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BIM implementation throughout the UK construction project lifecycle: An analysis

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ABSTRACT

Substantial impacts through BIM implementation may be achieved throughout all stages of the construction process. The paper measures BIM use throughout the project lifecycle, confirming BIM is most often used in the early stages with progressively less use in the latter stages. This research demonstrates via 92 responses from a sample of BIM users that collaboration aspects produce the highest positive impact. The process aspects are more important than the software technology. BIM necessitates investment in software and training however, smaller practices can afford it. Stakeholder financial benefits are ranked concluding that clients benefit most financially from BIM followed by Facilities Managers. Despite this, over 70% do not provide a 3D model and Cobie dataset at the conclusion of a project. Identification of Key Performance Indicators currently being used for BIM is provided and findings indicate a lack of industry expertise and training providing an opportunity for education providers.

1. Introduction

Building Information Modelling (BIM) is defined as the process of *generating, storing, managing, exchanging, and sharing building information in an interoperable and reusable way* [59]. It requires the development and use of a computer generated model to simulate the planning, design, construction and operational phases of a project [7]. The BIM Industry Working Group shows that the UK Government believes that its use brings many efficiencies and benefits across the project lifecycle [14]. The paper seeks to measure the impacts of BIM use throughout the project lifecycle. Current literature in the area tends to focus on individual sections of the construction process. Those papers which deal with BIM across the lifecycle do not focus mainly on the financial side of the process. This paper seeks to fill that knowledge gap. The research firstly investigates the different positive impacts of BIM. It analyses and ranks the benefits to determine the significance of the financial aspects. This is followed by an examination of BIM usage at the various lifecycle stages to indicate the frequency of financial savings at each stage of the process currently. The main financial beneficiaries of BIM adoption are determined, followed by the financial impact of a Project Execution Plan. Next the amount and content of information supplied at the end of the project are determined to ascertain the financial impact on future schemes, and Key Performance Metrics used in relation to BIM are ranked to provide a means of measuring the impact of BIM overall. Lastly the reasons for not implementing BIM are examined.

2. Literature relating to BIM

2.1. BIM impacts and outcomes

The BIM Industry Working Group [14] indicates that there are substantial organisational impacts through BIM implementation for all stages of the construction process. Arayici et al. [2] indicate that stakeholder collaboration expands organisational boundaries which enhances the performance of the project organisation during the design and construction process. This collaboration is further supported by Kymmell [45] and BSI [18]. However, a further impact highlighted by Howard and Björk [36] demonstrates the need when implementing BIM, to change business processes in addition to the simple promotion technology. BIM implementation may impact on all the processes within the project organisation and therefore cannot be treated in isolation as a software tool. It therefore may be defined as a process related rather than simply technology and that both approaches require BIM to be managed holistically. Holzer [34] concludes that BIM is a more accurate way of working. As the processes change BIM will reduce waste (materials, resources & cost) through improved designs and construction processes [4]. Nawari [51] attributes one of the successes

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of BIM to creating more sustainable communities. Another key aspect leading to similar improved accuracy, design and construction is 3D visualisation as identified by BIMhub [13] and Bentley [12].

However, to have a successful implementation of BIM processes, all members of the construction team need security of confidential data external and internal to the BIM model. The BIM model can be part of an extranet [19] however, this may lead to legal issues. There is the need to deal with the legal issues through the construction contract in order to reduce this significant risk [16,19,58].

The significance of the cost of implementing BIM in terms of resources and training has been seen to act as a substantial barrier within the construction industry [5,22,26,28,57,60]. Despite the significant cost of implementation BIM will ultimately be driven by clients [26]. Hore et al. [35] suggest that if adoption becomes a requirement then training must be subsidised by the Government to facilitate implementation.

The size of the organisations implementing BIM is a significant factor as it is easier to implement BIM within client or supply side SMEs [2] however it may be beyond the reach of some SMEs due to its cost [43].

This study ranked the various aspects of BIM adoption in order of importance.

