

EVALUATING THE IMPACT OF
BUILDING INFORMATION MODELING (BIM)
ON CONSTRUCTION

By
PATRICK C. SUERMANN

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“You say it best, when you say nothing at all.”

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LIST OF ABBREVIATIONS

Acronym	Full Term
3-D	Three Dimensions
4-D	Three Dimensions + Time
5-D	Four Dimensions + Money
A/E	Architect/Engineer
AECO	Architecture, Engineering, Construction, and Ownership
AFB	Air Force Base
AFCEE	Air Force Center for Engineering and the Environment (formerly Air Force Center for Environmental Excellence)
AFIT	Air Force Institute of Technology
AGC	Associated General Contractors
AIA	American Institute of Architects
AIM	Agile Installation Management (USAF)
AISC	American Institute of Steel Construction
ANSI/BOMA	American National Standards Institute/Building Owners and Managers Association
ASC	Associated Schools of Construction
AtoN	Aids to Navigation (USCG)
BEP	Business Enterprise Priority
BIM	Building Information Modeling
BOD	Beneficial Occupancy Date
BOMA	See ANSI/BOMA
BPR	Business Process Reengineering
BRAC	Base Realignment and Closure
CAD	Computer Automated/Assisted Design
CADD	Computer Automated Drafting and Design
CAMP	Capital Asset Management Portal (USCG)
CAMP	Compliance Assessment Management Program (USAF)
CCG	Consolidated Command Guidance
CD	Construction Documents (or Drawings)
CERL	Construction Engineering Research Laboratory
CES	Civil Engineer Squadron
CFO	Chief Financial Officer
CIFE	Center for Integrated Facility Engineering
CII	Construction Industry Institute
CMAA	Construction Management Association of America
COBIE	Construction-Operations Building Information Exchange
CONUS	Continental United States
COP	Community of Practice
COS	Center of Standardization
CSI	Construction Specifications Institute
CURT	Construction Users Roundtable
CWE	Current Working Estimate
DoD	Department of Defense

DP	Dynamic Prototype
ELA	Enterprise Licensing Agreement
ER	Engineering Regulation or Emergency Response
ERDC	Engineering Research and Development Center (USACE)
ERP	Enterprise Resource Planning
FFC	Federal Facilities Council (NAS)
FIC	Facility Information Council
FM	Facility Management (or Maintenance)
FY	Fiscal Year
GIS	Geospatial (or Geographical) Information Systems
GNP	Gross National Product
GSA	General Services Administration
GWOT	Global War on Terror
HAF/GIO	Headquarters Air Force/GeoIntegration Office
I&E	Installations & Environment
IAI	International Alliance for Interoperability
I-CMM	NBIMS Interactive Capability Maturity Model
IDIQ	Indefinite Delivery, Indefinite Quantity
IDM	Information Delivery Manual
IFC	Industry Foundation Classes
IFD	International Framework for Dictionaries
IM	Information Management
IOC	Initial Operational Capability
ISO/PAS	International Organization for Standardization Publicly Available Specification
IT	Information Technology
JICCEN	Joint Intelligence Center, Central Command
KML	Keyhole Markup Language
KPI	Key Performance Indicator
LBL	Lawrence Berkeley National Laboratory
LiDAR	Light Detection and Ranging
MCAR	Military Construction Army Reserve
MEP	Mechanical, Electrical, and Plumbing
MILCON	Military Construction
MP	Military Program
NAS	National Academy of Science or Naval Air Station
NASA	National Aeronautics and Space Administration
NAVFAC	Naval Facilities Engineering Command
NBIMS	National BIM Standard
NIBS	National Institute of Building Sciences
NIST	National Institute of Standards and Technology
O&M	Operations and Maintenance
OCA	Office of the Chief Architect (GSA)
ODUSD I&E	Office of the Deputy Undersecretary of Defense, Installations & Environment
OGC	Open Geospatial Consortium

OMB	Office of Management and Budget
OODA	Observe, Orient, Decide, Act
OPS	Onuma Planning System
P2	See PMBP or PM-AIS (USACE)
PA	Programmed Amount
PACAF	Pacific Air Forces (USAF)
PBS	Public Building Services (GSA)
PD	Position Description
PM-AIS	Project Management Automated Information System (USACE)
PMBP	Program and Project Management Business Process (USACE)
POM	Program Objective Memorandum
PY	Program Year
RA	Registered Architect
RMS	Resident Management System
ROI	Return on Investment
RP & ILM	Real Property & Installations Lifecycle Management
RPA	Real Property Accountability
RPAR	Real Property Acceptance Requirements
RPIR	Real Property Inventory Requirements
RTA	Ready to Advertise
SAME	Society of American Military Engineers
SCC	Sector Command Center (USCG)
SDD	Sustainable Design and Development
SDSFIE	Spatial Data Standards for Facilities, Infrastructure, and Environment
SF	Square Feet
TAP	Technology in Architectural Practice (AIA)
TGMP	Target Guaranteed Maximum Price
UFIRB	University of Florida Institutional Review Board
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USCENTCOM	United States Central Command
USCG	United States Coast Guard
USN	United States Navy
VDC	Virtual Design and Construction
VE	Value Engineering
WBDG	Whole Building Design Guide
WES	Waterways Experiment Station
WHECs	High Endurance Cutter (USCG)
XML	Extensible Markup Language

Abstract of Dissertation Presented to the Graduate School
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CONSTRUCTION

By

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This research assessed the impact of Building Information Modeling (BIM) implementation on construction projects according to six primary key performance indicators (KPIs) commonly used in the construction industry as accepted metrics for assessing project 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. In the first research phase, data was collected through a survey instrument intended to assess practitioners' perceptions about the impact of BIM on the six KPIs. Three iterations of the survey were conducted and it was determined that the highest ranking KPIs in order of most favorable responses were quality control, on time completion, and units per man hour. The second tier of favorable responses included overall cost and cost per unit. In this second phase of research, projects were evaluated through interviews and case studies on-site at two U.S. Army Corps of Engineer (USACE) Districts in Seattle, WA and Louisville, KY to determine their KPIs through embedded research. In the third phase of research, quantitative results were gathered from the USACE construction productivity database interface: the Resident Management System (RMS). Subsequently the pilot projects were compared to a control dataset consisting of similar facilities across the USACE using traditional approaches through benchmarks aligned

with metrics similar to the KPIs used in the surveys. Both BIM-based projects demonstrated statistically significant (favorable and unfavorable) performance differences when compared to the control dataset. Finally, an evaluation tool was developed and validated for implementing a construction productivity measurement system to supplement existing procedures suitable for evaluating construction productivity differences on BIM-based projects.

CHAPTER 1 INTRODUCTION

Background

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 (NIST 2004). Since this report, many have dubbed Building Information Modeling (BIM), an emerging technological information management process and product, as the answer to this problem. From the 2007 publication of the National BIM Standard (NBIMS), a BIM (i.e. a single Building Information Model) is defined as “a digital representation of physical and functional characteristics of a facility” (NBIMS 2007). 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 information technology (IT) architect for Chief Architect of the DoD Business Transformation Agency’s modernization effort for installations and environmental issues with the Department of Defense (DoD), Dana K. “Deke” Smith, FAIA, “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”(Smith 2006).

Purpose of the Study

Some potential stakeholders in BIM reside on opposite ends of a spectrum. On one side of the spectrum are those whose pervasive cynicism perpetuates a self fulfilling prophecy that BIM is just a lot of technological smoke and mirrors. These individuals feel that BIM is a trend that will pass before it ever aids the Architecture, Engineering, Construction and Operation (AECO)

industry. At the other end of the spectrum, some individuals believe that BIM is the panacea for all things ailing the AECO community. Most people fall somewhere closer to the middle of this spectrum. However, there is one thing that all people on this metaphorical BIM spectrum need in order to justify their positions, and that is empirical data. The implementation of BIM is progressing at a much faster rate than the amount of empirical data supporting its implementation. In turn, industry is not optimizing the pace of the implementation of BIM. Without data, few people can justify their adoption of BIM and those at the forefront of BIM technology may be moving in a direction that does not necessarily lead to success. Research is needed to substantiate investment in a new approach that will actually yield a return on investment and result in solutions to current problems.

Problem Statement

This research evaluated the impacts of BIM on federal construction projects according to commonly accepted metrics via qualitative means such as interviews and surveys followed by quantitative means such as analysis of case study data. The following research questions were explored:

- Does a Building Information Modeling (BIM) approach in the design phase have an impact on the construction phase? If so, how does BIM affect construction?
- What types of information can be leveraged in a BIM approach and to what degree?
- To what degree does BIM affect construction?
- How do owners determine whether investments in improved technology (BIM) result in measureable benefits?

Rationale and Theoretical Framework

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. Poised on

the precipice of a major cultural and technological shift to a BIM-based approach, proper research should be accomplished to ensure that the BIM implementation can show demonstrable positive impacts on traditionally accepted construction metrics. Therefore, this research will evaluate observed perceptions in the industry regarding BIM's impact on construction, which will subsequently orient specific research on pilot BIM projects according to prevailing industry perceptions. Additionally, quantitative construction productivity data will be evaluated for statistically significant differences on BIM-based projects compared to traditional projects in a control population of similar scope, size, and type. Finally, a tool will be proposed and validated for evaluating future project data for productivity differences.

Scope and Limitations

The results of this study will be limited to federal construction projects and will not include commercial, residential, or industrial construction, unless otherwise noted. This dissertation will include a literature review and data from across the industry, with a narrowed focus on researching real-world construction projects from one of the largest construction owners in the world, the U.S. Army Corps of Engineers with respect to their BIM implementation will be accomplished.

