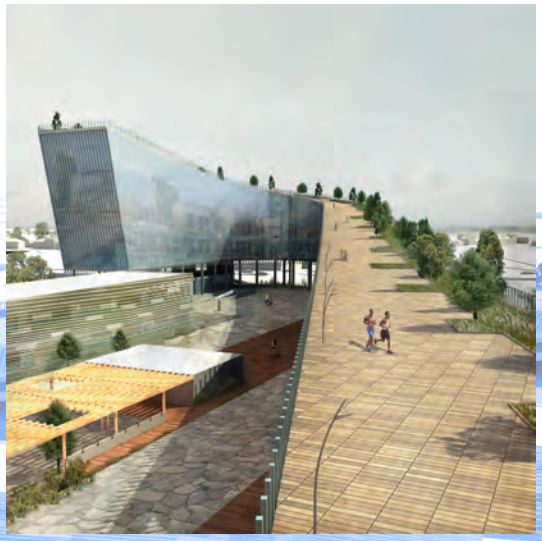
HEALTHY BUILDINGS: INNOVATION, DESIGN & TECHNOLOGY

ICAT 2016

ANTONIO GALIANO GARRIGÓS
TAHAR KOUIDER



CONFERENCE PROCEEDINGS OF THE 6TH INTERNATIONAL CONGRESS OF ARCHITECTURAL TECHNOLOGY
UNIVERSITY OF ALICANTE 12-14 MAY 2016

UNIVERSIDAD DE ALICANTE

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CONTENTS

THE IMPACT OF BIM ON THE DISTRIBUTION OF COST AND RETURN ON INVESTMENT IN UK CONSTRUCTION PROJECTS

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Abstract. It has been widely documented that when Building Information Modelling (BIM) is used, there is a shift in effort to the design phase. Little investigation into the impact of this shift in effort has been done and how it impacts on costs. It can be difficult to justify the increased expenditure on BIM in a market that is heavily driven by costs. There are currently studies attempting to quantify the return on investment (ROI) for BIM for which these returns can be seen to balance out the shift in efforts and costs to the design phase. The studies however quantify the ROI based on the individual stakeholder's investment without consideration for the impact that the use of BIM from their project partners may have on their own profitability. In this study, a questionnaire investigated opinions and experience of construction professionals, representing clients, consultants, designers and contractors, to determine fluctuations in costs by their magnitude and when they occur. These factors were examined more closely by interviewing senior members representing each of the stakeholder categories and comparing their experience in using BIM within environments where their project partners were also using BIM and when they were not. This determined the differences in how the use and the investment in BIM impacts on others and how costs are redistributed. This redistribution is not just through time but also between stakeholders and categories of costs. Some of these cost fluctuations and how the cost of BIM is currently financed are also highlighted in several case studies. The results show that the current distribution of costs set for traditional 2D delivery is hindering the potential success of BIM. There is also

evidence that stakeholders who don't use BIM may benefit financially from the BIM use of others and that collaborative BIM is significantly different to the use of 'lonely' BIM in terms of benefits and profitability.
Keywords. *Building Information Modelling, cost distribution, return on investment, BIM benefits, construction lifecycle*

1. Introduction and Research Rationale

In the effort to reduce construction costs by 15-20%, the UK Government set a mandate in 2011 for all centrally procured public construction projects to use fully collaborative Building Information Modelling (BIM) by 2016. Since then there has been a rapid uptake in the use of BIM on both government and private projects (NBS, 2015), incurring challenges which many studies are attempting to address and overshadow by demonstrating the benefits and return on investment (ROI). Currently, owners are faced with the dilemma of whether or not to utilise BIM based on these speculated benefits (Barlish & Sullivan, 2012). As of 2015, cost and client demand are still the major barriers to BIM uptake in the UK (NBS, 2015).

Building Information Modelling (BIM) can be defined as a process improvement methodology enhancing analysis/predictability of outcomes during the building lifecycle by leveraging data (Reddy, 2012). This process improvement involves usage of data rich 3D models in addition to traditional 2D deliverables to aid design, collaboration, coordination and construction activities. Such a change requires an investment of both cost and time. Cost and time are impacted by the initial financial investment in BIM. There are currently numerous studies attempting to quantify the ROI, however these studies quantify the ROI based on the individual stakeholder's/organisation's investment without consideration for any investment in BIM from the other stakeholders, or how it impacts on the other stakeholders. If a project stakeholder reports an increase in costs or profit on a BIM project do the other stakeholders experience a profit

increase, even if they aren't using BIM? Could other stakeholders be profiting from the investment of others?

