Building Information Modelling Adoption: An Analysis of the Barriers of Implementation

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Building Information Modelling Adoption: An Analysis of the Barriers to Implementation

Robert Eadie[1], Henry Odeyinka[2], Mike Browne[2], Clare McKeown[2] and Michael Yohanis[2]

Abstract

The UK Government has set a target date for the adoption of Building Information Modelling (BIM) by 2016. Despite the many benefits identified in literature there are also barriers to be overcome but there is little by way of research ranking the importance of each. To enable informed decision making during the implementation process this research provides a ranking of barriers. The study gathered information via a web-based survey from the top 74 United Kingdom based main construction contractors. The findings demonstrated that the barriers are reduced in importance after BIM adoption as the major hurdle of initial investment has been overcome reducing the "Fear" factor". The two most important barriers to implementing BIM overall are "Scale of Culture Change Required/Lack of Flexibility" and "Lack of supply Chain Buy-in". The low ranking awarded to "Lack of management support" and "Other Competing Initiatives" show the priority implementation is given in industry.

Keywords: Building Information Modelling, BIM, Use of BIM, Ranking Barriers to BIM implementation

Introduction

Building Information Modeling (BIM) has been defined as "*Computer Aided Design (CAD) paradigm"* producing "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" (Succar, 2009).

[1] School of the Built Environment, University of Ulster. Email:r.eadie@ulster.ac.uk
Phone +44 2890368590
[2] School of the Built Environment, University of Ulster.

However, Arayici and Aouad, (2010) show it goes further throughout the building lifecycle and can be used for facilities management. Efficiency and Reform Group, (2011) state BIM has been promoted by Governments as a means of promoting collaboration and reducing fragmentation in the construction industry. However, Khosrowshahi and Arayici (2012) in providing a roadmap for BIM adoption show that there are still obstacles to be overcome.

The UK Government BIM strategy is making Level 2 BIM mandatory for all publicly-funded projects from 2016 onwards. This is to produce collaboration among the construction design team and reduce the fragmentation in the construction industry identified in Government reports (Wolstenholme et al, 2009; Egan, 1998; Latham, 1994). The BIM Industry Working Group (2011) state in the UK the levels of BIM are:-

Level 0 – Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely exchange mechanism.

Level 1 – Managed CAD in 2 or 3D format using BS1192:2007 with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.

Level 2 – Managed 3D environment held in separate discipline "BIM" tools with attached data. Commercial data managed by an Enterprise Resource Planning application (ERP). Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary). The approach may utilise 4D programme data and 5D cost elements as well as feed operational systems.

Level 3 - Fully open process and data integration enabled by web services compliant with emerging IFC / IFD standards, managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes.

Worldwide, BIM targets have also been set. The BIM Industry working Group (2011) reports there are on-going national deployments of BIM across the USA, Scandinavia/Europe, and the Far East. However, despite the substantial pressure from government, client and other sources adoption still faces challenges due to the dramatic change in working practices required for its adoption (Jordani, 2008; Mihindu and Arayici, 2008).

While the literature identifies the barriers to the adoption of BIM within organisations it does not rank the importance of each relative to each other. This study aims to rank the relative importance of each of the barriers for BIM adoption identified from an extensive literature review.

Justification for the Study

With the targets above having been set by the UK government new adopters need to be aware of what must be overcome during the process. The importance of each barrier is therefore vital to adopters as a tool to determine where to focus their energy as they seek to implement BIM. The findings of this study will allow adopters to consider the worst barriers during the implementation process and adopt a strategy to overcome these. It was also hypothesised that users would rank the barriers to BIM differently than those who are yet to implement it.

Barriers for Bim Adoption

Lack of Senior Management Support

Ruikar *et al*, (2005) suggest a number of reasons why senior managers are reluctant to introduce new technologies and processes into their organisations. However, management support for the introduction of new technologies and processes is essential if the benefits are to be realised. Arayici *et al* (2011) suggest a bottom-up approach with "*learning by doing*" is a more efficient means of BIM implementation and dealing with resistance to change rather than top-down approach. However, they do suggest that successful implementation is as much about people and process as it is about the software and hardware used. They acknowledge that a Knowledge Transfer Partnership (KTP) was put into place to start the process. This shows "buy-in" from senior management.

Jung and Joo (2011) further confirm this by showing that the strategy and policy for specific levels of adoption is necessary to accelerate practical BIM implementation. Coates *et al* (2010) suggest Key Performance Indicators (KPI's) which can be used by management to measure the success of the implementation. Without this there is a lack of the vision of the success that implementation can bring and documentation of the benefits from a senior management standpoint.

