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EVALUATING INDUSTRY PERCEPTIONS OF BUILDING INFORMATION MODELING (BIM) IMPACT ON CONSTRUCTION

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SUMMARY: *This research assessed perceptions about the impact of the implementation of Building Information Modeling (BIM) on construction projects through data collection in three surveys. Survey questions centered on impact with respect to six primary construction key performance indicators (KPIs) commonly used in the construction industry as accepted metrics for assessing job performance. These include: quality control (rework), on-time completion, cost, safety (lost man-hours), dollars/unit (square feet) performed, and units (square feet) per man hour. Qualitative data was collected through a survey instrument intended to assess practitioners' perceptions about BIM impacts on the six Key Performance Indicators. The first survey was targeted at National Institute of Building Sciences (NIBS) Facility Information Council (FIC) National BIM Standard (NBIMS) committee members. The survey results indicated that the respondents felt that a BIM-based approach improves construction metrics compared to construction without BIM. Specifically, the highest three ranking KPIs in order of most favorable responses were quality, on time completion, and units per man hour. The second tier of favorable responses included overall cost and cost per unit.*

KEYWORDS: *BIM, Construction, NBIMS, Metrics, KPI*

REFERENCE: *Suermann P, Issa R (2009) Evaluating industry perceptions of building information modelling (BIM) impact on construction, Journal of Information Technology in Construction (ITcon), Vol. 14, pg. 574-594, http://www.itcon.org/2009/37*

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1. INTRODUCTION

In 2004, the National Institute of Standards and Technology (NIST) published a report stating that poor interoperability and data management costs the construction industry, approximately $15.8 billion a year, or approximately 3-4% of the total industry (Gallaher, et al. 2004). Since this report, the focus on Building Information Modeling (BIM) has intensified and many professionals have labeled BIM as the answer to this problem. From the National BIM Standard (NBIMS) published in December 2007, a BIM (i.e. a single Building Information Model) is defined as "a digital representation of physical and functional characteristics of a facility." Furthermore, a BIM represents a shared knowledge resource, or process for sharing information about a facility, forming a reliable basis for decisions during a facility's life-cycle from inception onward. In the words of the NBIMS Executive Committee Leader and former Chief Architect of the Department of Defense, Dana K. "Deke" Smith, R.A., "A basic premise of

BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder" (NBIMS 2007).

2. METHODOLOGY

2.1 Overview

This paper focuses on only the first phase of a four-part research plan, which proposes to accomplish data collection and analysis on Building Information Modeling impact on construction. Since this research will later focus on BIM impact on federal construction projects, these four phases will be aligned with a process familiar in the Department of Defense. The process was originally created by United States Air Force Colonel John Boyd (1927-1997). Information Management (IM) professionals have often used Boyd's model, which is widely known as the "OODA Loop" (Observe, Orient, Decide, and Act), to demonstrate the continual improvement process of strategic decision making. Boyd developed the process based on his earlier experience as a fighter pilot and he initially used it to explain victory in air-to-air combat. But in the later years of his career; he expanded his OODA Loop process into a grand strategy with benefits to anyone who needs to pragmatically and quickly manage information. The OODA Loop will be used here to structure the research to ensure that each phase builds on the one before it and in this way the conclusions will be logically valid.

Colonel Boyd's philosophy dictated that individually, people will observe unfolding circumstances and gather outside information in order to orient their decision making system to "perceived threats." Boyd states that the *orientation* phase of the loop is the most important step, because if decision makers perceive the wrong threats, or misunderstand what is happening in the environment, then the decision makers will orient their thinking in erroneous directions and eventually make incorrect decisions. Boyd said that this cycle of decision-making could operate at different speeds for different organizations but the goal is to complete the OODA Loop process at the <u>fastest tempo possible</u> for fighter pilots. However, just as the OODA Loop has been applied to many other endeavors, in this research, it will be customized or applied to structure the research to arrive at the best, not necessarily the fastest, choices and conclusions about BIM's impacts on construction. Through Boyd's OODA Loop; this research will be structured in four phases aligned with the ideas of *observation*, *orientation*, *decision*, and *action* (Boyd 2007). The work completed in this research in Phase I demonstrated nontrivial data regarding industry practitioners and academics' perceptions about BIM impact on construction.

2.2 Phase I: Observation

BIM is not yet widespread in the US Architecture, Engineering, Construction, and Operations (AECO) industry. Specifically, the 2006 iteration of the annual AIA Firm Survey indicated that only 16% of the firms surveyed had acquired BIM software and that only 10% of the firms were using the software for billable work. As such, there is little empirical data regarding its application and use. Therefore, in addition to the typical review of literature in the field, the qualitative survey administered in this research to garner initial data about practitioners' perceptions was needed. Specifically, the survey instrument collected data regarding perceptions about the effects of BIM on commonly accepted construction key performance indicators (KPIs). This survey data was used to determine current BIM practices and perceptions to formulate additional research hypotheses for use in Phase II. Phase I included publishing three iterations of a web-based and hard copy survey with the sole purpose of garnering industry stakeholders' impressions of BIM's effect on construction through specific construction metrics based on six (6) primary, quantitative construction KPIs: Quality Control, On time Completion, Cost, Safety, $/Unit, Units/Manhour as determined in a 2003 study by Cox et al. (2003). In this way, qualitative industry perceptions were quantified. The survey was hosted on http://www.zoomerang.com through an account login funded by the National Institute of Building Sciences, Facility Information Council (NIBS-FIC). In concert with the National BIM Standard (NBIMS) Committee testing team, a subset of the NIBS-FIC, this data was shared for their own empirical research. Later, the survey was issued in hard copy format to the attendants of the BIM4Builders™ Event in Gainesville, Florida in May of 2008.

2.2.1 Survey

After receiving University of Florida Institutional Review Board (UFIRB) authority, the first iteration of the survey was available from March 5, 2007 until April 5, 2007 and was advertised to the NIBS-FIC NBIMS Committee. This sample group was chosen because they are knowledgeable about BIM and have a high likelihood for providing actionable data. While the respondents affiliation with the NBIMS Committee obviously has the potential of biasing the results towards being more favourable to BIM impact on construction, it was deemed necessary to use this respondent pool to 1) get perceptions from those knowledgeable about BIM and 2) serve as a baseline in comparison to future iterations of more generalizable survey data.

In order to garner maximum participation from existing and new members, Survey #1 was advertised in two different ways: direct email through a distribution list and a website advertisement on the NIBS-FIC/BIM website where people join the committee. First, an email was sent to the FIC listserv distribution list. This listserv had 104 members from across the AECO industry at the time of the survey's launch. Halfway through the month-long survey availability, a reminder email was sent to the listserv asking for more people to complete the survey or for those who had started the survey to complete the survey. The second method of garnering qualified respondents was to advertise the survey on the NIBS FIC website, http://www.facilityinformationcouncil.org/bim, under their "NEWS" portion. Since most people only happen upon this website when signing up to join the NIBS-FIC NBIMS committee, and this website is only "advertised" in the AECO community, the possibility of tainting the data was considered negligible.

Survey #2 was available to the entire industry and advertised in a variety of media outlets including those here:

- The Associated Schools of Construction (ASC)
- The American Institute of Architects (AIA)
- The Associated General Contractors of America (AGC)
- The American Society of Civil Engineers Construction Institute (ASCE-CI)
- The United States Army Corps of Engineers (USACE)
- The Society of American Military Engineers
- The Architects, Engineers, and Contractors (AEC Café) website and newsletter
- The Geographical Information Systems (GIS Café) website and newsletter
- The "upFront – eZine" (sic)
- The Science and Technology for Architecture, Engineering, and Construction Annual BIM Conference (AEC-ST, May 15-17, 2007) in Anaheim, CA

In this way, the survey was open to a large cross section of the industry and ensured more generalizable results than the first iteration of the survey, which was only open to those on the NBIMS Committee.

Survey #3 was given in hard copy format to attendees of the BIM4Builders™ Event in Gainesville, FL in May of 2008. This also ensured survey data concerning perceptions from a myriad of fields including primarily contractors, architects, engineers, as well as some academics and corporate leadership.