This research investigates changes in cost and its distribution across the building lifecycle between the 2013 RIBA Plan of Work stages 2 to 5 (concept, developed and technical design and construction) which could indicate the ROI for different stakeholders. Also considered is the relationship between success of BIM and its monetary investment from each stakeholder's viewpoint, and whether more effort is required during design when BIM is utilised. How this shift in effort affects costs distribution is also realised as well as its implications on the profitability of other stakeholders.

2. Literature Review

There is currently little published literature analysing the distribution of cost in construction with respect to stakeholders and work stages, and where BIM may have an impact on cost. Regarding factors affecting capital expenditure and cost distribution, Smith and Jagger (2007) stated that the opportunities for the cost of a project to get out of hand are increasing along with the increasing complexity of buildings. Potts and Ankrah (2013) point out that poor planning at the early stages can result in cost and time overruns among other things. It is not uncommon for the early cost estimate of a project to be significantly different to the final cost (Shane, et al., 2009). In a study of 276 construction and engineering projects in Australia, Love, et al. (2013) calculated an average cost overrun of 12.22%. Risks are associated with the unknown so for management of cost, the identification and management of risk is important (Potts & Ankrah, 2013). When consultants use BIM, there is more transparency in what is being proposed meaning that contractors can reduce some of their risk margins for the unknown (Knutt, 2011).

Smith and Tardif (2009) explain that it is common for design firms to pass on the added cost of BIM to clients through fees whereas construction companies look to exploit BIM in reducing their project related expenses as well as generating more profit. However, the key to leveraging BIM to increase profits is by increasing value by reducing lifecycle time rather than raising fees. Conversely, the Royal Architects Institute of Canada (2009) acknowledges that since BIM requires more effort in the early stages of design, architectural fees for schematic design should be as high as 25% of their total fee compared to the minimum 12% for traditional 2D CAD. Saxon (2013) believes that because BIM is redefining how architects work, this will in turn redefine what they charge. With the increased effort in setting up a job and the new role of the information manager there is more work to do in RIBA stage 2 however there is less to do in RIBA stages 4 & 5. This shift in effort will come at a labour cost for the architect who may pass this on to either the client or the contractor who then may recoup that cost in a lower fee paid back to the architect during construction.

Indeed, McGraw Hill's (2014) report showed that contractors generally receive a greater portion of the financial benefits of BIM compared to design professionals with 50% of UK contractors reporting a positive return on their investment. The survey respondents were asked for their perception of ROI which when tracked with their level of BIM engagement suggests that the higher the level of BIM engagement, the higher the ROI. In the UK, 26% of contractors surveyed reported over 25% ROI; however how this is quantified is not clear. The survey only targeted contractors and no data was available on whether part of their investment in BIM was paying higher fees to their design consultants and sub-contractors, or how the return on investment was distributed among stakeholders, which is the focus of this research.

In the 2015 NBS BIM report, 56% of respondents shared that the fourth biggest barrier to BIM implementation was cost. With 44% of non-BIM users agreeing BIM brings cost efficiencies and 31% believing it increases profitability (NBS, 2015), it is clear the desire for investment is there but not clear on how much they would be willing to invest on BIM. In a study

of 35 construction projects, Bryde, et al. (2013) created a set of project success criteria based on knowledge areas from the Project Management Institute's (PMI) Project Management Body of Knowledge (PMBOK) (PMI, 2008). The highest-ranking benefit was Cost reduction or control. Whilst Bryde et al. (2013) documented the design and construction periods for most case studies, it was not evident in which period these benefits were perceived or which party (designer, contractor or owner) was inheriting the cost saving. A significant outcome of this study, supporting a positive ROI on BIM, was that the cost benefits far outweighed the costs for implementing BIM tools and processes, and that many of the BIM benefits are the result of an upfront investment that incurs savings later on, indicating a redistribution of costs.