CHAPTER 2 LITERATURE REVIEW

Introduction

Innovation and Technology in the United States Federal Government

In the mid-twentieth century, the federal government was one of the primary sources of innovation in American industry. This model worked well because of the United States Federal government's massive financial resources and a myriad of industries associated with its daily operations. This was especially true in the engineering community, as demonstrated by the well known examples of the Manhattan Project in the 1940s and subsequent innovations by NASA in the 1960s. Examples germane to the construction industry include the Department of Defense's (DoD's) adoption of Value Engineering (VE) initiatives as early as 1954 in the Navy's Bureau of Ships and its widespread construction adoption by the U.S. Army Corps of Engineers (USACE) in 1965. This carried over to Navy Facilities Engineering Command (NAVFAC) and the Public Building Service (PBS) of the U.S. General Services Administration (GSA) with their widespread adoption of value engineering in the early 1970s. More recently, the USACE surmounted the challenge of assuring quality on multi-million dollar construction (MILCON) projects by establishing Engineering Regulation (ER) 1110-1-12, "Engineering and Design – Quality Management" promulgating the importance of ensuring quality in construction. In turn, this 1993 regulation and standard operating procedure served as a springboard for the United States' move towards managing quality in construction industry-wide.

However, as early as the late 1980s and into the "tech-storm" of the 1990s, the federal government's bureaucratic methods have often hindered them from serving as the pathfinders of new roads to transformational or innovative excellence. Just as the DoD could be perceived as a beacon of innovation in the Cold War Era, their post Cold War resistance to adopting or lack of

successful adoption of Enterprise Resource Planning (ERP) via Geographical Information systems (GIS) showed a metaphorical “chink in their armor.” The DoD did not achieve significant success in implementing tactical level GIS until Colonel Brian Cullis championed the “GeoBase” initiative. Through this program, the U.S. Air Force achieved a complete cultural shift from inaccurate, CAD-based installation mapping to fully geo- and ortho-rectified GIS installation maps in less than four years, a relative miracle in terms of enterprise-wide business change in the DoD. However, considering that GIS maps have been mainstream products since 1969 and have been used extensively since the improvement of personal computers in the 1990s, the Department of Defense lagged behind the rest of the industry in implementing the technology (Cullis 2005).

On the threshold of another cultural shift, the DoD again faces a unique opportunity to make an equally significant contribution towards standardizing the way industry designs, constructs, and maintains its facilities. This time the DoD is seizing the opportunity to once again assert its ability to lead the industry. The idea is Building Information Modeling (BIM), or the attempt to “transform the building supply chain through open and interoperable information exchange” (NIBS 2007). The question remains however, does BIM really have any effect on the indicators which determine the success or failure of a construction project?

International View of BIM: The United Kingdom

Rob Howard makes a tongue-in-cheek remark that actually summarizes many technocynics’ views when he says, “The conspiracy between hardware and software suppliers to create demand for each others’ products forces users to invest frequently. More change results from the opportunities offered by new technologies than from feedback on users’ needs” (Howard 1998). Howard goes on to evaluate construction IT and predicting future, worthy developments. In a utilitarian way, Howard defines “successful” technology not by some nebulous scoring system,

but merely by what is most embraced by the greatest number of people. Products discussed include computer automated drafting (CAD), communication through various formats, and spreadsheets. Conversely, Howard foreshadows the lack of success when it comes to BIM by saying, “as the number of available CAD packages grew in the late 1970s and 1980s, the early ambitions for complete 3-D modeling and automated design were put aside and drawing production became the most realistic goal of architectural, and later, engineering consultants” (Howard 1998).

In his conclusion, Howard describes the necessary conditions for wide-spread market success of new construction computing technology and focuses nearly exclusively on the factors needed for successful, widespread use of interoperable data through BIM. He also addresses the culturally based need for cooperation on consensus-based standards in the following excerpt, “national governments will still need to provide support for representing their interests and to ensure that commercially led standards, developed internationally, meet a common need” (Howard 1998). This is exactly the mission of the National BIM Standard (NBIMS) committee.

In the years since Howard’s book, the renewed and nearly realized “ambitions for complete 3-D modeling and automated design” is threefold. First, as firms continue to improve, the proverbial “bar” has been raised for winning project solicitations, and firms need ever-better designs, analysis of their designs, and visualization tools to impress owners. Also, as facilities become more complex and schedules tighter, detecting errors through modeling is becoming a requirement, rather than a luxury. Third, being able to attach attributes to “smart,” queryable, object-oriented models allows users to ensure that constructability and sustainability concerns are met using the best data available. Howard summarizes the need and potential success for BIM when he states, “computer systems are seen currently as discrete aids to specific processes

but, with communications now sufficiently powerful, and with a growing base of electronic data, they will soon be seen as part of an overall process – the transfer of data from the mind of the client, through the computers of the project team, to the control and management of the building” (Howard 1998).

In another recent article, Lee (2005) indicated that it is evident that the benefits of BIM are not only valued by those in the United States or in the maintenance phase of the construction lifecycle, for that matter. Unlike Bazjanac’s (2004) work which refers to the lifecycle benefits of BIM, Lee is primarily concerned with the benefits of constructability, communication, and coordination during design and construction while trying to integrate and de-conflict the highly intricate systems indicative of today’s modern facilities. One important item to note is that Lee does not describe her research as BIM. Since the term “BIM” was originally coined by the Autodesk Company (Laiserin 2002), and most English firms use Graphisoft products instead of Autodesk, Lee’s paper refers to “n-D modeling” as an extension of building information modeling that is based off of intelligent objects rather than points, lines, and polygons. However, in references to Lee’s paper, this study will refer to “BIM” and “n-D modeling” synonymously.

The “n” in n-D CAD refers to the fact that there are typically “n” dimensions used for planning. Traditional projects in the past used 2D plan and elevation views to communicate design intent. Currently, many design firms are moving towards 3-D visualization programs that provide owners and builders the opportunity to “feel” what their project may look like. Finally, many in the construction industry are interested in 4-D products: those that show a 3-D model built over time, the fourth dimension. Through 4-D products, Lee hypothesized that designers and construction contractors will be more easily able to identify possible mistakes and conflicts

at the early stage of a construction project, and enable stakeholders to accurately predict the construction schedule (Lee 2005). With the term, “n-D modeling,” Lee proposes an idea where 4-D products are enhanced with further integration of multiple design dimensions into a “holistic model,” in essence – BIM. Specifically, Lee’s research set about to “define, develop, and validate the proposition n-D modeling project over a period of 18 months and included an academic research team workshop, a national and an international workshop (Lee 2005).”

During Lee’s workshops, the team determined one of the most difficult obstacles to BIM was interoperability. To answer the problem, Lee (and Bazjanac separately) espouse using the Industry Foundation Classes (IFCs) established by the International Alliance for Interoperability (IAI). Since these standards are the only one to receive the designation of “International Standards” in the form of ISO/PAS 16739, (Bazjanac 2004), they would seem to hold the most promise for creating a BIM that could be accepted by software developers and users alike. However, Lee’s research never succeeded in using these to create a BIM interface or a prescribed list of required data for an initially operationally capable (IOC) BIM. Instead, the research describes difficulties achieving consensus on specific design elements in Lee’s proposed case study. Specifically, the initial panel of academic, industry professionals, and clients could not agree on the window selection for their specific case study project of a research office. “For instance, from a crime prevention perspective, windows should be small, open inwards and positioned near the ceiling to reduce intruder access whereas from an access perspective, windows should be large, glare-free and positioned lower to enable a wide range of users to operate it” (Lee 2005). While Lee’s outcome was not atypical of a normal design or construction project, the research can be criticized for not accomplishing its objective due to being “short circuited” by competing design concerns or individual preferences.

BIM Applications and Research

BIM's increased presence in the marketplace has fueled a greater interest for research into new BIM technology, as well as studies regarding its level of market penetration and benefits in relation to ROI. Some of the leading research bodies and surveys are discussed here.

As discussed earlier, the desired approach of choice for success in making facility data as rich and robust as map data is leveraging the capabilities of Building Information Modeling (BIM).

Stanford's Center for Integrated Facility Engineering (CIFE)

In a landmark study started in 2006, Kunz and Fischer (2007) from Stanford University's Center for Integrated Facility Engineering (CIFE) studied virtual design and construction (VDC) and concluded that ". . . VDC is being used and significantly growing. As this growth proceeds and advances, users become more proficient they are more likely to perceive value and thus make organizational and strategic shifts in their operations." Later they noted that "advanced users report [increased efficiency] and indicate an important business opportunity for those who can provide VDC-based services early on. Owners, in particular, represent a client base largely unaware of the potential benefits that VDC provides" (Kunz and Fischer 2007). However, in addition to investigating reasons to adopt VDC or BIM, CIFE also investigated why firms are *not* using VDC. Figure 2-1 shows that the majority of owners and builders indicated that "the lack of need" or "lack of owner request" are the leading reasons for not using VDC on construction projects. Furthermore, of the projects using VDC, owners are nearly twice as likely to be non-users as the other parties to the design and construction process (See Figure 2-1). Following "lack of owner request" as the most often choice from respondents, CIFE's survey showed that the "near-majority of all other parties to the process cite need and owner request as the leading reason" (Kunz and Fischer 2007). It is also important to note that the comments associated with

the “other” response reveal that that many “non-user” respondents are in the process of starting a pilot project now, or “did not have access to a designer or contractor with enough VDC experience to risk a first attempt” (Kunz and Fischer 2007). This data suggests that most owners are unaware of the benefits that VDC can afford.

But what are the benefits of VDC or BIM? The CIFE survey showed that the majority of the responding firms were focused on the benefits of improved visualization (Figure 2-2).

