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BIM: innovation in design management, influence and challenges of implementation

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The construction industry is widely being criticised as a fragmented industry. There are mounting calls for the industry to change. The espoused change calls for collaboration as well as embracing innovation in the process of design, construction and across the supply chain. Innovation and the application of emerging technologies are seen as enablers for integrating the processes 'integrating the team' such as building information modelling (BIM). A questionnaire survey was conducted to ascertain change in construction with regard to design management, innovation and the application of BIM as cutting edge pathways for collaboration. The respondents to the survey were from an array of designations across the construction industry such as construction managers, designers, engineers, design coordinators, design managers, architects, architectural technologists and surveyors. There was a general agreement by most respondents that the design team was responsible for design management in their organisation. There is a perception that the design manager and the client are the catalyst for advancing innovation. The current state of industry in terms of incorporating BIM technologies is posing a challenge as well as providing an opportunity for accomplishment. BIM technologies provide a new paradigm shift in the way buildings are designed, constructed and maintained. This paradigm shift calls for rethinking the curriculum for educating building professionals, collectively.

Keywords: BIM; innovation; design management; FM; integration and collaboration

1. Introduction

It has been more than 18 years since the publication of Sir Michael Latham's report (Latham, 1994) that was followed by Sir John Egan's report (Egan, 1998) and still there are mounting calls for change in the construction industry (Elmualim, 2010). Clients and end-users argue a building takes too long, costs too much or is of poor quality standards. 'Why when so much has changed has so much stayed the same?' (Morton, 2008). The most documented examples include the early reports by Sir Michael Latham (1994) 'Constructing the team' and Sir John Egan (1998) titled 'Rethinking Construction' both of which demanded the ultimate goal of further satisfying clients' requirements. The Latham report of 1994 aimed to make the customer the leader of the process. Prior to the 1990s, he saw the industry as fragmented and hierarchical with a reluctance to introduce innovative solutions to customers' requirements. Clients did not always get what they asked for, he articulated. Recommendations were aimed to align the

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design function with the interests of the client, with particular regard to the organisation and management of the construction process (Adamson & Pollington, 2006). Building information modelling (BIM) has been presented as the panacea, the much needed change in construction. Owing to its project nature, the construction industry, adequately articulated in both these major reports, is widely viewed as a fragmented/diverse industry. The dominant cultural characteristics of the industry are: adverse relationship, low cost and lack of trust (Elmualim, 2010). The required change is cultural as well as technological. The espoused change calls for collaboration as well as embracing innovation in the process of design, construction and facilities management and across the supply chain.

This paper endeavours to engender a dialogue within the construction industry, particularly with regard to design management, innovation and the application of BIM as ground-breaking vehicles for collaboration. The aim of the paper is to contribute to a coherent and mutual understanding among construction participants, in design, construction and facilities management, of each other and advance the course of collaboration within the industry by adopting emerging digital technologies such as BIM.

1.1 *Background*

Since the 1940s, and specifically after the end of World War II, the construction industry has been continually pressurised to improve its practices, sustaining criticism for its poor performance by several government and institutional reports over the years. Most reports' authors concluded that the fragmented nature of the industry, lack of coordination and communication between parties, informal and unstructured learning process and lack of customer focus inhibits overall performance (Barrett, 2008; Egan, 1998; Elmualim, 2010; Latham, 1994). However, the diversity and fragmentation of the industry are due to various cultural values, processes and interests of diverse participating organisations in project delivery (Elmualim, Czwakiel, Valle, Ludlow, & Shah, 2009). Dainty, Green, and Bagilhole (2007) stated that each project is different in terms of both the product and the people involved. Diverse groups of people are expected to readily establish cooperative working relationships while engaged on different terms and conditions (Dainty et al., 2007).

Unquestionably, construction is one of the most important industries in all national economies worldwide (Rodwin, 1987). It accounts for over 4.5% of employment within the UK. According to recent figures, the UK construction industry employs more than 1.9 million people with 40% registered as self-employed. The UK construction industry is dominated by small and medium-sized enterprises with an annual output of more than £83.5 billion in 2007 (Office of National Statistics, 2010).

There are many professional groups that play a vital role in construction projects. These include architects, engineers, quantity surveyors, construction managers and facilities management. Fragmentation exists in the division of responsibility between the professions, professionals and contractors. These groups usually operate outside construction firms as independent consultants generating a high degree of misunderstanding and hostility (Morton, 2008). These conditions are the basis of the adversarial culture between contractors, subcontractors, suppliers and their clients. The goal within construction is to deliver a well-designed, quality product to meet clients' requirements, on time and within budget (Adamson & Pollington, 2006). However, this is rarely the case (Egan, 1998; Latham, 1994). According to Halliday (2008) 'the industry continues to design resource inefficient buildings, utilising polluting materials, over-specifying inefficient equipment, with poor attention to long-term communities'. The problems of poor industry performance can be associated with the common model for UK construction. The client commissions an architect who designs and then builders are found to build (Layard, Davoudi, & Batty, 2001). The architect or the design management team then relies on the services engineer to make them habitable (Turrent, 2007). Although there has been a shift towards construction managers taking control of the whole design and build process, work is still predominantly based on this common model. Indeed, this adds a new dimension of conflict with regard to the full control and responsibilities of design and construction projects management particularly when BIM is exploited. The issues of buildability are restricted at the design stage which inhibits speed, effective learning and cost control. Cost saving has dominated the construction industry's decision-making which does not always provide value (Halliday, 2008; Turrent, 2007). The traditional design method of construction gives little thought to the operational phase particularly from sustainable design point of view (Sassi, 2006; Vakili-Ardebili & Boussabaine, 2007). Calls for facilities management into the processes are mounting (Jensen, 2009), which further exacerbate the challenges for the industry in applying BIM. The client finds it hard to imagine how they or the end-users can operate the facilities once the design and construction were completed. Without engaging the end-user, the creative design process is lost, which often leads to long-term dissatisfaction. A common industry complaint is that members of design teams act independently of each other or may act against each other (Blyth & Worthington, 2001). This raises the questions on who have the most influence on the application of BIM and how the team can be integrated to enhance the possibilities offered by using BIM.

1.2 *Advocated change*

Latham (1994) gave a significant role to clients in promoting good design to provide value for money in terms of both cost and cost in-use. A well-designed building may not require a high level of specification, yet many buildings in the UK are over specified at an unnecessary cost. Problems emerge through lack of coordination between design and construction. Following the substantial critique of Latham (1994), Egan's report of 1998 proposed a change revolution. There was deep concern that the industry was under-achieving in terms of meeting its own needs and those of the client. Egan (1998) found there were too many clients who still equate price with cost, driving them to select designers almost exclusively on the basis of tendered price. The drivers for change included:

- Committed leadership of management to drive improvement.
- Customer focus and end-user value.
- Drive quality through innovation, on budget, on time, reduce wastage, after-sales care and reduced operational costs.

