A FRAMEWORK TO ASSIST IN THE ANALYSIS OF RISKS AND REWARDS OF ADOPTING BIM FOR SMEs IN THE UK

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Abstract. Building information modelling (BIM) adoption amongst larger construction firms and innovators seems to be on the increase. However, there is evidence to suggest that small and medium sized enterprises (SMEs) are currently lagging behind and are losing out in winning publicly funded projects. Guidance and frameworks to assist SMEs to make an informed decision about BIM adoption are currently lacking. There has been no systematic effort to date to bring together the results of research in SMEs' BIM adoption. Consequently, this paper seeks to bridge this gap and provide a conceptual framework to give a theoretical foundation to the study of brokering risks and rewards in the adoption of BIM for project delivery. This framework is comprehensive and includes trading off risks and rewards associated with several criteria, such as stage of involvement, project value, funding, and the procurement route chosen. The approach has been validated by a representative sample of BIM users and the findings of the validation are also presented. The findings of the framework validation reveal that early design stage, project size between £5 m and £50 m, private funding, and integrated project delivery procurement are the best opportunities that enable SMEs to maximise the benefits and minimise the risks, when adopting BIM.

Keywords: BIM, risk, reward, SMEs, involvement phase, project value, source of funding, procurement route.

Introduction

Building information modelling (BIM) is emerging as the industry standard approach to the modelling and management of building lifecycles from design and construction through to maintenance and eventual demolition. UK Government's Construction Strategy has pushed forward the programme for adopting BIM. BIM Level 2 became compulsory on publicly procured projects from April 2016. Consequently, future bidders on public building projects are required to work collaboratively through 3D models and exchange information based on standards such as the PAS 1192-2:2013. Specification for information management for the capital/delivery phase of construction projects using building information modelling (NBS 2013). More recently, there has been a wider drive to push the whole industry to embrace BIM so that it can capitalise on the benefits it confers (RICS 2014). BIM usage in the UK's construction industry has recorded a significant increase over the last few years. The survey published by the National Building Specification (NBS) shows that the percentage of industry using BIM rose

from 13% in 2010 to 39% in 2012. Fifty-four percent of industry is not using BIM but is aware of it while 77% said that they would be using it in the next year (NBS 2013).

However, BIM adoption primary concerns large companies. Smaller companies are still slow in embracing the new technology (SmartMarket Report 2012). Indeed, small and medium sized enterprises (SMEs) are lagging behind in BIM adoption and are losing out in winning publicly funded projects and potentially private sector ones too. It emerged that 40% of construction SMEs lose out on 90% of the public sector work they bid for, while more than half of SMEs claim to have identified a reduction in their rate of success in bidding for public sector contracts over the past five years (Federation of Master Builders 2013).

Blackwell (2012) warns that SMEs could well lose contracts in both the domestic and international markets if they remain slow in grasping and adopting BIM as a transformative technology and process. Losing out on business results in the SMEs feeling less competitive and

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innovative in comparison with their competitors (Harris 2013). This trend may continue if SMEs do not pay attention to investing in new technology and reforming their organisations in order to meet with the requirements of the industry.

SMEs seem to favour private projects where no BIM mandate exists. This sector is now a targeted area; the purpose being to "rescue" SMEs from losing business in the BIM environment. However, recent reports indicate that around two thirds of both public sector (65%) and private sector (70%) UK owners state that they will require BIM on their projects compared to 30% of US public owners and just 11% of US private sector ones (SmartMarket Report 2014). Therefore, over-reliance on private sector works is not a viable option. These statistics ought to rouse SMEs from traditional approaches and encourage new strategies to adopt new technology and collaborative practices.

It appears that SMEs are yet to be convinced that BIM is beneficial to them, and remain concerned about the potential risks to their business. It appears that guidance and frameworks to assist SMEs in making an informed decision about BIM adoption are currently lacking. This paper reports on the development of a conceptual framework to assist in the analysis of the risks and rewards of adopting BIM by SMEs in project delivery. The findings of the framework validation are also presented. The paper is divided into six sections. The introduction section presents the background knowledge and the research gap. Section 1 addresses current efforts to improve BIM adoption for SMEs. Section 2 examines the key factors affecting BIM adoption and details the rationale for the development of a conceptual framework. Section 3 outlines the adopted research methodology. Results and discussion of the validation of the framework are examined in Section 4. The conclusion section summarises the results and the contribution of the paper to existing knowledge as well as future research work.

1. BIM adoption by SMEs

Increasing BIM usage amongst SMEs is a key condition for achieving the transformation of the construction industry through BIM. SMEs are widely considered to be the backbone of major economies around the world (Love *et al.* 2004). An SME is usually defined by its characteristics including number of staff, turnover, asset size and capital requirement (Ibrahim *et al.* 1986; Hsu *et al.* 2012). In 2010 Canadian SMEs employed approximately 48% of the private sector workforce (Industry Canada 2011) and 85% of new jobs were created by SMEs in the period 2002–2010 (Eurostat 2012). In the UK, there are 950,000 SMEs that generate about 80% of the production cost of the UK construction industry (Robson *et al.* 2014). At the start of 2014, 99.3% of the 5.2 million private sector businesses were small, and 99.9% were small or medium sized (Department for Business Innovation & Skills 2014).