2.2.2 Survey Specifics

The survey was divided into four sections:

- Part I: Basic Demographic Information
- Part II: BIM Effects on KPIs
- Part III: Ranking KPIs
- Part IV: Free Answer

Part I was intended to find descriptive information about the respondents, to ensure that they were qualified to answer the questions, and to group answers from similar respondents together across the data pool. Most questions were standard for surveys such as gender, age, and the state where the respondent resided. Questions especially germane to the research were the following which were targeted at collecting the respondent's educational level, annual company revenue, and people's organizational role. Regarding organizational role, respondents were asked to make a selection from a list based on the organizational roles listed in Table 34 of the Construction Specifications Institute (CSI 2007). First, respondents were asked to select their overarching organizational role, and then the survey skipped to the question that addressed the proper organizational role with a follow-up question formulated to find out the specific role the respondent filled on a daily basis. These choices also came from the CSI's (2006) Omniclass Table 34 for organizational roles.

Part II of the survey served as the beginning of the primary data collection instrument. This part asked questions on each of the six construction KPIs in various formats with varying scales of favorable to unfavorable perceptions regarding the impact of BIM on construction. In this way, the possibility of errant responses from people just putting the maximum answer down for every question was avoided. At the beginning of Part II, respondents were asked to rate their perception of BIM's impact on the list of six construction key performance indicators. Specifically, question #14 of the survey addressed BIM's impact on units per man hour. Units per man hour were defined for respondents as "measure of completed units (typically square footage) put in place per individual man hour of work." The respondents' choices of answers ranged on a 5-point Likert scale from least favorable to most favorable with the following possible choices:

Severely Inhibits	Lessens	No Effect	Improves	Maximizes
1	2	3	4	5

The next question, #15, asked for the same perception about BIM's impact on "dollars per unit" or cost per square foot ($/SF) with the same choices on the 5-point Likert scale. Question #16, asked about safety. Regarding safety, respondents were asked to "read the following statements and choose the one that most closely matches your view of BIM's effect on safety." The answers, with regard to lost man-hours, were again arranged on a 5-point Likert scale:

Eliminates	Lessens	No Effect	Increases	Greatly Increases
1	2	3	4	5

The next question, #17, had to do with cost. Cost was defined as "cost variance in actual costs to budgeted costs." Here there were five sub-questions under this one question that centered on different types of costs including: General Conditions, Structural, Mechanical, Electrical, and Plumbing (MEP), Finishes, and Overall. Here, respondents could choose from a 5-point Likert scale, as well as the additional choice of Not Applicable or "N/A." The 5-point Likert scale had the following choices:

Max Variance: ($ Lost)	Worsens	No Effect	Improves	Max Variance ($ Saved)
1	2	3	4	5

Question #18 focused on "on time completion." The response options were similar to those for question #17 with the exception of variance equating to a "late" project on the unfavorable side of the scale to "max variance – early" on the favorable side of the scale.

The final question in Part II, #19, asked respondents what they thought about BIM's impact on quality control/rework. This question prepared the respondent for answering by saying, "quality control can be defined as percent (%) of rework in ($) compared to overall cost in ($)." The choices were:

Increases Rework	Worsens	No Effect	Improves	Nearly Eliminates Rework
1	2	3	4	5

Part III of the survey was structured to determine whether there was any one construction KPI which BIM impacted more than any other in a logical ranking fashion, so that it could be investigated more thoroughly in Phase II of the research while collecting case study data. Respondents were asked to rank the KPIs on a Likert scale from 1-10. This means that 1 would be a score showing that BIM inhibited construction to 5 equalling no effect to 10 showing the most improvement.

Part IV of the survey was intended to gather open ended responses from respondents that could help identify problems with the current survey, necessary points to investigate in future surveys, receive contact information if people wanted specific follow-up information, and give respondents a chance to express themselves if they felt the survey stifled their responses in any way.

The Summary portion of the survey was intended to determine respondents' personal definition of Building Information Modeling. There were four choices, including one response; "Don't Know" which was a response intended to eliminate unqualified respondents from tainting the data pool. The other choices included:

- BIM is 3D CAD
- BIM is a tool for visualizing and coordinating A/E/C work and avoiding errors and omissions
- BIM is an open standards based info repository for facilities lifecycles

3. RESULTS

The first survey was sent out to the NBIMS committee of the NIBS-FIC and was available from March 5, 2007 until April 5, 2007. Of the 105 people on the committee when the survey was closed out (as opposed to the 104 on the committee when the survey was launched), 50 respondents fully completed the survey for a 48% response rate. The information below represents a summary of the results from the first survey, Survey #1.

3.1 Survey#1: Part I: Basic Demographic Information

Figures 1 through 3 show the data gathered through the Zoomerang online survey or data analysis derived from the data in the survey. Regarding gender, 86% (43/50) of the respondents were male and 14% (7/50) female. The age data of the respondents shows that the mode response was also the median age group, the 45-54 year olds with an overall normal distribution of respondents. There was only one respondent under 25 years old. As far as education level, 86% (43/50) of the respondents had college degrees, with 56% (28/50) of them holding graduate or professional degrees. There was no definite trend indicated on the organizational revenue question, although the most frequent response was $1-$9.9 Million with 24% (12/50) of the respondents choosing this answer. Respondents' geographic locations were varied with 47/50 respondents living in the U.S. and three from outside the U.S. (Note: despite being the U.S. NBIMS committee, several members live and work outside the U.S., but are either American citizens or are liaisons for wider interests such as the North American BIM buildingSmart Initiative (sic), etc. so it is possible for respondents on the U.S. NBIMS listserv to live outside the U.S.) The most frequent response by state was from Maryland, with 18% or nine of the 50 respondents living there.

The organizational role data results showed that the two most frequent responses were from those with a Design Role with 44% (22/50) respondents and from those with a Management role, which accounted for 30% (15/50) respondents. Of the first most frequent response, Design Role, 73% (16/22) of the respondents were architects and 27% (6/22) respondents were engineers. For the second most frequent response, Management, 47% (7/15) were Vice Presidents in their organization and 40% (6/15) respondents were the Chief Executives of their organization.

3.2 Survey #1: Part II: BIM Effects on Construction KPIs

Respondents were asked to rate their perception of BIM's impact on six KPIs. In order to clearly compare each of the KPIs to one another, the frequency of positive responses [responses similar to "Greatly Improves" or "Improves"] were combined into the form of a percentage to simplify comparison between all six KPIs. This was done rather than taking the median or average because the responses were discrete variables that depended on frequency rather than comparing the KPIs across a continuous spectrum. The following list is organized in order of the highest rated to the lowest rated of the six KPIs: Quality Control/Rework (90%), On-time Completion (90%), Cost-Overall (84%), Units/Man hour (76%), Dollars/Unit (70%), and Safety (46%). This was calculated by evaluating responses that exceeded the neutral Likert value of 3 and comparing that to the total number of responses. For example, 34/50 respondents opined that BIM "Improved" the Quality Control/Rework KPI, as well as 11/50 respondents opined that BIM, "Nearly Eliminates Rework" for a total rating of 90% (45/50). Full data on the responses can be seen in Figures 2 and 3.

Cost was similarly broken down and the following list organized in the order of highest to lowest rated favorable opinion (i.e. assigned a value greater than 3 on the Likert scale) by the respondents: Overall (84%), Mechanical, Electrical, and Plumbing (78%), Structural (76%), General Conditions (70%), and Finishes (58%). It is important to note that 46% or 23/50 respondents also felt that BIM has "No Effect" on safety or lost man-hours in construction projects, making it the KPI that in their perception is the least impacted by BIM.

14. Units per man-hour: Units per man-hour is the measure of completed units (typically square footage) put in place per individual man hour of work.

Severely Inhibits	1	2%
Lessens	6	12%
No Effect	5	10%
Improves	34	68%
Maximizes	4	8%
Total	50	100%

15. Dollars($)/Unit: Dollars($)/Unit is the dollar value associated with putting one complete unit in place (e.g. cost per square foot)

Severely Inhibits	0	0%
Lessens	5	10%
No Effect	10	20%
Improves	30	60%
Maximizes	5	10%
Total	50	100%

16. Safety: Please read the following statements and choose the one that most closely matches your view of BIM's effects on safety.