It can also be difficult for senior management personnel with financial expertise, to identify the monetary value of BIM implementation (Giel et al, 2010). It is common to carry out Return On Investment (ROI) calculations when considering a purchase that has clearly identifiable costs and benefits (Azhar,2011; Giel et al, 2010; Glautier and Underdown, 2001; Roberts, 2004). This was investigated under two barriers called “Lack of Senior Management Support” and “Doubts about ROI/Lack of Vision of Benefits”.

Cost of Implementation (Software and Training)

Implementing BIM necessitates organisations to purchase the pertinent software and hardware and train their staff in the use of that software. The impact of that cost may vary according to the financial standing of the organisation. The high front-end cost of implementing BIM has been seen to act as a significant barrier to uptake within the construction industry (Azhar et al, 2011; Thompson and Miner, 2010; Crotty, 2012; Efficiency and Reform Group, 2011; Giel et al, 2010; Yan and Damian, 2008). However, Aranda-Mena et al, (2008), disagree indicating using case study research to indicate “consistent disagreement” with a position of high implementation costs associated with resources and expenses. In this context the evidence of the potential of BIM to reduce re-work, delays and ultimately cost, has not gone unnoticed by professionals in industry (Ahmad et al, 2010; BIMhub, 2012; Barlish and Sullivan, 2011; Costain Group, 2012; Hardin, 2009). However, construction is as much about business as it is about building (Fellows et al, 1983; Lowe and Leiringer, 2006). Therefore it is essential for those with commercial responsibilities within a contracting organisation to investigate the business case for implementing BIM (Autodesk, 2007; Giel et al, 2010). BIM however, is not just a software package, but also a process (Arayici et al, 2011b; Dickinson, 2010; Gu and London, 2010). While the process results in a beneficial outcome, Thompson and Miner (2010) show that the cost of its implementation must be paid for as well. Software packages need updates and therefore it is also necessary to consider the fact that BIM software packages will periodically need updated, which is an added cost (Lee et al, 2012).

In addition, there are currently several large software houses vying for dominance of the BIM software market, which is anticipated to be worth $6.5bn by 2020 (Martin, 2012). There are many different BIM applications on the market. The major elements of a building are currently accommodated by separate software packages, e.g. architectural, structural, MEP (BIMhub, 2012; Bentley, 2012; Campbell, 2007).

There is, however, a real fear that as software houses attempt to increase their market share in these areas of BIM by offering increasingly comprehensive packages, at some point in the future, one particular brand may attain total market dominance. If this were to happen, it would render obsolete software packages that many companies had invested heavily in (Dell and BD+C, 2012). Companies considering investing in a BIM-ready ICT infrastructure must factor redundancy, and the cost of software and hardware upgrades into their IT plans (Ahmad et al, 2010). This will not however, guarantee protection from the risk of obsolescence. The costs were segregated into two barriers for investigation “Cost of Training” and “Cost of Software”.

Scale of Culture Change Required

Introducing new processes into an organisation involves the shifting of the culture of the organisation, which carries with it, risks and challenges that are not limited to financial considerations, but also include the flexibility or versatility of the organisation’s people and systems (Yan and Damian, 2008; Ahmad et al, 2010; Azhar et al, 2007; Fellows et al, 1983; Zairi and Sinclair, 1995). These factors impact on the strategic decisions taken by Management, who must constantly refer to and augment their business plan, in an on-going effort to ensure business success (Langford and Male, 2001). Part of this process involves assessing the organisation’s strengths and weaknesses with regards to, amongst other things: people, finances, systems and physical resources. The implementation of BIM necessitates dramatic changes in business practices (Jordani, 2008; Mihindu and Arayici, 2008). This requires a large culture change within the organisation (Rowlinson et al, 2009, Watson, 2010). It may be that on assessing the culture and skills base of the organisation as in a SWOT analysis, senior management feel that by implementing BIM, they would simply be aligning their weaknesses with the threats in their external operating environment (Langford and Male, 2001). This has contributed to the relatively gradual adoption of BIM within the construction industry (Watson, 2010).

Other Competing Initiatives

Another factor which acts as a barrier to BIM up-take is the number of on-going initiatives that organisations are already engaged in. In the UK Government Construction Strategy (Cabinet Office, 2012), BIM is only one of 13 major initiatives that impact construction organisations. The others in the accompanying Action Plan, published in July 2011, identify a variety of undertakings to reform industry practice (in both the financial and construction elements), reduce waste and drive better value for money from procurement of construction. Construction clients are increasingly setting quality, health and safety, and environmental performance targets as contractual obligations (Harris and McCaffer, 2006; Kezner, 2004). In order to maintain or attain their status as competent in these areas, contractors are regularly involved in training and assessment activities, in order to become accredited by the relevant bodies (Harris and McCaffer, 2006). This represents a significant resource commitment to organisations in terms of finance and time, and to add the introduction of a new technology which requires such a culture change may just not make business sense to senior management.