The differences between SMEs and large organisations are expressed in terms of resources limitation, and competitive and functional structure. Generally, SMEs usually lack personnel, finance and knowledge relevant to management and adopting new technology as well as effective strategies of development (Jutla *et al.* 2002; Caskey *et al.* 2001). SMEs usually find it difficult to tackle barriers and limitations when the industry requires its sectors to change in order to catch up with the developments and the requirements of the country (Eurostat 2012). Typically, the amount of large companies adopting BIM are almost threefold more than smaller ones, the former making up 74% in 2009 and this figure continuing to rise up to 91% in 2012, whereas BIM adoptions in small firms are just around 25% in 2009, followed by small to medium firms which account for 41% (SmartMarket Report 2012).

Evidently, if BIM is to be the new methodology used by the industry to conduct construction projects then it has to accommodate all organisation sizes. However, the aforementioned figures indicate that adopting BIM amongst SMEs has, so far, not received enough attention by policy makers, the industry, and the research community. As a result, they have not fully recognised the benefits of using BIM in project delivery (Kouider 2013). This field of study has also attracted little attention, which is reflected in the limited number of publications that directly reference the use of BIM within SMEs. Consequently, it emerged that SMEs are pessimistic about BIM and consider BIM discriminates against small independent practices in the built environment sector, notwithstanding the fact that BIM implementation could be more easily achieved in comparison with larger organisations (NBS 2015).

Efforts to support BIM adoption amongst SMEs in the construction industry include the development of BIM support groups, standards and protocols. BIM4SME is responsible for providing resources, best practices and knowledge to SMEs to help them achieve BIM level 2 (Bim4sme.org). The BIM Protocol created by the Construction Institution Council in 2013 aims to clarify legal issues surrounding the obligations and rights of stakeholders on a BIM project (Bim4sme.org). The Public Available Specification (PAS) parts 2, 3 and BS1192-4 have been developed specifically for information management for the capital/delivery phase of construction, the operation phase of asset, and the exchange of information throughout the lifecycle of a facility (Bim4sme.org). In addition, a series of BIM frameworks has been developed to evaluate areas and to identify factors for practical BIM effectiveness (Jung *et al.* 2011) and multidisciplinary collaboration (Singh *et al.* 2011); optimising and simulating construction planning and scheduling (Song *et al.* 2012); identifying individual BIM competencies (Succar *et al.* 2013); and ensuring best value in construction projects (Liu *et al.* 2015). However, these frameworks and efforts have so far had little impact on SMEs adoption of BIM.

It appears that the surge of research to increase BIM adoption has, so far, had limited success in convincing SMEs. This failure is largely due to the lack of understanding of the basic business case, which has led SMEs ignoring the BIM agenda. Kouider (2013) found that not knowing what value SMEs can achieve from their money investment and how long it will take to get a return on the investment are two of the main barriers for BIM adoption. Indeed, BIM is perceived by SMEs to disrupt their work process, as well as having a significant impact on already scarce human and financial resources. Consequently, its implementation has several accompanying risks. SMEs find it difficult to weigh up the risks and rewards that they may face when they invest in BIM (Kouider 2013; Chien *et al.* 2014). Amongst other concerns such as a lack of skills and BIM knowledge, SMEs seem worried about BIM affordability (Liu *et al.* 2010; Eastman *et al.* 2011; Migilinskas *et al.* 2013), and return on investment is uncertain (Yang *et al.* 2008; Azhar *et al.* 2011, 2012; Won *et al.* 2013). Despite various efforts and initiatives, a recent study conducted by NBS (2015) revealed that "BIM adoption is moving from being led by innovators and early adopters, towards being a more mature market, where the mainstream is investigating and assessing the benefits of doing so".

Unfortunately, there is currently a lack of guidance and assistance for SMEs in how to adopt BIM in project delivery. Absence of standards and frameworks to evaluate the extent to which BIM can bring benefits to AEC through project delivery, especially for the SMEs, results in low rates of BIM adoption (Liu *et al.* 2010; Eastman *et al.* 2011; Migilinskas *et al.* 2013; Kouider 2013). SMEs are known to be a hard to reach groups and require specific assistance to encourage BIM adoption.

This research harnessed advances in identifying the practicality of BIM effectiveness to increase its implementation. The analysis of recent efforts, outlined in Table 1, helped determine the key issues affecting BIM adoption. This paper reports on the development of a comprehensive framework designed to assist SMEs in brokering the potential risks and rewards of adopting BIM, especially in the context of project delivery.

2. Conceptual framework to help in the analysis of the risks and rewards of adopting BIM for SMEs

A two-step approach to select relevant articles to be included in the study was adopted. For the first step, it was decided to screen the literature to identify sources developing methodologies for frameworks for BIM adoption.

