An Assessment of Building Information Modeling Value and Use

B. Becerik-Gerber & S. Rice
Department of Civil and Environmental Engineering, University of Southern California, Los Angeles, California, USA

ABSTRACT: With the implementation and use of Building Information Modeling (BIM) comes the need to understand where the industry as a whole stands in the execution process. This paper outlines benchmarks relating to implementation and value assessment of progression within the U.S. Architecture, Engineering, and Construction (AEC) industry. With these benchmarks industry members will be able to understand where the industry stands in terms of BIM implementation and use and also measure their own development in relation to the industry.

1 INTRODUCTION

The AEC industry is the largest industry in the world (Department of Commerce, 2007) with distinguishing characteristics such as highly fragmented organizations (Department of Commerce, 2002) unique projects, and relatively short period of production, outdoor and unstructured working conditions, and labor-intensive activities. Successful completion of AEC projects requires collaboration of numerous multidisciplinary and sometimes geographically separated team members. Continuous, accurate and real-time information sharing among project participants is key to resolve conflicts, speed up solutions, and keep projects on time and on budget. There are many reasons why the AEC industry is seen as inefficient (Khanzode, et al. 2006, Eastman, et al. 2008); among them are its field productivity and its production methods. While Building Information Modeling (BIM) is able to change these two aspects, each of these reasons provides insight into how data that supports the positive value of BIM can help to encourage a wider scale of implementation.

Whilst there is a wide range of definitions for BIM, in the context of this paper, the following definition is used: 'a modeling technology and associated set of processes to produce, communicate, and analyze building models.' (Eastman, et al. 2008) BIM is further specified by four attributes, which include intelligent digital representations of building components, components that behave in ways defined by data, consistent and non-redundant data, and coordinated data (Eastman, et al. 2008).

BIM software has been on the market for a number of years but industry-wide adoption of BIM to its full capacity has not been embraced yet. As of 2007, approximately half of industry representatives did not use any BIM software on projects (Gilligan and Kunz, 2007). Investments required (technology, process and organizational) are costly and adopting BIM requires substantial changes to how the industry has traditionally been designing and building AEC projects (Becerik and Pollalis, 2006). An increase in the availability of fiscal information will be significant as one of the primary motivators for actors in the AEC industry to adopt new innovations is the opportunity for measurement of direct gains and benefits in their own operations (Bjork, 2003). This paper summarizes the findings on the use and value for BIM and as a result aims to provide a benchmark to compare benefits and costs associated with it. The paper starts with an explanation of the research goals and methodology and continues with the summary of results. Recommendations are made for future research projects, followed by the concluding remarks.

2 RESEARCH METHODOLOGY & GOALS

A survey methodology was chosen as an effective method of data collection. A survey not only facili-

tates the release of confidential data but provides an instrument to collect information from across the breadth of the industry. It also provides a level of anonymity that encourages participants to freely give information about an unidentified project, thereby allowing the authors to gather general information and specific data without obtaining the confidential aspects of the project and its participants.

Survey questions were developed with information attained from interviews, research and literature reviews. The survey was widely distributed to the recipients by professional organizations and participating software vendors, and through newsletters, forums and blogs from March 29 through May 8, 2009. Throughout that timeframe 424 individuals completed the survey.

It is hard to accurately estimate how many potential respondents this survey was distributed to or what the actual return rate is. The survey invitation text and link were distributed via professional organizations' or vendors' email lists/announcements, often embedded with other topics and they were also posted in discussion boards and forums. No personalized and direct emails were sent. Although the survey was distributed to a vast number of respondents, not all recipients clicked on the link provided in announcements, discussion boards or forums. Also, authors anticipate that a respondent might have received the survey link from multiple organizations or groups. Nevertheless, the findings of the survey still represent useful information about the respondents and the topic as well as show trends within the industry.