Eliminates LOST MANHOURS	0	0%
Lessens LOST MANHOURS	23	46%
No Effect	23	46%
Increases LOST MANHOURS	2	4%
Greatly Increases LOST MANHOURS	2	4%
Total	50	100%

FIG. 1: Survey #1: Part II Responses about BIM's impact on construction KPIs (raw data from zoomerang)

17. Cost: Cost variance in actual costs to budgeted costs

Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.	Max Variance ($ Lost)	Worsens	No Effect	Improves	Max Variance ($ Saved)	N/A
General Conditions	0 0%	3 6%	8 16%	31 62%	4 8%	4 8%
Structural	1 2%	2 4%	3 6%	29 58%	9 18%	6 12%
Mechanical, Electrical, Plumbing	0 0%	3 6%	3 6%	27 54%	12 24%	5 10%
Finishes	0 0%	3 6%	12 24%	25 50%	4 8%	6 12%
Overall	0 0%	2 4%	2 4%	32 64%	10 20%	4 8%

18. On-Time Completion: On-Time Completion can be defined as construction duration variance from proposed schedule duration.

Max Variance (Late)	1	2%
Worsens	1	2%
No Effect	3	6%
Improves	41	82%
Max Variance (Early)	4	8%
Total	50	100%

19. Quality Control/Rework: Quality Control can be defined as percent (%)of rework in ($) compared to overall cost in ($).

Increases Rework	0	0%
Worsens	0	0%
No Effect	5	10%
Improves	34	68%
Nearly Eliminates Rework	11	22%
Total	50	100%

FIG.2. Survey #1: Part II Responses about BIM's impact on construction KPIs (raw data from Zoomerang)

3.3 Survey #1: Part III: Ranking Construction KPIs

Respondents were asked to rank the construction KPIs according to their perceptions of how well BIM improved the given KPIs on a scale of 1-10, with 10 showing the most improvement, 5 showing no effect, and 1 showing that BIM inhibits the given KPIs. Organizing the construction KPIs according to merely adding positive response frequency percentages (anything over a score of 5), the KPIs score the following in order from most to least favorable: Quality (94%), On-time Completion (88%), Units/Man-hour (86%), Dollars/Unit (80%), Cost (80%), and Safety (54%.) When weighting the answers for the degree of favorability according to the weighted average of the ranking scores provided by respondents, the KPIs scored in a slightly different order: Quality, On-time Completion, Units/Man-hour, Cost, Dollars/Unit, and Safety. This information is graphically illustrated in Figures 4 and 5. Figure 4 shows the percentages of favorable response frequency. Figure 5 shows weighted average scores according to their emphasized degree of favorability.

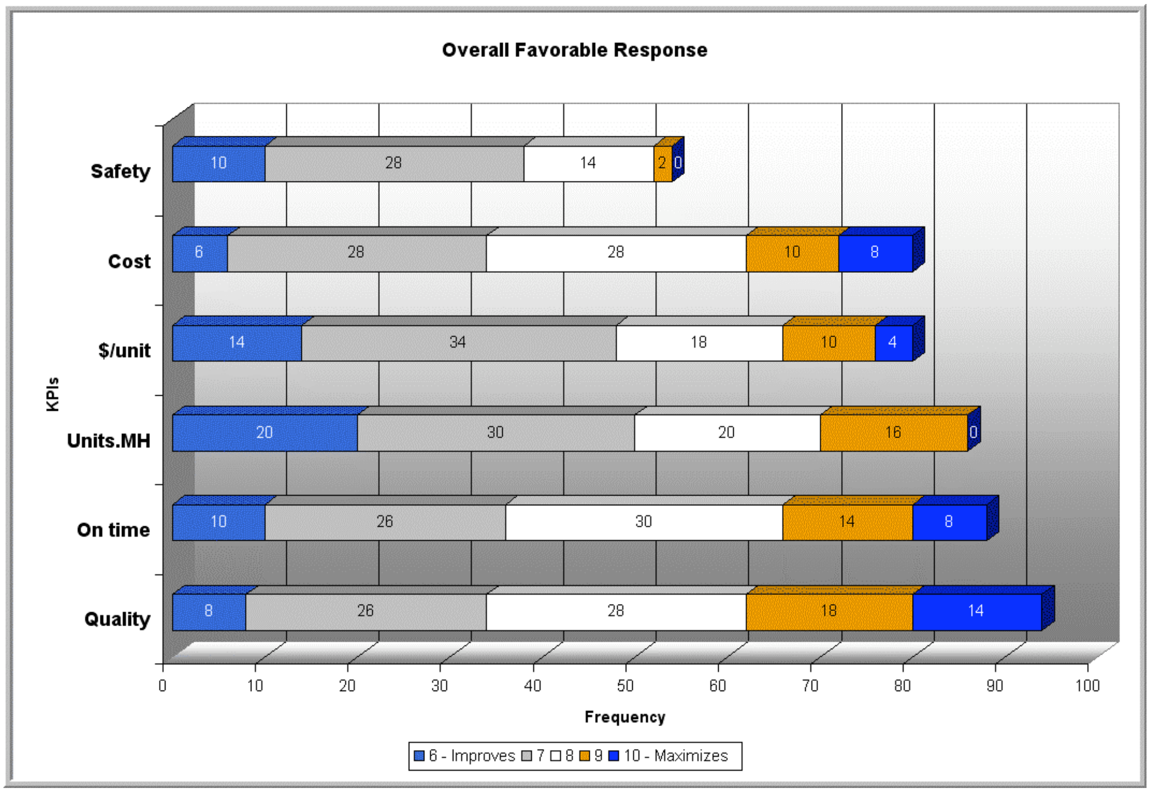


FIG. 3: Overall Favorable Responses when ranking KPIs with respect to impact on BIM (unweighted)

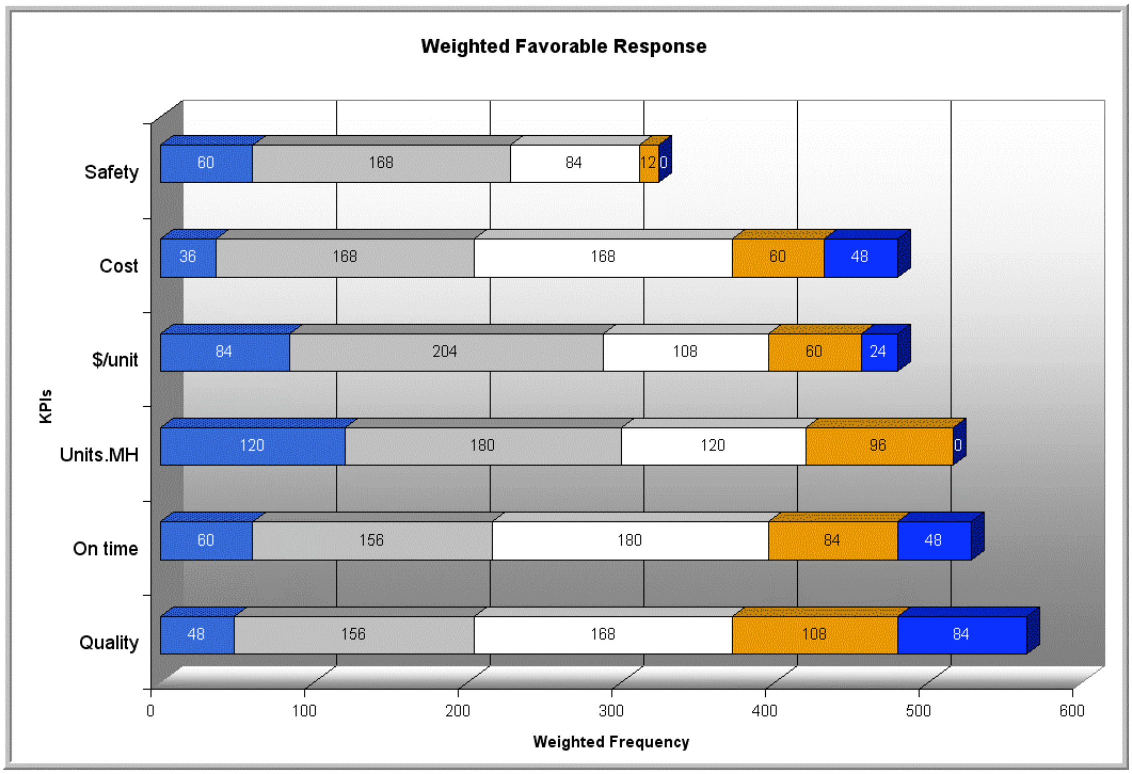


FIG. 4: Overall Favorable Responses when ranking KPIs with respect to impact on BIM (weighted)

