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AN ANALYSIS OF THE DRIVERS FOR ADOPTING BUILDING INFORMATION MODELLING

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SUMMARY: *Building Information Modelling (BIM) is one of the pillars of the UK Government Construction Strategy. While many benefits (drivers) of BIM are mentioned in literature there is little by way of research to evaluate their importance. The objective of the survey reported in this paper is therefore to fill this knowledge gap by identifying and prioritizing the factors driving BIM adoption to enable those seeking to adopt BIM to gain an understanding of the relative importance of each of these drivers in order to inform their strategic and operational decision making. The research sample was limited to the top 100 UK construction contractors with international business activity. Online survey respondents were asked to score on a Likert-type scale of 1-5 the level of importance they would place on the identified factors driving BIM adoption. Responses to the online survey were analysed using relative importance index and rank agreement factor. The study concluded that those who had adopted BIM ranked the drivers for BIM differently than those yet to implement a BIM solution. Overall, the study found that the three most important drivers for BIM implementation are "Clash Detection", "Government Pressure" and "Competitive Pressure". The top drivers for non-users of BIM could be grouped under pressure from external sources while operational drivers were more important for users of BIM.*

KEYWORDS: *Building Information Modelling, BIM users, non-users of BIM, BIM adoption drivers.*

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1. INTRODUCTION

In response to the global economic crisis, the UK Government, realized that the construction industry needed to become more efficient as reports historically indicate that it is inefficient and adversarial (Wolstenholme et al, 2009; Egan, 1998; Latham, 1994). The Government Construction Strategy (GCS) aims to use the Central Government's influence through its 45% share in the UK construction industries annual turnover, to encourage measures that will ensure sustainability for the future of the industry and, hopefully, drive the UK's emergence from recession (Efficiency and Reform Group, 2011). One of the issues in the efficiency drive is the minimum enforced adoption of fully collaborative 3-D Building Information Modelling (BIM) by 2016, with all project and asset information, documentation and data being BIM compliant. While many benefits and drivers are mentioned in literature there is little by way of research to evaluate their importance.

Building Information Modeling (BIM) has been seen by some as the panacea at the end of the long evolution of graphical representation of buildings resulting in a model containing structured information useful in the whole lifecycle of the project from design, through construction to operation and finally demolition. It exceeds a graphical model to provide data-rich 3D replications of a project. Amor et al. (2007) show that there has not been much research-based critical analysis of the adoption of BIM standards and their impact on the industry. However, Amor (2012) further indicates that there is a momentum behind BIM adoption and the construction industry will have a BIM-dominated transformation going beyond anticipated progress. Despite such studies, a detailed analysis of all the identified drivers for BIM is still missing. The objective of this paper is to explicate the drivers for BIM adoption on the basis of a broad literature study and analyse the importance of each of these for practice from the viewpoint of both active BIM users and non-users of BIM.

The knowledge gap addressed in this study is that while the drivers for BIM adoption were identified in BIM literature, it does not prioritize their order of importance. The aim of the study was to provide a comprehensive list of factors driving BIM adoption and rank them in order of relative importance. This will allow adopters to appreciate the most advantageous drivers for BIM in its adoption. A further hypothesis that this study sought to explore is that those who have already adopted BIM and are working with it rank the drivers to BIM differently than those who are yet to implement it.

2. DRIVERS FOR BIM ADOPTION

2.1 Government pressure

When implementing electronic practices the public sector develops and publishes policy documentation to ensure good practice. In the case of BIM, the UK Government is making Level 2 BIM mandatory on all publicly-funded projects from 2016 onwards (Efficiency and Reform Group, 2011).

The definition of the BIM levels in the UK by the BIM Industry Working Group (2011) is as follows:

- *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 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.

In Australia government advisors have also adopted a similar approach by suggesting early 2016 as a start date for compulsory BIM use on public sector projects (buildingSMART Australasia, 2012). The BIM Industry Working Group (2011) report suggests there are currently a number of national deployments of BIM across the USA, Scandanavia/Europe, and the Far East. This has contributed to many UK Government departments moving target dates forward. The Ministry of Justice (MOJ) requires all contractors bidding for four upcoming frameworks, worth a total of £2.4bn, to demonstrate BIM abilities in order to be considered (Fitzpatrick, 2012). In addition to direct strategy documentation, Arayici et al (2011) indicate that government policies put the building industry under pressure to provide value for money, sustainable design and construction, all of which are directly related to use of BIM. Policy such as this pressurises the industry to invest in and implement BIM in order to win public sector contracts. As the UK Government exerts its influence over the main contracting organisations it will become necessary to wholly integrate BIM into their work practices to survive prior to the deadlines set in its current strategy documents.