Table 1. Key factors affecting BIM adoption

Reference	Involvement phase			Project value			Source of funding		Procurement route		
	Design stage	Construction stage	Operation stage	< £5 m	≥ £5 m, ≤ £50 m	≥ £50 m	Public	Private	Traditional	Two-stage design and build	Integrated project delivery
Al-Hammad *et al.* (1997)	x	x	x								
Bryde *et al.* (2013)	x	x	x	x	x	x	x	x			
Negendahl (2015)	x	x	x			x	x	x			x
Succar (2012)	x	x	x								
Arditi *et al.* (1999)	x	x	x								
Oti *et al.* (2015)	x	x	x								
Eastman *et al.* (2011)				x	x	x			x	x	x
Eadie *et al.* (2015)									x	x	x
Luu *et al.* (2013)									x	x	x
Volk *et al.* (2014)						x	x	x			
Liu *et al.* (2010)				x	x	x					
Azhar *et al.* (2011)				x	x	x					
Yang *et al.* (2008)				x	x	x					
Byrne *et al.* (2011)									x	x	x
Cox *et al.* (2011)									x	x	x
Hogg *et al.* (2007)									x	x	x
Hughes *et al.* (2006)									x	x	x
Migilinskas *et al.* (2013)				x	x	x					
Won *et al.* (2013)				x	x	x					

A total of 226 citations were identified through the online database search. Articles not addressing the research focus were excluded. Those meeting the inclusion criteria were retrieved in full. The literature once extracted was critically appraised and discussed. A narrative approach was then selected to synthesise the data.

The final studies were scrutinised and nineteen articles were identified. A systematic literature review of these studies established a link between BIM adoption and involvement stage, project value, source of funding, as well as procurement route (Table 1). For each main component, a series of attributes were also identified. These factors paved the way to the development of the conceptual framework.

2.1. Involvement phase

The involvement phase refers to the timing of the engagement in project delivery in order to allow an SME to maximise rewards and minimise risks when adopting BIM to deliver projects (Al-Hammad *et al.* 1997; Negendahl 2015; Succar 2012). The involvement phase of project delivery is divided into three stages: design stage, construction stage, and operation stage.

The design stage is a combination of strategic decision making, preparation and brief, concept design, and technical design. This is considered as the most important stage of project delivery because decision making, assigning resources to parties, and allocating risks and rewards are made during this phase (Penttilä *et al.* 2007; Abrishami *et al.* 2014; Bryde *et al.* 2013; Negendahl 2015; Succar 2012). It is recognised that the involvement of key disciplines at the early stages of the project result in optimum benefits for project delivery (Lahdenperä 2012).

The construction stage is where contractors complete operations according to the conditions of the contract. It is the stage when work starts on site and visible progress is made (Fewings 2013). The process of coordinating human resources, materials, and machines is deployed at this stage (Li *et al.* 2012). The operation stage refers to the handover of the building and conclusion of the building contract. Undertaking of maintenance work in accordance with the schedule of services is assigned to this stage (Becerik-Gerber *et al.* 2011). Parties' involvement at the construction and maintenance/operation stages has less influence on project quality and outcomes as key decisions are taken at earlier stages of the process.

2.2. Project value

The construction industry is experiencing a major change towards projects of increasing complexity (Naoum 2003). Project's values vary from less than £5 m for small projects, to £5−£50 m for medium projects, and more than £50 m for large projects. Procurement choice is dependent on the complexity or size of projects, and aims to ensure completion on time and within budget (CIOB 2010). According to NBS (2015), small sized projects are associated with organisations which are slower in adopting new technology and have fewer staff compared to larger ones. This type of organisation struggles to win business especially in the current highly competitive environment. Medium sized projects are usually derived from a breakdown of complex projects, which are delivered by groups of SMEs. Each SME can be assigned a suitable unit of the project with a tight schedule of performance (Hatmoko *et al.* 2010). Thus, managing the collaborative performance of SMEs in conducting medium sized projects is significant. Similarly, managing parties participating in large sized projects also needs to be considered carefully. The general rule is that the larger the scope of the project, the more complex the participants will be (Volk *et al.* 2014). There has been an assumption that using BIM on small scale projects (e.g. less than £5 m) could be less likely to yield the level of benefit compared to projects of a larger scale (Bryde *et al.* 2013).

2.3. Source of funding

Project funding is sourced from either the public or private sector (Jaafar *et al.* 2012). Private clients are characterised by being increasingly better informed, more aware and more knowledgeable about how to get into the building process (SmartMarket Report 2014). They tend to expect best value from contractors and suppliers. This has led to a shift from "lowest-price wins" to "multi-criteria selection practices" in the contractor selection process, especially since the implementation of BIM (Wong *et al.* 2010). The public sector client, primarily the government, is observed to be the initiator of major developments in social amenity projects. It is involved in the construction of buildings such as schools and colleges, hospitals, universities, fire stations, prisons and museums (Office for National Statistics 2014). This sector is considered the main driver of the BIM agenda (British Standards Institution 2013). However, there is evidence to suggest that private clients are increasingly interested in BIM (SmartMarket Report 2014).

2.4. Procurement route

Procurement in construction projects is defined as a process whereby clients make decisions about how they will build (Hogg *et al.* 2007). The procurement stage plays a significant role in contributing to the success of any building project (Squires *et al.* 2011). Essentially, construction procurement is an array of considered risks that need to be examined carefully by stakeholders. Each procurement route has developed its own characteristics to suit different kinds and sizes of project (Nahapeit *et al.* 1985). As a general rule, the traditional procurement method is most suited for delivering small sized projects whereas design and build is used for projects with medium size, and integrated project delivery (IPD) is for large and complex projects (CIOB 2010). In traditional procurement, the client appoints consultants to design the project in detail. The tender documents are then prepared, includ-

ing drawings, work schedules, and bills of quantities. Constructors are then invited to submit tenders for the construction of the project (Hogg 2007). The two stage design and build method was developed to eliminate the liability gap between design and construction within the traditional method. The client benefits from single point responsibility by making the contractors solely responsible for design, construction and solving problems during the building lifecycle (Franks 1998; Masterman 2002). Integrated Project Delivery (IPD) advocates the early involvement of key parties (Lahdenperä 2012). IPD seeks to improve construction productivity by using a combination of partnering concepts and lean thinking to improve communication, eliminate waste, reduce costs, address expectations and generate value for all parties involved (Hardin 2009). IPD achieves significant improvements in six performance areas: quality, schedule, project changes, communication among stakeholders, environmental, and financial performance (Asmar *et al.* 2013).