Lack of Supply Chain Buy-in

BIM is seen as a driver for collaboration (Efficiency and Reform Group, 2011; Race, 2012; Crotty, 2012). The opportunity exists for front-end designers to collaborate with clients, main contractors, sub-contractors and fabricators, and other members of the supply chain for the purpose of integrated project delivery (Eastman *et al*, 2011; Race, 2012). It follows, then, that contractors aiming to provide collaborative BIM services to their clients will require their sub-contractors and fabricators to be "BIM literate". As main contracting organisations who are considering implementing BIM could arguably be described as the "early majority", it may be difficult for them to secure the competencies further down the supply chain, to fully exploit BIM's potential (Ruikar et al, 2005; Jung and Joo, 2011). It is essential, if the benefits associated with improved collaboration are to be achieved, that the BIM software packages in use by different project participants are "interoperable" (Pniewski, 2011). Interoperability has been defined as: *"...the ability of two or more systems or components to exchange information and to use the information that has been exchanged"* (IEEE Standards Board, 1990). Truly interoperable applications should be able to seamlessly exchange data, without introducing the possibility of introducing human error by requiring data duplication at interface (Moon et al, 2011).

Without this, the concept of collaboration is a farce, and BIM, instead of streamlining communication in the supply chain, will act as a barrier (Azhar et al, 2011). The more organisations involved the greater the difficulty as the variety of software programmes increases the further down the supply chain collaboration is required. Further, if the investment in BIM software represents a financial burden to large main contractors, it could potentially be financially out of reach for their sub-contractors. The technological maturity of companies in the supply chain is vital as *many do not possess the technology or know-how to take advantage of such innovations without significant financial and human-resource investment* (Aouad *et al*, 2006). This can be a significant barrier to implementation of BIM from a project standpoint.

Staff Resistance and ICT Literacy

A study by Mitchell and Demian (2006), on the implementation of construction project extranets CPEs, commented that it is common to encounter a resistance to change from staff. Distinct staff resistance to the adoption of new technologies and processes can also be witnessed (Ruikar *et al*, 2005; Wilkinson, 2005). This is the case especially when staff consider that they have been given insufficient training, and/or that the technology may threaten their employment (Ruikar *et al*, 2005; Griffiths *et al*, 2000). Arayici *et al* [5] conclude that the construction industry has been slow to tackle this resistance to change. Aouad *et al* (2006) further indicate a lack of skilled BIM operatives in the industry as a significant barrier to BIM adoption. Arayici *et al* (2009) suggest that a skill gap has arisen due to BIM implementation.

Legal Uncertainties

For the purposes of this study the various legal aspects of BIM have been combined under the title “Legal Uncertainties”. There are concerns regarding legal issues discussed in the literature. These will be discussed in this section. However, there has only been one legal case regarding BIM (Matthews, 2011). It related to the installation of ventilation ducting in a life sciences building in the United States of America. The mechanical, electrical and plumbing (MEP) Engineer neglected to tell the contractor the ducting construction sequence. The contractor was working off 2-D drawings, despite the fact that the MEP design had been done on BIM and ran out of space with only 70% of the construction complete.

For commercial reasons all parties agreed to settle out of court, splitting the multi-million dollar costs between them (Matthews, 2011). No legal precedent was therefore set, and the construction industry still awaits case law in regard to BIM. Oluwole (2011) identifies the following legal issues with BIM: duty of care including ownership and intellectual property and contractual arrangements including jurisdiction, virtual enterprising, recognition, taxation laws and government policies. Christensen *et al* (2007) identify authenticity as a major legal barrier for BIM while Race (2012) identifies product liability risks. Each of these will be examined in detail.

2.7.1 Ownership and Intellectual Property

The first legal issue raised by Oluwole (2012) relates to ownership. If the owner of the BIM application for the project was the client, they may claim ownership of the data and documents therein, as they are paying for the design. Conversely, designers will claim that their designs remain their own intellectual property. If a designer considers that they have lost competitive advantage through the client passing on information they may wish to pursue this in court. Determining who that party may be is not necessarily a simple process, especially as the industry moves towards fully-integrated Level 3 BIM (Udom, 2012). The UK BIM Industry Working Group (2011) recognised this as a problem and suggested that the ownership of copyright should generally reside with the author, not the individual who commissions it. Chao-Duivis (2009) disagrees arguing that the model is combined work, and therefore, the intellectual property right (IPR) or ownership should be treated as being similar to the output of conventional teamwork. However, there is no case law to support this position and this will remain a difficulty until a court makes a decision on a case and a precedent is set. The UK BIM Industry Working Group (2011) further state that this should not be a long term barrier to BIM adoption and simple solutions should be sought. Furneaux and Kivvits (2008) suggest that governments should be addressing these issues.