2.2 Client/competitive pressure

The construction industry is highly competitive, the current economic depression and reported signs of a triple dip recession has exacerbated this. In this climate clients are asking contractors, not to demonstrate ability to offer BIM alone, but describe capacity through a track record of successfully managed BIM projects. Lu and Li, (2011) suggest this can be achieved by indicating their position on the maturity triangle (People, Process and Technology). If clients require this deeper knowledge and application of BIM, strategic managers should be aiming to implement it before the stipulated Government deadline and to a higher level, in an effort to become "BIM experts" before the competition does. Coates et al (2010) cites this as one of the key reasons for BIM adoption in a case study of an architectural practice. Liu et al (2010) further confirm that external forces from clients and competitors play a large role in BIM adoption.

2.3 Desire for innovation to remain competitive

Li et al (2008) have identified that BIM can be used as part of a construction project extranet (CPE). Ruikar et al (2005) labelled construction companies who were employing CPE's as "visionaries" and conclude that whilst there was no industry requirement for uptake of this technology, the main driver was the aspiration to be at the forefront of this aspect of the industry. Moore (2003) identified the few "technology-orientated" firms who have successfully utilised CPEs on construction projects as "early adopters". Early adopters are organisations who opted to adopt technological solutions for no reason other than to stay 'ahead of the game' and conclude that the risks associated with implementation are outweighed by the competitive and other advantages available to them from being 'ahead of the pack' in terms of technological capabilities. The overarching drivers for these firms were identified as being business goals and not technological goals. TRADA (2012) argue that current adopters of BIM are now in the latter stages of the 'early majority', heading towards the 'late majority'. Ruikar et al (2005) further argue that the late majority are those firms who implement new technology only when they are required to, or to avoid being left behind.

2.4 Improving the capacity to provide whole life value to client

The most advanced BIM products currently available have the capability to deliver environmental, energy, cost, schedule and spatial analysis; and as such, can be used collaboratively by project stakeholders to deliver real whole life value (WLV) to clients (Azhar et al, 2011).

The Latham and Egan reports slated the construction industry for its intrinsic inefficiencies and waste (Egan, 1998; Latham, 1994). Reduction of construction waste and improvements in efficiency and quality were further emphasised 10 years after the Egan report was published (Wolstenholme et al, 2009). A paradigm shift from capital cost to whole life costing was proposed. The effect that building design can have on construction and business-operating cost is significant, with increases in operating productivity offering substantial savings for the client/end-user (Barlish & Sullivan, 2012; Deutsch, 2011; Emmitt, 2007). The ratio of 1:5:200, equating to Build Cost : Maintenance and Building Operation Costs : Business Operating Costs, highlights how quality in design can produce benefits (Lock, 2007). This involves the consideration of how the building environment will influence its occupants and increase productivity through increased well-being, work quality and output; resulting in lower levels of sick leave or absenteeism, in the case of a commercial building (Evans et al, 1998). These measures, although quantified in monetary terms for commercial concerns, apply equally to public service and not-for-profit organisations; with occupier well-being a universal phenomenon, and savings, rather than increased profits, the main concern.

The 4D scenario modelling can allow examination of facilities management, methods of demolition and decommissioning, or to innovative designs that lend themselves to versatile re-use. With an intelligent model, employed by an experienced team which has the knowledge and competencies to fully exploit its capabilities, BIM can be instrumental in delivering WLV (Grilo and Jardim-Goncalves, 2010).

2.5 Streamlining Design Activities and Improving Design Quality

The design process in the UK normally involves the RIBA plan of work moving through Stages C (Concept) to E (Technical Design) by producing a variety of themes and designs, presenting them to the client and seeking approval and comment (Deutsch, 2011; Emmitt, 2007). Even on 3-D CAD where designs are still drawn line by line this process is relatively slow and involves several design review meetings, resulting in several drafts (Emmitt, 2007). This is especially the case when dealing with an infrequent or naïve construction client (Tunstall, 2006).