Goals of the survey are:

- To understand the current status of BIM adoption and use by the industry;
- To identify and establish a benchmark for costs and benefits associated with BIM;
- To explore how BIM investments have been valuable for the AEC industry;
- To enable an organization with limited resources to compare their costs and benefits to other AEC projects.

The survey is broken down into four sections with a total of twenty-two questions. The first section focused on general questions relating to the type of company, software and BIM use percentages. The second section was project specific and focused on descriptive information of a particular project that the respondent has selected. Sections three and four concentrate on the costs and the benefits of BIM implementation and use, respectively.

3 CURRENT STATUS OF BIM IMPLEMENTATION AND USE

Even though the distribution of the survey was across a range of industry professions, interestingly, approximately one third of the respondents are from Architecture firms, these were followed by engineering firms (12%), architecture/engineering (11%), contractors (10%), construction managers (9%), and BIM consultants (8%). The large response rate from architecture and engineering firms can be attributed to the high interest on the topic from these groups or to the high adoption rates by these groups. Also majority of the respondents are in senior management (70%). This could be due to the senior management's interest in the topic as well as the nature of questions in the survey.

Almost half of the respondents fell into either of the following two categories when asked about their firm's level of implementation: implemented for less than 10% of projects or for 100% of projects. The rest of the results are spread out almost evenly in between the two ends. One of the reasons for this might be that the respondent firms that just started implementing BIM and those that fully adopted BIM are interested in the value study. However, this result might be a representation of where the industry stands in terms of BIM implementations. The high end of the spectrum might be the innovators, who adopted BIM fully, and early adopters and early majority might be following the innovators.

When different professions are analyzed, architects and contractors have higher BIM utilization and experience rates than the construction managers and building/facility owners. Respondents were asked on how many projects they have implemented and used BIM personally. Again, the status of implementation falls at the two ends of the spectrum, but this time on an individual level. Most respondents (39%) said they have used BIM on more than 10 projects. The next largest group for number of projects BIM was used on was 'none, this is the first.' Architects and contractors are the most experienced groups in terms of number of projects they have used BIM software. The group with the least experience with BIM software is the construction managers. In order to assess respondents' BIM experience level with their selected projects, the survey asked how much of their time they spent on tasks that require hands on BIM experience. Interestingly almost a quarter of the respondents spent less then 10% of their time on BIM related tasks. Similar to number of project respondents used BIM software for, architects have more hands on experience while contractors have a little less and CMs spend the least amount of their time on tasks that require hands on BIM use.

Respondents were asked to select all software solutions they used and Autodesk BIM software prod-

ucts are widely used in the U.S. AEC industry among all types of respondents. The industry adopted BIM solutions that focus on design and engineering (Revit, Archicad, Tekla, etc) more widely and use them more extensively than the ones that focus on specialty solutions such as cost estimating, 4D scheduling, code checking (VICO, Synchro, Solibri, etc). Architecture firms use other Autodesk solutions such as Revit MEP, Revit Structure and Navisworks but not as widely as architectural solutions. These results show that Architects are heavily involved in the design aspects of projects and their services are not as diversified as other firm types. Contractors utilize broader range of BIM specialty solutions (such as cost and change control, code review, 4D scheduling, etc) compared to architecture firms.

Respondents were asked to choose a specific project and answer questions with that particular project as a reference point. Some questions asked to compare outcomes on the selected BIM project with either a similar project that did not use BIM or with an aggregation of historical non-BIM experiences. The top five types of projects that were selected, in order of frequency, are Commercial, Residential or Mixed, Academic/Educational, Medical and Institutional. Corporate Office, Industrial, Civil or Cultural, Hospitality, Entertainment and Sports, Transportation, Power, Military or Government, Retail, and Religious Buildings all followed. Over a third of the responses were split evenly between Commercial and Residential. The results were similar when analyzed by different firm types. The number of commercial, residential or mixed use and academic/educational type of projects is higher throughout the industry than the transportation, power, and religious types of projects. Therefore, the findings don't suggest that BIM solutions are more applicable to one type of project than the other. Primarily, these projects fell into the $1 million to $9.99 million value range followed by the group between $10 million to 19.9 million range. Notably, 29% of the projects were $100 million or more, which suggests that BIM is seen as more suitable for larger projects.