3.4 Survey #1: Part IV: Comments

A few of the most representative comments made by the respondents were:

- Respondent # 3: A BIM will likely affect KPIs rather than the other way around. A good, comprehensive, structured source of accurate data that all the stakeholders can access will reduce stove pipes, redundant data and inaccurate information. It will make it easier to keep the data current and to verify it.
- Respondent #7: The questions that are being asked are of the type that an A/E would ask. You may want to look at asking that questions that a builder, vendor, or trade contractor would ask.
- Respondent #8: The way you ask your questions, it seems as if you assume that BIM should save time and money. In reality, I believe that the BIM makes your planning, scheduling, estimating, etc. more accurate. I have quite often seen that BIM corrects errors, misconceptions and the net effect may be additive (but save the contractor the time, money and the embarrassment of a mistake). If there was inadequate time or more planned for a given scope, than it may it may be just as likely to add time or money as save (sic).
- Respondent #13: More KPIs: Reduction in Claims, Improved public outreach/agency coordination, More sustainable structures
- Respondent #16: BIM will minimize change orders, and will also reduce the initial project cost. Contractors will sharpen their pencils and will provide pricing per known factors, the number of unknowns and field coordination efforts are reduced.
- Respondent #17: While BIM a goal to strive for and is relevant to certain projects - the fractured nature of the A/E/C (sic) industry means that it will be a long time before BIM has a significant overall effect on the industry

3.5 Survey#1 Summary Definition Question and Conclusions

The summary question in this survey asked respondents which definition of BIM most closely matched their own. No respondents chose the answers "Don't Know" or "BIM is 3D CAD." Therefore, none of the responses were eliminated from the data pool. As shown in Figure 6, the definition of BIM drafted by the NIBS-FIC NBIMS Committee received the most responses, "BIM is an open standards based information repository for facilities' lifecycles," with 70% or 35/50 respondents making this selection. The other response was, "BIM is a tool for visualizing and coordinating AEC work and avoiding errors and omissions," received 30% or 15/50 responses. While this response is not necessarily incorrect, it does not align with the NBIMS' view of the definition, which means that 15% of the respondents from the NBIMS committee have a personal definition of BIM that is different than the committee's formal definition. Thus, there is still some work to be done for the NBIMS Committee to educate and inform the AECO community, even within its own organization. However, because of people's membership on the committee, their proven expertise, and the fact that only generally acceptable definitions of BIM were selected, all the data was assumed valid and no respondents' individual surveys were "thrown out."

Also of interest on this survey was that several people actually thought that BIM "hindered" safety. It is unclear whether these respondents did not understand the question, errantly entered their answers, or genuinely thought that BIM hindered safety. This needs to be investigated further.

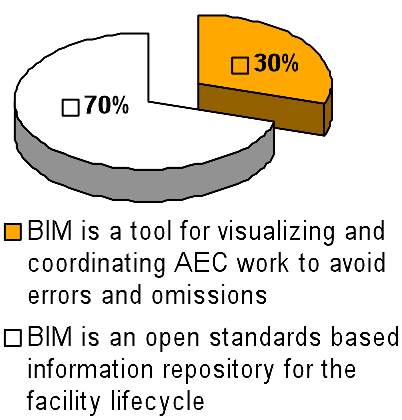


FIG. 5: Answers to definition of BIM Question in Survey #1

3.6 Survey #2

Survey #2 was based on survey #1, but had some minor edits to the way questions were sequenced or asked after implementing advice from respondents who took Survey #1. The survey was available from April 30 to October 30, 2007, or exactly six months. It is important to note that the survey was open to the general population at large and anyone could complete a copy of the survey and experienced 95 completed surveys, out of an unknown sample size pool, due to industry-wide availability.

3.7 Survey #2: Part I: Basic Demographic Information

Figures 6 – 8 show the data gathered through the Zoomerang online survey, or data analysis derived from the data in the survey. Regarding gender, 88% of the respondents were male and 12% were female. The age data of the respondents shows that the mode response was the 35-44 year olds with an overall relative normal distribution of respondents. Different from the NBIMS Survey, this survey had younger respondents, which is understandable, considering it was open to all public practitioners. As far as educational level is concerned, 87% of the respondents had bachelor's degrees or higher, nearly the same as Survey #1.

There was no definite trend indicated on the organizational revenue question, although the most frequent response (with a monetary value) was $1-$9.9 Million with 16% (14/90) of the respondents choosing this answer. The most frequent answer overall was “Don’t know.”

Respondents’ geographic locations were varied with 87/93 respondents living in the U.S. and six from outside the U.S. The most frequent response by state was from Washington, with 11% or ten of the 93 respondents living there, most likely due to advertising the survey while conducting embedded research in Seattle.

1. Please indicate your gender.		
Male	82	88%
Female	11	12%
Total	93	100%

2. Please select the category that includes your age.		
17 or younger	0	0%
18-24	1	1%
25-34	15	16%
35-44	27	29%
45-54	25	27%
55-64	19	20%
65 or older	6	6%
Total	93	100%

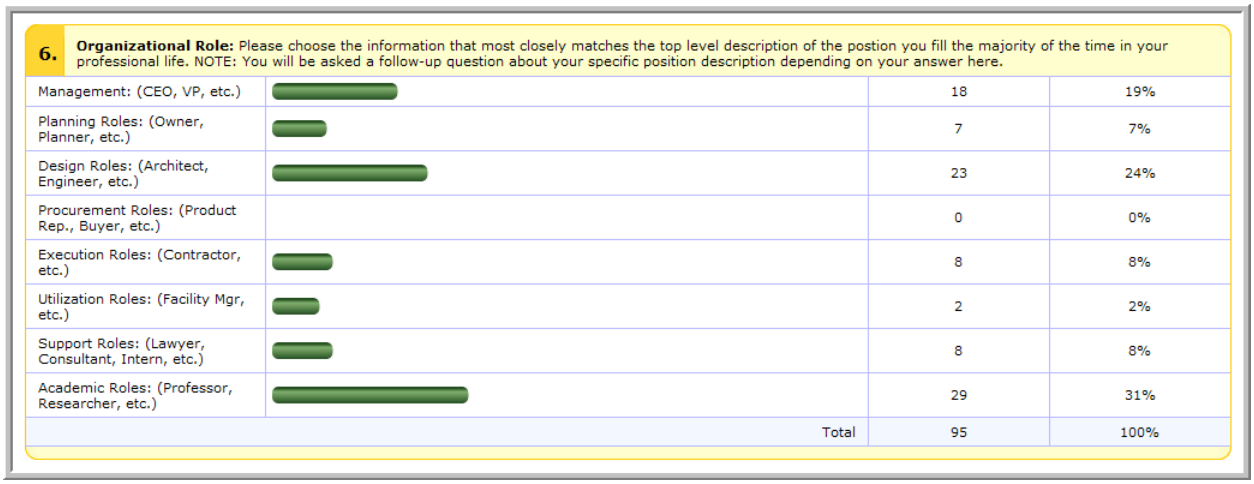
3. What best describes your level of education?		
High school graduate or equivalent	0	0%
Some college	5	5%
Associate degree	7	8%
Bachelor's degree	19	20%
Graduate or professional degree	62	67%
Prefer not to answer	0	0%
Total	93	100%

FIG. 6. Survey #2 screen capture of the results to survey questions 1-3

4. What are the annual revenues of your company/organization?		
Under $10,000	1	1%
$10,000 to $49,999	1	1%
$50,000 to $99,999	1	1%
$100,000 to $499,999	10	11%
$500,000 to $999,999	1	1%
$1,000,000 to $9,999,999	14	16%
$10,000,000 to $49,999,999	4	4%
$50,000,000 to $99,999,999	6	7%
$100,000,000 to $1 Billion	14	16%
Over $1 Billion	10	11%
Don't know	17	19%
Don't work	2	2%
Prefer not to answer	9	10%
Total	90	100%

FIG. 7. Survey #2 Screen capture of the results to question 4

The organizational role data results showed that there were three primary responses from the eight choices. The most frequent response was from those with Academic Roles with 31% (29/95) of the respondents. Next most frequent were those with Design Roles with 24% (23/95) and Management with 19% (18/95) of the respondents. Of the top most frequent response, Academics, 79% of those respondents were Assistant Professors or higher. Of those who responded "Design Role," 64% (14/22) of the respondents were architects and 36% (8/22) of the respondents were engineers. For the third highest frequent response, Management, responses were evenly divided between Chief executive, Vice President, and Partner.