In contrast, BIM models can offer walk-through visualisations to assist clients in the decision-making process and therefore reduce ‘preference’ changes later in the contract (Eastman et al, 2011). Real-time, on-line contributions from designers with no geographical restraints can ‘suggest’ changes to the client visually on screen (Azhar et al, 2008; Bentley, 2012). This is achievable due to the object-orientated nature of BIM, as opposed to the line-orientated nature of CAD. Assuming the correct object properties have been loaded into the system, designers can simply retrieve objects and manipulate the objects on screen (Campbell, 2007; Hardin, 2009). In addition, basic building elements can be replicated on screen from a bank of completed models that designers already possess therefore enabling simple and realistic formation of concept designs. As a result clients may acquire a realistic sense in 3D of how the facility will look, feel and operate, and how well it will fit into its surroundings prior to detailed design. The role of the contractors design manager in the early stages of the design process is one of a communicator, facilitator and advisor (Lock, 2007; Walker, 2007). Ultimately the contractors design manager will ensure that the client scope of the build meets the available budget and that the design will need minimal re-work and satisfies the client’s needs (Emmitt, 2007; Woo, 2007). BIM offers the tools and processes that facilitate all of these functions.

2.6 Designing health and safety into the construction process

BIM models allow visualisation of the construction sequence. In a Health and Safety context this could be invaluable if supplemented with practical information from the construction site and information from HSE directives and legislation. The construction site can be made intrinsically safer (Kiviniemi et al, 2011). Just as the building can undergo simulations for the purpose of designing in energy efficiency and whole life value, so the construction process can be examined, simulated, and scenario-tested to eliminate or reduce risk of accident or injury. This can then be communicated effectively to those who will physically implement it.

2.7 Improving communication to operatives

BIM offers contractors an additional means of communication with their workforce. Sacks et al (2009) show that 4D BIM has the facility to display animated construction sequences on screen and this is being utilised by designers and construction planners to communicate the sequence of operations that operatives are required to carry out. The opportunity to show even unskilled operatives how, when and where the building will be constructed, can only improve the process on site. Further, with the significant increase in the globalisation of the construction workforce, the number of non-native operatives has increased, increasing the importance of supplementing the required provision of translators with visual models (Tutt et al, 2011).

Furthermore, communication is a two-way process. There may be ‘buildability’ issues that have simple, site-level solutions for which craftsmen or operatives may have suggestions. In this, BIM, through visual animation, can promote collaboration on a micro-level with the workforce.

2.8 Cost savings and monitoring

One of the limitations of 2D drawings, even on CAD packages, is that it is only ever possible to present one view of the building at a time, (Campbell, 2007). Aside from the obvious issues regarding clarity of design information the traditional approach of presenting contractors with sections, elevations and details, referenced to overall plans, has proved to provide contractors with insufficient information, (BIMhub, 2012; Crotty, 2012). Usually this leads to the submission of “Requests for Information” (RFIs) by the contractor. RFIs are often the cause of delays and occasionally require re-design, both of which are a cause of project cost overrun, (Dickinson, 2010). A central BIM model with attached object information, if available for interrogation by all project actors, can reduce the number of RFIs drastically (Azhar et al, 2008; Barlish & Sullivan, 2012; Deutsch, 2011). A report on the Mortenson Group found that the use of BIM reduced RFIs by 32% (Applied Software, 2009). This leads to efficiency and cost savings through BIM.

Projects by their nature are dynamic, and subject to change influenced by external and internal forces (Winch, 2010). Therefore, it is often the case that despite a detailed feasibility analysis at inception and thorough costing pre-tender, events will take place that will alter the projected contract sum. It is necessary to monitor these events, calculate the cost overrun, and take mitigating actions (Walker, 2007; Lock, 2007).

Whilst there are many issues that can push costs up, BIM can have a positive influence, if the issue is that of a required design change. Providing the object and the project-specific information have been loaded into the application, BIM has the capacity to generate cost estimates for a given design change (Campbell, 2007). These need not only be based on the cost of the materials and construction fees, rather, they can account for the out-of-sequence work, delays to other works packages, the time of year for weather-sensitive activities, and even incorporate contingency sums from the risk management exercise. Further, if the contractor is proficient in the use of the BIM application, they can produce fast and reasonably accurate estimates of cost implications, to use as a starting point for mitigating actions.