2.7.2 Contractual Arrangements

Security issues have been seen as a difficulty with many computer based systems relating to e-procurement in construction (Eadie *et al*, 2010). Parties need security of confidential data both within the BIM model and when the BIM model is part of a construction extranet, clarity on the issues involved, and have this reflected in the construction contract, otherwise a significant risk to the contract will be introduced (Breetzke and Hawkins, 2009; Christensen et al, 2007; Udom, 2009).

BIM solutions can be used to support the facilities management of the completed construction project, (Lewis *et al,* 2010). In many cases the facilities management is passed to an organisation other than the one that carried out the construction. This changeover of liabilities and responsibilities provides an opportunity for confusion and uncertainty.

2.7.3 Product Liability Risks

Due to the possibility of repeated and uncontrolled use of design documents by clients, the BIM Model may come to be legally viewed as a "product", thus giving rise to product liability risks (Race, 2012). This could potentially mean that the old system whereby constructors or designers are relieved of liability for construction or design defects after six years, when contracts are “under hand” or twelve years “under deed”, could become obsolete. This could result in contractors or designers being held liable for defects included in the BIM model almost indefinitely (Race, 2012; UK Parliament, 1980). The use of BIM is similar to contract alliancing, used in Australia and New Zealand for large infrastructure and public projects which requires a waiver of all liability claims (Cleves and Mayer, 2011). They suggest the risk of litigation among the principal participants including the client can be removed by this waiver. However, many clients will be reluctant to provide such a waiver.

2.7.4 Professional Indemnity Insurance

A designer in a construction project must ensure that their design work is covered by Professional Indemnity insurance (Wallbank, 2011). Wallbank (2011) further identifies two reasons why insurers are reluctant to cover construction organisations in this regard:

- They feel that they are covering liabilities which are impossible to accurately predict at the inception of a project;
- They are concerned that, should a claim arise, there may be blurring of the delineation of responsibilities between parties to contract.

The added risk means that the cost even with protocols and addenda can be prohibitive to all but the largest projects.

2.7.6 Authenticity

Furneaux and Kivvits (2008) state that it is relatively simple to amend or fake digital records, or change dates, times or other metadata associated with them that if challenged, courts may disregard the evidence altogether or place less weight on it than on paper records. The issue is whether the integrity of the record can be established (Christensen et al, 2007). Further, in the case of an email or communication sent over a BIM system or extranet, although the record can be proved to have been sent and even proved to have been sent from a particular machine, it is not necessarily so easy to prove which person actually sent it. In cases such as this, the evidence would be considered inadmissible by the courts (Christensen et al, 2007). This issue could cause some alarm to construction teams who rely heavily on the software system to keep their records.

For the purposes of this study the various legal aspects of BIM have been combined under the title “Legal Uncertainties”.

Summary of the identified Barriers for BIM

From the detailed sections above Table 1 summarises the literature sources for the Barriers for BIM. This paper seeks to fill the knowledge gap in the literature by differentiating by order of importance. The aim of this study is to rank the importance of each of the identified barriers for BIM in relation to each other. This will allow adopters to pay special attention to the most onerous barriers to BIM adoption. Once these are overcome the process of BIM implementation should become more straightforward. As stated previously, a further hypothesis is that those who have already adopted BIM and are working with it will rank the barriers to BIM differently than those who are yet to implement it.

Table 1: Summary of the Literature on Barriers for BIM

Barrier	Literature Source
Lack of Senior Management Support	Jung and Joo (2011); Arayici et al (2011); Coates et al (2010)
Doubts about ROI/Lack of Vision of Benefits	Arayici et al (2011); Lee et al, (2012); Coates et al (2010)
Cost of Training	Yan and Damian, (2008); Coates et al, (2010); Azhar, (2011); Crotty, (2012); Efficiency and Reform Group, (2011)
Cost of Software	Thompson and Miner, (2010); Azhar, (2011); Crotty, (2012); Efficiency and Reform Group, (2011); Giel *et al*, (2010); Lee *et al*, (2012)
Scale of Culture Change Required/Lack of Flexibility	Yan and Damian, (2008); Rowlinson *et al*, (2009); Jordani (2008); Mihindu and Arayici (2008); Watson, (2008);
Other Competing Initiatives	Cabinet Office, (2012);
Lack of supply Chain Buy-in	Aouad et al (2006);
Staff Resistance	Arayici *et al*, (2009); Yan and Damian, (2008);
ICT Literacy of Staff/Lack of Technical Expertise	Arayici *et al,* (2009); Yan and Damian, (2008); Aouad *et al* (2006);
Legal Uncertainties	Udom, (2009); Oluwole, (2011); Christensen et al, (2007); Race, (2012); UK BIM Industry Working Group, (2011); Chao-Duivis, (2009); Furneaux and Kivvits, (2008);