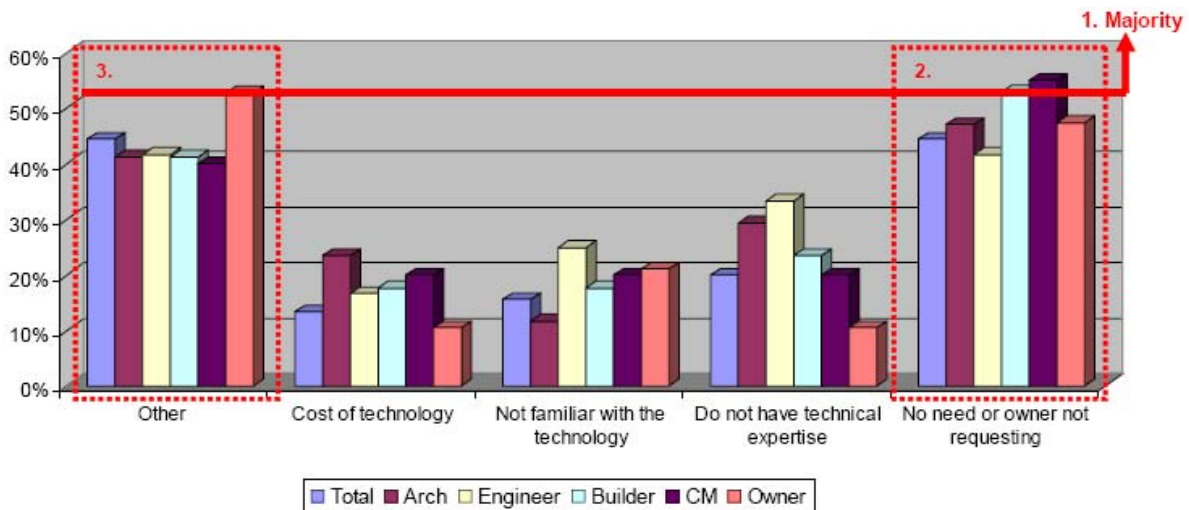


Figure 2-1. CIFE Survey Results: Reasons for not using VDC (Source: Kunz and Fischer 2007).

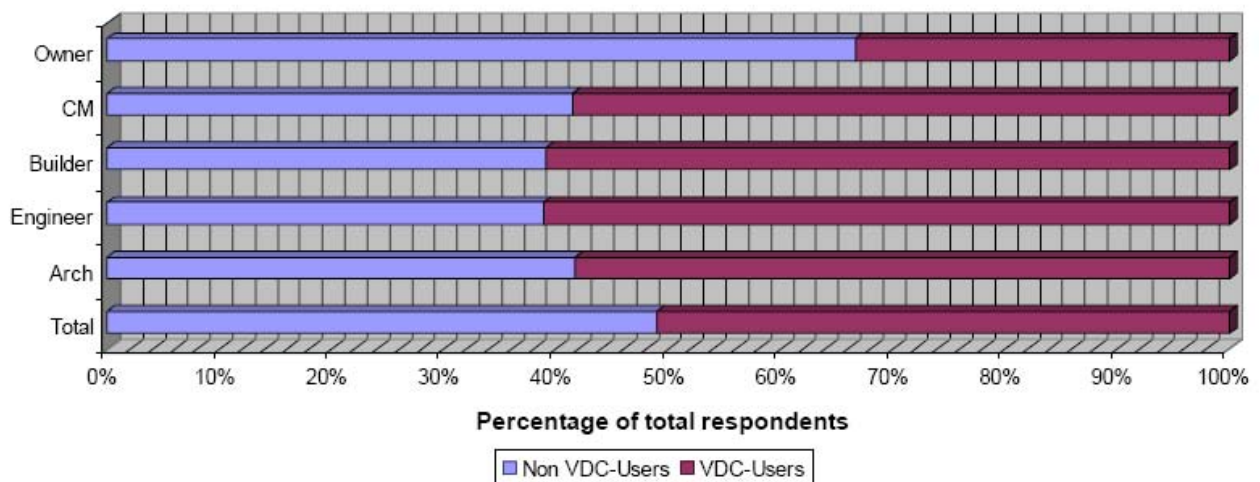


Figure 2-2. CIFE VDC Survey Results: Respondents not using VDC on projects (Source: Kunz and Fischer 2007).

Regarding non-users, owners were nearly twice as likely to be non-users than the other stakeholders in the design and construction process. Nearly 2/3 of the specialties respondents report using VDC on at least one project (Kunz and Fischer 2007). In the future, the CIFE survey offers evidence of short range and long range growth opportunities for VDC or BIM. When asked about which VDC phases the respondents had made significant progress in, the responses show that BIM implementation was much more mature in 2007 than in 2006 in the areas of supporting construction documents and supporting conceptual design (See Figure 2-3). The responses show that, while there is a wide range of sophistication in use of VDC, there is a clear division between use of visualization methods and more sophisticated analytical methods. With the majority of respondents as the dividing line between levels of sophistication, the majority of respondents used visualization activities such as clash detection, design presentation, and space planning. Conversely, less than the majority of respondents report being engaged in leveraging VDC data for downstream processes such as analytical methods like cost estimation or energy analysis (Kunz and Fischer 2007).

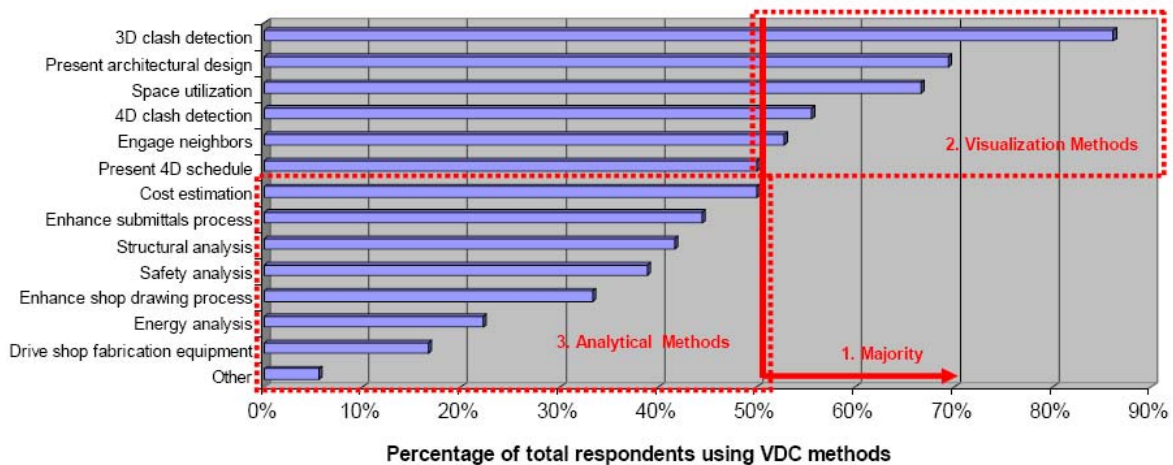


Figure 2-3. CIFE VDC Survey Results: “Business Purposes for VDC at Individual Organizations” (Source: Kunz and Fischer 2007)

Still noted, but less than the majority of respondents, cited benefits that fell into the “analytical methods” category with tasks such as cost estimating, structural analysis, and energy analysis. This data point suggests that VDC is primarily focused on benefits to architects, not engineers, constructors, owners, or operators; which may suggest why most owners do not request VDC or BIM services on their construction projects. Additionally, the survey sought to capture the perceived value VDC offers to practitioners of the AECO industry. Of the four choices, respondents said that architects received the highest perceived value from VDC or BIM, followed in order by owners, general contractors, with the least perceived value for subcontractors (See Figure 2-4). The majority of construction stakeholders reported seeing qualitative value from using VDC. Regardless of organizational role, all respondents saw the primary beneficiaries of VDC as first, Architects, and then Owners close behind, but with the least value being enjoyed by Subcontractors. This data suggests that those who use VDC consistently see value for themselves and others in the process. However, CIFE’s individual interviews confirm the survey data but contrarily indicated that subcontractors may actually receive the most direct financial benefit (Kunz and Fischer 2007).

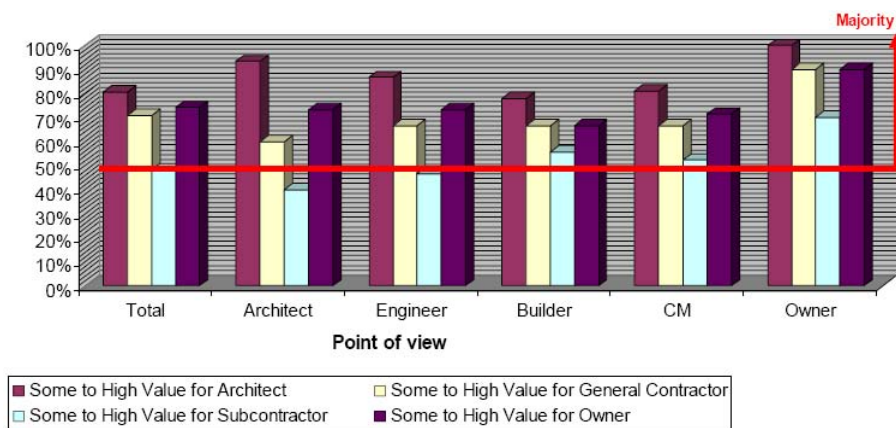


Figure 2-4. CIFE VDC Survey Results: “Perceived value to four parties from different points of view” (Source: Kunz and Fischer 2007)

Areas that remained nearly the same as in 2006 were total respondents using VDC methods supporting field construction management and supporting operations and maintenance (O&M.) The only phase that actually had fewer responses in 2007 than in 2006 was using VDC in the pre-project planning phase. Perhaps this could represent a shift in the paradigm of the respondent’s focus on the informational aspects of VDC or BIM and less on considering VDC-compliant while simply creating 3-D massing models or other various virtual methods used in this phase (Figure 2-5). The respondents report dramatic progress across nearly all of the AEC process. Specifically, VDC in the design phase progress grew by 25%-35%. Also, supporting the creation of construction documents more than doubled from 2006-2007, indicating a new level of emerging sophistication by contractors. There were only “nominal gains in support” of O&M. Finally, it is notable that VDC use on pre-project planning decreased. The data suggest that designers increased their VDC use more quickly than construction, O&M or pre-project planning (Kunz and Fischer 2007).