2.9 Time savings

Time is a vitally important project parameter to the success of a construction project (Lock, 2007). The requirements to plan, re-plan, generate cost- and time-forecasts as a reaction to developments (or in fact crises) throughout the project, or in an effort to find savings, are ever-present in construction. Should a design change be required for any reason, the process involved would normally involve requesting a meeting with the design team, after which design alterations would be drawn up and issued to the contractors and Quantity Surveyors (QS) for costing; and then, perhaps, the repetition of the process until a satisfactory compromise between design and cost is achieved. With a 5-D BIM application, the client, PM, contractors and designers can even meet online to discuss design changes, and the cost can be altered immediately. A study by Azhar et al (2008) revealed that BIM can produce up to an 80% reduction in the time taken to generate a cost estimate.

It can be seen then, that the process of altering and agreeing the design change, cost estimation as a result of design changes, and production and updating of registers and schedules, could be reduced from days in duration to hours (BIMhub, 2012; Eastman et al, 2011).

2.10 Accurate Construction Sequencing and Clash Detection

4-D BIM can be used to create detailed sequencing of construction works (BIMhub, 2012). BIM further proffers visualisation of the interfaces between different elements of the built asset, referenced to time (Deutsch, 2011; Eastman et al, 2011). However, BIM can produce visual representations and animated simulations of physical clashes between different elements of the building, and depending on model detail, between the building and temporary works (Campbell, 2007; Leite et al, 2009). Historically, clashes in structure, services and fabric were usually only noticed during the construction phase of the project resulting in redesign and rework, and often incurred non-recoupable costs (Azhar et al, 2008; Azhar, 2011).

Significant time and cost-savings can be achieved through effective and efficient production works scheduling (Azhar, 2011). When construction falls behind programme on a particular building element, it has a consequential knock-on effect on materials ordering, fabrication and delivery of follow-on building components. The realistic sequencing and costing of construction works, saves significant time and money through reduced rework and delays to programme. 4-D BIM offers detailed scheduling tools that can accurately predict the duration of each construction task, the upcoming tasks and the associated resource requirement; as well as allowing the programmer to factor in float for unforeseen events, delivery programmes and inclement weather (Azhar, 2011; Eastman et al, 2011).

Azhar et al (2008) found that clash detection can offer savings of up to 10% of contract value and reduce project duration by up to 7%. These savings go some way towards the target of 15% project savings through BIM set by the UK Government (Efficiency and Reform Group, 2011) therefore reducing the common causes of disputes prevalent within the construction industry.

2.11 Automation of schedule/register generation

The process of scheduling is often insufficiently performed in terms of scenario testing, with the result that many construction projects fall behind schedule early on in the build (Edum-Fotwe & McCaffer, 2000). BIM allows programmers to generate new delivery schedules for each scenario enacted, creating efficiencies in document generation and distribution (Azhar, 2011). When things go wrong on a construction project, new schedules of works must be created, based on the predicted new duration of construction tasks. From these schedules, fabrication and delivery programmes must be developed. This is a time-consuming activity and is prone to change (Harris & McCaffer, 2006). The facility to quickly create new scenarios, and thus schedules, electronically, and then deliver them to project stakeholders, can significantly reduce the iterative tasks involved in managing change on construction projects.

2.12 Facilitating increased pre-fabrication

Site activities are often dictated by weather, and are always carried out within the confines of a construction schedule (Tam et al, 2007). The ability to pre-fabricate building elements off-site and simply assemble on-site presents significant saving in both time and cost. Hence, BIM offers manufacturers of building components detailed and information-rich models, which can be interrogated for manufacturing details, can reduce information requests and improve output quality (Eastman et al, 2011). A study of the application of BIM on a large healthcare project in the USA revealed that it is possible to achieve 100% pre-fabrication for mechanical systems installations, and zero clashes in MEP installation activities. This, in turn, yielded 20-30% labour savings for the MEP sub-contractors, and thus savings further up the value chain (Olofsson & Eastman, 2008). Nawari (2012) suggests that BIM models have innumerable advantages in the off-site construction domain including speed, economy, sustainability and safety. Again, these are significant savings, which can have a huge impact on the competitiveness of a contracting organisation.