2.5. Conceptual framework for BIM adoption by SMEs

Frameworks are developed to assist and guide research effort, enhance exchanging information or knowledge, and to consolidate relevant concepts into a descriptive or predictive model (Jung *et al.* 2011; Kirs *et al.* 1989). There has been no systematic effort to date to bring together the results of research in SMEs' BIM adoption. Consequently, this paper seeks to bridge this gap and provide a conceptual framework to give a theoretical foundation to the study of brokering risks and rewards in the adoption of BIM for project delivery.

Notwithstanding the proliferation of literature examined, no studies attempted to develop a framework that postulated criteria for brokering risks and rewards, associated with BIM adoption for project delivery by SMEs (see Table 1). The recent and increasingly widespread use of BIM in the construction industry (Shepherd 2004) and the lack of engagement of SMEs (Federation of Master Builders 2013) with a BIM agenda have created a need to develop a conceptual model. The model then requires testing to ascertain if the prevailing assumptions can form the basis for the development of an accepted theory in the field.

The conceptual framework of this study is illustrated in Figure 1 was established based on key factors (Table 1) synthesised from existing literature in this field to address the gap in knowledge. It outlines the entire context that SMEs are considering when they adopt BIM to deliver construction projects. It emerges that there are four broad issues in the study of BIM adoption that have impact on SMEs:

1. Involvement phase, which includes design stage, construction stage, and operation /maintenance stage.
2. Project value, which consists of projects less than £5 million, between £5 million and £50 million, and greater than £50 million.
3. Source of funding, which is concerned with projects funded by either public or private clients.
4. Procurement route, which deals with traditional method, two-stage design and build, and integrated project delivery.

In addition, the risks and the rewards associated with each criterion are also synthesised from existing literature and are stored in the risk and reward profiles. They are then used to determine the potential risks and rewards linked to each criterion. Depending on users' selection, different risks and rewards are generated, thus providing an informed basis for decision-making on the best course of action for BIM adoption. These potential risks and rewards are assessed in terms of their likelihood of occurrence and level of impact on an SME. To ensure improved accessibility, the framework is presented to SMEs online through a friendly user interface. The advantage of this method is its ease of use, enhanced accessibility, and attractive presentation.
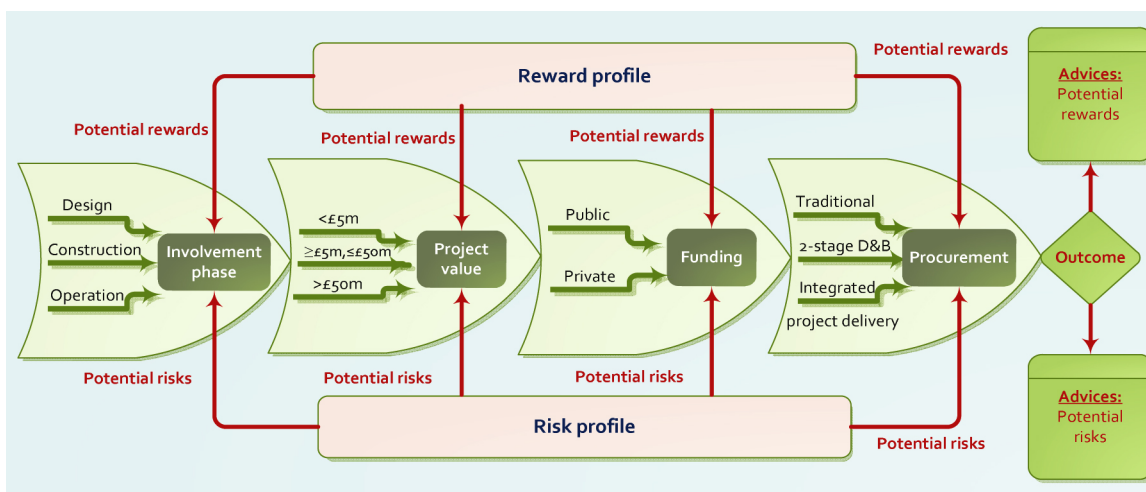