2.2. BIM application across the project lifecycle

After analysing the significance of the impacts in the application of BIM the research investigated the use of BIM at the various stages in the construction lifecycle. For the purposes of this research the project lifecycle is defined as encompassing project inception, feasibility, design, construction, handover, operation, maintenance and eventual demolition. Key literature defines the various stages using BIM as feasibility [6,20,32], design [3,6,32], preconstruction (detail design and tender) [3,6,20,28,33], construction [3,7,31,38,60] and operation and management [7,38]. BIM is cited as being useful and providing benefits at these stages however, omitted from the literature is the frequency of use by organisations at each stage of the project lifecycle. This paper seeks to provide empirical evidence from the contracting parties on this issue.

2.3. The financial benefits of BIM to the parties involved

Previous research suggests that financial benefits can be achieved through BIM adoption. Jardim-Goncalves and Grilo [39] analyse the savings by company size. Two-thirds of BIM users have reported a positive return on investment on their overall investment in BIM [50]. The BIM Industry Working group [14] indicates that the financial savings can be achieved over all the stages of the project lifecycle. Akcamete et al. [1] indicate that operation and maintenance of the building, the role of the Facilities Managers, equates to 60% of the overall costs of the project. They further suggest that great financial gains can be achieved by targeting this aspect of a project. Furneaux and Kivvits [27] indicate that substantial cost savings through the increased interoperability of the BIM software could result in clients and building users/occupants/operators saving up to two thirds of the overall $15.8 billion per year spent in Australia. Again substantial savings can be achieved in BIM as consultants can produce fully worked up drawings at “half time at half cost” [60]. Contractors and Specialist Contractors demonstrated a reduction of 1%–2% of cost of Mechanical, Electrical and Plumbing Engineering (MEP) systems on a large size healthcare project [42]. Suppliers also benefit from more accurate costs and additional specifications [30]. In addition to the construction industry benefitting in relation to costs, Software Vendors are also shown to have a large return on investment from BIM implementation [10]. However, while the literature is specific on the cost benefits of BIM implementation it does not indicate which of the disciplines benefits most or rank the cost benefits by discipline.

2.4. Project Execution Plan use for BIM projects

The implementation of BIM throughout the project lifecycle is normally laid down in a BIM Project Execution Plan (PEP) [48]. The BIM PEP identifies where the maximum benefits of BIM can be achieved during the planning, design, construction and operational phases of a project [48]. This plan provides an overall programme to ensure that all organisations in the design and construction teams are fully cognisant of their responsibilities connected to BIM implementation in the project workflow. Once the plan is created the progress against this plan is monitored to gain the maximum benefits from BIM. It is a critical success factor in the management of BIM to deliver higher levels of project performance.

2.5. BIM information supplied at the end of the project

Although the Construction, Design and Management (CDM) regulations in the UK specify that as built drawings are provided at the end of the contract, Huber et al. [37] suggest that in the majority of cases this contains as-designed information rather than as-built information. Goedert and Meadati [29] suggest that this information is traditionally supplied as 2D information only. However, with the advent of BIM they further suggest that to develop a 3D as-built model was currently more time consuming than traditional 2D as-built however, it could be supplied [29]. Tang et al. [56] demonstrate how a Multi-Disciplinary BIM Model (MDM) can be used for as-built purposes. From BIM stage 2 individual disciplinary BIM models within each discipline provided separately may be supplied at commissioning and handover [55]. East and Brodt [25] demonstrate the rationale supporting the efficiencies achieved through an additional Facilities Management (FM) Dataset being provided at the end of the construction phase using the example of Cobie. However, current use of these methods in construction is not well documented.

2.6. BIM KPI/metric measurement

The full benefits of BIM need to be measured over the lifecycle of the project to ensure that continual improvement can be achieved. Luu et al. [47] identify performance measurement as an essential element of efficiency. Generally in construction the headline Key Performance Indicators (KPIs) identified by Kagioglou et al. [40] are employed. The use of KPIs allows schemes to be benchmarked against similar schemes to identify standards in the national performance of the construction industry and identify areas for improvement [40]. Constructing Excellence [21] further demonstrates that KPIs can facilitate systematic performance improvement and specify the following list for the construction industry:

1. Client satisfaction — product;
2. Client satisfaction — service;
3. Defects;
4. Predictability — cost;
5. Predictability — time;
6. Profitability;
7. Productivity;
8. Safety;
9. Construction — cost;
10. Construction — time.