In their study into the perceived effect of BIM on cost/fees in the US building industry, Becerik-Gerber and Rice (2010) noted that 85% of respondents are absorbing the cost of BIM in terms of software, hardware and training and that just 10% are able to pass this cost on to the client by way of fees where the client sees the investment as reusable and retainable. Over half the respondents reported both cost and time-savings on projects but with no mention of where these savings were made, and by whom. Whilst project duration was reduced on BIM projects, the schematic and conceptual design phases took longer (Baddeley & Chang, 2015). Furthermore in their analysis of BIM implementation throughout the project lifecycle in the UK Eadie, et al (2013) concluded that financially, the client and facilities managers benefit most from BIM. They also pointed out that the size of a company has an impact on implementation due to proportion of overhead allowances in larger companies, but there was no indication of relationship to life cycle stages or stakeholders.

3. Project Description and Research Methods

The impact of BIM on costs distribution throughout the design and construction phases was investigated in this study in comparison with the costs distribution within a traditional construction workflow, in terms of ownership, magnitude and categories of costs. The effects of these changed cost distributions on the length of the lifecycle phases ware also investigated. Qualitative and quantitative data was collected from existing literature, an online questionnaire, interviews and case studies related to stages 2-5 of the RIBA Plan of Work and the findings thoroughly triangulated and verified to ensure validity. Data was visualised to find a correlation of where costs are, who is incurring them and when. The research considered all building/infrastructure projects in UK however scope was limited to using case studies of building projects only. These were grouped by lifecycle stages: 2- Concept design / 3- Developed design / 4- Technical design, and 5- Construction stage. Participants in the data collection represented the following groups: Design consultants (architecture and engineering) / Contractors / Sub-contractors / Clients, owners and operators.

The process for deriving substantial evidence to whether BIM may or may not have an impact on cost distribution during design and construction in the UK was first taken from the concept that BIM is costing people more in design and costing less in construction. The use of qualitative data was important to identify reasons based on assumptions, observations and experiences that need to be tested; hence data collected might be subjective by nature (Naoum, 1998). Moreover, with this research being based on cost, quantitative data was also collected in the questionnaire, which was the quantification of qualitative data. This data was reviewed against literature to indicate similarities, novelties or contradictions. Pearson's Correlation Coefficient (R) was calculated to highlight associations and relationships (Naoum, 1998) between cost, time and profitability. The proportion of variance between responses showing association or

relationship predictable from another response was investigated by coefficient of determination (R2).

The online questionnaire contained both open and closed ended questions about the following categories: a) the cost of BIM to the organisation, b) the impact BIM has on the cost and duration of project phases and c) who is paying and benefiting from BIM d) Percentage ROI on BIM for each work stage. The questionnaire accumulated 108 responses. The interviews identified and quantified cost elements across RIBA stages 2-5 with comparisons between 4 project scenarios and their impact on cost, time and fees: 1) all stakeholders use BIM, 2) no stakeholders use BIM, 3) BIM stakeholder hands to non-BIM stakeholder, 4) non-BIM stakeholder hands to BIM stakeholder; 7 interviews were conducted representing all disciplines in the construction industry. Candidates were chosen based on their experience and exposure to commercial and operational aspects of BIM, and were director or associate director level with responsibilities in strategic management of BIM and costs on projects. For each scenario above, the interviewee was to comment on the impact of BIM on **costs**, **profitability**, **resources**, **time** across the previously mentioned work stages. BIM's impact on these categories was to be described as less or more than traditional projects across a Likert scale of 1-5, and asked to describe any change using a list of cost overrun factors collated from the literature review. If one stakeholder reported an increase in one stage and another found a decrease in another stage the change factors were used to find relationships to support or refute the theory that BIM has an impact on cost distribution. Such factors could include resource, scope and time management.

Data collected from the questionnaire and interviews was used to select suitable project types to examine as case studies. The most common project types where BIM was used were commercial and educational with 89 and 80 responses respectively, most using Design Build procurement methods. The next highest used procurement method was Private Financed Initiative (PFI), primarily used in healthcare, for which 73 respondents'

organisations were involved with. Hence 2 commercial / residential design and build projects, a healthcare PFI project and an education project were investigated.