2.13 Facilitating facilities management activities

Traditionally, the handover of a built facility from the contractor to the client involves the collation of ‘as-built’ drawings, operation and maintenance manuals, and warranties and guarantees (Crotty, 2012). However, it has often been the case that valuable information regarding the optimal maintenance and operation of that facility is lost during this transition (Evans et al, 1998).

Rather than replacing traditional Facilities Management systems, the BIM model can be linked to an existing FM system to provide an accurate and complementary “real-time” data set, that makes asset management faster and more accurate (Zhang et al, 2009). BIM can offer a data-rich, real-time platform from which to programme and monitor preventative maintenance, and carry out space management activities. Real-time, preventive maintenance scheduling enables facility managers to proactively plan maintenance activities, appropriately allocate maintenance staff, and reduce corrective maintenance and emergency maintenance repairs. Provided that the information pertaining to building element maintenance is logged into the model correctly pre-handover, facilities managers can expect to save up to 70% on what would have otherwise been reactive maintenance (Lewis et al, 2010).

2.14 Improving built output quality

An IDC study (2009) concludes that by using BIM on large-scale retail projects, Westfield was able, through enhanced design, to increase the lettable floor space area offered to their client. The consequence was a win-win solution providing a more pleasurable shopping complex for customers, and also a more profitable retail outlet for the client. The benefits of improved design through BIM can lead to an improved build ability and end-product, with the additional benefits of a reduction in complications during the construction phase (Bazjanac, 2005; Samuelson & Björk, 2010).

Given the prevalence of long-term PFI/PPP contracts, contractors can hope to avail of sustained savings throughout the duration of the contract, which can be used as a marketing tool when bidding for these types of contracts (Dundas & Wilson, 2009).

3. SURVEY 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 selection 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 these were contacted. A response was received from 30 organisations. Bartlett et al (2001) indicated that 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 30, as Bartlett's method assumes a 65% return rate. Bartlett et al. (2001) state this provides an alpha of 0.1 and a t of 1.65 and the maximum margin of error that can be expected to be produced by following this method is 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 drivers of BIM utilising mean rank analysis and the relative importance index (RII) formula to establish the respondent's ranking on each of the BIM drivers 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 computed on the data obtained from the survey questionnaire there were some drivers/barriers which scored identically. If the drivers scored identically in terms of rank, consideration of the level of rankings provided were then considered to enable differention: 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 drivers 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:

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

where:
Ri,1 is the ith rank of an item in group 1,
Ri,2, is the ith rank of an item in group 2,
N is the total number of items, which is the same for each group,
Rj,2 is the jth rank for each item in group 2, and
j = N – i + 1.

Percentage Disagreement (PD) between the two groups is the ratio RAF to RAFmax. It can be determined using the equation shown below (Chan & Kumaraswamy, 1996):

$$PD = \frac{RAF}{RAF_{max}} \times 100$$

The Percentage Agreement between the rank orders obtained from the two groups can then be calculated respectively as (Chan & Kumaraswamy, 1996):

$$PA = 100 - PD$$

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 drivers were then plotted on a spider diagram (Figure 1).

4. FINDINGS PROVIDING RANKED BIM DRIVERS

The drivers were analysed using Mean rank analysis (Mean – see Table 1) and Relative Importance Index (RII – Table 1). 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 obtained results are shown below.

TABLE 1: Summary of the literature on drivers for BIM

BIM Drivers	Respondents Using BIM					Respondents not using BIM				
	Mean	No. = 3	No. ≥ 4	RII	Rank	Mean	No. = 3	No. ≥ 4	RII	Rank
Clash Detection	4.056		13	0.811	1	4.091		10	0.818	4
Cost Savings through Reduced Re-work	3.778		13	0.756	2	3.818		6	0.764	10
Improve Design Quality	3.722		14	0.744	3	3.455	4	6	0.691	16#
Accurate Construction Sequencing	3.667		9	0.733	4	4.000		9	0.800	6
Improve Built Output Quality	3.611		12	0.722	5	3.818		7	0.764	9
Desire for Innovation	3.444		9	0.689	6	3.455		5	0.691	17
Competitive Pressure	3.333		8	0.667	7	4.545	1	10	0.909	2^
Government Pressure	3.278	4	9	0.656	8#	4.636		11	0.927	1
Improve Capacity to Provide WLV to Client	3.278	3	9	0.656	9	3.636		7	0.727	12
Streamline Design Activities	3.222		10	0.644	10	3.364		5	0.673	18
Time Savings	3.222		8	0.644	11	4.000		8	0.800	7
Cost Savings through Reduced RFI's	3.111	5	7	0.622	12^	3.455	2	6	0.691	14^
Improve Communication to Operatives	3.111	5	7	0.622	12^	3.909		6	0.782	8