6. Organizational Role: Please choose the information that most closely matches the top level description of the postion you fill the majority of the time in your professional life. NOTE: You will be asked a follow-up question about your specific position description depending on your answer here.

Management: (CEO, VP, etc.)		18	19%
Planning Roles: (Owner, Planner, etc.)		7	7%
Design Roles: (Architect, Engineer, etc.)		23	24%
Procurement Roles: (Product Rep., Buyer, etc.)		0	0%
Execution Roles: (Contractor, etc.)		8	8%
Utilization Roles: (Facility Mgr, etc.)		2	2%
Support Roles: (Lawyer, Consultant, Intern, etc.)		8	8%
Academic Roles: (Professor, Researcher, etc.)		29	31%
	Total	95	100%

FIG. 8. Survey #2 Screen capture of the results to question 6 – Top level description of organizational role

3.8 Survey #2: Part II: BIM Effects on KPIs

Figures 9 and 10 show respondent perceptions regarding BIM impact on the six KPIs. In order to clearly compare each of the KPIs to one another, the frequency of positive responses [responses similar to "Greatly Improves" or "Improves"] were combined into the form of a percentage to simplify comparison between all six KPIs. This was done rather than taking the median or average because the responses were discrete variables that depended on frequency rather than comparing the KPIs across a continuous spectrum. The following list is organized in order of the highest rated to the lowest rated of the six KPIs: Quality Control/Rework (85%), Cost-Overall (83%), On-time Completion (76%), Units/Man hour (67%), Dollars/Unit (67%), and Safety (37%). It is important to note that because "Units/Man hour" and "Dollars/Unit" were had the same frequency of favorable answers; the negative values were assessed, which made Units/Man hour more highly favored than "Dollars/Unit."

15. Units per man-hour: Units per man-hour is the measure of completed units (typically square footage) put in place per individual man hour of work.

Severely Inhibits	1	1%
Worsens	3	3%
No Effect	28	29%
Improves	50	53%
Maximizes	13	14%
Total	95	100%

16. Dollars($)/Unit: Dollars($)/Unit is the cost associated with putting one complete unit in place (e.g. cost per square foot)

Severely Inhibits	2	2%
Worsens	8	8%
No Effect	22	23%
Improves	51	54%
Maximizes	12	13%
Total	95	100%

17. Safety: Please read the following statements and choose the one that most closely matches your view of BIM's effects on safety.

Eliminates LOST MANHOURS	4	4%
Lessens LOST MANHOURS	31	33%
No Effect	50	53%
Increases LOST MANHOURS	7	7%
Greatly Increases LOST MANHOURS	3	3%
Total	95	100%

FIG. 9. Survey #2 screen capture of the various results to first three KPIs: Units per man-hour, Dollars/Unit, and Safety

18. Cost: Cost variance in final, actual costs compared to original, budgeted costs. Note that 1 = Max Unfavorable Variance(Final cost is MORE than original) and 5 = Max Favorable Variance(Final cost is LESS than original)

Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.	Max Unfavorable Variance	Worsens	No Effect	Improves	Max Favorable Variance	N/A
General Conditions	0 0%	9 9%	29 31%	45 47%	7 7%	5 5%
Structural	0 0%	2 2%	19 20%	51 54%	21 22%	2 2%
Mechanical, Electrical, Plumbing	1 1%	1 1%	10 11%	47 49%	32 34%	4 4%
Finishes	0 0%	6 6%	35 37%	46 48%	4 4%	4 4%
Overall	0 0%	2 2%	12 13%	71 75%	8 8%	2 2%

19. On-Time Completion: On-Time Completion can be defined as construction duration variance from proposed schedule duration.

Max Variance (Late)	0	0%
Worsens	2	2%
No Effect	17	18%
Improves	62	65%
Max Variance (Early)	14	15%
Total	95	100%

20. Quality Control/Rework: Quality Control can be defined as percent (%)of rework in ($) compared to overall cost in ($).

Increases Rework	0	0%
Worsens	2	2%
No Effect	12	13%
Improves	62	65%
Nearly Eliminates Rework	19	20%
Total	95	100%

FIG. 10. Survey #2 screen capture of results to last three KPIs: Cost, On-Time Completion, and Quality Control/Rework

This was calculated by evaluating responses that exceeded the neutral Likert value of 3 and comparing that to the total number of responses. For example, 50/95 respondents opined that BIM "Improves" Units per man-hour, as well as 13/95 respondents opined that BIM, "Maximizes" Units per man-hour, for a total rating of 67% (63/95).

Cost was similarly broken down and the following list organized in the order of highest to lowest rated favorable opinion (i.e. assigned a value greater than 3 on the Likert scale) by the respondents: Overall (83%), Mechanical, Electrical, and Plumbing (83%), Structural (76%), General Conditions (54%), and Finishes (52%.)

It is important to note that 53% or 50/95 respondents also felt that BIM has "No Effect" on safety or lost man-hours in construction projects, making it the KPI that in their perception is the least impacted by BIM, similar to the results in Survey #1.

3.9 Survey #2: Part III: Ranking KPIs

Figure 11 shows respondents KPI rankings according to their perceptions of how well BIM improved the given KPIs on a scale of 1-10, with 10 showing the most improvement, 5 showing no effect, and 1 showing that BIM inhibits the given KPIs. Organizing the construction KPIs according to merely adding positive response frequency percentages (anything over a score of 5), the KPIs score the following in order from most to least favorable: Quality (83%), Cost (83%), On-time Completion (79%), Dollars/Unit (74%), Units/Man-hour (69%), and Safety (46%).

21. **PART III: Ranking KPIs** Please rank the key performance indicators according to your perception of how well BIM improves the given KPI metric with 10 showing the most improvement, 5 showing no effect, and 1 showing that BIM inhibits the given KPI.

Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.	1	2	3	4	5	6	7	8	9	10
Units/MH	0 0%	0 0%	2 2%	2 2%	25 26%	19 20%	26 27%	13 14%	4 4%	4 4%
On-Time Completion	0 0%	0 0%	0 0%	2 2%	17 18%	15 16%	23 24%	22 23%	9 9%	7 7%
Safety	1 1%	0 0%	1 1%	4 4%	43 45%	18 19%	17 18%	6 6%	2 2%	3 3%
Cost	0 0%	0 0%	2 2%	3 3%	11 12%	23 24%	32 34%	12 13%	9 9%	3 3%
$/Unit	0 0%	0 0%	1 1%	3 3%	20 21%	22 23%	24 25%	18 19%	4 4%	3 3%
Quality Control / Rework	0 0%	0 0%	0 0%	2 2%	14 15%	13 14%	18 19%	26 27%	13 14%	9 9%

FIG. 11. Survey #2 screen capture of Ranking KPI responses

In order to take into account degree of favorability, rather than simply positive frequency, responses were multiplied by their relative weight (6-10) and calculated. After accomplishing this operation, this resulted in: Quality (4.98), Cost (4.98), On-time Completion (4.74), $/Unit (4.44), Units/Man-hour (4.14) and Safety (2.88) for the same order as frequency of positive responses.

3.10 Survey #2: Part IV: Free Answer

A few of the most representative comments made by the respondents are listed here, because there were too many comments to show in one figure.

- Not sure the survey is applicable to the entire scope of "BIM"... seems to be construction centric, In that context it is good as far as it goes
- Your definitions of BIM are very shallow and limited to technology. BIM is a process that is implemented within a building projects using technologies that facilitate the collaboration, open standards and communications that allow Building Information to be contributed by the right experts at the right time thus creating a database that can be viewed in reports, graphics, 2D or 3D and other means to communicate the means by which it can be constructed. The BIM data must be useful during the entire life cycle of the building. Look at definitions of BIM by CURT, The AIA paper on the Integrated Practice and FIATECH. Tool for Contractors are just part of BIM. Tools for visualizing and

coordinating AEC is just part of BIM, BIM is NOT 3D CAD as some vendors would have us believe. BIM may be fererally [sic] supported for specific applications and they are going to hold the industry accountable for using the BIM process and implementing useful tools to meet the goals of the owners. The Owners organization (CURT) rules the roost. They have the money and want the buildings built so we need to listen to them.