A fundamental shortfall in the industry is the separation of design from the project process which results in poor building performance in terms of flexibility in use, operating and maintenance costs and sustainability. Designers must work in close collaboration with other participants in the project process and design for whole life costs. However, the same problems can still be observed today, well over 10 years after the publication of those two milestone reports (Latham, 1994; Egan, 1998). Inefficiency and waste accounts for almost 30% of the capital costs of construction and much of this could be avoided through cooperative working (Egan, 1998). Design management, as a process, is still, and to a great extent, divorced from the construction and operational phases leading to buildings not performing to their intended outputs. This is indeed documented as the 'creditability gap' in the Post-Occupancy Review of Buildings and their Engineering programme that studied 23 buildings (Bordass, Cohen, Standeven, & Leaman, 2001). The gap between design and operation is due to the fragmentation of the industry and cultural difference and cost implications (Way & Bordass, 2005; Elmualim et al., 2009).

Furthermore, clients and their building designer do not invest in post-occupancy evaluation (POE) studies of their assets as it is difficult to establish who should pay and who should conduct such studies (Bordass & Leaman, 2005). It is argued that such fragmentation inhibits performance improvements and prevented continuity of teams that are essential for efficiency (Egan, 1998).

The shortfalls of the UK construction industry require significant changes in culture, attitudes and working practices. The trend in construction procurement is to move away from fee competition towards a selection process based on the balance of quality and price. Competitive tendering based on lowest cost could become a thing of the past. Collaboration throughout the construction process is paramount (Egan, 1998). A holistic view of construction taking into account design and construction, management of the facility and demolition should be used (Martin & Guerin, 2006; Duffy, 2000). This idea can be orientated towards the primary objective of creating and sustaining appropriate built environments for users. This requires a shared vision among key stakeholders for maximising value across the life cycle (Barrett, 2008; Elmualim, 2010). The conventional construction process is generally planned, designed and constructed; which often acts as a barrier to utilising the skills and knowledge of suppliers and constructors effectively in the design and planning of projects (Egan, 1998).

The design of a facility must consider the needs and requirements of the end-user to meet organisational requirements. Design management decisions should not be limited to one person, but involve a number of professions to consider all possible outcomes. It is important to get the design right as more can be done to enhance value and meet the needs of end-users. Design management decisions should focus on the end-product (Atkin, Borgbrant, & Josephson, 2003). Barrett (2008) called for extensive communication between building design and construction, and maintenance. If a building costs £10 million to construct, then in 20 years the building will have cost £20 million to operate and maintain. Other debated ratios include 1 : 5: 200, where for every one pound spent on design and construction, there are £5 spent on maintenance and £200 on the running cost of business (Macmillan, 2004). Sexton and Lu (2009) advocated actionable research for improving construction performance. It is argued that design management is the most crucial stage in the process and should have scope for adaptation throughout the construction stage. Most of the effort in construction is in reducing the 1, but designers need to reduce the 5 and 200 through good briefing and design management (Macmillan, 2004). Design management decisions on a final design before fully assessing client and user needs and problems may prove very costly (O'Reilly, 1987).

1.3 *Design management and innovation*

In the construction industry, creative minds develop the designing process into a complex multidisciplinary process that needs to be carefully managed in order to improve the efforts of many people who represent the welfares of their respective organisations. Hence, design management is a prerequisite from the very early phases of a project so as to help with the congress of organisations and individuals and to help manage their collective actions (Emmitt, Matthisjs, & Otter, 2009). To understand design management, it seems apparent that an individual (or a group of individuals) needs a common understanding between 'design' and 'management' if the complementarities of the architects' and managers' competencies are to be imposed effectively. There are myriads of definitions and understanding for the term 'design management'. Emmitt (1999) was critical of the evolving discipline and the existence of the design manager. However, there has been a rapid growth of architectural design practises with multiple design partners in multidisciplinary projects and this has resulted in the emergence of 'design management' as a discipline as well as an academic field of enquiry (Emmitt et al., 2009; Sebastian & Prins, 2009).

It has been observed that the categorisation of design management approaches, can be seen within design organisations and design projects by focusing on the design actors (people), design processes and design products (Boyle, 2009; Sebastian & Prins, 2009). Sebastian and Prins (2009) further go on to recognise design management in design organisations (mainly focusing on people and processes) through their approach in managing business strategies and working processes within the architectural firm, and also the inter-organisational relationships between the architectural firm, client and other stakeholders (Sebastian & Prins, 2009). Design management in design projects (mainly focusing on processes and products) are recognised through their approach for managing the architectural quality, design tasks and information and creative teamwork in design (Sebastian & Prins, 2009). Most organisations attempt to manage design projects by applying systematic planning, communication techniques and decision-making protocols (Emmitt, 1999). Mainstream architectural design practises are changing. Collaborative processes in the design stage are taking new forms (Sebastian & Prins, 2009) particularly where emerging technologies are used.

To meet these changes and challenges, architectural design management skills need to be re-evaluated to advance new and innovative design strategies, for an open building, as well as influencing the final product across the supply chain. Studying innovation is widely becoming a mainstream discipline in economics and business management particularly to understand and evaluate technological and organisational change (Gann, 2003). The discipline as an academic field contains a large volume of knowledge about concepts, theoretical models, case studies, technology modelling tools and government and industry strategies and policies. Innovation is tied considerably with organisations abilities to improve on their current products, services, processes and working practices for competition, market growth and economic performance as well as customer choice, social and environmental sustainability and quality of life as a whole (Gann, 2003). Contrary to the general practice of low cost tendering in the construction industry, innovation is widely envisaged as the driver for sustained competitiveness and economic growth. It is the force behind which firms fail or succeed/decline or thrive (Baumol, 2002). Innovation, however, is intertwined with human creativity which is linked to other similar concepts of human intelligence, adaptation and agency (Gann, 2003). Innovation can be seen as the creation of solutions that resonate with the concern of the time. Solutions that enable adaptation within the changing context of space and time. 'Innovation is often or always created through analogy and metaphor – through associations of ideas, so that change is slow and gradual'. 'Innovation often occurs when we just "see what happens if I try this"' (Hodder, 1998). Innovative creativity is triggered by linking and making good sense of multi-faceted things that are defined within established and contextualised terms. It can be seen, therefore, as establishing links rather than creating differences within a given context (Hodder, 1998).