BIM Drivers	Respondents Using BIM					Respondents not using BIM				
	Mean	No. = 3	No. ≥ 4	RII	Rank	Mean	No. = 3	No. ≥ 4	RII	Rank
Facilitate increased Pre-Fabrication	3.056		9	0.611	14	3.545		5	0.709	13
Client Pressure	3.000		6	0.600	15	4.545	1	10	0.909	2^
Automation of Schedule/Register Generation	2.944		5	0.589	16	3.727		8	0.745	11
Design H & S into the Construction Process	2.778		6	0.556	17	4.091		9	0.818	5
Facilitate Facilities Management Activities	2.778		4	0.556	18	3.455	2	6	0.691	14^
Total	59.39					69.55				
Total Mean Score	3.299					3.864				

Key
^ = Joint ranking after No. 3 Analysis
# = Ranked after No. 3 Analysis

The figures in Table 1 show that those who had not used BIM perceived the drivers as more important than those who had, with a total score of 69.55 compared to the Yes respondents' score of 59.39. The drivers may not be perceived as important by those respondents who have already implemented BIM as they do not feel under the same pressure in general to implement BIM. This hypothesis is supported by the ranking of the top three drivers as selected by the Non-users, "Government Pressure", Competitive Pressure and Client Pressure (1st and Joint 2nd places). Those who had already implemented BIM ranked the same drivers 8th, 7th and 15th respectively.

The top three drivers as perceived by those already using BIM were, "Clash Detection", "Cost savings through reduced re-work" and "Improving design quality". The rankings indicate what the respondents deem through experience to be the greatest benefits from implementing BIM rather than the initial drivers for initial implementation. Similarly, the three least important drivers for those who already implemented BIM, in order of importance were, "Automation of Schedule/register generation", "Design health and safety into the construction process" and "Facilitate facilities management activities". This may also be due to the fact that BIM had been implemented recently by the majority of the organisations involved resulting in a lack of experience in preventative and corrective maintenance, respectively. This indicates a lack or integration of BIM into the operational phase of the life cycle of buildings to date.

The three least important drivers for those who had not implemented BIM were, "improve design quality", "desire for innovation" and "streamline design activities". This is in contrast with those with understanding of the opportunities for design efficiencies with BIM. Earlier in the questionnaire 29 out the possible 30 respondents (96.67%) indicated that their organisation participated in Design and Build contracts, negating the theory that they were design naïve. The fact that desire for innovation was ranked 17th out of 18 by those yet to implement BIM is congruent with the hypothesis set out by Moore (2003), which states that late adopters of technology do so out of necessity and that those who value innovation will tend to be "early adopters".

The figures in the next Table 2 indicate that the rank agreement factor between the two groups is 6.06 and the RAFmax is 6.39. This produces a Percentage Disagreement (PD) of 94.783% and a Percentage Agreement of only 5.217%. This finding strongly supports the hypothesis at the beginning of the paper that those who have already adopted BIM will change their perceptions as to the most important drivers to BIM by ranking them differently than those who are yet to implement it.

TABLE 2: RAF, PD and PA values for Drivers

Driver	Users Rank	Non-Users Rank	Ri1-Ri2	Abs	J	Ri1-Rj2	Abs
Clash detection	1	4	-3	3	14	-13	13
Cost savings through reduced re-work	2	10	-8	8	5	-3	3
Improve design quality	3	16	-13	13	11	-8	8
Accurate construction sequencing	4	6	-2	2	2	2	2
Improve built output quality	5	9	-4	4	13	-8	8
Desire for innovation	6	17	-11	11	8	-2	2
Competitive pressure	7	2	5	5	14	-7	7
Government pressure	8	1	7	7	7	1	1
Improve capacity to provide whole life value to client	9	12	-3	3	18	-9	9
Streamline design activities	10	18	-8	8	12	-2	2
Time savings	11	7	4	4	1	10	10
Cost savings through reduced rfi's	12	14	-2	2	2	10	10
Improve communication to operatives	12	8	4	4	17	-5	5
Facilitate increased pre-fabrication	14	13	1	1	9	5	5
Client pressure	15	2	13	13	6	9	9
Automation of schedule/register generation	16	11	5	5	16	0	0
Design health and safety into the constr. process	17	5	12	12	10	7	7
Facilitate facilities management activities	18	14	4	4	4	14	14
			Abs Sum	109		Abs Sum	115
			RAF	6.06		RAF MAX	6.39
			PD	94.783			
			PA	5.217			