Fig. 1. Conceptual framework to help in the analysis of the risks and rewards of adopting BIM for SMEs
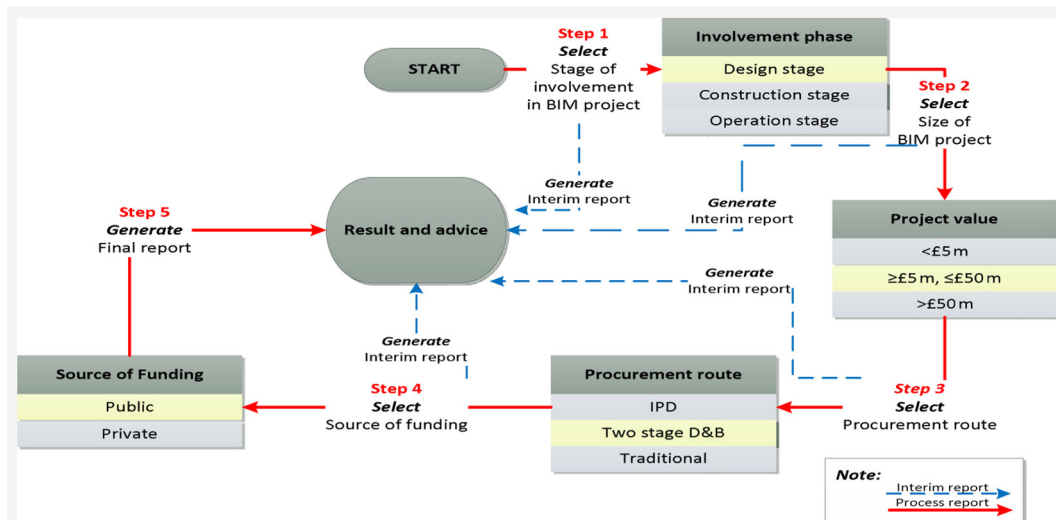
Fig. 2. The workflow diagram of the framework

The workflow diagram of the framework is illustrated in Figure 2. It shows that there are a total of five steps that are used to anticipate the risks and opportunities involved in using BIM in project delivery. These steps start with identifying the involvement phase (e.g. design stage). The framework then deals with the project value (e.g. $\geq £5\,m \leq £50\,m$), the procurement route (e.g. two stage D&B), as well as the source of funding (e.g. Public) as criteria to generate a final recommendation at the end of the assessment process. The process of these steps is demonstrated in Figure 2. The framework also allows SME users to generate interim reports at each step of the process. These reports include presenting risks and rewards at every step of the process (indicated by dash lines). The risks and rewards are calculated based on the weight of the criteria. Risks and rewards associated with the criteria were also validated and then used as informative output in the final report of the assessment process.

3. Research methodology

The primary research method in this study uses a process of activities known as framework validation. Framework validation entails checking that the system complies with its own requirements and is free from failures or incorrect behaviour (Ferreira *et al.* 2009). This process is conducted by obtaining objective evidence establishing that the system will perform its intended functions. Consequently, the validation of the conceptual framework helps to deter-

mine the level of robustness and usefulness of the criteria for SMEs to enable them to maximise the benefits and minimise the potential risks.

An initial pilot study was conducted with six SMEs as a precursor to the validation of the framework. The purpose of this pilot study was to ensure that the evaluation of each criterion of the framework was meaningful and easy to follow. Feedback led to adjustments to the criteria and the design of the framework. Subsequently, an online structured questionnaire survey was deployed for the validation of the criteria of the framework. The survey sought to examine the impact of each attribute, within the framework, on SME organisations, in terms of their potential risks and rewards.

Rank order questions were selected for this survey, using Qualtrics platform which provides an individual token system for survey management. This ensures that participants cannot undertake the survey twice and all data is stored in an online MySQL data base. The rank order question type allows participants to rank a set of items against each other. This type of question has the benefit of requiring respondents to identify how elements or choices compare to each other and determine the most important ones to participants (Cao *et al.* 2015). Figure 3 illustrates how respondents had the opportunity to classify the criteria from the most to the least important by dragging and dropping the available choices into an appropriate order. They were asked to rank between elements within a situation to ascertain the most and the

Fig. 3. Sample of ranked questions by a respondent

least important attributes in terms of the likelihood of occurrences and impacts of BIM implementation in project delivery. The survey included five sections which is detailed in Table 2 below.

Participants in the survey were limited to companies with BIM experience, working in the UK, and were largely selected from the main BIM groups on LinkedIn. These include BIM4SME (857 members), BIM Architecture (18,214 members), and BIM Experts (41,281 members). To determine the sample size, Czaja *et al.* (1996) suggest that sample size *ss* could be calculated by using the following formula:

$$ss = \frac{Z^2 * e(1-e)}{c^2},\qquad(1)$$

where:

z: Z score: 1.96 – the most common confidence intervals;

c: 10% – confidence interval, expressed as a decimal;

e: 50% – the worst case percentage picking choice, expressed as a decimal.

As a result:

$$ss = \frac{z^2 * e(1-e)}{c^2} = \frac{1.96^2 * 0.5(1-0.5)}{0.1^2} = 96.04 .$$

However, there are currently 950,000 SMEs in the UK construction industry (House of Commons 2015), so the new sample size should be:

$$new\ ss = \frac{ss}{1+\dfrac{ss-1}{pop}} = \frac{96.04}{1+\dfrac{96.04-1}{950.000}} = 96.03.$$

This result suggests that 96 responses are needed for a valid sample size.

To cater for a poor response rate, 20−30% above the sample size is believed to be the norm (Takim *et al.* 2004). Therefore, the sample size of this survey is determined as follows:

$$ss = \frac{96.03}{0.2} = 480\ participants.$$

An invitation letter with a link to the online survey included was sent to 480 personal emails in the UK, selected carefully from the aforementioned BIM groups. Before the survey went live, three pilots and two semi-structured interviews were conducted with personnel with BIM experience to ensure the content of the questionnaire and the uniform understanding of the research issues were obtained. As a result of the invitation to be involved in the survey, 115 participants responded positively. However, only 93 participants completed all the questions in the survey.