Within the construction industry, innovation is notoriously known to be difficult to define and proceduralise (Green, Newcombe, Fernie, & Weller, 2004). Furthermore, current debates of innovation continue to raise further questions about the nature and characteristics of innovation as well as construction. The concept of innovation is further related with aspects of knowledge creation for continuous improvement in product design and delivery. Within construction academia, the understanding of innovation is still considered to be under-developed and highly fragmented (Green et al., 2004). However, innovation is practiced when knowledge from previously separated domains is exchanged and combined in new ways (Justesen, 2004). The result of this innovative practice is innovation when and only when this combination of domains leads to the successful diffusion of a new product, process or service. Innovative practice is therefore not merely about getting new ideas and generation of an invention, but equally about successful exploitation and diffusion of that invention (Rogers, 1983). Justesen (2004) further strengthens this perspective when she defines innovation as the practice of creation, conversion and commercialisation.

Innovation and innovative practice therefore rely very much on the existing knowledge networks in an organisation, and how such networks of conversation allow for or prevent different domains of knowledge from being connected in new and meaningful ways.

Egbu (2004) stated that there is still ongoing debate on whether the construction industry and many of the construction organisations are innovative or not. He argues that there are those who suggest that the construction industry is less innovative than many other industries and they do so on the basis of a weak premise. However, although Egbu (2004) presented many arguments on why innovation is important to the construction industry and builds a case on why building dynamic capabilities is vital for organisational innovations, he does not present a clear case on how innovation actually takes place within construction firms (Egbu, 2004). In his argument he mentions that because construction organisations are project-based organisations networking, communities of practices, storytelling, coaching, mentoring and quality circles are important mechanisms for sharing and transferring tacit knowledge in project environments. He goes on further to state that communities of practices are needed to encourage individuals to think of themselves as 'members of professional families' with a strong sense of reciprocity and that the networking processes which encourage sharing and the use of knowledge for project innovations are important.

Having said that, innovation, as a practice in the construction industry, has been characterised as important, but ill-defined as a concept (Sundbo, 1997) although incremental process innovations are common and highly regarded for cultural change. However, the industry attitude towards risk inhibits innovation and the prolonged imposition of process innovations by clients has led to initiative overload (Green et al., 2004). Incremental innovations are defined as small-scale changes based on current knowledge. Their effect is minimal and predictable and they emanate from within the organisation. Incremental innovations are distinguished from radical innovations which are characterised by breakthroughs and large-scale change, which are unpredictable in appearance and effect. Radical innovations tend to emanate from outside the current industry, and provide a new way of understanding a phenomenon and formulating approaches to problem solving. Radical innovation is very rare because by their nature they result in significant change (Egbu, 2004; Green et al., 2004). It is interesting thus to note that the social capital aspects of innovation do not feature very much in the debates on innovation in the construction industry.

It is evident that innovation while developing as a discipline lacked a common definition and hence the concept used in construction provision is ambiguous (Green et al., 2004; Sundbo, 1997). Rogers (1983) states that, 'an innovation is an idea, practice or object that is perceived as new by an individual or unit of adoption' (Rogers, 1983). Rogers (1983) found that the rate of adoption of any innovation is in its suitability to fit in with the values, beliefs and past experiences of the social system it is being introduced to. Rogers (1983) states, 'the diffusion of innovations is often a social process, as well as a technical matter'. Henderson states that 'despite rhetoric to the contrary, design work does not flow in a neat linear pattern, but rather is beset, like those on the "yellow brick road to Oz", with innumerable diversions, mishaps and patch-ups' (Henderson, 2007). These 'diversions, mishaps and patch-ups' must reach a consensus to enable the technology to meet the needs of the organisation that it is being created in. Indeed, there are various models of innovation that help to understand innovation as a process (Noor & Pitt, 2009). While in construction innovation is considered to be a social process, within facilities management, for example, innovation is seen mostly as a technical process (Cardellino & Finch, 2006).

Innovation is considered as one of the most pressing components of the competitive advantage of organisations (Porter, 1998). Goyal and Pitt (2007) considered innovation as essential for survival of the organisation. This is particularly true in construction due to the complex nature of the industry and the financial pressures facing it. Innovation as a process is vital for the construction industry to advance and deliver the aspired change agenda.

1.4 *Building information modelling*

BIM is the process of generating and managing building data during its life cycle (Kymmell, 2008). It uses three-dimensional (3D) and real-time dynamic building modelling software to increase productivity in building design and construction (Eastman, Teicholz, Sacks, & Liston, 2008; Holness, 2008; Kymmell, 2008; Sacks, Radosavljevic, & Barak, 2010) and even into facilities management (Asojo & Pober, 2009). BIM can be described as virtual design and construction with a prerequisite for collaboration Harvey, Bhagat, Gerber, Kotronis, & Pysh*,* 2009). BIM can be used to demonstrate the entire building life cycle, including the processes of construction and facility operation. Quantities and shared properties of materials can be extracted. Scopes of work can be isolated and defined by using various parameters of BIM software. Systems, assemblies and sequences can be shown in a relative scale with the entire facility or group of facilities (Kymmell, 2008; Sinopoli, 2010). Furthermore, it can provide a common platform for collaboration by sharing both graphical and non-graphical information of any building or infrastructure project (Shen, Shen, & Sun, 2012).

The interoperability requirements of construction documents include the drawings, procurement details, environmental conditions, submittal processes and other specifications for building quality. It is anticipated by proponents that BIM can be utilised to bridge the information loss associated with handing a project from design team, to construction team and to building operators (facilities managers), by allowing each group to add to and reference back to all information they acquire during their period of contribution to the BIM model (Kymmell, 2008). Therefore, BIM can save time and reduce cost by reducing construction change orders (Sinopoli, 2010).

There is little doubt that object-based parametric modelling has had an enormous influence on the emergence of BIM. There are many design, analysis, checking, display and reporting tools that can contribute to BIM of a building such as, Revit, Bentley Systems, ArchiCAD, Digital Project, Architectural Desktop (AutoCAD – based applications), Tekla Structures, DProfiler, etc. Many information components and information types are needed to fully design, develop and construct a building (Eastman et al., 2008). The BIM tools considered here are only the latest in several generations of tools, but they are also proving to be revolutionary in their influence (Eastman et al., 2008). Object-based parametric modelling resolves many of the fundamental issues in architecture and construction and it makes way for an easy and rewarding transition for those in the industry (Kymmell, 2008). Eastman et al. (2008) have reported a reduction in drawing errors due to a central building model, elimination of repetitive designing and drawing, elimination of errors due to spatial interferences and design ambiguities and a central database of data to be some of the immediate payoffs. There are various challenges in adopting BIM such as resistance to change, adaptation of existing workflows to lean-oriented programmes, training, clear understanding of responsibilities among the team and lack of understanding of the required high-end hardware resources (Arayici et al., 2011). However, the technology is fast advancing and further integrated into gaming for real-time visualisation (Yan, Culp, & Graf, 2011). BIM is further utilised for its economic effects (Jung & Joo, 2011) and for addressing conflicts and safety problems (Zhang & Hu, 2011). Furthermore, BIM systems are increasingly being utilised for sustainable design processes and design rating analysis such as LEED and BREAM (Azhar, Carlton, Olsen, & Ahmed, 2011).