- Like most trends moving through the construction industry, contractors perceive the need to adopt BIM as a distinguishing capability that separates their company from the rest of the pack. There is also an energized atmosphere that motivates us to explore this new technology. This is partly driven by our own sense of adventure but also driven by software and hardware developers who promise to solve all of our problems with the new tools. I am very interested in learning the results of your survey, although I think it's a rapidly moving target that would yield different results in a year from now.
- An interestsing [sic] format. You have selected what I perceive are key variables and it will be interesting to see you final results.
- Experienced sever learning curve on initial project. Bentley software was found to be not up to the task in many respects. No gain on that project, in fact, probably a more expensive approach with multiple problems flowing from the approach itself, but we do expect these metrics to improve over time. Enjoyed the ability to perceive conflicts between disciplines in the design before discovered during fieldwork. Prime and subs were not prepared to make efficient use of the offered BIM information. Cost estimates easier to update after design changes. Expect this is the wave of the future and holds much promise we did not achieve in our initial attempt.
- BIM is a great tool for new construction because it builds from the ground up. As a tool for rehab work, unless the project is on a fairly large scale, more effort goes into producing the BIM than can be done by doing a design in 2-D and providing contractors with existing reference drawings. The production of BIMs for an entire installation is a costly proposition when done at one time, and even greater when done for several installations at the same time. No one can really afford to BIM all they own to the BIM level of a new facility. BIM as needed should be the process until the evolution of BIM is fully developed to where a building has been mostly BIM'd [sic] because of work to it. Using BIM to produce 2-D plan sets has no advantage over using any CAD application to do the same. Unless construction contractors have a means to use BIM themselves, BIM will be slow growing. As for their use in asset management, until facilities managers understand their usefulness and are able to ue [sic] them with other tools, providing BIM files to them at the completion of construction is a waste. Our use of BIMs have not shown any change in construction cost or safety, but did increase the effort and cost to do BIM because of a learning curve. Additionally, the majority of our BIMs were produced by contract, which required review of all existing drawings and on-site verification visits to produce as-built facilities. This was very expensive work, and they are used only to produce 2-D plan sets and primarily as a space management tool.
- Everyone's concept of BIM is based on their perspective. All BIM are not created equal and will continue to be inconsistent until there is an effective national standard that addresses all phases of a facility, including concept, design, construction, and O&M.

3.11 Survey #2: Summary

Figure 12 shows the results of the summary question in this survey, which asked respondents which definition of BIM most closely matched their own. No respondents chose the answers "Don't Know" or "BIM is a general contractor's virtual approach to planning site logistics." Therefore, none of the responses were eliminated from the data pool. However it is significant that 55% of the respondents answered that "BIM is a tool for visualizing and coordinating AEC work and avoiding errors and omissions," when the NBIMS definition, "BIM is an open-standards based information repository for facilities' lifecycles," garnered only 20% of the respondents' answers. In fact, even more people (21%) chose to specify their own definition of BIM, showing that BIM is still "defining itself" within the context of the AECO industry. Free response definitions mostly answered that BIM represented "all of the above" answers or focused on the process, rather than the product. See Figure 13 and 14 for a complete list of these responses:

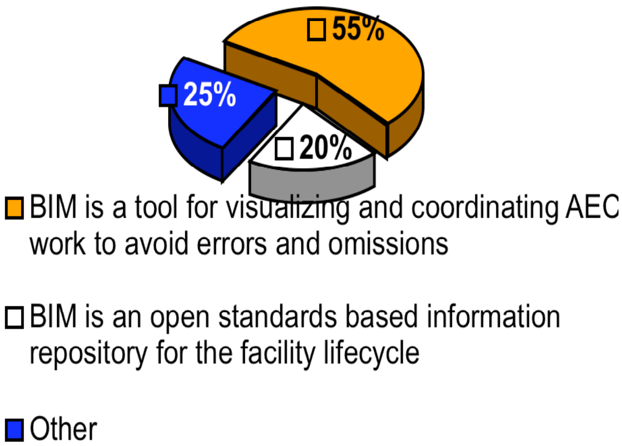
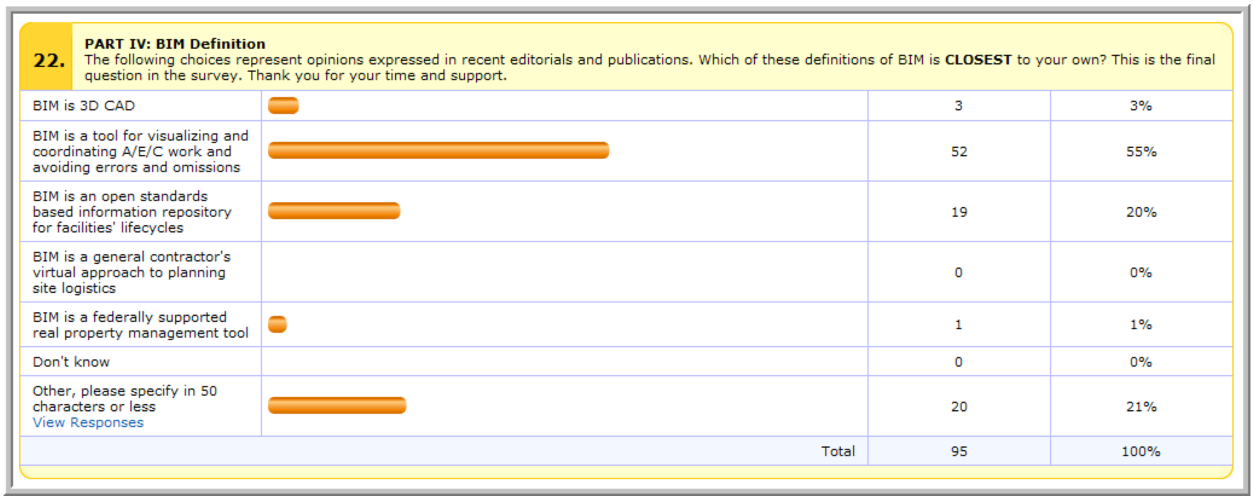


FIG.12: Survey #2: Answers to definition of BIM Question

#	Response
1	all of the above (except Don't know)
2	50 characters is not enough - see #16
3	is a diginal model with inbeded interactive info
4	BIM is a tool to build it before you build it
5	tool that facilitates des, const & fac. mgement
6	a tool for visualizing and coordinating A/E/C work
7	Modeling of building data quanativly & graphical
8	BIM is 3D parametric modeling and intelligent
9	the above are not quite right. BIM is a process...
10	BIM is an information repository for facilities li
11	data driven model allowing reuse of the model data
12	BIM isn't CAD, but it facilitates communication
13	BIM is a designer tool with no effect on construct
14	depository of data/information needed to build
15	Building data repository supporting all quarries
16	BIM is a model-based building representation.
17	BIM is a lot of "All of the above."
18	Methodology for AEC proces documentation
19	BIM integrates information needed by participants
20	Object-oriented 3D models

FIG. 13. Survey #2 BIM Definition Free Response Answers



22. PART IV: BIM Definition
The following choices represent opinions expressed in recent editorials and publications. Which of these definitions of BIM is **CLOSEST** to your own? This is the final question in the survey. Thank you for your time and support.

BIM is 3D CAD	3	3%
BIM is a tool for visualizing and coordinating A/E/C work and avoiding errors and omissions	52	55%
BIM is an open standards based information repository for facilities' lifecycles	19	20%
BIM is a general contractor's virtual approach to planning site logistics	0	0%
BIM is a federally supported real property management tool	1	1%
Don't know	0	0%
Other, please specify in 50 characters or less View Responses	20	21%
Total	95	100%

FIG. 14. Survey #2 screen capture of Summary question

In all, the primary differences between the Survey #1 and Survey #2 can be summarized in the following list:

- Slightly younger respondent pool
- Many more academics in the respondent pool
- Slightly LESS favorable overall towards BIM in Survey #2 (Specifically in Survey #2, there were 2-4 respondents who replied that BIM "extremely hindered" all KPIs in the construction phase. More investigation is required to determine if this outlier reflected valid opinions or was caused by confusion surrounding the survey instrument.)
- Opined that Cost is benefitted more by BIM in Survey #2
- Greater disagreement on the definition of BIM in Survey #2

3.12 Survey #3

Survey iteration #3 was issued on May 11, 2008 as conference attendees checked into the BIM4Builders™ event in Gainesville, Florida as discussed in Chapter 2, "Materials and Methods." Although the survey was very similar to the first two iterations, it was offered in hard copy format and consequently edited to one page for time and logistics constraints of the conference. The following information discusses the results of Survey #3 and concludes with a summary and comparison of the different trends noted from Surveys #1, 2, and 3.