Over fifty percent of these projects are delivered under the traditional method of design-bid-build and design-build. The rest fell into the following categories: construction management (CM) at risk, Integrated Project Delivery (IPD), CM for fee, performance based contract, project alliance, Engineering Procurement Construction (EPC), and Design Assist. Although the traditional design-bid-build delivery system is still the most widely used delivery system, it is interesting to note that many of these projects are delivered under more recent and collaborative delivery methods such as design-build and IPD.

Respondents were asked which tasks they used their BIM software for on the chosen project. Visualization, clash detection and building design were close as the top three; each had more than 60% of respondents. As-built model generation, building assembly and construction sequencing followed. Program/massing studies, construction cost estimating, model based estimating and feasibility studies round out the top ten uses. Also, used in some measure were alternative development, direct fabrication, environmental analysis, code review, building facilities management, LEED certification compliance, and forensic analysis.

4 PRELIMINARY VALUE ASSESSMENT OF BIM

In order to maintain some confidentiality, the cost/benefit questions primarily asked for percents in relation to the overall project costs. Although there are many costs/benefits associated with BIM implementation and use on a project, this section considers tangible benefits (quantifiable and measurable in monetary terms) associated with BIM use and the survey does not focus on semi-tangible (quantifiable but difficult to measure, e.g. improved data availability, enabled faster reporting and feedback) or intangible benefits (neither quantifiable nor easy to measure, e.g. improving the effectiveness and performance of the organization). Respondents were also asked to provide their comments regarding their answers to this survey or to the realized value of BIM software in general. When these comments were analyzed, the authors realized that several of these comments were on the value of BIM. Relevant comments are included in this section.

When asked what percent of total job cost was spent on outside BIM consultants or BIM outsourcing companies, overwhelmingly respondents said that no consultants had been hired and a fraction had spent less than 1% of total project cost on a consultant. Based on these results, use of BIM consultants and outsourcing companies is limited in the industry. When different disciplines are analyzed, the results are very similar. However, architects and engineers hire BIM consultants and outsourcing companies less than contractors and construction managers.

A substantial number of industry members are absorbing costs of BIM software, software upgrades, hardware, hardware maintenance and training (around 85%). While there are some that are able to pass it on through fees to the owner, very few owners are covering any of these costs. Many of these costs are retainable and reusable. Therefore, if the owner is not a frequent builder, they might not invest in these expenses. It is surprising to see how few respondents were able to pass on the costs to the owner through fees (around 10%). Although the percentages don't change dramatically when different firm types are compared, architecture, engineering

and A/E firms paid for these costs themselves more than contractors and construction managers. Among all disciplines, owners covered the software and upgrade, hardware and maintenance and training costs for CM firms more than others and CM firms were also able to pass the costs to owner through their fees. A/E firms never passed the costs to the owner through fees, they either paid for themselves or owners paid for these costs. Owners covered these costs for engineering firms and contractors more than the other firm types responded to this survey. The value of these costs as it is compared to the overall net revenue was mostly below 0.5% of net revenue and very few spent more than 5% of net revenue on these costs.

When asked how their space and staff requirements might have changed because of BIM implementation, the respondents overwhelming (almost half) said that they remained unchanged. More said that they needed less space or staff than those that need more space or staff. While originally the change in printing, document shipping and traveling costs was thought to be a benefit, half of the respondents agree that there is no change in these categories. However, when percentages on reduction of costs (around 45%) are compared to the ones on the increase side (less than 5%), BIM use has a positive impact on costs in these categories. Several commented on travel costs and indicated that these costs increased by choice because they can get more work done faster and jobs are better coordinated because their client contact has increased.