2. Method

The objective of this study was to carry out a comparative review on the perception and status of this important technology, BIM, within design management to identify the key drivers and barriers to its commercial exploitation, and to recommend a strategy for the future. The research work paradigm is well positioned within an interpretative research context (Denzin & Lincoln, 1998) as the aim is to critically review the change agenda within construction and the implications of the adoption of innovative technologies such as BIM. Furthermore, the research paper uses a critical literature review of the main three threads of the paper; construction change, innovation and design management and the use of BIM coupled with a questionnaire survey. The questionnaire survey was carried out and was open for three weeks in May 2009 using an online survey programme that automatically administers and gathers data from the responses. In total, 143 responses were received.

2.1. *Respondents demographics*

Out of the 143 respondents, more than three-quarters were from mainland UK and the Republic of Ireland, and most were from England. European participants accounted for about 1%, whereas the rest, about 24%, came from countries such as USA, India, Ghana, China, Russia, South Africa, Australia, Canada, Malaysia, UAE and some other middle-eastern countries. The respondents were from an array of designations across the construction industry such as construction managers, designers, engineers, design coordinators, design managers, architects, architectural technologists and surveyors. A majority of them (47.6%) were based in a ‘Building Contractor’ organisation, followed by construction management consultants (11.2%) and those in an architectural design practise (9.8%). The organisations were mostly of the ‘large-scale operation’ type; that is, almost 47% of the respondents came from an organisation of over 500 employees. This shows that most respondents represented large construction organisations in the UK. The rest came from what could be described as small and medium enterprises (SME). Only about 14% of the respondents came from those operating with less than 10 people. Demographics information shows that these organisations largely dealt with commercial operations (about 70% of them). Other projects such as schools (43.7%), industrial (34.5%), infrastructure (27.5%), repairs and maintenance followed suit with 25.4%. Social and private housing accounted for 30.3 and 31.7%, respectively.

3. Results and discussion

There was a general agreement by most respondents (44%) that the design team was responsible for design management in their organisation – with the design manager/director having overall control. Other popular responses included project manager, senior/management/director, architect and engineer. Some respondents stated that the person responsible varied depending on the project size and the stage in the process.

Most of the organisations stated that they employ design managers. The majority of them (up to 73%) in fact believe that design management is necessary to ensure clarity during the process, a better quality build and to also ensure that projects were completed to the required specification on time and on budget. It was also observed that to ensure the design was properly managed and to reduce the project risk, up to 59% of these organisations employed design managers, leaving only 35% without one while the remaining, approximately 6%, were still considering the option.

Many respondents stated that it is hard to define what a design manager is because the role varies depending on the project size and type, as well as the organisation. There is a general consensus in the view that a design manager is someone who manages and coordinates the design process from the procurement stage through to completion of the project. Responses indicated that the design manager is responsible for ensuring the project is completed to specification, on time and on budget.

In recent times, the role of the architect has moved away from being a 'master builder'. This has occurred over time whereby the industry has got fragmented into various specialised branches, with the latest being that of a 'Design Manager'. In fact, the survey points out (Figure 1), that around one-third of the people agree on the design manager having a relatively strong role to play in innovation. This comes from a fraternity of professionals, who believe that their organisation gives relatively high priority for innovation and also agree that their organisation gives support to design managers to explore innovative solutions to tackle problems.

It is an academic view that innovation and the opportunity for maximum effect for innovation to be effective, is during the early stages of the project. Once the drawings of plans and quantities have been chalked out, the possibility curve to review and press for innovation exponentially decreases. This viewpoint is shared within the construction industry too as Figure 2 shows, whereby over two-thirds of the respondents agree that the design manager has the maximum influence on innovation during outlining of the proposal itself. Some have pointed out that the point of maximum influence is even before this and should happen during strategic briefing of the project (Figure 3). There is, however, still some disparity within the fraternity itself regarding who they believe has the most control on innovation. Around one-third of the respondents, as shown in Figure 2, thought that the project architect plays the major role with his holistic vision of the building whereas some believe that the design manager and the client hold the leash on innovation (23.8 and 21.7%, respectively). A small fraction of the respondents were inclined towards the project manager to have maximum control (14.7%). Indeed, this showed a polarised view on control of the process of innovation in practice. The results show the disparity in the responses and hence can be seen as a reflection on the fragmentation of the industry.

Innovation is not necessarily throwing out the old but instead, it is about refreshing the old to make it relevant to the new. In an industry where the stakes are high, such as construction, innovation is far and in between and stakeholders are generally unconvinced by the chances of successful execution of an untested product/process/idea to work (Green et al., 2004). However, it is observed in Figure 4, that the majority of respondents in this survey (a little over 50%) agree that the benefit of innovation lies in an enhanced project value for the customer. Most do agree that innovation brings in an element of efficiency to construction of the building. There is more or less, a neutral response as to whether innovation ultimately increases the profitability of a project. This is understandable as there tends to be a disparity between the predicted benefits of innovations as compared with reality. However, what most (about half) of the respondents

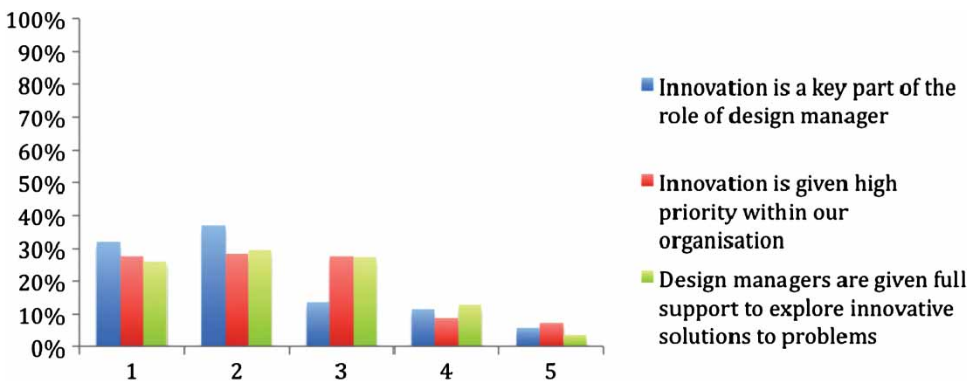

Figure 1. Importance of innovation and role of the design manager in innovation (1= strongly agree; 5= strongly disagree).