Table 3 provides an overall ranking from the combination of the two groups. This indicates that "Clash Detection" is currently the greatest driver for BIM. "Government Pressure" and "Competitive Pressure" are ranked second and third overall respectively. This shows the importance of active promotion of BIM by Government departments and the targets set by policy documents. It further indicates that the shift to BIM enabled working is being enforced through external influences rather than internal organisational conviction. The closer the RII value gets to 1 the more important the driver is.

The difference in Users and Non-Users perceptions of the importance of BIM drivers is illustrated graphically in the following Figure 1.

TABLE 3: Overall Rank Drivers for BIM

Driver	**Agg. RII**	**Rank**
Clash Detection	**0.815**	**1**
Government Pressure	**0.791**	**2**
Competitive Pressure	**0.788**	**3**
Accurate Construction Sequencing	**0.767**	**4**
Cost Savings through Reduced Re-work	**0.760**	**5**
Client Pressure	**0.755**	**6**
Improve Built Output Quality	**0.743**	**7**
Time Savings	**0.722**	**8**
Improve Design Quality	**0.718**	**9**
Improve Communication to Operatives	**0.702**	**10**
Improve Capacity to Provide Whole Life Value to Client	**0.691**	**11**
Desire for Innovation	**0.690**	**12**
Design Health and Safety into the Construction Process	**0.687**	**13**
Automation of Schedule/Register Generation	**0.667**	**14**
Facilitate increased Pre-Fabrication	**0.660**	**15**
Streamline Design Activities	**0.659**	**16**
Cost Savings through Reduced RFI's	**0.657**	**17**
Facilitate Facilities Management Activities	**0.623**	**18**
Total	**12.893**	