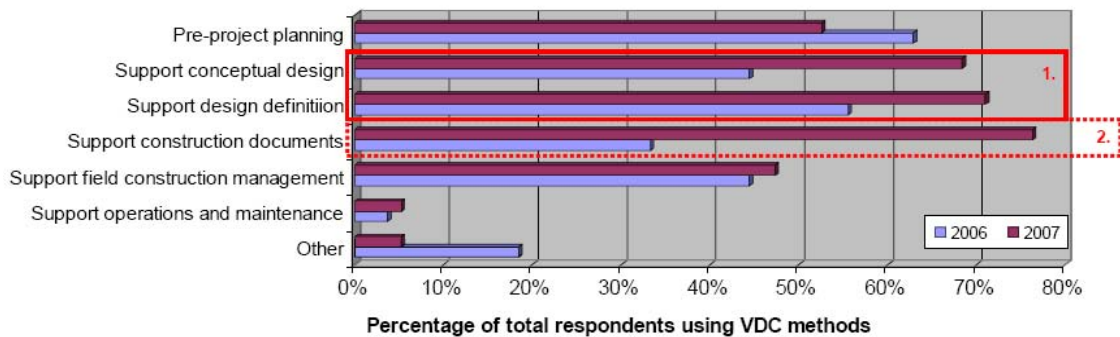


Figure 2-5. CIFE VDC Survey Results: “In which project phases did you make significant progress?” (Source: Kunz and Fischer 2007)

Lastly, the CIFE survey also asked questions that sought to reveal trends in quantitative value from real world projects using VDC. Specifically, the CIFE study focused on the amount of contingency set aside, risk management, change order, response latency, monthly cost

conformance, and final project schedule. In summary, the survey found that the majority of firms still retained the same amount of contingency on jobs run with VDC, but that 30% of respondents perceived that contingency would be reduced on similar projects run with VDC on a new project of similar scope using VDC/BIM. More interestingly, over 50% of respondents saw reduction in risk associated with projects on which they used VDC. A tactical level indicator of operational risk is unbudgeted change orders. While most respondents answered that they did not know if there was a difference on projects run with VDC, the most frequent response other than “don’t know” was that 20% of the respondents reported that their VDC projects usually were more than 10% better when it came to unbudgeted change orders in comparison with similar non-VDC projects. CIFE also reported “dramatic improvements in latency on projects using VDC, a finding which is also supported by interview data” (Kunz and Fischer 2007). Most respondents who answered that VDC improved latency said that it improved their operations by 2-7 days reduction in response time compared to similar projects that did not use VDC. Lastly, still significant, but less dramatic improvements came in the areas of cost and schedule. Roughly 10% of respondents thought that monthly cost was improved by 5-10%. Regarding time or schedule key performance indicators, the CIFE survey reported that only 15% of respondents reported that they knew or tracked schedule compliance, but that 100% of that group reported schedule improvements ranging from on time to greater than 30 days ahead of schedule.

Top criteria for BIM solutions: survey results

While CIFE is a globally respected research leader in the field of VDC, they are not the only research organization interested in BIM. Dr. Lachmi Khemlani, of the University of California at Berkeley and founder/editor of *AECbytes* (an e-journal devoted to BIM) publishes monthly news, case studies, and research about BIM online. In her article titled, “Top Criteria for BIM Solutions: AECbytes Survey Results,” Khemlani reveals the results of a BIM survey

that went out to 5,500 registered subscribers with a 12% response rate for approximately 660 completed surveys which makes its results noteworthy. According to the article, “The results of this survey indicate that at the present time, the need for drawing production is still paramount, making this the top ranking criterion for BIM solutions across all categories of firms and respondents” (Khemlani 2007). Figure 2-6 shows the fully rank-ordered list of criteria evaluated in the survey according to perceived order of importance from respondent data.

Rank	Criterion	Weighted Average
1	Full support for producing construction documents so that another drafting application need not be used	8.83
2	Smart objects, which maintain associativity, connectivity, and relationships with other objects	8.66
3	Availability of object libraries	8.34
4	Ability to support distributed work processes, with multiple team members working on the same project	8.16
5	Quality of Help and supporting documentation, tutorials, and other learning resources	8.02
6	Ability to work on large projects	8.00
7	Automated setup, management, and coordination, reducing traditional CAD management tasks	7.91
8	Multi-disciplinary capability that serves architecture, structural engineering, and MEP	7.82
9	Ability to support preliminary conceptual design modeling	7.79
10	Direct integration with cost estimating applications	7.47
11	Support for construction-related tasks such as quantity take-off, estimating, and 4D scheduling	7.45
12	Direct integration with energy analysis applications	7.43
13	Extensibility and customization of the solution	7.18
14	Direct integration with structural analysis applications	7.13
15	Direct integration with project management applications	6.98
16	IFC compatibility	6.70
17	Number of third-party developers developing add-on applications for the tool	6.38
18	Built-in ability to generate highly-photorealistic renderings and animations	6.34
19	The market share leadership position of the vendor offering the BIM solution	4.85

Figure 2-6. AECbytes Survey, “The stand-alone criteria, ranked according to their order of importance for all the respondents.” (Source: Khemlani 2007)

This is important because it shows that while much of the talk regarding BIM focuses on the “I” portion, or leveraging information for decision making, the survey results suggest that the current, strongest need for industry practitioners and BIM remains the need to produce [antiquated] drawings. Clearly, there is a schism between BIM advocates like the National

Building Information Model Standard Committee and the BIM practitioners who responded to this survey from the AECO industry at large. Along the lines of proprietary software, it was interesting to note that “direct integration seems to be preferable for interfacing with analysis tools and other supporting technologies as opposed to interoperability through open standards such as the IFC” (Khemlani 2007). With results like these, it is easier to understand why software firms (i.e. the vendors) are not as interested in pursuing interoperability as bodies like the International Alliance for Interoperability (IAI) and National BIM Standard (NBIMS) committee, because these results indicate that clients actually prefer direct integration rather than interoperability. Whether or not this is directly a result of vendors “leading” clients to prefer direct integration is a research question that remains un-answered.

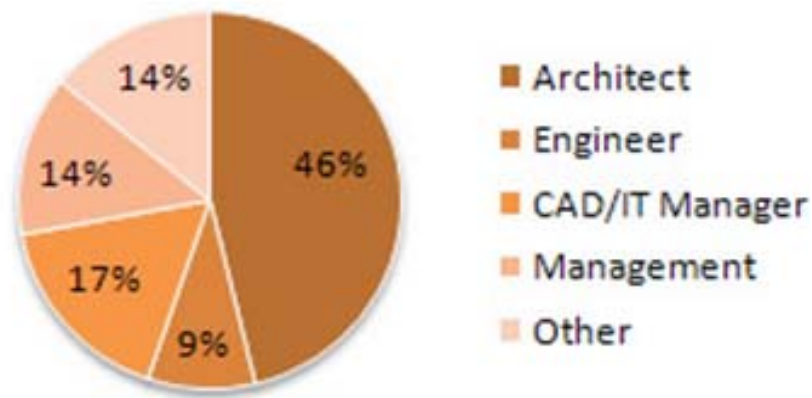


Figure 2-7. AECbytes Survey, “Professional Role of Respondents” (Source: Khemlani 2007)

The results were weighted towards document production. Therefore, it is important to evaluate the focus areas or job responsibilities of the respondents in this survey to try to explain the results. Figures 2-7 and 2-8 show the respondents’ professional roles and services. While Khemlani notes that the survey provides some “particularly useful feedback to all the BIM vendors, it provides useful insights on what is most important and what isn’t” (Khemlani 2007). The weighting of interest on construction document generation, object associativity, and object

libraries can be attributed to the fact that 80% of the respondents' day to day work is providing architectural services.