While these KPIs are general they may also be applied to BIM. However, prior to using the headline KPIs it is imperative that research identifies what industry is currently measuring. Kagioglou et al. [40] state that Key Performance Indicators are defined as an amalgamation of various measures however it is yet to be determined what these measures for BIM are. Targeted improvements can only be made when the performance of BIM projects are clearly evaluated. Yuan et al. [61] state that KPIs generally allow comparison between the actual and estimated performance on the basis of three factors, effectiveness, efficiency, and quality. This research identifies what is currently being measured in industry as a precursor to further work on identifying a specific set of BIM related metrics.

2.7. Reasons for not using BIM on projects

The reasons for not using BIM and metrics on some projects were then investigated. The following reasons were identified from literature outlined below and provided as example reasons to the respondents prior to completing. Respondents were also invited to provide their own reasons:

- Lack of expertise within the project team [44,49]
- Lack of expertise within the organisations [41,44,49]
- Lack of client demand [15,17]
- Cultural resistance [23,24]
- Investment cost [4,28]
- Lack of additional project finance to support BIM [9]
- Resistance at operational level [11]
- Reluctance of team members to share information. Team communications with the owner were adversely affected on 8% of occasions and between the team on 5% of occasions by adoption of BIM according to Leicht et al. [46].
- Lack of immediate benefits from projects delivered to date [54]
- Legal issues around ownership, IP & PI insurance [19,52,53].

The study then ranked the above reasons in order of impact.

3. Methodology

A web-based survey package (Limesurvey™) was used to disseminate a structured questionnaire to gather the information from respondents. Limesurvey™ contains an individual token system for survey management. This ensures that only responses from the sample organisations are stored in an on-line MySQL™ database. On 4/7/2011 the BIM Experts group on LinkedIn contained a membership of 6958. The survey was limited to BIM users and the membership number of 6958 was deemed to be the total population for calculation of the necessary sample size [8]. A random sample from this group of those who were able to be contacted resulted in the respondent breakdown indicated in Table 1. Each of those randomly chosen was contacted by phone to ensure that they worked in the UK construction field, the person was responsible for BIM within the organisation and that they were willing to partake in the survey. Interviews with key BIM adopters took place to confirm the content of the survey. After a pilot and the three semi-structured interviews, the survey went live on 2 June 2012 and was closed to further responses on 27 July 2012. The random sample contained a majority of organisations adopting BIM practices containing over 100 employees (69.57%). Organisations tendering for larger government schemes would generally be in this category. The result indicated that these organisations are actively implementing BIM in an effort to meet the government deadlines.

The random nature of the sample resulted in respondents from all professions within the construction industry. The professions in the sample are indicated in Table 2. Organisations were allowed to select all the professional duties that they carried out and provide details of additional duties. This resulted in Multidisciplinary practices selecting more than one duty. Three extra professional duties — “Built Asset Consultants”, “Construction Lawyer” and “BIM Consultancy and Draughting” were added to the original list.

Table 1
Organisation size from sample.

Organisation size	Number	Percentage of respondents	Cumulative %
Greater than 500	44	47.83%	47.83%
101–500	20	21.74%	69.57%
51–100	12	13.04%	82.61%
21–50	4	4.35%	86.96%
11–20	3	3.26%	90.22%
1–10	9	9.78%	100.00%
Total	92		

Table 2
Sample breakdown by professional duties.

Professional duties	Frequency	Percentage of respondents
Architect	30	32.61%
Building services/M&E Engineer	17	18.48%
Principle Contractor	16	17.39%
Project Management	14	15.22%
Civil Engineer	14	15.22%
Quantity Surveyor	13	14.13%
Structural Engineer	12	13.04%
Facilities Management	5	5.43%
Public Client	5	5.43%
Building Surveyor	4	4.35%
BIM Consultancy and Draughting	3	3.26%
Specialist Contractor	2	2.17%
Private Client	2	2.17%
MEP Design	2	2.17%
Built Asset Consultants	1	1.09%
Construction Lawyer	1	1.09%

The results of this survey are a snapshot in time and the data and perceptions of those surveyed will alter during the period up to the 2016 deadline [26]. Therefore, as the survey will be repeated to measure progress towards that deadline, the results have been deemed to be continuous data. For a population of 8000, an alpha of 0.05 and a t of 1.65, the sample size should be 119 [8, p.48]. The calculation of 119 is based on a response rate of 0.65, therefore the study required 78 responses. The number of responses received was 92.