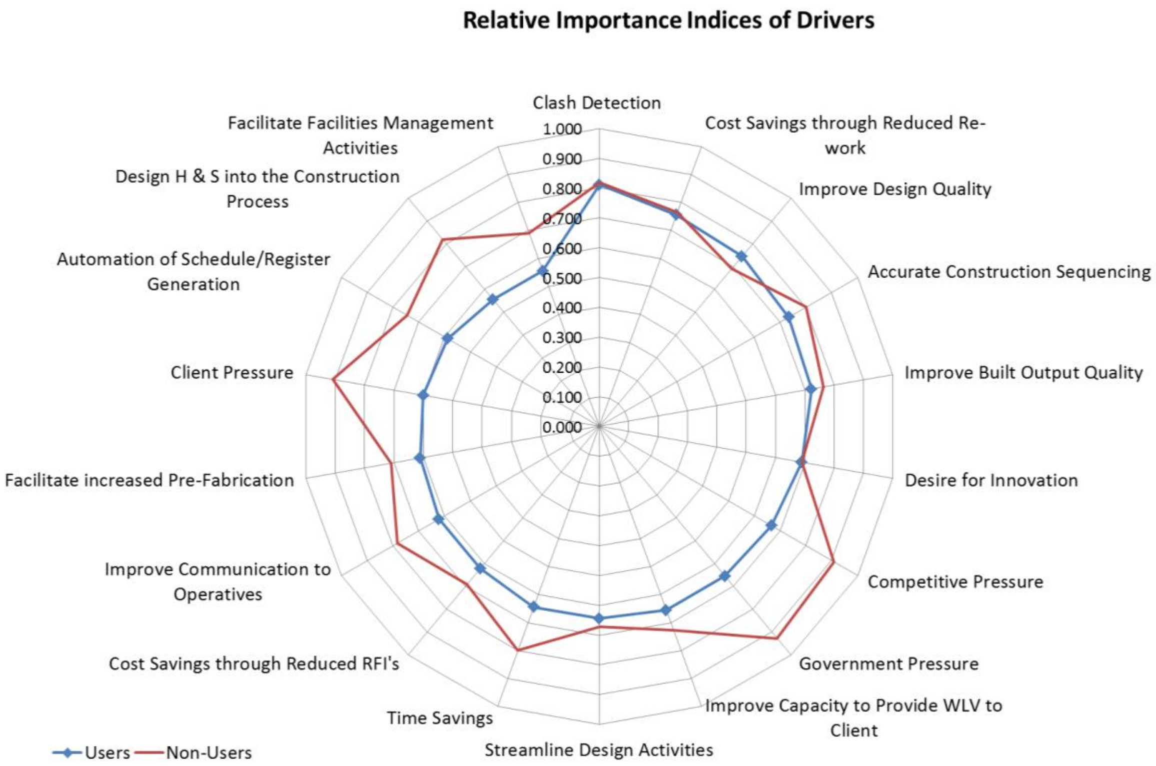

FIG. 1: RII values for Users and Non-Users of BIM

Figure 1 displays a visual summary of the comparison between those who had already implemented BIM and those who were still to use BIM. When represented this way, it is clear just how much more important the drivers are to those who have not implemented BIM in general. In only one area, "improving design quality", did those who had already implemented BIM rank the driver higher than those who have not. "Cost savings through reduced re-work", "desire for innovation" and clash detection" were all scored very similarly by the two groups. Interestingly, those who had yet to use BIM appear to be more interested in the opportunities that BIM can offer for facilities management activities.

Respondents were also asked to identify any further drivers for BIM. Six respondents submitted additional drivers for this question. Two of these answers were options that respondents were given to choose from and were ignored. Two further responses stated there were no further drivers. One driver identified was "sales promotion to clients", although this could be argued to come under the banner of "competitive pressure". A further statement reproduced below contained the cost implications but in addition "inventory generation for complex products".

5. CONCLUSIONS

Building Information Modelling (BIM) is emerging as a prerequisite for many projects as clients are increasingly demanding it. This is especially important now that a deadline has been set for adoption to allow organisations to pursue UK government work. In this light the many advantages of BIM adoption and its innovative way of conceptualising, managing, designing and constructing the project, in addition to managing it as an asset through to demolition, becomes vital to informed clients and hence survival of many large contracting organisations. This paper identified eighteen drivers for BIM adoption from literature and ranked these in order of importance. In addition to these drivers identified from literature, two further drivers, "sales promotion to clients" and "inventory generation for complex products" were also identified.

The paper demonstrated the importance of the drivers to BIM changed on adoption and experience. It proved that pressure from a variety of sources; Government, Competitive and Client (1st and Joint 2nd places respectively) were the most important drivers for BIM adoption from those who have no yet used BIM. This highlights the importance of the UK Governments BIM Strategy and the deadlines set within it. It also suggests that other Governments, nationally and internationally would benefit from adopting this strategy. However, once BIM is implemented the importance of operational drivers becomes evident. Respondents who had adopted BIM within their organisations ranked "Clash Detection", "Cost savings through reduced re-work" and "Improving design quality" as first, second and third respectively. Therefore suppliers of BIM software need to emphasise the different BIM drivers available to ensure organisation select the relevant drivers best suited to their business needs depending on the experience of the organisation that is interested in their software.

This is further emphasised by the Percentage Disagreement (PD) value of 94.783% and a Percentage Agreement value of only 5.217%. 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 drivers to BIM by ranking them differently than those who are yet to implement it.

This is further developed as all drivers - excluding the "Improving Design Quality" driver are ranked of greater importance by those who have not implemented BIM than those who have. "Cost savings through reduced re-work", "Desire for innovation" and Clash detection" were all scored very similarly by the two groups. This demonstrates that the importance of all but the "Improvement of Design Quality" falls after implementation.

The three least important drivers for those who already implemented BIM, in order of importance were, "Automation of Schedule/register generation", "Design health and safety into the construction process" and "Facilitate facilities management activities". The fact that only one of the respondents had used BIM for five years, with the remainder two years or less indicates that lack of experience exists in using BIM for preventative and corrective maintenance. This may indicate a lack or integration of BIM into the operational phase of the life cycle of buildings to date. Further research may be required to identify whether the ranking of the drivers for BIM change after this experience is gained.

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 driver perceptions, depending upon their level of corporate BIM maturity.

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