When project phase durations are analyzed, schematic and conceptual design phases are slightly increased in duration, whereas detailed design phase duration is reduced. This could be attributed to the fact that BIM projects require more time to set up and additional services might be added during the early design phases. Some of the respondents commented that BIM is forcing them to model more than they anticipate. Others commented that they have not noticed any change in design as it is a purely creative venture that is not aided or hindered by technology. Almost all respondents agree that construction drawings phase is almost non-existent. There was a consensus that the quality of the documents produced has been improved substantially when BIM is used. There are less errors and omissions and the use of BIM increases accuracy of documents albeit with additional upfront effort. They also agreed that these improvements are realized as benefits in the construction phase as well as overall project costs. There is a substantial difference in the value added to the project in the way of presenting design options, design visualization, quantity takeoff checking, and discipline coordination. Overall almost all of the respondents are split between thinking that bid preparation phase takes less time and that the time it takes is unchanged, whereas less than 10% think this phase takes more time. The results are similar on the construction side but even fewer think that it takes more time. Comments provided also support that construction phase takes less time due to the coordinated documents with less errors and omissions.

Respondents were also asked how the use of BIM affects the overall project cost and schedule. Although a third of respondents believe there is no change on the overall duration or cost, the majority thinks that there is a 0-25% improvement in terms of cost and schedule due to the use of BIM. The survey also examined the ratio of dollar amounts of approved change orders, claims and disputes and correcting errors and omissions to overall project costs and found that close to a third of the respondents ranked the ratio of dollar amount of approved change orders to overall project cost as less than 0.5%. Almost two-thirds of the respondents ranked the ratio of dollar amount of claims and disputes to overall project cost as less than 0.5% and just over half of the respondents ranked the ratio of dollar amount of correcting errors and missions to overall project cost as less than 0.5%.

One of the objectives of this survey is to find out how uses of BIM affect the project profitability. Just over 40% of respondents said that profitability increased while about 10% of the respondents say that their project profitability has decreased and 20% said there is no change in project profitability. About 30% indicated that they don't know. One combination that was examined was the profitability with percent of projects within a firm that use BIM. When looking that the two ends of the implementation spectrum, where respondents implemented BIM for less than 10% projects and 100% of projects, we find that there are a similar number of respondents in each peak. When compared to the responses of the profitability question, of the less than 10% group only, 17% of people provided a response of increase, decrease or unchanged. Of those who answered the 100% of projects, 32% provided one of those responses. This is disparity might be because the first group is not able to determine profitability on projects that are not complete and they have a smaller amount of completed projects to draw information from. Upon further examination, the authors found that in the first group (10% of projects or less) the percent that found an increase was the same percent that found a decrease, 25%, while no change was at 50%. Within the second group (100% of projects), 73% found an increase in profitability and only 3% stated a decrease; no change had 23% of the responses.

While the items that were designated as costs (e.g. software, hardware, training, staff, space, printing, document shipping, and travel) seemed either to be unchanged (in the case of staff, space, printing, document shipping and travel costs) or seemed to be

a relatively small percentage of project costs, less than 0.5% (in the case of software, hardware and training). While over all, project costs seemed to be reduced between 0% and 25%. The major benefits seemed to appear in the schedule reduction, which is reflected in the increase in profitability seen on projects. This is perhaps why firms have not been passing implementation costs to the owners through fees. They see a value gain by an increase in profitability per project.

Some of the respondents commented that BIM utilization has not reflected positively on the profitability of their projects. The initial model setup is still very time consuming because the software forces the design to be modeled early on translating into a disproportional time spent in schematics and early design stages, compared to the standard process in other drafting software. Others believe that BIM software has little effect on overall project success or profit; that is mostly a function of project management, fee and contract negotiation, and client and contractor cooperation. They have found that BIM's advantages are typically involved in marketing, conceptual design, construction document creation, and the ability to offer visualization services. Respondents who are implementing BIM for the first time think that they are making a huge investment to embrace the technology and their profitability is affected negatively. Nevertheless, they indicated that they are learning from this experience and hoping that they will leverage the initial investment with the subsequent projects.