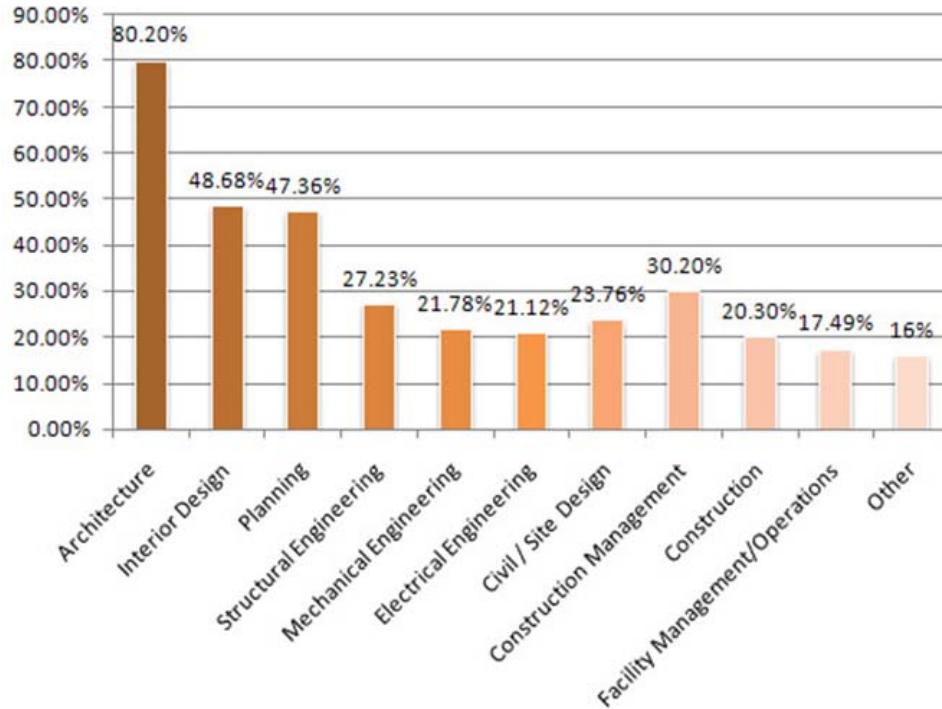


Figure 2-8. AECbytes Survey, “Disciplines Practiced by Respondents’ Firms (multiple choices allowed)” (Source: Khemlani 2007)

Another interesting item of note was the question, regarding which software platform the respondents were using. Until this survey, there were no unbiased, widely disseminated studies showing which software platforms were preferred by BIM operators. As shown in Figure 2-9, an overwhelming majority of respondents, more than all the others combined, answered that they were using Autodesk’s Revit software. This was also corroborated in the McGraw-Hill 2008 BIM Smart Market Report, which showed that 67% of its respondents also used Revit, making it the highest used platform by nearly a 2:1 ration compared to non Autodesk software applications.

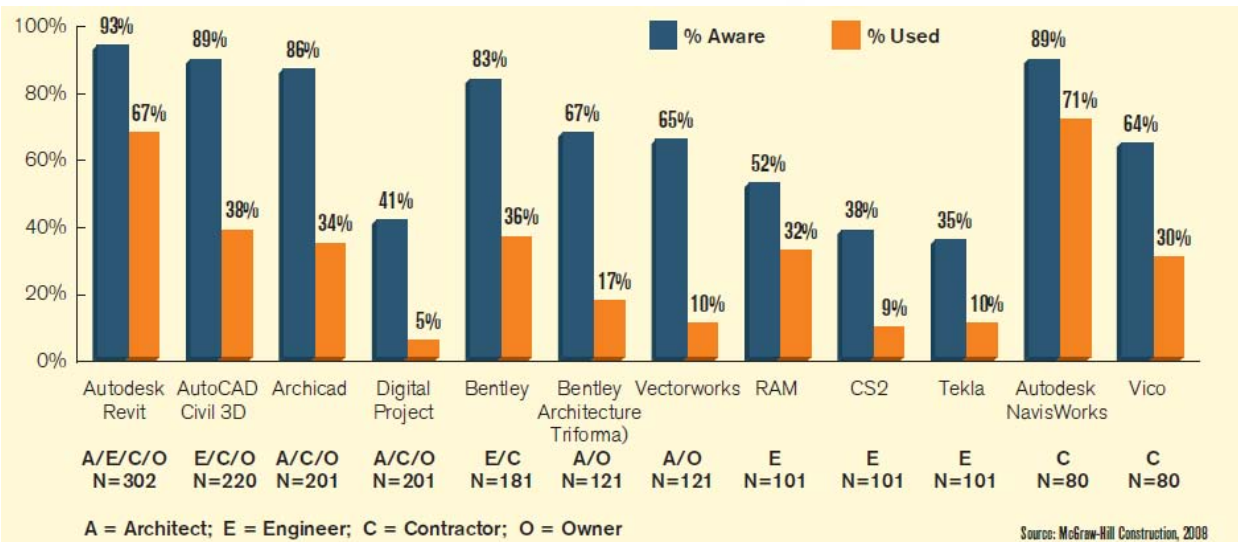
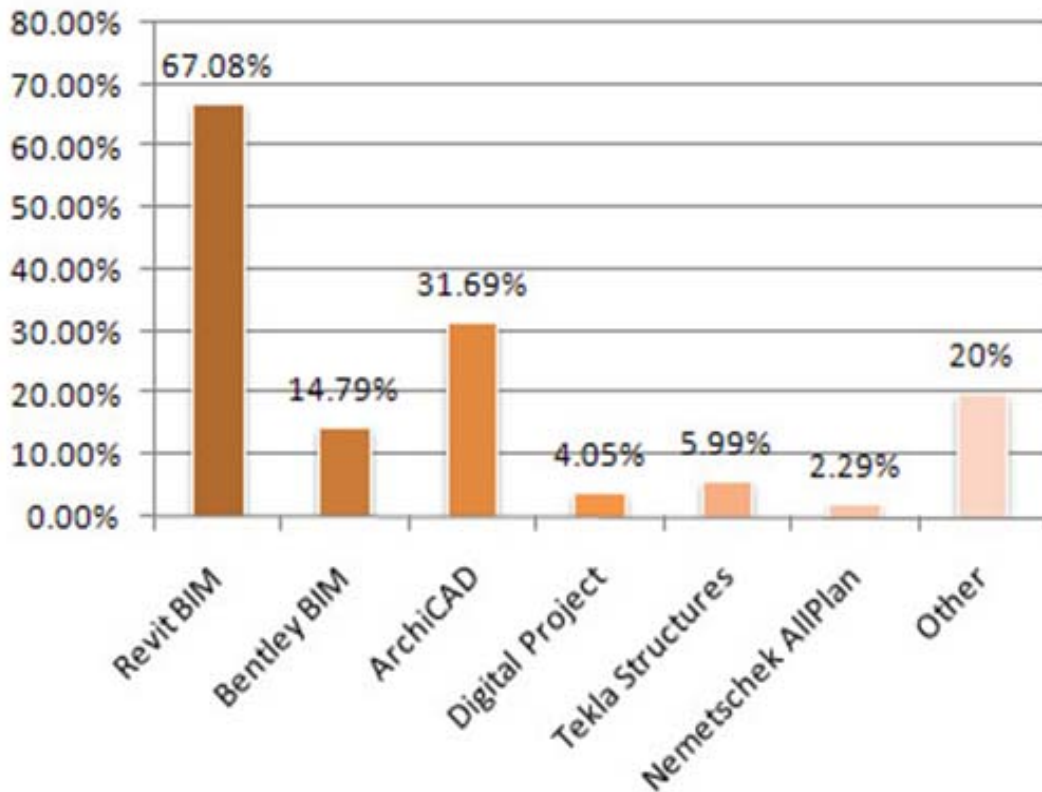


Figure 2-9. AECbytes, “BIM Solutions currently Being Used or Evaluated (multiple choices allowed)” and 2008 McGraw-Hill “Awareness of BIM-related tools” (Source: Khemlani 2007 and Gudgel 2008)

Another benefit of Khemlani’s survey is that it provides what has turned into nearly the “holy grail” of BIM research. In her article, she lists a short, easy-to-read summary and

comparison of the two leading BIM solutions (in terms of company revenue but not in terms of respondents percentage in this survey), Revit and Bentley. Khemlani states, “Looking at the same results from a Bentley-Revit comparative standpoint, the top criteria seem to be well balanced out against their respective strengths, which again is surprising given the significantly larger proportion of respondents using Revit” (Khemlani 2007).

For example, Khemlani feels that the top ranked criterion of “full support for construction documentation” is definitely a key strength of the Bentley platform, because of its software architecture built on top of the powerful CAD capabilities of MicroStation. Conversely, the second ranked criterion, “smart objects that maintain associativity, connectivity, and relationships with other objects” is “definitely a key strength of the Revit platform, having been built into the application from the start.” Lastly, with regard to the development of object libraries, “there is more activity happening on this front for Revit, while Bentley’s federated database approach lends itself better to distributed work processes, varied workflows, and large projects” (Khemlani 2007).

In all, Khemlani goes on to evaluate several other categories and compares the Revit to Bentley users’ answers, but she summarizes by saying, “The results of the survey clearly indicate that the AEC industry is still very much reliant on drawings for conducting its business of designing and constructing buildings, which is why the most important requirement for BIM applications that has emerged . . . is the ability to provide full support for producing construction documents so that another drafting application need not be used” (Khemlani 2007). However, with that said, the author also notes that BIM, as a technology, is still in its “formative stage and solutions in the market are continuing to evolve as they respond to users’ specific needs.” Indeed, if industry practitioners are not asking for interoperability in BIM software, it will not

become one of the forces that shape software creation, and in turn will tie users to “direct integration” in proprietary software *ad infinitum*.

Construction Management Association of America (CMAA) survey of owners

The Construction Management Association of America (CMAA) Survey of Owners sheds some light on the state of BIM in the American construction industry. In the joint publication of their eighth annual survey of owners, FMI, a construction-specific research and consulting firm, partnered with the CMAA to determine the current state and future trends in the construction industry. The subtitle, “The Perfect Storm – Construction Style” alludes to the current market forces that are driving technological adoption at a greater rate than in the previous seven years of the survey. Specifically, the authors state, “A fresh tool – Building Information Modeling (BIM) is enabling and supporting this change in philosophy, process, and approach, which will allow owner organizations, in turn, to weather the coming storm of construction industry challenges” (D’Agostino et al. 2007). The report goes on to list seven key challenges that are acting as the drivers for accelerating change in the industry. A paraphrased list is included here:

- Aging infrastructure
- Aging workforce
- Existing personnel retention and new personnel attraction
- Accelerated schedules, global demand for construction and design, and project complexity
- Alternative financing and project delivery systems
- Increased global competition for resources and assets
- Needed investment in education and training and subsequent demonstrable return on investment (ROI)

In order to respond to these industry drivers, the report focuses much of its analysis of its approximately 200 respondents' answers that collectively pointed to BIM adoption as the primary response to the preceding industry challenges. In particular, the report says that "approximately 35% of all respondents have used BIM processes and technology for one or more years" (D'Agostino et al. 2007). The trend has increased from 3% in 2003 to 4% in 2004, 6% in 2005, 11% in 2006, and now 35% in 2007. With an exponential uptake rate, BIM is moving from a tool or approach with promise to a tool or approach that is in use. More telling is that 74% of the owner organizations using BIM surveyed said they were "likely" (21%) or "extremely likely" (53%) to recommend its use to other owners (D'Agostino et al. 2007).