The questions adopted two main scales: a five point ranking scale with 5 the highest rank and a scale of often, occasionally and never. Based on this five point ranking scale a standard method of ranking the various aspects of BIM was used throughout the research using the relative importance index (RII) formula to establish the respondent's ranking on each of the responses.

RII is defined by the following formulae:

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

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.

4. Findings on the status of BIM in the UK construction industry

4.1. Main definition of BIM impacts

The respondents were required to rank the impacts of BIM previously discussed in the literature section of this paper. The results in Table 3 indicate that the stakeholder collaboration aspect of BIM implementation ranks as the highest impact. The second place ranking of the impacts of BIM suggests that the respondents considered that the underlying aspect of BIM was process as opposed to technology (Table 3, RII 0.863). However, the visualisation benefits were thought to be not as significant as the increased collaboration, reduction of waste and accuracy (RII of 0.524 against RIIs of 0.872, 0.813 and 0.809

Table 3
Ranking of BIM impacts.

Number of Rank R & Weighted Value W impact	Rank 5	Weight 5	Rank 4	Weight 4	Rank 3	Weight 3	Rank 2	Weight 2	Rank 1	Weight 1	Total	$\sum W$	RII	Rank
Collaboration is key to successful BIM	61	305	20	80	2	6	1	2	8	8	92	401	0.872	1
BIM is a process rather than a technology	57	285	21	84	6	18	2	4	6	6	92	397	0.863	2
BIM will reduce waste (materials, resources & cost)	44	220	30	120	6	18	4	8	8	8	92	374	0.813	3
BIM is a more accurate way of working	43	215	23	92	18	54	3	6	5	5	92	372	0.809	4
BIM requires new contractual arrangements	28	140	37	148	16	48	9	18	2	2	92	356	0.774	5
The industry is not yet clear on what BIM is	18	90	37	148	17	51	18	36	2	2	92	327	0.711	6
BIM requires significant investment in resources & training	20	100	29	116	20	60	19	38	4	4	92	318	0.691	7
The use of BIM will ultimately be driven by clients	16	80	28	112	30	90	14	28	4	4	92	314	0.683	8
Using BIM will lead to more sustainable communities	12	60	36	144	27	81	10	20	7	7	92	312	0.678	9
It is easier to implement BIM within SMEs	8	40	22	88	41	123	13	26	8	8	92	285	0.620	10
Training must be subsidised by Government to facilitate implementation	13	65	15	60	29	87	24	48	11	11	92	271	0.589	11
The key aspect of BIM is 3D visualisation	6	30	14	56	30	90	23	46	19	19	92	241	0.524	12
BIM is beyond the reach by some SMEs due to its cost	9	45	8	32	25	75	29	58	21	21	92	231	0.502	13

respectively). This indicates that the quality of the resulting outputs is more important to the respondents than the process that they are arrived at. This supports the hypothesis in the literature section of this paper that the overall results of BIM need to be examined in relation to the complete project lifecycle, from concept, through construction, Facilities Management and demolition. BIM could assist in the enabling works phase, effective planning and management of the demolition and decontamination of the site, which could contribute towards achieving environmental sustainability targets. However, BIM technology is a relatively recent development in comparison to the lifespan of a building or structure; examples of structures to be demolished with a BIM model are not available. This is a potential area for future research to measure the complete lifecycle of the facility and the effectiveness of BIM.

While it was recognised that BIM requires significant investment in cost and training (Ranked 7th with an RII value of 0.691), it was also shown that this additional cost was not beyond the reach of smaller practices as this impact was ranked in last place with an RII of 0.502.

The RII value given to “BIM requires new contractual arrangements” (0.774) indicates that further research into the adaption of the standard forms of contract will have to take place to incorporate BIM to deal with issues relating to electronic documentation and the facilitation of new collaborative working practices rather than simply incorporating additional contract conditions.