5 RECOMMENDATIONS FOR FUTURE RESEARCH

While this survey represents a first step towards understanding and benchmarking the realized value associated with the use and implementation of BIM, subsequently, there are several avenues that should be pursued. Some were not at all addressed in the survey, for example, the intangible and semi-tangible benefits and costs associated with BIM. Although it might be possible to quantify and benchmark some of these semi-tangible benefits, this aspect was also not examined in this study. These would be better examined in detailed case studies with extensive interviews and concurrent project documentation. Additionally, the concept of cost avoidance as a means of savings was not analyzed in detail. Some of the responses themselves elicited additional questions, for example, which types of projects are more profitable and why? Are the benefits amplified for higher value projects? What other costs are being reduced to see the overall reduction in projects costs? In addition, although the survey was distributed via newsletters, blogs and forums, when the results are analyzed, the respondent firms were mostly from the U.S. It would be worthwhile to distribute the survey internationally to analyze use and value of BIM for different regions. Finally, the survey or versions of the survey could be distributed at future points in time to compare the progression of change in the costs and benefits as the industry as a whole becomes more proficient and experienced with the software and process.

6 CONCLUSIONS

Implementation and adoption of BIM is still not uniform between different industry groups. While architects, engineers and contractors have implemented BIM more widely than contraction managers and building/facility owners, several respondents commented that it is too early to determine the value for BIM. According to these respondents, in order to effectively study the value for BIM and for significant returns on investment to be noticed, timeframe of 5-8 years is needed as the industry is still at its early stages of BIM adoption. Results on number of BIM projects, or respondents' personal BIM experience support these comments. Many firms are still working on initial deployment of BIM and even though there are some efficiencies achieved such as consistency, accuracy, availability and coordination of project information, there are still huge and steep learning curves and generational difference in those that are ready to adopt and make the investment. Many believe that BIM is used on a limited basis and the true value of BIM has yet to be achieved.

Currently, the industry is implementing BIM solutions for more obvious tasks such as visualization and/or clash detection, rather than newer and sophisticated tasks such as environmental analysis, direct fabrication, building code review, and/or facilities management. In order BIM solutions to be implemented to their full capacity, more collaborative structures and contractual agreements, such as IPD, are needed. Additionally, the industry is more often implementing BIM on large-scale projects. In order to effectively spread the costs of implementation, the use of BIM for a wider range of project scales should be considered. Although there is a consensus on positive impact of BIM on project outcomes and firm profitability, there is still skepticism.

While there is a trend of not charging owners specifically for BIM tasks, it seems that the increased profitability of each project makes it unlikely that professionals will need to amend their fee structures. This is significant because there has been a legitimate concern that work was being executed without compensation.

As with any technological advance there is the fear that jobs will be made redundant. In the case of BIM, there is certainly a reduction on the amount of people but overwhelming the staffing and space

needs seem to be unaffected by the use. It is possible that with industry wide experience increasing, there will be a need for less people but more likely; the implementation will be more widespread and penetrating. This breadth and depth will counteract the increase in productivity.

With these benchmarks as guidance the industry will be able to compare not only their current position but also plan their future trajectory in relation to others, both in the same discipline and in collaborator's fields. The survey may also help industry professionals to establish a means to track and measure their own value assessments across different project types. Additionally, with these benchmarks the process of long-term measurement and tracking can begin.

7 ACKNOWLEDGEMENTS

The authors wish to thank the following organizations, software companies, forums, newsletters and blogs for their help and participation in distributing the survey: BuildingSmart Alliance, AECBytes, CMAA, Fiatech, Gehry Technologies, Beck Technologies, TEKLA, VICO, AGC Forum, BIM Experts, Club Revit, Collaborative Construction Resources, Group For Building Information Modeling, USC-AGC Symposium, ConstructionSoftwareReview.com, Breaking Down the Walls, and WILL2PLAY Inc. The authors would also like to specially thank Deke Smith of BuildingSmart Alliance, the USC Cinematic Arts Complex project team members and Lachmi Khemlani of AECBytes for their instrumental input and assistance with survey development and distribution.