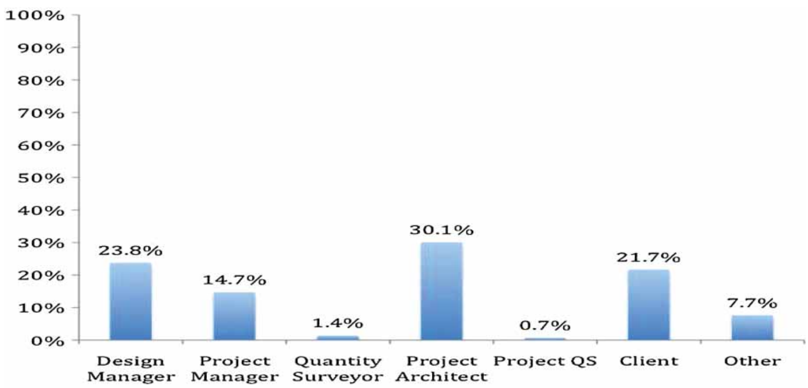

Figure 2. Who do you feel has the most control on innovation?

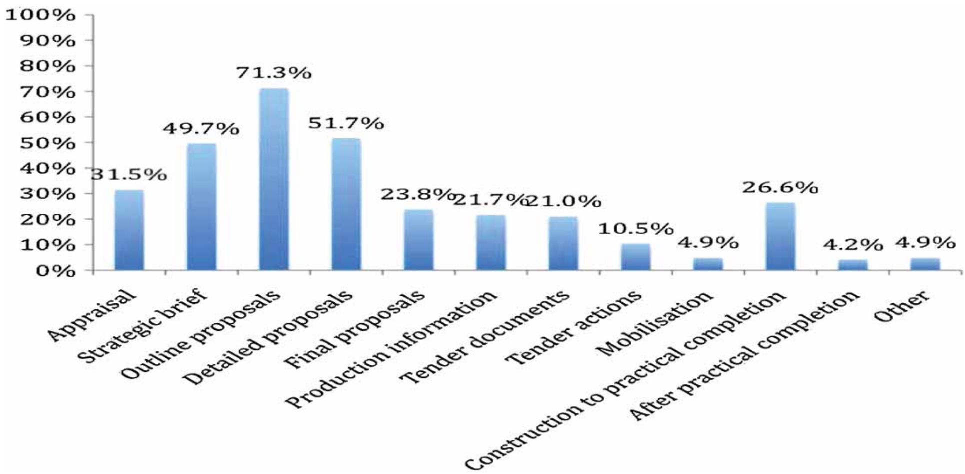

Figure 3. When do you feel a design manager has the most influence on innovation?

agreed upon was that innovation has no benefit in reducing the programme of construction projects.

The above answer calls for understanding who the respondents think is involved in assessing innovation itself. The results show that 79.7% agree on the design manager getting a lead in this role, with the project architect getting an approval of about 72%. In declining order of selection, the project manager, the client, the quantity surveyor and the project quantity surveyor (QS) have been a part of the selection with decreasing percentages of 69.9, 55.2, 49.7 and 37.8%, respectively.

The above observation is also well reflected with the results as to who the respondents believe has the most influence on innovation. The design manager is the choice with the largest agreement of 42.7%. However, here the respondents thought that the client has a larger influence than the project architect with a 42% agreement on the client over the project architect of 37.8%. The rest to follow are the project manager (30.1%), quantity surveyor (13.3%) and the project QS (11.9%).

The respondents were given a few key benchmarks against which they would assess a new idea. The most crucial benchmark selected by a majority of the respondents was cost with a selection by almost 86.7% of the respondents. Given the practical realm from which the respondents

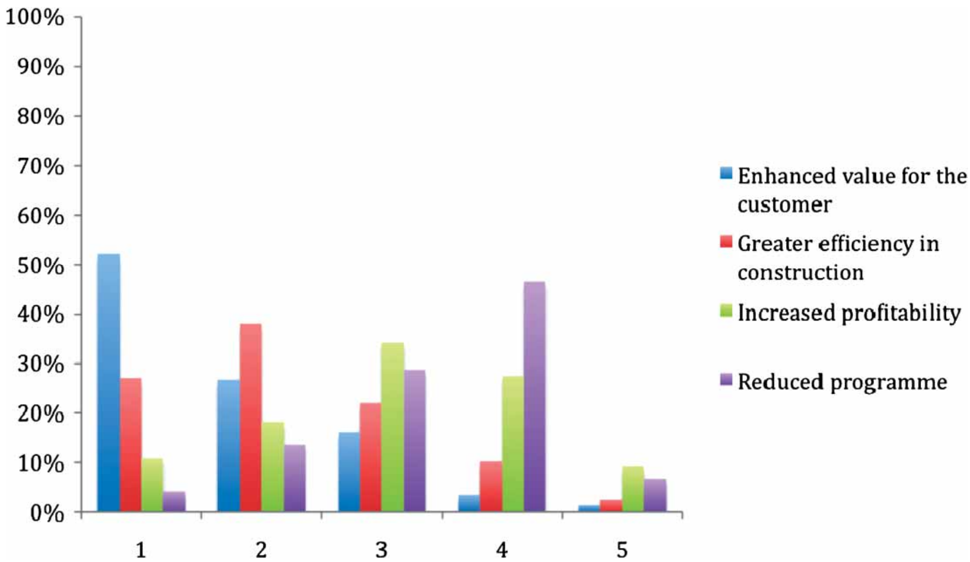

Figure 4. What benefit do you think innovation brings to a construction project? (1= strongly agree; 5= strongly disagree).

came, buildability followed second on the list with a majority of 75.5% of the respondents agreeing on it. The rest to follow with declining order of importance were, time (60.1%), environmental (44.1%), legislation (34.3%) and others (14%). The survey also reveals an important trend that tends to highlight the general approach of professionals in the construction industry. When the respondents were asked if they carry out a normal assessment process of an innovation after the project was completed, only 42% of them agreed. An emerging field of POE is on the rise and is being implemented by most clients to understand the benefits or pitfalls of decisions made during planning stages. However, POE as a means of assessment was absent in the responses to the survey. This further strengthens the argument of the 'credibility and the knowledge gap' between the design and operation of facilities (Bordass et al., 2001; Bordass & Leaman, 2005, Elmualim et al., 2009; Way & Bordass, 2005).

When the respondents were given a list of options as to what they thought best defined BIM, as shown in Figure 5, the majority (38.7%) selected BIM to be a 3D modelling software, that does the analysis and documentation for the buildings life cycle. The other selection that was thought to be appropriate (31.7%) was software that uses 3D and intelligent computable data for project collaboration. Other selections included definitions such as: a computer modelling programme with 3D visualisation (14.1%); software that creates an intelligent and computable 3D data set (9.9%); and leveraging 3D software for internal design and coordination (1.4%).

With regard to the usage of BIM, presently around one-third of the organisations that the respondents came from have already started using BIM. The survey also shows that the respondents believe that a greater use of BIM will result in an overall improvement in construction best practise with up to 63% agreement. It was also observed that almost 31% of the respondents felt that they do not know enough about BIM to have an opinion on its incorporation, whereas only 6% declined its improvement potential. The results showed that there is a need for increasing awareness, education and research work to stipulate the potentialities of using BIM.