3.1. Data analysis methodology

This research adopted the voting analytic hierarchy process (VAHP) methodology developed by Hadi-Vencheh and Niazi-Motlagh (2011) to calculate the weight and rank elements of the issues being investigated. This model is inherited from the analytic hierarchy process (AHP), which is popular for multiple criteria decision making in systems involving many levels and the use of the theory of measurement through pair-wise comparisons (Marjanavie *et al.* 2010). In this method, Hadi-Vencheh and Niazi-Motlagh (2011) proposed a formula to calculate the weight of elements independently from the total number of responses and the scale of ranking. The weight of every element is calculated based on the number of elements and the number ranks (votes) in each order (place). This model is matched to the purpose of the research as ranking between elements from the most important to the least important and the number of elements varies depending on the issues being invested. The voting and ranking model is as follows:

$$\partial_{rr} = \max \sum_{s=1}^{s} x_{rs}\ w_s;\qquad(2)$$

$$\sum_{s=1}^{s} x_{rs}\ w_s \le 1 \quad r = 1, 2, ...S;$$

$$w_1 \ge 2w_2 \ge 3w_3 \ge ... \ge 0;\qquad(3)$$

$$\sum_{s=1}^{s} w_s = 1,$$

Table 2. Details of survey design

Section	Assessment criteria	Task
1. Personal information	Role within their organisation; Length of professional experience; Length of BIM experience; Size of organisation that they are working for.	In section 1, the participants were asked to provide their personal information. In each section from 2 to 5, they were asked to rank between elements, from the most to the least likely, to allow SMEs to maximise the benefits and minimise the risks when adopting BIM. In addition, they were also required to rank the risks and rewards associated with each item, from the most to the least likely, in terms of their likelihood of occurrence and level of impact on an SME.
2. Stages of involvement	Design stage; Construction stage; Operation/maintenance stage.	
3. Project value	Less than £5 million; Between £5 million and £50 million; Greater than £50 million.	
4. Source of funding	Pubic funded project; Private funded project.	
5. Procurement route	Traditional; Two-stage design and build; Integrated project delivery.	

where x_{rs} is the total votes of the rth element for the sth place. In this survey, r equal to s is also the number of elements within an issue of investigation. w_s is the constraint standing for the difference in weight between s^{th} and $(s+1)^{th}$ place. The successive steps to analyse the data are as follows:

Step 1 − calculate w_s. For example, the involvement phase in the framework of this study consists of three sub-criteria: Design stage, Construction stage and Operation stage. Therefore, by using the Eqn (3):

$$w_1 \geq 2w_2 \geq 3w_3 \geq 0;$$

and

$$\sum_{s=1}^{s} w_s = 1.$$

As a result, w_s will be: $w_1 = 0.545455$; $w_2 = 0.272727$; $w_3 = 0.181818$.

Step 2 − calculate the weight and rank criteria by using the VAHP formula (2): $\partial_{rr} = \max \sum_{s=1}^{s} x_{rs} \, w_s$.

The result of this process can be seen in Table 3.

Table 3. Priority votes of 3 criteria from 93 respondents in the survey

Criteria	1st	2nd	3rd	Weight	Normal	Rank
Design	64	11	18	41.182	0.443	1
Construction	15	69	9	28.636	0.308	2
Operation	14	13	66	23.182	0.249	3
Total	93	93	93	93	1	

Consequently, based on the scale of ranking, the VAHP method has helped to determine the weight for each criterion. The weights were subsequently normalised and then ranked. Similarly, this process of calculation is applied to all the other criteria of the framework.

4. Results and discussion of the validation of the framework

A total of 93 participants responded to the survey, which amounts to 96.8% of the target (96 responses). Participants of the survey are working for different types of organisation ranging from micro (less than 10 staff) to large (greater than 250 staff). This sample selection was expected to achieve a full range of views on BIM in terms of risks and rewards, when adopting it to deliver construction projects. The sample breakdown is shown in Table 4 and the size of organisation is defined by the European Union criteria (European Commission 2015).

As expected, the survey revealed that the majority of the organisations that have adopted BIM in project delivery are large organisations (33.33%). It can be inferred that these types of organisations are more likely to be getting ready to achieve BIM adoption at level 2 by 2016. Furthermore, a large number of participants, accounting

for the second highest responses (27.96%) in the survey, are working for micro organisations, across the UK.

Table 4. Organisation size from sample

Organisation size	Number	Percentage of respondents	Cumulative %
1−10 (micro)	26	27.96%	27.83%
11−50 (small)	19	20.43%	48.39%
51−250 (medium)	17	18.28%	66.67%
> 250 (large)	31	33.33%	
Total	93	100	100

A large number of participants, accounting for the second highest responses (27.96%) in the survey, are working for micro organisations, across the UK. Despite the larger participation amongst SMEs, the results revealed that the majority of the organisations that have adopted BIM in project delivery are large companies (33.33%). This is in agreement with previous studies revealed that these types of organisations are more likely to be getting ready to adopt BIM (NBS 2015). Indeed, large gaps amongst organisations in terms of BIM adoption was found, and the large one is still dominant (Electrical Contractor Association 2015).