Methodology

Data was collected via an online questionnaire. Limesurvey™ was used to collect the survey data via the Internet. This software package gathered responses from sample organisations through a web-based interface and stored these in an on-line MySQL™ database. The sample was limited to the top 100 UK construction contractors. These organisations were known to have an international presence. According to the UK BIM Strategy very large main contractors can exert great pressure on organisations further down the supply chain (Efficiency and Reform Group, 2011).

Each organisation in the "Construction Index Top 100, 2011" (The Construction Index, 2011) was contacted. Pre-notification identified that the classification of construction companies used by the Construction Index allowed the inclusion of firms other than main contracting organisations, such as large sub-contracting organisations and multidisciplinary consultancy firms. In total, 74 out of the 100 companies listed were main contracting organisations, all of which were contacted. A response was received from 30 organisations. Bartlett *et al* (2001) indicated for a population size of 100, and considering that the data is continuous in nature, the minimum sample size is 46. This shows that the minimum number of completed questionnaires that would provide a valid sample is the 30 achieved as Bartlett's method assumes a 65% return rate. Bartlett *et al,* (2001) states this provides an alpha of 0.1 and a t of 1.65 and thus the margin of error to be produced by following this method has a 10% chance of being greater than 3%. The responses received were from a range of individuals at management level within the organisations. Eighteen responses were from those who had implemented BIM and twelve from those who had not.

The standard method of ranking the barriers of BIM utilising mean rank analysis and the relative importance index (RII) formula to establish the respondent's ranking on each of the BIM barriers was adopted.

RII is defined by the following formulae:-

$$Relative\ Importance\ Index(RII) = \frac{\sum W}{A\ x\ N}\ (0 \leq index\ \leq 1)$$

Where:

W is the weighting given to each element by the respondents. This will be between 1 and 5, where 1 is the least significant impact and 5 is the most significant impact;

A is the highest weight; and
N is the total number of respondents.

When the RII was carried out on the data obtained from the survey questionnaire there were some barriers which scored identically. In order to differentiate between barriers in terms of rank, consideration of the level of rank: the number of respondents scoring 4 or more, and those scoring 3 were noted. In some cases, it was still not possible to differentiate between the barriers using this approach; thus it was decided to give joint rankings when the scores were the same.

A comparison was carried out between those who had implemented BIM practices and those who had not using the Rank Agreement Factor (RAF).

RAF is defined by the following formulae:-

$$RAF = \frac{1}{N}\left[\sum_{i=1}^{N} \left|R_{i,1} - R_{i,2}\right|\right]$$

The maximum RAF (RAF_{max}) is calculated as shown below:

$$RAF_{\max} = \frac{1}{N}\left[\sum_{i=1}^{N} \left|R_{i,1} - R_{j,2}\right|\right]$$

Where;

$R_{i,1}$ is the rank of item *i* in group 1,
$R_{i,2,}$ is the rank of item *i* in group 2,
N is total number of items, which is the same for each group,
$R_{j,2}$ is the rank of item *j* in group 2, and;
$j = N - i + 1$.

Percentage Disagreement (PD) between the two groups is the ratio RAF to RAF_{max}, and it can be determined using the equation shown below:

$$\mathrm{PD} = \frac{\mathrm{RAF}}{\mathrm{RAFmax}} \times 100$$

The Percentage Agreement between the rank orders obtained from the two groups can then be calculated as shown below:

PA = 100 – PD

A higher RAF value shows that the agreement between the two groups is weaker. A RAF value of zero indicates a complete agreement. To provide further elucidation the barriers were then plotted on a spider diagram (Figure 1).

Findings Providing Ranked BIM Barriers

The barriers were analysed using Mean rank analysis (Mean – Table 2) and Relative Importance Index (RII – Table 2). Where the result produced a similar score the ranking was segregated using the largest number of values ranked 4, then the largest number of values ranked 3. The results are tabulated in Table 2.