Other surveys conducted in the USA showed similar trends. Complementary to these results and according to Eastman et al. (2008) '25% of US architectural firms surveyed in 2007 reported

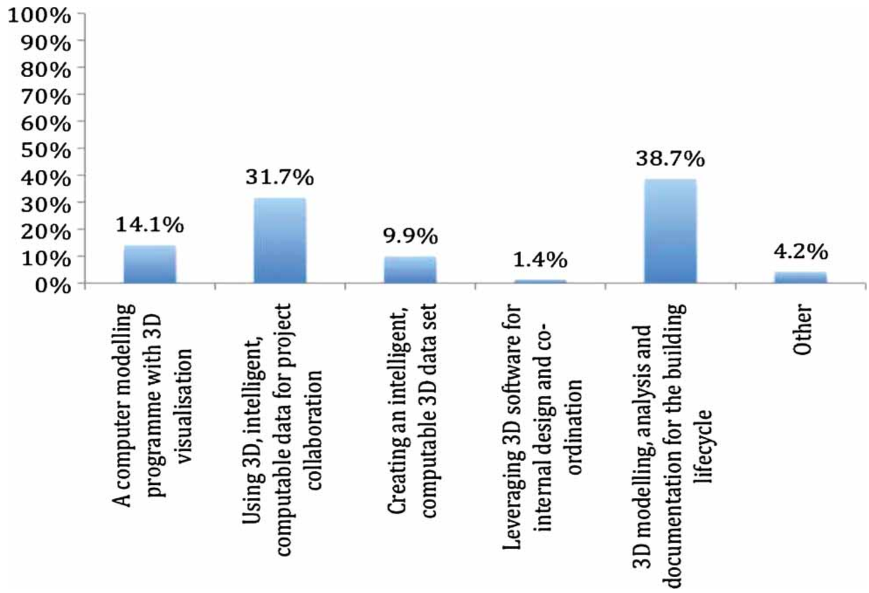

Figure 5. What do you understand to be the best definition of BIM?

already using BIM tools for "intelligent modelling"'. More specifically, 74% of the firms surveyed reported using 3D/BIM tools, but only 34% of those claimed they use it for 'intelligent modelling' (i.e. not simply for generation of 2D drawings and visualizations).

When the respondents were asked what they believed was the percentage of organisations that are currently using BIM for some of their projects, the survey shows that 42.3% of the respondents believe that less than 5% of the organisations are currently using BIM and almost 27.5% of them think that the range is more between 5 and 10%. Only about 2.1% of the respondents thought that more than 50% of the organisations are currently using BIM.

In the USA, it is estimated that in the next five years, building designers will continue to adopt BIM, and by the end of the period, 60–70% of firms will have worked on a project making full use of BIM, compared with the 25% that use it today (Eastman et al., 2008). Eastman et al. (2008) further stated that the two main drivers for broad adoption of BIM are client demand for enhanced quality of service; and productivity gain in preparing documentation.

The apparent reasons for BIM systems not having permeated into mainstream organisations are variable and diverse. When the respondents were asked the same reason for their own organisation 46.4% of them acknowledged not being familiar enough with BIM to use it, whereas another 22.7% indicated that they do not know it at all. Only about 14.4% said that they have not had the opportunity to use it yet, whereas 3.1% decided not to implement BIM for any specific reason.

Specific reasons for not implementing BIM were variable across the fraternity from about 20.4% stating that they lack the capital to invest in getting started with the hardware and software to about 2% stating that BIM is too risky from a liability standpoint to warrant its use. Other prominent responses as shown in Figure 6 were: 15.3% stating that the benefits of BIM do not outweigh the cost to implement it; another 15.3% state that the benefits are not tangible enough to warrant its use. About 8.2% of the respondents also said that they were reluctant to initiate new workflows, or to train its staff. However, almost 37.8% did not know themselves as to why they had not implemented BIM as yet.

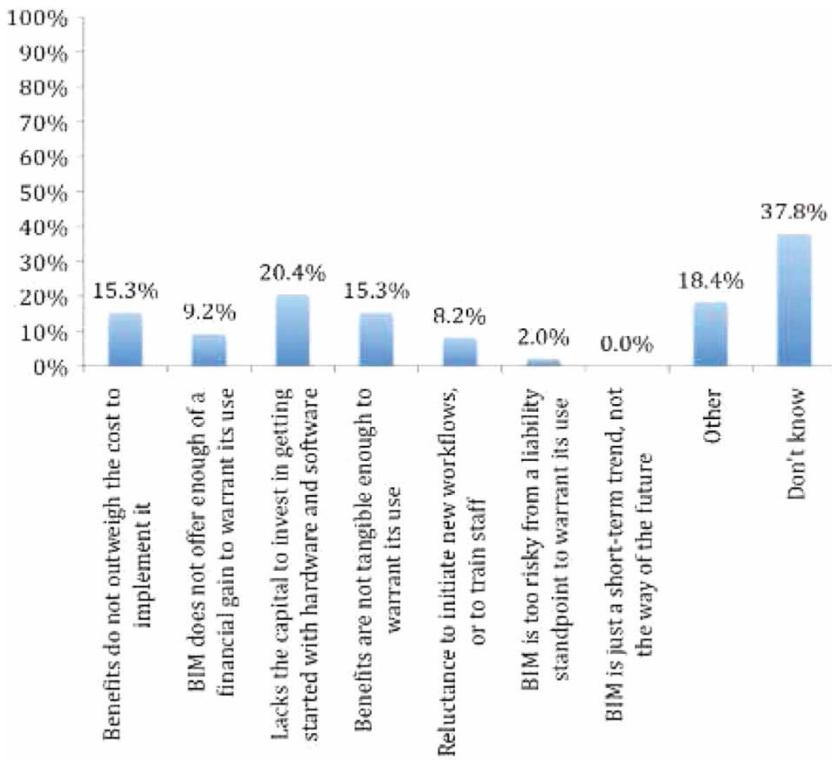

Figure 6. What was the primary reason for not implementing BIM?

There are various challenges that are facing the construction industry in the installation of BIM. The three major factors ranked by the respondent as challenges were: training staff on new process/workflows (56.8%), effectively implementing the new process/workflow (another 56.8%) and understanding BIM enough to implement it (54.5%). Other popular reasons were: training staff on new software/technology (47.7%), establishing the new process/workflow (34.1%) and realising the value from a financial perspective (36.4%). Some other reasons followed such as trying to understand and mitigate the liability (9.1%) and purchasing software/technology (13.6%).

If the issues of penetrating BIM into mainstream construction are to be mobilised, the industry needs to also understand what kind of assistance the organisations would like to receive if they decided to adopt BIM. Majority of respondents, about 70.2%, indicated that they would like to have a clear understanding of the benefits that outweigh the cost and other factors included in adopting BIM. Another 35.1% said that they would like to attend workshops to discuss BIM uptake and for further information. Another 19.1% said that they would like to receive a recommendation of a way forward with regards to software and hardware, whereas about 18.1% said that their organisation would like to receive the required training and technical know-how.