The next step was to evaluate the benefits and hurdles associated with BIM adoption in the industry. The two highest ranked responses from all respondents, among both BIM users and non-users were that BIM's primary benefits were "Improved Communication and Collaboration Among Project Participants" and "Higher Quality Project Execution and Decision-Making." Owners responding to the *Eighth Annual Survey of Owners* reported lack of expertise and lack of industry standards as two of the greatest hurdles to pairing enabling technologies with collaborative construction processes. The top three highest ranked BIM hurdles for BIM users and non-users were the same three elements: "Lack of Expertise, Lack of Industry Standards, and Greater System Complexity." This data substantiates the need for training and standards to meet the growing complexity of today's architectural landmarks and sustainability initiatives with a through strategic BIM approach throughout the AECO industry. In a technological area with much promise, but little direction, the DoD faces the unique opportunity to standardize their approach to BIM through deployment, testing, and modifying BIM operations and processes that

will benefit the AECO industry at large, thus contributing a BIM Standard Operating Procedure (SOP) that will eventually become the overall industry standard.

Lawrence Berkeley National Laboratory

Another very active research body in the United States is the Lawrence Berkeley National Laboratory (LBL). According to LBL's BIM expert, Dr. Vladimir Bazjanac, "the product conception-construction-delivery process in most other industries follows the 'design-test/verify-manufacture-deliver-warranty' script. In contrast, the AECO industry seems to employ the 'convince-build-pray' modus operandi" (2004). While this comment can be viewed as a tongue-in-cheek commentary on the state of construction, the science of manufacturing versus the "art" of construction has long been a divisive debate. But, adopting BIM does not have to mean that all construction must adhere to a "cookie cutter" manufacturing approach. Rather, a facility's BIM should include all the information that makes it unique, and not just boilerplate information used on all construction projects.

Bazjanac points out that before BIM can be successful, there must be consensus regarding the accepted definition of BIM. Used as a noun, according to Bazjanac (2004), a BIM is "an instance of a populated data model of buildings that contains multidisciplinary data specific to a particular building." Additionally, he says, "it is a static representation of that building (i.e. it uniquely defines that building in a section of time) – it contains 'raw' data that that define the building from the point of view of more than one discipline. Data contained in a BIM are also 'rich:' they define all the information pertinent to the particular building component. A three-dimensional 'surface' model of building geometry alone that is used only in visualization is usually not a BIM. A BIM includes all relationships and inheritances for each of the building components it describes; in that sense it is 'intelligent.' A data set that defines only a single 'view' of a building (i.e. that describes a specific single type of performance), such as a data set

that, for example, includes all data a structural engineer may need for structural calculations (but nothing more) is, by itself, not a BIM” (Bazjanac 2004).

After reading the definition and intent of BIM as expressed above, some opponents may feel a valid argument is, “that with such ‘rich’ data, describing even the most minute detail about every intricacy of even the ‘simplest’ structure, BIM would be too unwieldy and the overwhelming amount of data would be impossible to maintain” (Bazjanac 2004). This is a similar argument many members of the military used when they were resisting change to mapping in GIS. “But who will maintain the data? Who will update the data?” were common cries from technophobes and specialists alike. The “secret” to successful adoption and deployment of BIM is that it is NOT a “big brother” database with endless amounts of data on every facet in a facility. Rather, a successful BIM should include “pointers’ to external databases where the people are already maintaining the most up to date data” (Bazjanac 2004). An example could include a window or door schedule. Rather than put all the factory production and warranty data about a facility’s windows and doors in the actual BIM, the BIM would include direct pointers or hyperlinks to the data from a company like Andersen windows or to JELD-WEN doors warranty data. In this way, the relative “footprint” of a BIM would be as small as possible, and its information would be dynamic – changing as often as necessary to meet the industry demand. And as Deke Smith, FAIA notes, this requires industry-wide collaboration and open standards.

Federal Historical Perspective on the Facility Lifecycle

At the “Government Industry Forum” held October 31, 2006 sponsored by the Federal Facilities Council affiliated with the National Academy of Sciences (NAS) and National Research Council (NRC), there were three panels and associated categories of BIM briefings that were very telling about the level of work completed by each entity. The first, “BIM: Grass Root

experiences” consisted of the U.S. Air Force, the U.S. Navy, and the Construction Operations Building Information Exchange (COBIE) initiative ERDC and NASA. The second, “BIM: Agency-wide Actions” grouped the USACE, the USCG, and the GSA together. Lastly, the most advanced panel, titled, “BIM: Pushing Standards to the Edge,” consisted of representatives from the National Institute of Building Sciences Facility Information Council’s (NIBS-FIC) NBIMS Initiative, American Institute of Steel Construction (AISC), Construction Specifications Institute (CSI), Open Geospatial Consortium (OGC), and IAI.

U.S. Federal Marketplace accounts for 500,000 buildings and facilities valued at \$300 billion with more than \$17 billion spent annually on their operation and maintenance by at least 25 different agencies responsible for their lifecycles (FFC 2006). Specifically, the DoD is one of the largest real estate and real property owners in the world. The Fiscal Year (FY) 2008 DoD Base Structure Report listed more than 545,700 facilities, on more than 5,400 sites, and approximately 30 million acres of real estate with a Plant Replacement Value (PRV) of \$706 Billion (DoD 2008). In the 2009 Fiscal Year appropriation and authorization DoD-wide for Military Construction (MILCON) were approximately \$1,783,998,000 and \$2,248,702,000 respectively (DoD 2009). Needless to say, the DoD faces unique challenges to construct, operate, and maintain its massive infrastructure investment. However, as discussed previously, the DoD has succeeded at turning past challenges into opportunities to affect change in the private sector, and hopes to lead the push to improving the entire facility lifecycle through BIM. In particular, the process of real property acceptance after initial or beneficial occupancy and real property inventory maintenance is an under-investigated and non-standardized area of the construction lifecycle. Until 2003, little effort had been expended on the topic. However, at that time in 2003, the Office of the Deputy Undersecretary of Defense for Installations and the

Environment (ODUSD I&E) realized that one of the most fundamental elements of real property management is real property accountability (RPA) and recognized Real Property & Installations Lifecycle Management (RP&ILM) as a Business Enterprise Priority (BEP.) In November 2003, the ODUSD I&E began with a business process reengineering (BPR) effort to delineate and promulgate real property inventory requirements (RPIR). On January 26, 2005, a BPR summary with policy and technical recommendations (i.e., the RPIR document) was approved by the Installations and Environment (I&E) Domain Governance Board. The RPIR document serves as a foundation to facilitate and enable development of a modernized real property inventory that will meet the Department's current and future requirements for asset accountability and valuation. The Real Property Acceptance Requirements (RPAR) BPR effort was subsequently conducted as an extension of the RPIR effort. This document covers the portion of the real property life cycle where a designated DoD real property official acquires legal authority over an asset from a construction agent or other official. RPAR BPR meetings were held from January through July of 2005, and the project will culminate upon the release of the RPAR document, expected in the spring or summer of 2006. This document contains all of the requirements necessary to accept real property into the Department's inventory from a construction agent (e.g., USACE, NAVFAC, etc.) According to the RPAR document, "all new real property asset information will be integrated, consistent, and in a standardized electronic format." (RPAR V5.0, 2006) Nevertheless, no format has been specified to this point, but the services are working towards integrating the guidelines set forth in the RPAR document into a BIM approach compatible with already standardized DoD Spatial Data Standard for Facilities and the Environment (SDSFIE) compliant GIS maps. The various BIM approaches are being tailored to best suit the needs of owners, facility managers, and emergency responders. In the near future,

evaluations of the BIM concept will be realized through prototype field tests on real-world projects.

The General Services Administration

The GSA Public Buildings Service (PBS) Office of the Chief Architect (OCA) established the National 3-D-4-D BIM Program in 2003 (Matta 2009). The primary goal of the program is to phase in 3-D, 4-D, and BIM adoption for all major projects. Additionally, the GSA hoped to create a knowledge portal community and a six-part BIM Guide Series. As of January 2009, Series 01, 02, and 03 are available online with Series 04-7 in various unpublished stages (Matta 2009).

In between 2003 and 2006, the GSA completed 10 pilot projects before becoming the first large owner to formally mandate BIM on their jobs. In November of 2006, the GSA promulgated the requirement for contractors to use BIM products or processes to accomplish design on all Fiscal Year (FY) 2007 designs (Hardy 2006). As the manager of more than 342 million square feet of office space serving 1.1 million federal employees, the GSA is one of the largest real property managers in the world, making this mandate a major event with far-reaching implications in the AECO industry (Hardy 2006).