The respondents represented many professions within the construction industry, as indicated in Table 5. They were asked to list the professional duties that they are carrying out for their company. The professional experience and BIM experience of participants was highly relevant, as detailed in Table 6. The experience of the respondents is to ensure knowledge and experience of participants within the issues under investigation and the validity of collected data. The results showed that more than 70% of participants had more than four years of experience in the construction industry, and about 55% had more than four years of working with BIM in project delivery (Table 6). It seems that there is an increasing trend for professionals

Table 5. Sample breakdown by professional duties

Professional duties	Frequency	Percentage of respondents
Architecture	18	19.35%
BIM manager	15	16.13%
Quality surveyor	12	12.9%
BIM professional	10	10.75%
BIM coordinator	9	9.68%
BIM technician	7	7.53%
BIM consultant specialist	6	6.45%
Civil engineer	4	4.3%
Structural engineer	4	4.3%
Construction designer	1	1.08%

to have BIM experience in accordance with the growth in BIM adoption. This finding concurs with the SmartMarket Report (2014), which revealed that the number of organisations with five and more years' experience in BIM use doubled between 2009 and 2012: from 6% to 13% for those with five years' experience, and from 18% to 36% for those with more than 5 years' experience. Indeed, an investment in upskilling staff in BIM is increasingly seen as critical as it enables organisation to have more competencies to compete with other rivals (Fewings 2013).

Table 6. Experience of participants

Years of experience	Professional experience		BIM experience	
	Number	% of respondents	Number	% of respondents
1−3 years	27	29.03%	41	44.09%
4−10 years	31	33.33%	45	48.39%
>10 years	35	37.63%	7	7.53%

4.1. Stages of involvement

Respondents were asked to rank the stage of involvement in projects from the most to the least likelihood of occurrence. The results in Table 7 indicate that the design stage is ranked as the best stage with the weight of 0.443. This is followed by the construction stage and the operation stage, occupying the weight of 0.308 and 0.249 respectively.

Table 7. Stages of involvement that allow an SME to maximise rewards and minimise risks

Criteria	1st	2nd	3rd	Weight	Normal	Rank
Design	64	11	18	41.182	0.443	1
Construction	15	69	9	28.636	0.308	2
Operation	14	13	66	23.182	0.249	3
Total	93	93	93	93	1	

The findings show that the SMEs who usually participate in the early stage of project involvement are likely to get more opportunities to maximise rewards and minimise risks. This trend is downward, reaching the lowest point in terms of benefits and the highest level of risks in the events of organisations participating in projects tardily. This can be explained by the phenomenon that critical decisions have been taken in the early stages of the project. Lahdenperä (2012) found that the

later decisions are made, the more expensive the design changes are. The findings of this study confirm previous research that by starting in very early stages of the project, stakeholders are more likely to see the benefits of BIM such as enhancing coordination, productivity, and business operations (Light 2011). Indeed, early involvement means higher chance to minimize waste and increase value through visualising model, which can help to avoid errors and omissions (Azhar *et al.* 2012). By doing so, any errors, omissions, risks can be identified and mitigated early. This can help parties obtain significant waste reduction across the whole project (Azhar *et al.* 2011). In addition, high collaborative working in the early stages of the project can lead to more time for managing and predicting implications on construction, maintenance and operations, and as a result, project performance can be improved dramatically (MacLeamy 2004).

4.2. Project values

In terms of project value, the participants were asked to rank types of project value from most to least in terms of enabling for SMEs to maximise rewards and minimise risks when using BIM to deliver BIM projects. The survey shows that the best project value for BIM is between £5 million and £50 million, closely followed by projects greater than £50 million and less than £5 million (Table 8). The difference in terms of weight between elements is 0.028, when comparing the first ranked element to the second one, and 0.003 for the difference between the second ranked item and the lowest ranked one.

The result of this study demonstrated that whatever the project value is, BIM is potentially beneficial. It suggests that BIM could be relevant to various project values, including humbler projects-less than £5 m in value. This finding challenges the prevailing assumption that we should not bother with BIM for small-scale projects (i.e. NBS 2015; Bryde *et al.* 2013). Indeed, research found that BIM is applicable to projects of all scales, and it is useful in assisting organisations to build small as well as high-risk projects successfully (Furneaux *et al.* 2008). However, industry currently perceives the prime added value of BIM is in managing large and complex projects, where failures in communication are more likely. Therefore, BIM is seen as essential in addressing the various challenges, such as clash detection, schedules and communication (Azhar *et al.* 2011). This attitude often resulted in ignoring BIM adoption in the context of a lower project value. Levy (2012) argued that smaller projects are also

Table 8. Value of project that allows an SME to maximise rewards and minimise risks

Criteria	1st	2nd	3rd	Weight	Normal	Rank
Between £5 million and £50 million	27	60	2	31.455	0.353	1
Greater than £50 million	31	16	42	28.909	0.325	2
Less than £5 million	31	13	45	28.636	0.322	3
Total	89	89	89	89	1	

vulnerable to erroneous quantitative analysis, and therefore BIM is more critical as these types of buildings "tend to have smaller budget margins, and even a small error may lead to project damaging cost overruns".

4.3. Source of funding

Essentially, public and private clients are the main sources of funding for construction projects. For this question, participants were asked to rank whether public or private sector is the potential sector that allow them to maximize the benefits and minimize the risks in adopting BIM. Results presented in Table 9 show that both private and public source of funding are significant, as they are respectively closely related (0.51 and 0.49). This result concurs with a recent findings, which indicates that around two thirds of both public sector (65%) and private sector (70%) UK clients require now BIM on new projects they will be starting (SmartMarket Report 2014).