4. Discussion of Results

Results from questionnaires (figures 1 and 2) demonstrate an increase in costs incurred for designers and contractors during design phases compared with traditional 2D delivery. However, profitability is higher for both categories (and more so clients) during the construction phase resulting in an overall increased ROI in projects in general on BIM implementation.

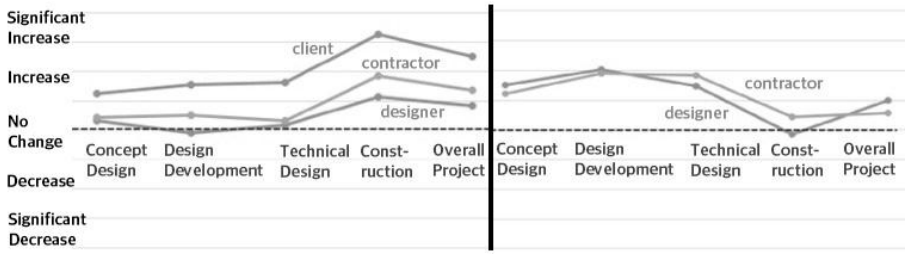

Figure 1. Impact of BIM Implementation on Profitability (left) and Costs (right) of a project

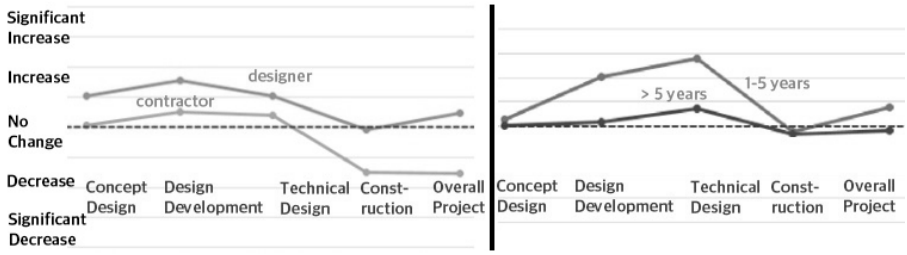

Figure 2. Impact of BIM on duration (left) and staff numbers (right) resourced to projects

As for duration of the projects there is an increase for architects during design phases due to increased BIM deliverables. Contractors however, display a marked reduction of project time duration during the construction phase, which might explain the increased overall profitability as opposed to designers. A higher rate of staff retention on BIM projects is also noted for newly BIM-adopting organisations (1-5 years) versus more "BIM mature" organisations (>5 years) which can be due to setting up new teams, roles and responsibilities within the different disciplines to manage BIM projects.

Calculating Pearson's Correlation Coefficient (R) between staff numbers and overhead costs on a project revealed an association of 56%. Further analysis using Coefficient of Determination (R2) revealed that 27% of the variation between the responses to the project overhead costs might be explained by the variation in the number of staff on projects. Regarding impact of BIM on profitability, the largest association between the drivers for BIM adoption and the impact on profitability was reducing costs, with 39% similarity (R) and 15% variance (R2). The driver for enhancing efficiency and saving time had less association with profits at 29%. It is noteworthy that coordination and collaboration were seen capable of both saving and increasing time. Architects believed training and skills where among their top 3 factors impacting duration. The correlation R between overall project cost and duration revealed an association of 64%. Further analysis using R2 revealed that 31% of the variation between the responses to project duration could be explained by the variation in cost on a project.

When asked who should pay for BIM, the majority indicated the client in the beginning of a project and then the contractor during construction. When asked how BIM is financed for costs associated with implementation and ongoing maintenance, there was little differentiation between the 2 except that in some cases the client contributes to implementation and that costs are then absorbed by the organisation for ongoing maintenance. This result differs from the research by Becerik-Gerber & Rice (2010) who reported 85% of respondents saying their organisation pays. One result that

is consistent however is that still only 10% of respondents are passing the costs on through their fees. Furthermore 62.5% of architectural practices believed they are investing the most in BIM and 33% believed contractors are investing the most in BIM. Only 15% of contactors believed architects invest the most and 72% believed that they themselves invest the most.