One of the immediate implications for software vendors was that the GSA required firms to validate that they could meet the GSA's requirements. Firms went through four rounds of validation testing using a GSA test case building. According to the Series 02 GSA BIM Guide, "The GSA Concept Design View is a model view of the Industry Foundation Classes (IFC) BIM modeling standard that was developed and published by the IAI" (Kam 2006). Upon showing that they met the GSA requirements, firms in turn received the designation as GSA compliant. Only four companies and five applications received this singularly distinctive designation. They were Onuma's "Onuma Planning System," Bentley's "Architecture," Graphisoft's ArchiCAD,

and Autodesk's "Architectural Desktop" (Now known as AutoCAD Architecture) in conjunction with "Inopso," and Autodesk's "Revit." As a benefit, this pushed software vendors to prove that their software actually worked in the GSA case study according to various interoperability and functionality concerns. Additionally, the precedent created by competitive pilot projects among software vendors to certify functionality is a model that is very appealing and may become commonplace in the future. Conversely, this also effectively limited the field to only four competitors and ensured that all contractors who worked with the GSA would be forced to pursue a path aligned with one of these four vendors. However, there are few, if any, mainstream software outside this small circle of major firms, so the benefits most likely outweigh the disadvantages.

Furthermore, the Series 02's Appendix has almost 50 pages of information that reads like a user's guide for accomplishing specific tasks such as creation and analysis within the five software platforms. This is accomplished through screen captures and other rich means of conveying tactical level information for practitioners, making it a very valuable tool for those working in the field.

Most importantly, the GSA will forever be linked to bringing BIM to the forefront of the AECO industry. The GSA did not stop at simply mandating BIM, but instead added to the body of knowledge through their unique software certification approach, their pilot projects and copious data collection, and user friendly and robust BIM Guide Series.

The GSA won two 2007 BIM awards from the AIA-TAP Community of Practice under the "Juries' Choice" category in recognition of their contributions to the AECO industry. The GSA Submissions covered "Our National BIM Program: Highlights from 2006" and "2006 Pilot Project Successes: Building Information Modeling." Going from the general to specific, this

section will discuss the two submissions in order from the BIM Program at large to the more specific case studies.

GSA: “Our National BIM Program: Highlights from 2006”

The GSA submission to the AIA-TAP 2007 BIM Award selection panel consisted of an executive summary of their reasons for pursuing BIM technology and process improvements, as well as a description of their “BIM Toolkit.” Paraphrasing their own summary, the GSA said that their primary goal for adopting a BIM approach was to “advocate and employ value-adding digital visualization, simulation and optimization technologies to increase quality and efficiency throughout project lifecycles and beyond” (Kam 2007) As stated earlier, the GSA felt that they showed support at the highest levels by mandating that projects receiving design funding in fiscal year 2007 and beyond submit a spatial program BIM as one of the prerequisites of final concept approval. Also, they actively promoted the implementation of additional BIM technologies above this mandated minimum throughout the project lifecycle. However, their view of encouraging BIM implementation on a project-by-project basis could be viewed critically as not in line with the portfolio-based or enterprise planning systems promulgated in the NBIMS, Version 1.0. However, after these test cases, it is more likely that practitioners will engage in more open collaboration with industry, and see further project opportunities as they gain more team experiences and the technology matures. The GSA was clear about focusing their entry on their successes in implementing, advocating and supporting 3-D and 4-D BIM technologies, but with a specific focus on their spatial program validation efforts.

In order to further their BIM program, the GSA partnered with many academic institutions such as Harvard, Georgia Tech, Penn State, and Stanford and national standard and professional organizations including AIA, IAI, AGC, NIBS, NIST, CURT, CMAA, and FIATECH. The stated business drivers for the GSA mandating BIM was their spatial program validation

requirements (Figure 2-10). From their AIA-TAP submission, the GSA states: “ Prior to requiring a spatial program BIM, area take-offs were calculated by hand using manually projected poly-lines and relied heavily on the spatial measurement knowledge of the individual performing the analysis” (GSA 2007). However, there were additional concerns including: missing, incomplete, or inaccurate facility documentation, organizational initiative to reduce their building inventory’s average annual energy consumption by 35%, improved FM practices, and automated checks for addressing circulation and security requirements.

- Office Building, Atlanta, GA
- Courthouse, Cedar Rapids, IA
- Office Building, Portland, OR
- Office Building, Washington, DC
- Office Building, Washington, DC



Figure 2-10. GSA: “Projects using BIM for spatial program validation” (Kam 2007)

Some examples of cost, schedule quality, and efficiency benefits from the GSA include:

- Having space measurements available to project teams within minutes to 90% accuracy
- Capturing as-built data of existing buildings to 4 mm accuracy in a matter of hours using laser scanning
- More accurate estimations of energy performance, and major savings through mechanical system optimization
- Improved means of communication between tenant agencies and during pre-bid conferences
- A reduction in construction duration by 19% on a renovation project using [a] 4-D Phasing technique

- Uncovered design errors and omissions (e.g. envelope and coordination omissions) in an office building design

The GSA program highlights also points out that their focus is not solely on BIM, but also on 3-D laser scanning, 4-D phasing, energy performance and operations, and circulation design validation. However, their primary focus was on spatial program validation and they accomplished five projects that tested and validated these capabilities (Figure 2-10).

Among the noted drivers for BIM-based spatial validation were incorrect spatial programs causing over-design and cost overruns, promoting data reliability, and inefficiency concerns. The perceived benefits from implementing the BIM-based approach included: [unquantified] cost savings, increased quality by embedding American National Standards Institute/Building Owners and Managers Association International (ANSI/BOMA) rules into BIM analysis tools, and design efficiency by automating architects' spatial programs. The mission of the Building Owners and Managers Association International (BOMA) is to enhance the human, intellectual and physical assets of the commercial real estate industry through advocacy, education, research, standards and information (BOMA 2007).

At the tactical or technical level, the GSA developed a specialized "Concept Design View" of the requirements for spatial data management. Their organization-specific Concept Design View is a model view of the IFC BIM modeling standard developed and published by the creator of IFCs, the IAI. In addition, the GSA collaborated with software vendors and validated applications through four rounds of testing using a test case building as discussed earlier. The GSA built on the traditional 2D, Construction Drawing process and created the 3-D Concept BIM Model process (Figure 2-11).

The key is that the ANSI/BOMA rules intelligently automated the traditional approach fraught with uncertainty and lacking in standardization. Additionally, once this application

proved fruitful, supplemental benefits became apparent, such as “tenant stacking plans and reports” and floor calculations (Figure 2-12).

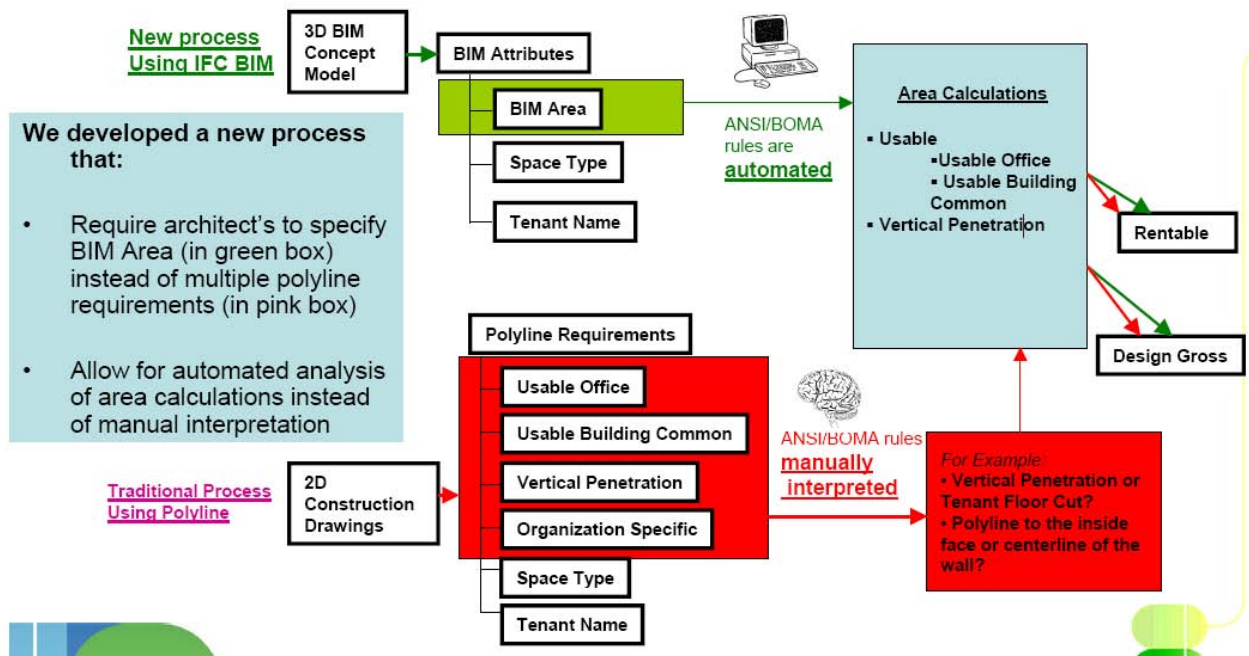


Figure 2-11. GSA: “[GSA] Innovates process change in space measurement” (Kam 2007)

Our spatial program BIM analysis tool:

- Incorporates ANSI/BOMA rules and spatial measurement expertise
- Automatically analyzes the spatial program for efficiency ratios and area calculations
- Produces tenant stacking plans and reports