Table 9. Sources of funding that allow an SME to maximise rewards and minimise risks

Criteria	1st	2nd	Weight	Normal	Rank
Private funded projects	45	40	43.329	0.51	1
Public funded projects	40	45	41.671	0.49	2
Total	85	85	85	1	

The current trend of adopting BIM for project delivery is not only affecting public clients (British Standards Institution 2013), but they are also required by the private sector. This finding is fundamental in encouraging SMEs to invest BIM in their organisations to be able to win public projects, as they are currently relying heavily on private projects where a BIM mandate has not been applied yet. Blackwell (2012) warns SMEs against slow uptake of BIM, leading to a loss of contracts in both the domestic and international markets. Above all, this trend may worsen their rate of success in winning bids for public sector contracts (Federation of Master Builders 2013). Furthermore, the findings of this study is urging for new strategies by SMEs to adopt BIM technology and collaborative practices to be able to win both public and private projects in an increasingly competitive market.

4.4. Procurement routes

In the construction industry, procurement routes are considered as the backbone in terms of the process of project delivery. A selection of an appropriate procurement route could reduce project cost dramatically and enhance the probability of project success (Gordon 1994; Luu *et al.* 2005). Consequently, when making decisions about whether to adopt BIM in project delivery or not, a consideration of procurement routes cannot be ignored. In this survey, participants were asked to rank three kinds of procurement routes, presented in Table 10. The question required respondents to rank the potential that

organisations can see in terms of maximising the rewards and minimising the risks when adopting BIM to deliver construction project, according to the different types of procurement route.

Table 10. Procurement routes that allow an SME to maximise benefits and minimise risks when adopting BIM

Criteria	1st	2nd	3rd	Weight	Normal	Rank
Integrated project delivery	61	5	19	38.091	0.448	1
Two-stage design and build	17	50	18	26.182	0.308	2
Traditional	7	31	47	20.818	0.245	3
Total	85	85	85	85	1	

The findings indicated in Table 9 show that the integrated project delivery procurement route is the best method to conduct BIM projects (0.448), followed by two-stage design and build, and traditional procurement with the weight of 0.308 and 0.245 respectively. This finding supports the assumption that BIM together with the integrated project delivery procurement method can help organisations to improve communication, eliminate waste, reduce costs, address expectations and generate value for all parties involved in projects (Hardin 2009; Asmar *et al.* 2013). There is currently a large gap between the highest and the lowest element of investigation with the weight of 0.203. Moreover, traditional procurement is considered as the most popular method and widely used by SMEs to deliver projects (The Chartered Institution of Building 2010). As such, this result provides a useful reminder to SMEs when they make decisions about adopting BIM to implement construction projects. The risks and rewards associated with procurement methods may vary greatly and SMEs need to consider this carefully.

Conclusions

This paper has proposed a conceptual framework to assist with the brokering of risks and rewards in adopting BIM in construction project delivery. Four key criteria were identified namely: involvement phase, project value, source of funding and procurement route. This conceptual model was validated by 93 participants from UK companies using BIM.

The validation of the framework revealed the four most significant factors that are able to help SMEs to maximise the benefits and minimise the risks in adopting BIM to deliver construction projects. (1) The most significant phase to participate in BIM projects is the design phase. This stage is identified as the essential stage in which all the key decisions are taken. Early involvement in BIM projects is critical to maximise the rewards and minimise the risks. Stakeholders must use the opportunity to influence key decisions that have significant impact on projects during construction, and maintenance/operations. (2) Regardless of project value, BIM is seen as beneficial

in any case. Although projects valued between £5 million and £50 million seem the best choice for optimum BIM benefits, the gap between this type of project compared to other groups is very small with the difference of 0.028 and 0.003 in terms of weight, compared to second ranked and lowest ranked respectively. This finding is meaningful in encouraging and enhancing organisations working on different types of projects to invest in BIM in their organisations. (3) Private clients remain the main sector that SMEs need to pay attention to when conducting BIM projects. The traditional close relationship between SMEs and private clients is changing. This is mainly because the demand from private clients in BIM implementation has increased in recent years, whereas SMEs are still slow in investing in BIM. (4) SMEs should pay particular attention where traditional procurement is used as the most popular method of deploying BIM projects. The study shows that this kind of method is the least beneficial for BIM compared to its counterparts, which accounts for the weight of 0.245. The highest ranked method is the integrated project delivery procurement route, which occupies 0.448 in terms of weight. Therefore, the risks and rewards of using BIM to conduct construction projects under the traditional procurement method may be questionable. SMEs need to carefully consider alternative procurement routes before investing in BIM for their organisation.

Future work includes the development of an online decision support system (DSS) to assist SMES in brokering the risks and rewards of adopting BIM in project delivery. The DSS is designed based on the results of the validated framework. It helps SMEs to identify the most and the least important likelihood of occurrences and the impacts of alternatives on their organisation when adopting BIM to deliver construction project. In addition, rewards and risks associated with criteria, which are stored in risk and reward profile, are also used to clarify selected alternatives. The DSS is built using HTML5, PhP, and AJAX, together with the high security database management system MySQL. In addition, it is designed as an online tool which helps to increase the accessibility as well as the simplicity of dissemination to SMEs. A representative sample of SMEs will be selected for trialling and validating the DSS.

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