When asked the percentage of ROI on BIM for each work stage, 60% of respondents claimed their organisation does not formally measure BIM. Of those that did, the most common method was quantifying the reduction of clashes on site during the construction phase. This indicates that the return of BIM is not being fully tracked and that organisations may benefit from adopting a set of metrics for defining BIM success. A 43% association R between the overhead costs and profitability was calculated, which might suggest that the extra cost in training, software and hardware is having an impact on profitability. With overall profitability being reported, it was important to realise the relationship between BIM statuses of stakeholders, i.e. how one stakeholder's use of BIM affects another. Respondents were asked to comment on their own profitability when certain stakeholders are also using BIM as well as how their use of BIM impacts the profitability of others. Results showed that the profitability of BIM has less to do with BIM usage of individuals but more to do with whether or not others are using BIM. This may be due to that when BIM is sporadically used, coordination can be more difficult especially for building services, a discipline requiring high levels of coordination. Main contractors appear to be the biggest benefactors when everyone is using BIM as many of their activities rely on successful coordination. Overall, recipients of information produced using BIM are better off than those producing information using BIM for others. BIM is impacting costs distribution in a way that those who receive BIM information are profiting from those who produce BIM information. Hence organisations are only getting higher return on their investment when they are receiving information produced using BIM in addition to producing it.

When it came to benefits, 12.5% of architectural practices believed architects are benefiting the most, 50% believe it is contractors and 33%

believe clients are the biggest benefactor. 50% of contractors believe they are benefiting the most whereas 34% believe clients are benefiting the most and only 6% believe architects are benefiting. There is a shift in volume from those investing to those benefiting, namely the client is gaining the most from the least investment, which supports the conclusions above that those on the receiving end of BIM are benefiting the most. The most significant benefits reported to organisations were coordination and collaboration.

Some of these results clarify the assumptions on the effects of 'front-loading' the energy exerted on a project, which was the most mentioned cost impact. Results suggest that front-loading creates pressure and increased costs during initial life-cycle stages, impacting profitability as well if coupled by the challenge of lack of coordination and collaboration when BIM is not used by all but only by some disciplines on the project.

The following patterns were observed from the interviews:

- All interviewees involved in projects during the concept design stage reported few benefits in terms of time savings or profitability from BIM during that stage as most deliverables are still 2D and there isn't a great level of detail in the information that would benefit from using BIM. When requested to use BIM at this stage, costs increased
- When using BIM for their own benefit, organisations' BIM costs were less as a whole than when using BIM collaboratively. This coincides with the research of Love & Irani (2002) who mention that a company's custom interfaces can be barrier to effective communication and coordination affecting costs
- When organisations have to use or produce BIM deliverables for others, they spend more time as scope increases which in turn increases cost
- When requested to use BIM, setting up collaboration initially takes more time and can reduce profitability, especially in the technical design stage
- When receiving information produced using BIM from others, organisations are more profitable as the information is more accurate

and can result in less rework/re-iterations when producing own deliverables

- Those at the end of the information delivery chain will benefit the most whereas those at the beginning benefit the least. This trend is confirmed by the questionnaires where a spike in costs, time and resource were experienced during the design stages and profitability improvements in construction suggesting that the investment made during design is paying returns during construction

Costs on average are lower when all parties use BIM. Also profitability is at its maximum in construction so potentially those not involved in construction are missing out on the returns for their investment in BIM. On average, profitability and time can be seen to bear a relationship where less time equals more profits. After combining the results from all interviewees, the responses correlation coefficient R between profitability and time was calculated this revealed an association of 85%. This shows that the longer the duration, the less the organisation will profit. The correlation coefficient between fees and costs has a 61% association suggesting that an increase in costs to a stakeholder could result in an increase in their fees to recoup costs.

Case studies were chosen to represent the most common project types and procurement methods mentioned by respondents to the questionnaire. With the data available, the following observations were made. In all but one project the architect, structural engineer and services engineer were required to coordinate their design using BIM. Additionally, certain BIM deliverables were required to support methods of construction (hence all disciplines using BIM). Projects 1 and 2 demonstrate the difference between adopting BIM for own benefit compared to using it because it is required. In Project 1, the designers were requested to use BIM, which was not part of their normal processes so a cost of implementation had to be passed on in the fees. In Project 2 however, the architect conducted their own pilot independent of their contractual deliverables that was tailored to their own needs. They did it in a carefully chosen environment that suited

the pilot and they received financial gain without passing on their implementation costs.