4.2. BIM application across the project lifecycle

BIM is most often used in the design (54.88%) and pre-construction stages (51.90%) of projects (Table 4). BIM is used to a lesser extent in the construction stage as 34.67% of the respondents state that they use it often and 52% are utilising it occasionally. Only 26.92% use BIM often for early feasibility work. The statistics concerning the operation and management of the building show it is only used often in a limited number of occasions (8.82%). The limited use in the operation and management phases may be due to the fact that many companies have only just adopted BIM or other Facilities Management software such as Archibus which may be linked to existing Building Management Systems (BMS) are the preferred choice. The projects that they are working on have many occasions not progressed to the operation and management stages.

The results in Table 4 may also be attributed to BIM being maintained within the expertise of the project team. Few clients are able to utilise the outputs. It is expected that this will change as clients become more aware of the value of the process and expectation rises. Once this expertise increases and is adopted clients will increasingly obtain the full benefits of BIM and the benefits will be realised throughout the project lifecycle including the operation and management phases. As BIM is increasingly used throughout the industry there is a need to continue with this research to determine its impact upon overall project performance including demolition.

4.3. Ranking of financial benefits of BIM to the parties involved

The financial benefits of BIM have been documented in literature. However, few publications indicating the ranking of the stakeholders benefits have been published. This study indicates that clients benefit most from BIM implementation (RII = 0.852). In second place (RII = 0.846) are the Facilities Managers. This indicates that BIM is not being used to its full potential. There is a disconnection between this result and previous findings. The benefits to Facilities Managers in respect of how much Facilities Management has to gain from BIM, suggest that the “operation and management” phases need particular attention in future research. “Software Vendors” (RII = 0.834) and “Principal Contractors” (RII = 0.819) are the remaining members of the top half of the ranking in Table 5. While all the disciplines benefit from the use of BIM (all have an RII above 0.6) it is evident from the rankings that suppliers fair less well that the other disciplines and the users (all of remaining parties have an RII value of greater than 0.7).

4.4. Project Execution Plan use for BIM projects

BIM PEPs have been used extensively to assist in the implementation of BIM at all stages of delivering the construction project [48]. Table 6 shows that they are starting to become more used with 44.62% using them often. However, the benefits of utilising BIM execution plans are still only realised often by less than 50% of organisations. This indicates

Table 4
BIM use during the construction stages.

Use during the construction project stages	Often No.	Often %	Occasionally No.	Occasionally %	Never No.	Never %
Feasibility	21	26.92%	41	52.56%	16	20.51%
Design	45	54.88%	35	42.68%	2	2.44%
Preconstruction (Detail design & Tender)	41	51.90%	31	39.24%	7	8.86%
Construction	26	34.67%	39	52.00%	10	13.33%
Operation & management	6	8.82%	31	45.59%	31	45.59%

Table 5
Financial ranking of BIM benefits to the parties involved.

Financial benefits of BIM party involved	Rank 5	Weighted	Rank 4	Weighted	Rank 3	Weighted	Rank 2	Weighted	Rank 1	Weighted	Total	$\sum W$	RII	Rank
Clients	37	185	27	108	10	30	2	4	1	1	77	328	0.852	1
Facilities Managers	31	155	29	116	14	42	0	0	0	0	74	313	0.846	2
Software Vendors	37	185	20	80	17	51	2	4	1	1	77	321	0.834	3
Principal Contractors	22	110	40	160	11	33	2	4	0	0	75	307	0.819	4
Building Users/Occupants	18	90	30	120	18	54	5	10	3	3	74	277	0.749	5
Consultants	16	80	34	136	17	51	6	12	3	3	76	282	0.742	6
Specialist Contractors	15	75	27	108	26	78	6	12	0	0	74	273	0.738	7
Suppliers	8	40	20	80	27	81	17	34	2	2	74	237	0.641	8

that their increased use more effective and efficient project management practice and benefits realisation across the whole of the project lifecycle.

4.5. BIM information supplied at the end of the project

As built drawings need to be supplied at the end of a project. However, this has not been adequately researched for BIM projects. The findings indicate that by far the most common way that BIM projects are handed over is in 2D format (71.01% often, 23.19% occasionally and only 5.80% never) (Table 7). The most beneficial aspect to the Facilities Managers (the Cobie dataset) is not being provided in 70.49% of cases. This indicates that the Facilities Management cannot be carried out in the most efficient way and the potential cost savings cannot be realised.