Table 2: Ranked BIM Barriers

	Respondents Using BIM					Respondents not using BIM				
	Mean	No = 3	No ≥ 4	RII	Rank	Mean	No = 3	No ≥ 4	RII	Rank
Doubts about ROI/Lack of Vision of Benefits	3.053		8	0.611	1	3.273	4	4	0.655	7^
Scale of Culture Change Required/Lack of Flexibility	2.737		6	0.547	2	3.727		8	0.745	2
Cost of Training	2.684		4	0.537	3	3.273	4	4	0.655	7^
Cost of Software	2.632		4	0.526	4	3.455	2	6	0.691	3^
Lack of supply Chain Buy-in	2.368		6	0.474	5	4.000		7	0.800	1
Other Competing Initiatives	2.368		5	0.474	6	2.909		5	0.582	9
Lack of Senior Management Support	2.316		3	0.463	7	2.818		4	0.564	10
ICT Literacy of Staff/Lack of Technical Expertise	2.263		3	0.453	8	3.455	2	6	0.691	3^
Staff Resistance	2.211		1	0.442	9	3.273	5	4	0.655	5^
Legal Uncertainties	1.947		3	0.389	10	3.273	5	4	0.655	5^
Total	**24.579**				**Total**	**33.455**				
Total Mean Score	**2.458**					**3.345**				
* = Ranked after > 4 Analysis										
^ = Joint ranking after No. 3 Analysis										
# = Ranked after No. 3 Analysis										

The figures in Table 2 show that those who had not used BIM perceived the barriers as more important than those who had, with a total score of 33.455 compared to the User respondents' score of 24.579. The barriers may not be perceived as important by those respondents who have already implemented BIM as they have overcome the major hurdle of initial investment. It shows that once familiarity with BIM software and processes are achieved that the barriers do not appear to be as insurmountable. This hypothesis is supported by the ranking of the top four barriers as selected by the Non-users, "Lack of supply Chain Buy-in", "Scale of Culture Change Required/Lack of Flexibility", "ICT Literacy of Staff/Lack of Technical Expertise" and "Cost of Software" (1st to 3rd place respectively). The latter two were ranked in joint 3rd place. This indicates that the first three all have to do with skills and availability of expertise. Once the adoption of BIM has taken place these are overcome and those with experience are either trained or brought into the organisation negating the effect of these barriers. Those who had already implemented BIM ranked the same barriers 5th, 2nd, 4th and 8th respectively.

The top three barriers as perceived by those already using BIM were "Doubts about ROI/Lack of Vision of Benefits", "Scale of Culture Change Required/Lack of Flexibility" and "Cost of Training". Experience has changed the discernment in relation to the rankings provided. However, still to the fore are barriers that could be overcome by promotion of BIM.

Conversely, the three least important barriers for those who already implemented BIM, in order of importance were, "Legal Uncertainties", "Staff Resistance" and "ICT Literacy of Staff/Lack of Technical Expertise". Contributory factors may be that there have been little by way of case law which impacts on BIM, staff have already adopted the procedures so any resistance has faded and they have already up skilled to implement BIM. This is indicated by the reduced ranking for the above barriers.

The three least important barriers for those who had not implemented BIM were, "Lack of Senior Management support", "Other competing Initiatives" and "Cost of Training". This demonstrates that senior management are aware of the importance of the deadlines and are supporting the move towards BIM adoption.

The importance of this support is shown in the lowly rank given to other competing initiatives demonstrating that the adoption of BIM within the organisation is being provided with a semblance of priority to enable the Government objectives of Level 2 BIM adoption by 2016 to be achieved.

Table 3: RAF, PD and PA values for BIM Barriers

	Users	Non-Users					
Barrier	Rank	Rank	Ri1-Ri2	Absolute	J	Ri1-Rj2	Absolute
Doubts about ROI/Lack of Vision of Benefits	1	7	-6	6	5	-4	4
Scale of Culture Change Required/Lack of Flexibility	2	2	0	0	5	-3	3
Cost of Training	3	7	-4	4	3	0	0
Cost of Software	4	3	1	1	10	-6	6
Lack of supply Chain Buy-in	5	1	4	4	9	-4	4
Other Competing Initiatives	6	9	-3	3	1	5	5
Lack of Senior Management Support	7	10	-3	3	3	4	4
ICT Literacy of Staff/Lack of Technical Expertise	8	3	5	5	7	1	1
Staff Resistance	9	5	4	4	2	7	7
Legal Uncertainties	10	5	5	5	7	3	3
			Absolute Sum	35		Absolute Sum	37
			RAF	3.50		RAF MAX	3.70
			PD	94.595			
			PA	5.405			

The figures in Table 3 indicate that the rank agreement factor between the two groups is 3.50 and the RAF_{max} is 3.70. This produces a Percentage Disagreement (PD) of 94.595% and a Percentage Agreement of only 5.405%. This result strongly supports the hypothesis that BIM adopters change their views on the most significant barriers to BIM subsequent to implementation by ranking them differently than those yet to adopt BIM.