This study further researched into the changes in service provisions since the implementation of BIM within the respondents' business/organisation (for those who have already implemented it – 31%). About one-third (34.1%) of the respondents reported that there has been a change in their third-party integration and consulting. About 18.2% of the respondents have reported a change in the process in which the shop drawings were produced and submitted. Another 20.5% have reported a change in their construction management department. Some 27.3% are not really sure if there was any change at all, while about 15.9% reported no change at all. And finally, the respondents were asked as to what are the issues or problems that can be overcome by the implementation of a BIM system within an organisation. The highest ranked response of 64.3% was that it brings about an efficient collaboration among the construction stakeholders. Another set of respondents (54.8%) stated that BIM has an ability to assess the design alternative and life cycle effects. Many agreed (about 52.4%) that it makes available an accurate documentation of building development. Some (47.6%) even agreed that it brings about a transparency within various sectors in common understanding of project cost, schedules and project progress.

4. General observations

As the results have shown, the respondents felt that BIM is certainly most likely to affect the construction key performance indicators of 'Quality' and 'Time completion' in a positive way. The results were encouraging as what is witnessed was a first-hand response from a knowledgeable group of individuals from the architectural, engineering and construction (AEC) fraternity. More such research is needed in order to corroborate the 'BIM-favourable' results presented in this paper.

This survey needs to be read within a larger perspective and with an understanding that the respondents filling out this survey would have a partiality for being more favourable to BIM than the typical industry professional due to their interest in the field and willingness to take time to fill the survey. It would be very interesting to also look at the effect of a BIM approach through real-world construction case studies. This shall offer a more compelling argument for BIM adoption by AEC firms than simply the perceptions described herewith.

5. Conclusions

According to its critics, the construction industry has to change. The espoused change of industry renowned for its adversarial relationship and lack of trust is based on collaboration and innovation. This paper investigated the relationship between design management, innovation and the role of BIM in advancing collaboration in response to the required change. The paper presented results of questionnaire survey that was conducted to establish the understanding and perception with regard to design management, innovation and the adoption of BIM. Majority of respondents were based in the UK with other respondents representing Europe, USA, India, Ghana, China, Russia, South Africa, Australia, Canada, Malaysia and UAE.

The literature documented that innovation is a difficult concept to grasp and ill-defined in construction. The survey results show that there were variations on the views on who has most influence on innovation. The respondents were divided between the project architect (30%), design manager (24%) and the client (22%). This clearly can be seen as indication of the diversity and fragmentation of construction. Most of the respondents come from organisations that employ design managers. The majority of them (up to 73%) in fact believe that design management is necessary to ensure delivery in time and specified cost with control over the innovation process particularly during outlining of the proposal of projects. More than half of the respondents indicated that the benefit of innovation lies in enhancing project value for the client. With regard to the usage of BIM as an innovation tool, presently around one-third of the organisations that the respondents came from have already started using BIM. The survey also showed that the respondents believe that a greater use of BIM will result in an overall improvement in construction best practise with up to 63% in agreement. Specific reasons for not implementing BIM were variable across the fraternity from about 20.4% stating that they lack the capital to invest in getting started with the hardware and software to about 2% stating that BIM is too risky from a liability standpoint to warrant its use. Other responses were stating that the benefits of BIM do not outweigh the cost to implement it; another 15.3% stated that the benefits are not tangible enough to warrant its use. About 8.2% of the respondents also said that they were reluctant to initiate new workflows, or to train its staff. However, almost 37.8% did not know themselves as to why they had not implemented BIM as yet.

There are various challenges that are facing the construction industry in the application of BIM. The three major factors ranked by the respondents were: training staff on new process/workflows; effectively implementing the new process/workflow; and understanding BIM enough to implement it. Other reasons were: training staff on new software/technology; establishing the new process/workflow; and realising the value from a financial perspective.

It seems there are a number of economic, technological and social factors that are likely to drive BIM into the mainstream construction practices. The possibility of moving into the production of building components will increase the demand for highly accurate and reliable design information, so that these components can be transported with a higher degree of confidence. Specialisation and commoditisation of design services is another economic driver in favour of BIM. The demand for close collaboration between the design and construction models will eventually drive the adoption and development of BIM even further. Perhaps, the most important economic driver for BIM systems and their adoption could be the intrinsic value that their quality of information will provide to building clients and users.

However, there are numerous obstacles to the progress of BIM too within the industry such as, technical barriers, legal and liability issues, resistance to changes in employment patterns, the need for education and training and regulations. The value to be driven from the application of BIM will undoubtedly stimulate the debate around the industry transformation. In an industry renowned for its complex project-based nature and domination of SMEs, BIM provides a paradigm shift in the way buildings are designed, constructed and maintained. Such a paradigm shift illustrated the stringent need for trans-disciplinary curriculum in the industry.

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References

Adamson, D., & Pollington, T. (2006). *Change in the construction industry reform movement* 1993–2003. London: Routledge.

Arayici, A., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). Technology adoption in the BIM implementation for lean architectural practice. *Automation in Construction*, *20*, 189–195.

Asojo, A., & Pober, E. (2009). Building information modeling (BIM) strategies: Pedagogical models for interior design. *Design Principles and Practices: An International Journal*, *3*(2), 159–186.

Atkin, B., Borgbrant, J., & Josephson, P.-E. (2003). *Construction process improvement*. London: Wiley-Blackwell.

Azhar, S., Carlton, W. A., Olsen, D., & Ahmed, I. (2011). Building information modelling for sustainable design and LEED rating analysis. *Automation in Construction*, *20*, 217–224.

Baumol, W. J. (2002). *The free-market innovation machine*. Princeton and Oxford: Princeton University Press.

Barrett, P. (2008). *Revaluing construction*. Oxford: Blackwell.

Blyth, A., & Worthington, J. (2001). *Managing the brief for better design*. London: Spon Press.

Bordass, B., Cohen, R., Standeven, M., & Leaman, A. (2001). Assessing building performance in use 2: Technical performance of the probe buildings. *Building Research and Information*, *29*(2), 103–113.

Bordass, B., & Leaman, A. (2005). Making feedback and post-occupancy evaluation routine 3: Case studies of the use of techniques in the feedback portfolio. *Building Research and Information*, *33*(4), 361–375.