4.6. BIM KPI/metric measurement

For the first time this paper identifies and measures the metrics used to measure BIM's success in the construction industry. These measure the current aspects of BIM over the lifecycle of the project. However, it can be seen that a wide variety of metrics are used but the overall cost (often used by 50%) and the cost of changes (often used 50.91%) are the most frequently measured aspects of BIM (Table 8). This is followed by the time aspects in terms of measuring programme duration (42.86%).

4.7. Reasons for not using BIM on projects

Finally, in measuring the lack of use of BIM in projects, 82.61% considered that it would have been beneficial on projects it was not used on with only 17.39% considering that the application of BIM would not have made any difference to the project. Again this suggests over the lifecycle of a project that the benefits are commonly known. However, a ranking has not been provided on why BIM adoption did not take place. Table 9 indicates that the top two reasons for not implementing BIM on projects are “Lack of expertise within the project team” (RII, 0.741) and “Lack of expertise within the organisations” (RII 0.715). This indicates that there is potential for education and training providers to fill this void and “bring the industry up to speed”. Lack of client demand was ranked third indicating that government clients are seeking BIM implementation and that private sector clients are less demanding. Considering that the study previously indicated that clients have the most benefits from BIM it is envisaged that this reason will drop in importance in the future. The lack of importance indicated in the ranking of Lack of immediate benefits from projects delivered to date and legal issues around ownership, IP & PI insurance indicates that the benefits of BIM adoption are realised and organisations are going to adopt the system that their clients suggest.

5. Conclusions

The research shows that within Building Information Modelling (BIM) across the lifecycle of a project the stakeholder collaboration aspects related to its adoption produce the highest positive financial impact. This is in line with long term UK government policy in relation to reducing fragmentation within the construction industry. The process aspects of BIM were ranked in second place indicating that the management aspects of adopting BIM were more important than the technology in the software itself in terms of financial significance. However, the visualisation brought about by the 3D models was considered as less significant compared to the increased collaboration (ranked first), management aspects of the process (ranked second), reduction of waste (ranked third) and accuracy (ranked fourth) in the impacts of BIM. While BIM necessitates significant investment in cost and training, it may be concluded from its lowest rank that the additional cost was not beyond the reach of smaller practices. This shows that all sizes of practices can meet the government's target date.

The relative novelty and recent developments within BIM technologies have not permitted assessment of the entire lifecycle as yet. Design life for most building structures exceeds the length of time that the industry has used BIM. However, this paper measures BIM use in the design, preconstruction, construction and operation stages. It finds in this snapshot of industry adoption that BIM is most often used in the design and pre-construction stages, with notably lesser use in the construction stage. BIM is little used in the operation and management stages of the projects with less than 10% often using it during this period. This may be because BIM adoption is still at an early stage. It is expected that this will rise as BIM becomes further embedded within construction contracts. It is therefore indicated that the early financial benefits are deemed most important for those currently adopting BIM. Further investigation into the value of the financial savings at each stage needs to follow this work.

Although the financial benefits of BIM have been documented in literature this paper is one of the first to rank the significance of these

Table 6
Project Execution Plan use in BIM projects.

	Often No.	Often %	Occasionally No.	Occasionally %	Never No.	Never %
Has a Project Execution Plan been used for BIM projects	29	44.62%	28	43.08%	8	12.31%

Table 7
Information supplied at the end of the project.

Information supplied at the end of the project	Often No.	Often %	Occasionally No.	Occasionally %	Never No.	Never %
2D information only	49	71.01%	16	23.19%	4	5.80%
Individual disciplinary BIM models provided separately	14	21.54%	38	58.46%	13	20.00%
Multi-Disciplinary Model (MDM) provided	15	23.08%	22	33.85%	28	43.08%
FM dataset provided (e.g. Cobie)	8	13.11%	10	16.39%	43	70.49%

Table 8
BIM KPI metric measurement for BIM.