The overall ranking of the barriers is provided in Table 4. This is produced from an aggregated RII value which takes into account a combination of the results from the users and non-users of BIM.

Table 4: Overall Ranking for BIM Implementation Barriers

Barrier	Agg. RII	Rank
Scale of Culture Change Required/Lack of Flexibility	**0.646**	**1**
Lack of Supply Chain Buy-in	**0.637**	**2**
Doubts about Return on Investment/Lack of Vision of Benefits	**0.633**	**3**
Cost of Software	**0.609**	**4**
Cost of Training	**0.596**	**5**
ICT Literacy of Staff/Lack of Technical Expertise	**0.572**	**6**
Staff Resistance	**0.548**	**7**
Other Competing Initiatives	**0.528**	**8**
Legal Uncertainties	**0.522**	**9**
Lack of Senior Management Support	**0.513**	**10**
Total	**5.803**	
Mean	**0.580**	

Table 4 provides an overall ranking from the combination of the two groups. This indicates that "Scale of Culture Change Required/Lack of Flexibility" is the greatest barrier to BIM adoption. "Lack of supply Chain Buy-in" and "Doubts about Return on Investment/Lack of Vision of Benefits" are ranked second and third overall respectively, with the cost barriers relating to software and training following. This indicates that organisations are unsure as to their own capabilities and those in their supply chain. It highlights the importance of training and promotion of the benefits of BIM to enable the cultural and skills change to take place. The closer the RII value gets to 1 the more important the barrier is. The difference in Users and Non-Users perceptions of the importance of BIM barriers is illustrated graphically in Figure 1.

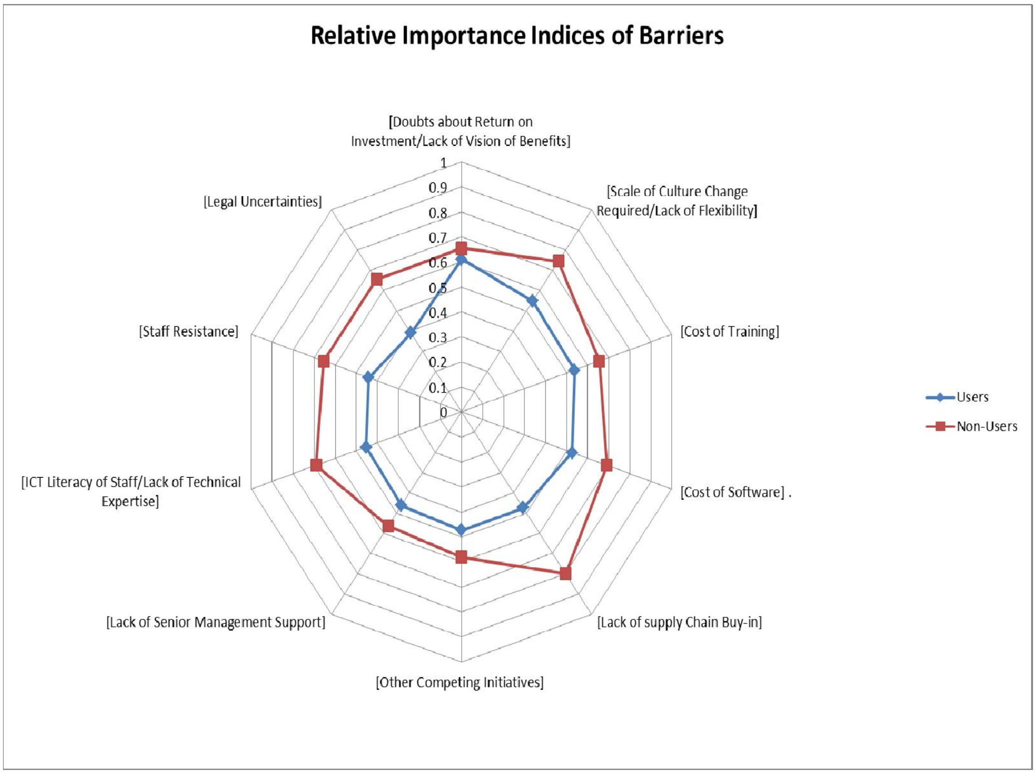

Figure 1: RII values for Users and Non-Users of BIM

Figure 1 displays a visual summary of the comparison between those who had already implemented BIM and those who were still to use BIM. Figure 1 represents just how much more important the barriers appear to those who have not implemented BIM in general. All of the barriers were deemed to be greater to those yet to use BIM. The barrier relating to "Doubts about Return on Investment / Lack of vision of Benefits" was ranked the closest between users and non-users. This indicates that the perception of the importance between the two groups did not reduce much upon implementation. It indicates that there may be work still to be done as far as promoting the benefits of BIM. The barrier ranking which showed the greatest variance between the users and non-users was "Lack of Supply Chain Buy-in". This shows that despite initial concerns prior to BIM adoption there is a general willingness on the part of the supply chain to adopt BIM once the commitment for implementation to proceed has been achieved.