Boyle, G. (2009). *Design project management*. Aldershot: Ashgate.
Cardellino, P., & Finch, E. (2006). Evidence of systematic approaches to innovation in facilities management. *Journal of Facilities Management*, *4*(3), 150–166.
Dainty, A., Green, S., & Bagilhole, B. (2007). *People and culture in construction*. London: Spon.
Denzin, N., & Lincoln, Y. S. (1998). *The landscape of qualitative research: Theories and issues*. London, UK: Sage Publications, Inc.
Duffy, F. (2000). Design and facilities management in a time of change. *Facilities*, *18*(10/11/12), 371–375.
Eastman, C., Teicholz, T., Sacks, R., & Liston, K. (2008). *The BIM handbook – A guide to building information modeling*. Hoboken, NJ: John Wiley & Sons, Inc.
Egan, J. Sir. (1998). Construction task force: Rethinking construction. Retrieved September 2009, from http://www.constructingexcellence.org.uk/download.jsp?&url=/pdf/rethinking%20construction/rethinking_construction_report.pdf
Egbu, C. O. (2004). Managing knowledge and intellectual capital for improved organizational innovations in the construction industry: An examination of critical success factors. *Engineering, Construction and Architectural Management*, *11*(5), 301–315.
Elmualim, A. A. (2010). Chapter 11: Culture and leadership in stakeholder management. In E. A. Chinyio & P. Olomolaiye (Eds.), *Construction stakeholders management* (pp. 174–192). London: Wiley-Blackwell Publishing.
Elmualim, A. A., Czwakiel, A., Valle, R., Ludlow, G., & Shah, S. (2009). The practice of sustainable facilities management: Design sentiments and the knowledge chasm. In S. Emmitt. (Guest Editor), *Special Issue: Design Management for Sustainability. Architectural Engineering and Design Management*, *5*(1/2), 91–102.
Emmitt, S. (1999). *Architectural management in practice: A competitive approach*. Harlow: Longman.
Emmitt, S., Matthisjs, P., & Otter, A. (2009). *Architectural management: International research and practice*. London: Wiley-Blackwell.
Gann, D. M. (2003). Guest editorial: Innovation in the built environment. *Construction Management and Economics*, *21*(6), 553–555.
Goyal, S., & Pitt, M. (2007). Determining the role of innovation management in facilities management. *Journal of Facilities Management*, *25*(1/2), 48–60.
Green, S. D., Newcombe, R., Fernie, S., & Weller, S. (2004). *Learning across business sectors: Knowledge sharing between aerospace and construction*. Reading: The University of Reading, p. 84.
Halliday, S. (2008). *Sustainable construction*. Oxford: Butterworth-Heinemann.
Harvey, R., Bhgat, T., Gerber, D., Kotronis, J., & Pysh, D. (2009). BIM as a risk management platform enabling integrated practice and delivery. *Journal of Building Information Modeling*, (Fall), 14–17.
Henderson, H. (2007). Achieving legitimacy: Visual discourses in engineering design and green building code development. *Building Research and Information*, *35*(1), 6–17. Routledge Taylor and Francis.
Hodder, I. (1998). Creative thought: A long term perspective. In S. Mithen (Ed.), *Creativity in human evolution and prehistory* (pp. 61–77). London: Routledge.
Holness, G.V. R. (2008). Building information modeling gaining momentum. *ASHRAE Journal*, *50*(6), 28–40.
Jensen, P. A. (2009). Design integration of facilities management: A challenge of knowledge transfer. *Architectural Engineering and Design Management*, *5*(3), 124–1135.
Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automation in Construction*, *20*, 126–133.
Justesen, S. (2004). Innoversity in communities of practice. In P. Hildreth & C. Kimbe (Eds.), *Knowledge networks: Innovation through communities of practice* (pp. 79–95). London: Idea Group.
Kymmell, W. (2008). *Building information modelling: Planning and managing construction projects with 4D CAD and simulation*. New York: McGraw-Hill.
Latham, M. Sir (1994). The Latham Report: Constructing the Team. Retrieved September 2009, from http://www.specify-it.com/CIS/Doc.aspx?AuthCode=&DocNum=84343
Layard, A., Davoudi, S., & Batty, S. (2001). *Planning for a sustainable future*. London: Spon Press.
Macmillan, S. (2004). *Designing better buildings: Quality and value in the built environment*. London: Spon.
Martin, C. S., & Guerin, D. A. (2006). Using research to inform design solutions. *Journal of Facilities Management*, *4*(3), 67–180.
Morton, R. (2008). *Construction UK: Introduction to the industry* (2nd ed.). Oxford: Blackwell Publishing.
Noor, M., & Pitt, M. (2009). A critical review on innovation in facilities management service delivery. *Facilities*, *27*(5/6), 211–228.

Office of National Statistics. (2010). *Construction statistics annual, London*. UK: Office of National Statistics.
O'Reilly, J. J. N. (1987). *Better briefing means better buildings*. Watford, UK: Building Research Establishment.
Porter, M. E. (1998). Clusters and the new economics of competition. *Harvard Business Review*, *76*(6), 77–91.
Rodwin, L. (1987). *Shelter, settlement and development*. Nairobi: UNCHS (Habitat).
Rogers, E. (1983). *The diffusion of innovations* (3rd ed.). New York: The Free Press.
Sacks, R., Radosavljvic, M., & Barak, R. (2010). Requirements for building information modelling based lean production management systems for construction. *Automation in Construction*, *19*, 641–655.
Sassi, P. (2006). *Strategies for sustainable architecture*. London: Taylor and Francis.
Sebastian, R., & Prins, R. (2009). Collaborative architectural design management. In S. Emmitt, P. Matthisjs, & A. Otter (Eds.), *Architectural management: International research and practice* (pp. 105–118). London: Wiley-Blackwell.
Sexton, M., & Lu, S. (2009). The challenges of creating actionable knowledge: An action research perspective. *Construction Management and Economics*, *27*(7), 683–694.
Shen, W., Shen, Q., & Sun, Q. (2012). Building information modeling-based user activity simulation and evaluation method for improving designer-user communications. *Automation in Construction*, *21*, 148–160.
Sinopoli, J. (2010). *Smart building systems for architects, owners, and builders*. Oxford: Elsevier (Butterworth-Heinemann).
Sundbo, J. (1997). *Innovation in services – Denmark. service development, internationalization and competences* (Working Paper No. 2). Roskilde: Roskilde University
Turrent, D. (2007). *Sustainable architecture*. London: RIBA Publishing.
Vakili-Ardebili, A., & Boussabaine, A. H. (2007). Creating value through sustainable building design. *Architectural Engineering and Design Management*, *3*, 83–92.
Way, M., & Bordass, B. (2005). Making feedback and post-occupancy evaluation routine 2: Soft landings – involving design and building teams in improving performance. *Building Research and Information*, *33*(4), 353–360.
Yan, W., Culp, C., & Graf, R. (2011). Integrating BIM and gaming for real-time interactive architectural visualisation. *Automation in Construction*, *20*, 446–458.
Zhang, J. P., & Hu, Z. Z. (2011). BIM- and 4D based integrated solution of analysis and management for conflicts and structural safety problems during construction: 1. Principles and methodologies. *Automation in Construction*, *20*, 155–166.