BIM KPI metric measurement for BIM	Often No.	Often %	Occasionally No.	Occasionally %	Never No.	Never %	Total
Requests for information (RFIs)	22	39.29%	18	32.14%	16	28.57%	56
Change orders	21	38.18%	18	32.73%	16	29.09%	55
Cost (overall)	28	50.00%	16	28.57%	12	21.43%	56
Cost of changes	28	50.91%	15	27.27%	12	21.82%	55
Programme duration	24	42.86%	20	35.71%	12	21.43%	56
Person's hours worked	20	35.09%	20	35.09%	17	29.82%	57

benefits to each of the stakeholders. This study indicates that clients followed by Facilities Managers benefit most from BIM implementation. This indicates that BIM is not being used to its full potential as the lowly use statistics in Facilities Management suggest. While the findings indicate that all disciplines benefit from the use of BIM with an RII value of above 0.6, it is evident from the rankings that suppliers fair less well than the project stakeholders. All of the remaining parties have an RII value of greater than 0.7 with the exception of the suppliers.

The realisation of the findings of Marzouk et al. [48] relating to the benefits of using BIM Project Execution Plans through the adoption process is weak with less than 50% of organisations using them often. The increased use of Project Execution Plans in mapping the positive outcomes of BIM at all stages in the construction cycle could see further benefit realisation and lead to increased use and financial savings in the latter stages of the project lifecycle.

The CDM regulations require as built drawings to be supplied at the end of a project. However, the mode of communicating this information has not been adequately researched for BIM projects. The findings indicate that by far the most common way that BIM projects are handed over is in 2D format with the most beneficial aspect to the Facilities Managers (the Cobie dataset) not being provided in 70.49% of cases. This infers that Facilities Management may not be carried out in the most efficient way and the potential cost savings may not be fully realised. Clients should start to specify within the contract documentation that the supply of the data rich model will be a contract condition and therefore compulsory at the end of the project. This may even extend to the issue of a specific certificate within the contract as a condition precedent to the issuing of the Certificate of Completion. This will allow the efficiency gains that increased accuracy in Facilities Management and operational aspects of the works will provide.

As a precursor to future research in this area this paper identifies and measures the metrics currently used to measure BIM success in the industry. These measure the current aspects of BIM over the lifecycle of the project. However, it can be seen that a wide variety of metrics are used but the overall cost (often used by 50%) and the cost of changes (often used 50.91%) are the most frequently measured aspects of BIM. This is followed by the time aspects, while programme duration achieved 42.86% measurement. Future work will identify whether the standard Key Performance Indicators within the construction industry could be adapted to cover these aspects of the works.

Finally the research indicates that the main reason for not adopting BIM on current projects relates to the lack of expertise within the project team and external organisations. This could be the reason why the benefits of 3D modelling and BIM have not been fully realised in construction in a similar way to that documented in other industries such as car manufacturing and machinery design. It is hoped that the opportunities this indicates for education providers and industry through continuing professional development events will be seized and that the full financial benefits of BIM will be realised.

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Table 9
Ranking of reasons for not using BIM.

Reason for not using BIM in order of importance	Rank 5	Weighted	Rank 4	Weighted	Rank 3	Weighted	Rank 2	Weighted	Rank 1	Weighted	Total	$\sum W$	RII	Rank
Lack of expertise within the project team	32	160	29	116	14	42	6	12	11	11	92	341	0.741	1
Lack of expertise within the organisations	29	145	28	112	16	48	5	10	14	14	92	329	0.715	2
Lack of client demand	28	140	29	116	13	39	8	16	14	14	92	325	0.707	3
Cultural resistance	26	130	27	108	17	51	7	14	15	15	92	318	0.691	4
Investment Cost	23	115	21	84	21	63	14	28	13	13	92	303	0.659	5
Lack of additional project finance to support BIM	21	105	19	76	26	78	11	22	15	15	92	296	0.643	6
Resistance at operational level	12	60	20	80	28	84	17	34	15	15	92	273	0.593	7
Reluctance of team members to share information	13	65	21	84	23	69	19	38	16	16	92	272	0.591	8
Lack of immediate benefits from projects delivered to date	11	55	23	92	21	63	20	40	17	17	92	267	0.580	9
Legal issues around ownership, IP & PI insurance	7	35	11	44	28	84	24	48	22	22	92	233	0.507	10

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