8 REFERENCES

Baldwin A., Betts M. and Blundell D. 1998. Measuring the benefits of IT innovation, construct IT. *Centre of Excellence*.

Becerik B. and Pollalis S. N. 2006. Computer aided collaboration for managing construction projects. *Design and Technology Report Series* Cambridge: Harvard Design School.

Becerik B. 2004. A review on web-based project management tools and their adoption by US AEC industry. *International Journal of IT in AEC*.

Bjork B. 2003. Electronic document management in construction research issues and results (Turk Z. Editor). *Journal of Information Technology in Construction* 8: 105-117.

Brynjolfsson E. 1993. The productivity paradox of information technology. *Communications of the ACM* 67-77.

Department of Commerce, Bureau of Economic Analysis. 2007. Gross domestic product by industry accounts. http://www.bea.gov/industry/gpotables/gpo_action.cfm?anon=97733&table_id=24583&format_type=0 (accessed June 04, 2009).

Department of Commerce, Bureau of Economic Analysis. 2002. 2002 Economic Census: Advance summary statistics for the United States. US Census http://www.census.gov/econ/census02/advance/TABLE1.HTM (accessed May 4, 2009).

Eastman C., Teicholz P., Sacks R. and Liston K. 2008. *BIM Handbook: A guide to building information modeling for owners, managers, designers, engineers, and contractors.* Hoboken: John Wiley & Sons.

El-Mashaleh, M.S. 2007. Benchmarking information technology utilization in the construction industry in Jordan. *Journal of Information Technology in Construction* 12: 279-291.

Gerber, D.J. (2009). The Parametric Affect. *Design and Technology Report Series.* Cambridge: Harvard Design School.

Gilligan B. and Kunz J. 2007. VDC use in 2007: significant value, dramatic growth, and apparent business opportunity. *CIFE, Stanford University Center for Integrated Facility Engineering* http://cife.stanford.edu (accessed April 18, 2009).

Keen P.G.W. 1991. *Shaping the future: business design through information technology.* Boston: Harvard Business School Press.

Khanzode A., Fischer M., and Reed D. 2008. Benefits and lessons learned of implementing building virtural design and construction (VDC) technologies for coordination of mechanical, electrical and plumbing (MEP) systems of a large healthcare project. *Journal of Information Technology in Construction* 13: 324-342.

Khanzode A., Fischer M., Reed D., and G. Ballard. 2006. A Guide to Applying the Principles of Virtual Design & Construction (VDC) to the Lean Project Delivery Process. *CIFE, Stanford University Center for Integrated Facility Engineering* http://cife.stanford.edu/online.publications/WP093.pdf (accessed May 14, 2009).

Khemlani L. 2004. The Eureka Tower: a case study of advanced BIM implementation. *AECBytes*, http://www.aecbytes.com/feature/2004/EurekaTower.html (accessed May 13, 2009).

Kymmell W. 2008. *Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations.* New York: McGraw-Hill.

Mitropoulos P. and Tatum C.B. 1999. Technology Adoption Decisions in Construction Organizations. *Journal of Construction Engineering and Management* 330-338.

Rivard H. 2000. A survey on the impact of information technology in the canadian architecture, engineering and construction industry. *Journal of Information Technology in Construction* 5: 37-56.

Sacks R. and Barak R. 2008. Impact of Three-Dimensional Parametric Modeling of Buildings on Productivity in Structural Engineering Practice. *Automation in Construction* 439-449.

Svavarsson D., Björnsson H., Ekström M., and N. Bergendahl. 2002. Evaluating IT Investments in the AEC Industry, *Ninth European Conference on Information Technology Evaluation.* France: Université Paris-Dauphine.

Zee H. 2002. *Measuring the Value of Information Technology*. Hershey: Idea Publishing.