutions and applying interventions that can help the sector achieve substantial benefits, mainly through collaboration. Collaboration is largely a cultural issue which is difficult to change and unlikely to be forced. Still, it is possible to be nurtured through consistent engagement and support tailored to SMEs. A precondition to this is the development of an advanced and detailed understanding of the functional and organisational characteristics of the sector, largely SME-dominated, supply chains (London and Kenley, 2001; Vidalakis et al., 2011). Indeed, this study highlighted important variations of SMEs in the adoption and implementation of BIM. These variations, based on company size and discipline, suggest the heterogeneity of SMEs which reflects on the effectiveness and appropriateness of BIM adoption strategies and initiatives. It also underlines the requirement for further investigation into the diverse information needs and requirements of SMEs that will enable better communication and collaboration across organisational boundaries and the sector as a whole. Lastly, a major implication relates to 'one-size-fits-all' type of solution for collaborative BIM adoption by SMEs. The study argued that, each SME and its associated supply chain should be examined before recommending any BIM adoption and implementation strategy. Without such an approach implementing BIM may lead to failures which can be counter-productive.

Based on the above, it will be imperative to conduct further research on the relationship between supply chain characteristics and SME BIM adoption potential. Furthermore, the correlation between BIM soft and software skills should be thoroughly investigated. Although, the study did not focus on this relationship, it will be imperative to further conduct a detailed study to understand the links between the different skill sets which are required for the optimal adoption and implementation of BIM.

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