3.13 Survey #3: Part I: "Basic Demographic Information"

Part I asked similar questions of respondents regarding gender, age, education, annual revenue, and organizational role. This information was later used to cross tabulate people's demographics with their responses. However, in order to garner the most information to form reliable trend data, the results of this final survey were analyzed as a subset of the compilation of all three surveys. Therefore, the following results will take into account data from all three surveys and will look for emerging trends from all of the data in its entirety. After including completed surveys from all three iterations, there was a very favorable "N" value of 202 completed surveys.

The results of the demographics of all 202 completed surveys showed that the most likely respondent was male, over 55 years old, held a graduate degree, and worked for a company with annual revenue under $100Million (Figure 15). The organizational roles of the respondents was evenly distributed across management, design, academic, and other fields.

Variable	Categories	Percentage Comparisons Between BIM Definition Categories & Survey Variables								
		1. BIM is an open standarsd based information repository for facilities' lifecycles		2. BIM is a tool for visualizing and coordinating A/E/C work and avoiding errors and omissions		3. Other		Total		
		N	%	N	%	N	%	N	%	% total
Gender	Male	54	30.5%	76	42.9%	47	26.6%	177	100.0%	87.62%
	Female	9	40.9%	9	40.9%	4	18.2%	22	100.0%	10.89%
Age	Under 35	12	24.5%	18	36.7%	19	38.8%	49	100.0%	24.26%
	35 to 54	35	33.3%	47	44.8%	23	21.9%	105	100.0%	51.98%
	55 & Older	16	34.8%	21	45.7%	9	19.6%	46	100.1%	22.77%
Education	Bachelor	12	24.0%	27	54.0%	11	22.0%	50	100.0%	24.75%
	Graduate	41	33.9%	46	38.0%	34	28.1%	121	100.0%	59.90%
	Other	9	33.3%	13	48.1%	5	18.5%	27	99.9%	13.37%
Revenue	Under $100m	36	40.0%	36	40.0%	18	20.0%	90	100.0%	44.55%
	$100m to $999.9m	5	15.6%	14	43.8%	13	40.6%	32	100.0%	15.84%
	$1b & over	10	30.3%	15	45.5%	8	24.2%	33	100.0%	16.34%
Role	Management	16	35.6%	17	37.8%	12	26.7%	45	100.1%	22.28%
	Design	20	40.0%	22	44.0%	8	16.0%	50	100.0%	24.75%
	Academic	7	17.9%	20	51.3%	12	30.8%	39	100.0%	19.31%
	Other	20	29.4%	28	41.2%	20	29.4%	68	100.0%	33.66%
Survey Group	Builders	9	15.5%	20	34.5%	29	50.0%	58	100.0%	28.71%
	NBIMS	35	70.0%	15	30.0%	0	0.0%	50	100.0%	24.75%
	At Large	19	20.2%	52	55.3%	23	24.5%	94	100.0%	46.53%
Total Survey Respondents		63	31.0%	87	42.9%	52	25.6%	202	100.0%	100.00%

FIG 15. Compilation of Demographic and BIM Definition Data from Survey #1, 2, and 3. (Note: Most frequent responses are highlighted in yellow).

3.14 Survey #3: Part II: "Ranking Key Performance Indicators"

Similarly, all three survey iterations' data was compiled regarding KPI ranking. There was a clear trend here with respondents answering in the positive (BIM improves the KPI) to negative (BIM inhibits the KPI) in identical order, which speaks to the validity of the data. As seen in Figure 16, the order that respondents ranked the KPIs from most to least favorable were:

- Quality, with 87.7% saying BIM improves this KPI
- Cost, with 83.7% saying BIM improves this KPI
- Schedule, with 82.8% saying BIM improves this KPI
- Productivity, with 74.9% saying BIM improves this KPI
- Safety, with only 53.7% saying BIM improves this KPI

•

Variable	Categories	Productivity				Schedule				Safety			
		Inhibits		Improves		Inhibits		Improves		Inhibits		Improves	
		N	%	N	%	N	%	N	%	N	%	N	%
	Male	47	26.6%	130	73.4%	31	17.5%	146	82.5%	83	46.9%	94	53.1%
Gender	Female	1	4.5%	21	95.5%	1	4.5%	21	95.5%	7	31.8%	15	68.2%
	Under 35	9	18.4%	40	81.6%	7	14.3%	42	85.7%	20	40.8%	29	59.2%
	35 to 54	26	24.8%	79	75.2%	15	14.3%	90	85.7%	44	41.9%	61	58.1%
Age	55 & Older	13	28.3%	33	71.7%	10	21.7%	36	78.3%	27	58.7%	19	41.3%
	Bachelor	11	22.0%	39	78.0%	6	12.0%	44	88.0%	26	52.0%	24	48.0%
	Graduate	29	24.0%	92	76.0%	21	17.4%	100	82.6%	51	42.1%	70	57.9%
Education	Other	7	25.9%	20	74.1%	4	14.8%	23	85.2%	13	48.1%	14	51.9%
	Under $100m	20	22.2%	70	77.8%	13	14.4%	77	85.6%	40	44.4%	50	55.6%
	$100m to $999.9m	8	25.0%	24	75.0%	6	18.8%	26	81.3%	18	56.3%	14	43.8%
Revenue	$1b & over	5	15.2%	28	84.8%	4	12.1%	29	87.9%	16	48.5%	17	51.5%
	Management	9	20.0%	36	80.0%	9	20.0%	36	80.0%	22	48.9%	23	51.1%
	Design	14	28.0%	36	72.0%	10	20.0%	40	80.0%	26	52.0%	24	48.0%
	Academic	14	35.9%	25	64.1%	6	15.4%	33	84.6%	14	35.9%	25	64.1%
Role	Other	13	19.1%	55	80.9%	9	13.2%	59	86.8%	31	45.6%	37	54.4%
	Builders	14	24.1%	44	75.9%	9	15.5%	49	84.5%	21	36.2%	37	63.8%
	NBIMS	7	14.0%	43	86.0%	6	12.0%	44	88.0%	23	46.0%	27	54.0%
Survey Group	At Large	29	30.9%	65	69.1%	19	20.2%	75	79.8%	49	52.1%	45	47.9%
Total Survey Respondents		**50**	**24.6%**	**152**	**74.9%**	**34**	**16.8%**	**168**	**83.2%**	**93**	**46.0%**	**109**	**54.0%**
			2		**5**		**3**		**3**		**1**		**6**

Variable	Categories	Cost				Quality				Unit Cost			
		Inhibits		Improves		Inhibits		Improves		Inhibits		Improves	
		N	%	N	%	N	%	N	%	N	%	N	%
	Male	26	14.7%	151	85.3%	22	12.4%	155	87.6%	38	21.5%	139	78.5%
Gender	Female	4	18.2%	18	81.8%	0	0.0%	22	100.0%	3	13.6%	19	86.4%
	Under 35	8	16.3%	41	83.7%	3	6.1%	46	93.9%	7	14.3%	42	85.7%
	35 to 54	11	10.5%	94	89.5%	9	8.6%	96	91.4%	22	21.0%	83	79.0%
Age	55 & Older	11	23.9%	35	76.1%	10	21.7%	36	78.3%	12	26.1%	34	73.9%
	Bachelor	6	12.0%	44	88.0%	3	6.0%	47	94.0%	8	16.0%	42	84.0%
	Graduate	20	16.5%	101	83.5%	15	12.4%	106	87.6%	26	21.5%	95	78.5%
Education	Other	3	11.1%	24	88.9%	3	11.1%	24	88.9%	6	22.2%	21	77.8%
	Under $100m	15	16.7%	75	83.3%	10	11.1%	80	88.9%	22	24.4%	68	75.6%
	$100m to $999.9m	4	12.5%	28	87.5%	3	9.4%	29	90.6%	5	15.6%	27	84.4%
Revenue	$1b & over	3	9.1%	30	90.9%	1	3.0%	32	97.0%	4	12.1%	29	87.9%
	Management	7	15.6%	38	84.4%	5	11.1%	40	88.9%	11	24.4%	34	75.6%
	Design	12	24.0%	38	76.0%	7	14.0%	43	86.0%	14	28.0%	36	72.0%
	Academic	8	20.5%	31	79.5%	9	23.1%	30	76.9%	8	20.5%	31	79.5%
Role	Other	5	7.4%	63	92.6%	3	4.4%	65	95.6%	10	14.7%	58	85.3%
	Builders	6	10.3%	52	89.7%	5	8.6%	53	91.4%	9	15.5%	49	84.5%
	NBIMS	10	20.0%	40	80.0%	3	6.0%	47	94.0%	10	20.0%	40	80.0%
Survey Group	At Large	16	17.0%	78	83.0%	16	17.0%	78	83.0%	24	25.5%	70	74.5%
Total Survey Respondents		**32**	**15.8%**	**170**	**84.2%**	**24**	**11.9%**	**178**	**88.1%**	**43**	**21.3%**	**159**	**78.7%**
			4		**2**		**6**		**1**		**2**		**4**