Respondents were also asked to identify any further barrier for BIM. Eight respondents submitted additional comments on barriers. One suggested that there were no further barriers than those identified.

One suggested that a lack of knowledge was probably main reason for not fully adopting BIM to date. This was already investigated under the "Lack of Technical Expertise" barrier. The next comment related to ownership and liability which was investigated under "Legal Uncertainties". Two organisations suggested that "Procurement Routes" and the speed of procurement on fast track Design and Build schemes was a barrier. They considered that this resulted in using "tried and tested" methods rather than having to take time and rethink the process. Fear of the unknown, anticipated learning curve length and the ability to take a project through from inception were the last three barriers identified. This reinforces the findings in relation to the barriers to BIM adoption, in that, the "Fear" factor is reduced on adoption and while barriers are perceived greater prior to adoption in the main they reduce substantially once BIM is implemented.

Conclusions

Building Information Modelling (BIM) in the latest UK government strategy has been set a deadline of 2016 on all government projects. Without implementing BIM organisations will not be accepted onto UK government projects as they will lose out at the tender stage. With this increased pressure through the government strategy and in light of the many advantages of BIM adoption, such as its innovative way of conceptualising, managing, designing and constructing the project, in addition to managing it as an asset through to demolition, organisations are seeking to implement it in order to survive. However, if successful implementation is to take place there are a number of barriers to be overcome. This paper identified ten barriers to BIM adoption from literature and ranked these in order of importance. In addition two respondents, when identifying additional barriers indicated "Procurement Route" and speed of procurement on fast track Design and Build schemes. Fear of the unknown, anticipated learning curve length and the ability to take a project through from inception were the last three additional barriers identified.

The paper demonstrated the importance of the barriers to BIM changed on adoption and experience. Non BIM users perceived the barriers as more important than Users, with a total score of 33.455 compared to the User respondents' score of 24.579. This indicates that the barriers are deemed not as important by those respondents who have already implemented BIM as they have overcome the major hurdle of initial investment.

Acquaintance with the BIM software and processes breaks down barrier importance. This hypothesis is supported by the ranking of the top four barriers as selected by the Non-users, the first three all have to do with skills and availability of expertise. Once BIM is implemented these aspects are surmounted and the effect of experience negates their effect.

The top three barriers as perceived by those already using BIM were "Doubts about ROI/Lack of Vision of Benefits", "Scale of Culture Change Required/Lack of Flexibility" and "Cost of Training". Experience has changed the discernment in relation to the rankings provided. However, still to the fore are barriers that could be overcome by promotion of BIM.

Conversely, the three least important barriers for those using BIM related to legal issues where the lack of effect of case law impacting on BIM contributed to its low ranking, staff having already implemented BIM are no longer resisting and have already up skilled to implement BIM. This is indicated by the reduced ranking for these barriers. For non-BIM users the lowest barriers in the ranking demonstrated that senior management were committed to BIM adoption. This commitment is further seen in the low rank given to other competing initiatives.

The difference in ranking between users and non-BIM users is further emphasised by the Percentage Disagreement (PD) value of 94.595% and a Percentage Agreement of only 5.405%. This finding strongly supports the original hypothesis of this paper; respondents who have already adopted BIM will change their perceptions as to the most important barriers to BIM by ranking them differently than those who are yet to implement it.

This is further developed as all barriers are ranked of greater importance by those who have not implemented BIM than those who have. However, the variance between the users and non-users varied. The lesson learned from the barrier relating to "Doubts about Return on Investment / Lack of vision of Benefits" which was ranked with least variance between users and non-users indicates that the perception of the importance between the two groups did not reduce much upon implementation. This demonstrates that policy alone will not drive BIM adoption. A promotion of the benefits of BIM is required. The barrier ranking which showed the greatest variance between the users and non-users was "Lack of Supply Chain Buy-in".

This demonstrates that despite initial concerns prior to BIM adoption there is a general willingness on the part of the supply chain to adopt BIM once the commitment for implementation to proceed has been achieved.

This paper reinforces the importance of BIM to the UK construction industry as a whole yet clearly indicates that different stakeholders within the large contractor sector will have differing barrier perspectives, depending upon their level of corporate BIM maturity. It is also clear from the research that to successfully overcome the barriers in the implementation of BIM, a company must attend to the softer issues surrounding internal 'change management' in addition to the harder technical issues.

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