Projects 3 and 4 demonstrate the risk taken in investing in BIM in the early stages for a contractor. This risk is also highlighted in the results from the client/owner/operator interview in who saw the risk in investing in BIM being outweighed by reduced risks later in construction. In projects where there is a risk allocation or contingency, there may be the opportunity not to lower this but to re-distribute the risk allocation from construction to design.

5. Conclusion

This research presented evidence to show that BIM has a substantial impact on costs distribution and which is currently more comprehensively realised and understood. Highlighting the impact of BIM, as a process improvement methodology on the distribution of costs, has been achieved by revealing the placement of costs incurred in a project and their magnitude as impacted by BIM. This has also been achieved by reporting the experiences of stakeholders who are receiving mixed returns on their investments that bear relation to their input into the design and construction process.

BIM's impact on costs during design and construction phases is such that certain costs are redistributed which could in turn impact methods of procurement. The impact of BIM is not only moving costs within the construction lifecycle in terms of time but also between stakeholders as certain costs move from one stakeholder to another. This is discovered in the interview results where the information, produced by those who have made an investment in BIM, has a positive return on those who receive this information who have reduced costs.

When BIM is used during design and construction there is evidence from the analysed results that there is more effort required up front, and better realising its impact should help planners in calculating fee structures

and preliminary costs on projects who may still be following a cost and fee structure that once supported 2D delivery. When BIM is used within this traditional cost and fee structure, its usefulness is hindered which alters cost, duration and the workload of stakeholders, with particular impact on designers. There is evidence to show that BIM is benefiting those who either use it to produce information and those who use the information produced by it. However these two benefits are absorbed differently depending on who the stakeholder is and when they are involved in the construction lifecycle.

KEY FINDINGS

Cost	Coordination and collaboration can be expensive initially. The more the collaborative effort, the more time and cost is spent in design however there is less error and rework during construction
	The cost of collaboration is more expensive for those who have used BIM for less than 5 years as they have a steeper learning curve than those who have developed their capability independently through the use of lonely BIM (non-collaborative BIM)
	For stakeholders to receive a fair return on their investment on BIM there would need to be a redistribution of costs. Currently, the benefits are passed onto the contractor and the client
Fees	As the costs incurred by stakeholders are increased with the use of BIM they are generally only able to pass this cost on in their fees when they are contractually required to use BIM
Profitability and ROI	Users of information created from BIM can be more profitable than those who produced the information in the first place
	Some stakeholders who don't even use BIM can benefit financially from the BIM use of others
	Those who use BIM for their own benefit can sometimes be more profitable than those who use it in a collaborative environment
	Those who have been using BIM for more than 5 years tend to be more profitable in a collaborative BIM environment than those who have used it for less than 5 years

Time	The use of BIM requires a significant shift in workload placing more work into the developed and technical design stages
	Using BIM collaboratively takes more time to produce deliverables than when using it independently
General	The current distribution of cost is hindering the potential success of BIM and hence more consideration should be made in structuring fees and allocating costs during design and construction with respect to the impact BIM has during these phases
	Those who are investing in BIM should be aware of the return others are receiving from their investment to understand its true value to their own organisation

The findings in this research are based on the assumptions and experiences of experts within the industry however further investigation into specific types and sizes of organisations and projects may yield more consistency and accuracy revealing even more truths.

For the case studies, more data and more analysis and metrics produced on live projects using BIM from design to construction would increase the opportunities for analysis to reveal more results related to effects of BIM on costs. These could be carried into operation and maintenance as well which was outside the scope of this research yet plays an important part in the construction lifecycle. Evidence in the results from the client interviews suggests there are further returns on the investment in BIM during operation.

As a process improvement methodology, BIM is still relatively new and as highlighted in the research, its impact on costs distribution can vary with the experience of the organisation. There is no way to test its full potential without all parties being at the same level of maturity and capability. In this particular period during BIM's implementation and adoption it is important to realise how it impacts those who are working together. The 2016 UK BIM mandate as mentioned in the introduction doesn't just call for the use of BIM, but the use of *collaborative* BIM.

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