FIG 16. Compilation of KPI Ranking Data from Survey #1, 2, and 3. (Note: Negative or inhibiting factors are indicated in gray and positive or improving values are indicated in yellow with the rank (1-6)below each in corresponding colors for inhibiting or improving)

3.15 Survey #3: Part III: "BIM Definition"

In Part III, respondents were asked to choose from a list of BIM definitions and pick the definition that was closest to their own. Of most interest was whether a respondent's organizational role affected their response and if there was a trend present where one organizational role chose a single definition by a large margin compared to another. Looking at Figure 17 it is clear that the answers are fairly well distributed, but that the most common definition answer for all four categories (management, design, academic, and other) of career fields' most frequent choice was related to BIM as a "tool for visualizing and coordinating A/E/C work and avoiding errors and omissions." This differs from the NBIMS definition of BIM as an "open standard-based information repository for facilities' lifecycles," which was the second most frequently chosen definition overall. However, with the high rate of selection of "Other" or write-in definitions for BIM, it is clear that the industry has not reached a consensus definition for the true essence of BIM.

Variable	Categories	Percentage Comparisons Between BIM Definition Categories & Survey Variables								
		1. BIM is an open standarsd based information repository for facilities' lifecycles		2. BIM is a tool for visualizing and coordinating A/E/C work and avoiding errors and omissions		3. Other		Total		
		N	%	N	%	N	%	N	%	% total
Gender	Male	54	30.5%	76	42.9%	47	26.6%	177	100.0%	87.62%
	Female	9	40.9%	9	40.9%	4	18.2%	22	100.0%	10.89%
Age	Under 35	12	24.5%	18	36.7%	19	38.8%	49	100.0%	24.26%
	35 to 54	35	33.3%	47	44.8%	23	21.9%	105	100.0%	51.98%
	55 & Older	16	34.8%	21	45.7%	9	19.6%	46	100.1%	22.77%
Education	Bachelor	12	24.0%	27	54.0%	11	22.0%	50	100.0%	24.75%
	Graduate	41	33.9%	46	38.0%	34	28.1%	121	100.0%	59.90%
	Other	9	33.3%	13	48.1%	5	18.5%	27	99.9%	13.37%
Revenue	Under $100m	36	40.0%	36	40.0%	18	20.0%	90	100.0%	44.55%
	$100m to $999.9m	5	15.6%	14	43.8%	13	40.6%	32	100.0%	15.84%
	$1b & over	10	30.3%	15	45.5%	8	24.2%	33	100.0%	16.34%
Role	Management	16	35.6%	17	37.8%	12	26.7%	45	100.1%	22.28%
	Design	20	40.0%	22	44.0%	8	16.0%	50	100.0%	24.75%
	Academic	7	17.9%	20	51.3%	12	30.8%	39	100.0%	19.31%
	Other	20	29.4%	28	41.2%	20	29.4%	68	100.0%	33.66%
Survey Group	Builders	9	15.5%	20	34.5%	29	50.0%	58	100.0%	28.71%
	NBIMS	35	70.0%	15	30.0%	0	0.0%	50	100.0%	24.75%
	At Large	19	20.2%	52	55.3%	23	24.5%	94	100.0%	46.53%
Total Survey Respondents		63	31.0%	87	42.9%	52	25.6%	202	100.0%	100.00%

FIG 17. Compilation of BIM Definition Data from Survey #1, 2, and 3. (Note: Focus on whether organizational role affected definition selection. Most frequent responses are highlighted/yellow).

The authors hypothesized before the research began that there might be significant trends in the responses due to the demographics of gender, age, education, revenue, and role. Specifically, the interest was whether architects would differ in their responses about BIM as compared to contractors. As noted by Zuppa et al (2009) in a parallel project, the most notable trend was that architects were less favourable about BIM's impact on project cost than contractors; contradicting the researchers' notional hypothesis. However, there were no other definitive trends tied to demographics, making the responses appear homogenously untied to survey demographics, with equal levels of favourability for the KPIs across the survey groups.

4. FUTURE RESEARCH: PHASES II-IV, ORIENTATION, DECISION, AND ACTION

As discussed earlier in the paper, future research is already planned for this topic. Phase II will include building on the data garnered in Phase I from the three surveys and will test the primary research hypothesis and possible follow-on hypotheses by conducting embedded research on federal construction projects. The rationale behind this research is that federal entities have provided testbeds for implementing new ideas and new technologies in the past in the field of construction. While federal work has not always led the way on implementing new technological initiatives, recent strides in the Department of Defense, and United States Coast Guard (USCG) demonstrate that they are exceeding typical industry rate of BIM adoption. However, despite recent promulgation of BIM procedures in documents like the GSA BIM Guide and USACE BIM Roadmap, there is little documented evidence on BIM's impact on the construction phase of the facility lifecycle. Therefore, future research proposes to evaluate BIM effects on federal construction projects according to the KPI metrics listed in the survey. The specific locations where the embedded research will be conducted due to their considerable experience at managing projects through BIM methodologies are:

- U.S. Army Corps of Engineers (USACE), Seattle District
- U.S. Army Corps of Engineers (USACE), Louisville District
- U.S. Coast Guard Naval Engineering Support Unit (NESU), Charleston, South Carolina
- U.S. Central Command (US CENTCOM), MacDill Air Force Base, Florida

After assessing and analyzing the data and comparing it to longitudinal data from construction projects similar in size and scope to those studied in Phase II, Phase III will include revisions and changes to the data collection model. In addition, a wider cross section of construction projects will be studied including commercial and industrial projects. Phase III entails comparing the data collected in Phases I and II to longitudinal data. This would be accomplished by using data collected and maintained by research bodies such as the USACE Civil Engineering Research Laboratory (CERL) or the Construction Industry Institute (CII) and comparing their baseline construction data to BIM case study data from Phase II. Lastly, the data will be analyzed to determine if trends exist that demonstrate significant differences in productivity or performance according to the construction KPI metrics.

In Phase IV, after the bulk of the data is collected, the lessons learned from conducting the embedded research will be applied to a further revised methodology recommended for future case study data collection. Additionally, noted trends will be discussed in the research analysis portion of this document and recommended for consumption and implementation by federal entities and construction firms for recommended best business practices that yield the most productivity improvements. In this way, the research will *act* on the lessons learned, fulfilling the OODA Loop. Possible additional case study data will include trend analysis on commercial and industrial projects and comparison to the federal construction projects case study data

5. CONCLUSION

As the results suggest, the respondents felt that BIM is most likely to positively impact the construction KPIs of quality and on time completion. More research needs to be conducted in order to corroborate the "BIM-favorable" results here. While the respondents are certainly knowledgeable about BIM because of the demographics shown herein and membership on the NBIMS listerv, Survey #1 results need to be taken as a part of the greater whole of all the surveys' and realize that all respondents filling out these surveys have the propensity for being more favorable to BIM than the typical industry professional, due to their interest in the field and willingness to take time to fill out the survey. Additionally, quantifying the impact of a BIM approach through real world construction case studies will offer a more compelling argument for BIM adoption by AEC firms than simply the perceptions described here.

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