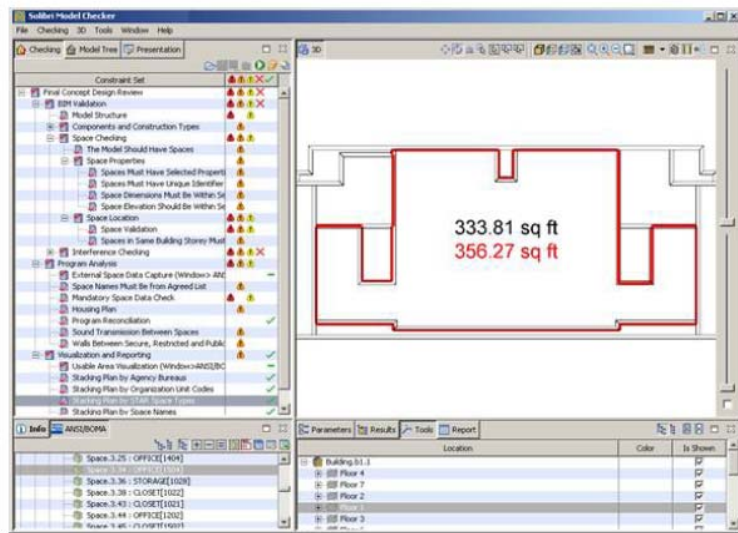
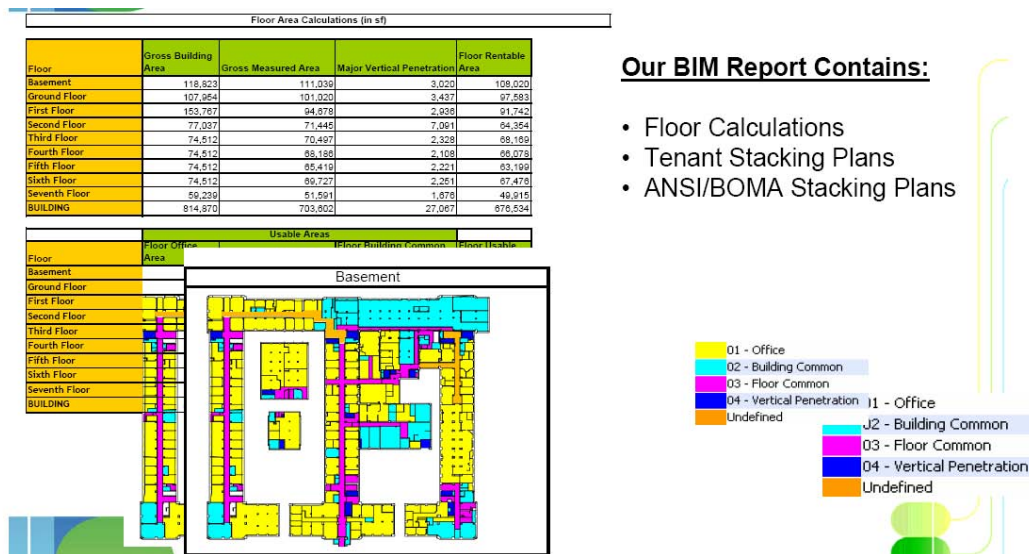


Figure 2-12. GSA: “Incorporating design expertise.” Note: “Solibri Model Checker” used in screen capture of tenant stacking reports (Kam 2007)

Lastly, in the GSA’s submission, they also discussed their Toolkit approach which (Figure 2-13) includes their GSA BIM Guide Series, as well as their extensive website listing that has been referenced and discussed previously in this chapter. Of note, however, is their commitment to educating themselves through internal activities such as naming regional BIM Champions and creating a community of knowledge to support and diffuse information sharing across their organization. This effort included creation of an internal knowledge portal, development of a sample scope of work and contract language for 3-D and 4-D BIM services, and dissemination of information at regional conferences and project based consultation.



Our BIM Report Contains:

- Floor Calculations
- Tenant Stacking Plans
- ANSI/BOMA Stacking Plans

Figure 2-13. GSA: “Automatically generate a BIM Report.” (Ho 2007)

GSA: “2006 Pilot Project Successes: Building Information Modeling”

The BIM projects highlighted in the GSA’s submission under “Pilot Project Successes” established new levels of excellence in the drive to improve the facility lifecycle through technological and managerial means (Ho 2007). The GSA accomplished approximately 20 pilot projects that fell into four major categories in their submission. These included the following

categories with the number of projects highlighted in the submission next to the category in parentheses:

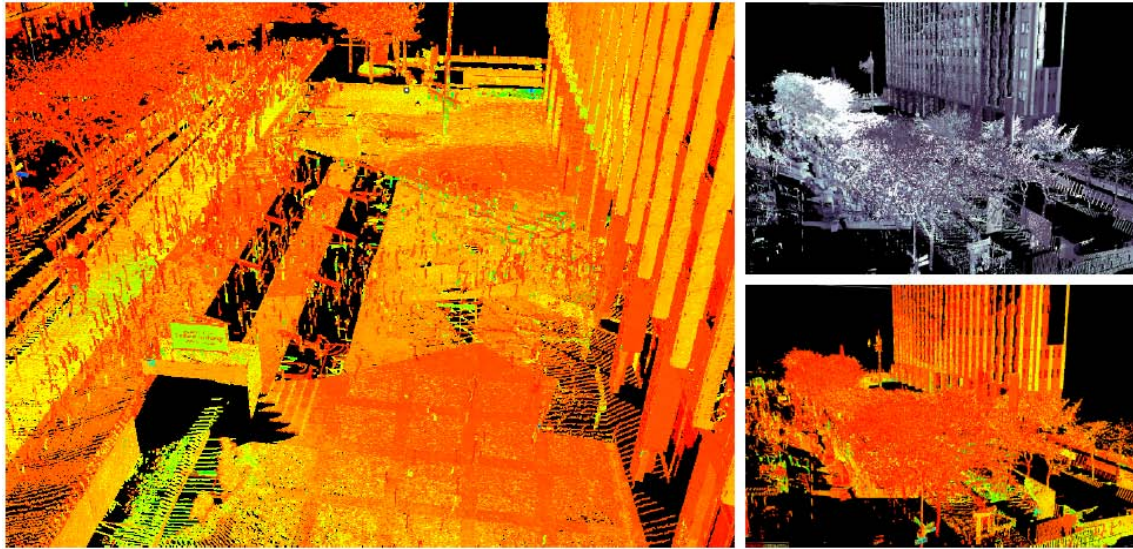
- 3-D Laser Scanning (7)
- 4-D Phasing (3)
- Energy Performance (3)
- Circulation Validation (1)

Through the GSA's implementation of over 20 pilot projects using an array of BIM technologies across the country, their organization showed documented and quantifiable improvements in quality, efficiency, and cost savings in 2006. This entry highlighted a few of the successes from "uncovering and mitigating errors and omissions, predicting potential obstacles and their impacts, introducing better design solutions, enhancing tenant and contractor communications, to optimizing budget and schedule options" (Ho 2007)

Consequently, the GSA pilot program provided a catalyst and strong incentives for industry participation to use BIM to aid their traditional approach in the facility lifecycle. The 3-D Laser Scanning projects (Figure 2-14) were successful because they were the best at automating accurate, as-built data in instances where legacy data was incomplete or inaccurate or no data existed.

The GSA felt that their 3-D laser scanning projects provided superior accuracy, non-invasiveness, and cost and time savings. Their 3-D models created models of existing buildings with accuracy to 4mm in only a few hours work that contributed to the reduction in RFIs, errors, omissions, and redundant coordination. Furthermore, they used their 3-D laser scanning for verifying structural designs and found major errors that resulted in major savings and untold possible savings in liability or litigation in the future. Lastly, the GSA also applied their 3-D

models to help customers visualize historic preservation and site context with respect to new projects (Figure 2-15).



3D Laser Scanning Pilot Project

- 2 days of scanning in parallel with 2.5 days of surveying
- 5 weeks to convert points into 3D model (40 hours of modeling)
- covers plaza area, parking ramps, upper parking level, and exposed parking utilities

Figure 2-14. GSA: “3-D Laser Scanning Pilot Project” benefits and details (Ho 2007)

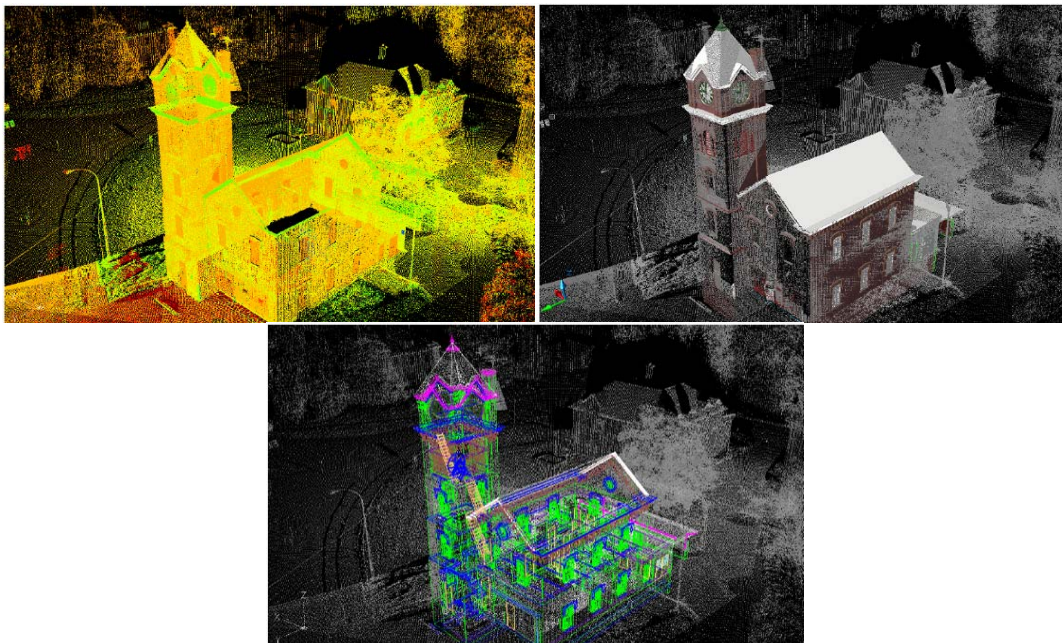


Figure 2-15. GSA: Progression of 3-D Laser Scanning Data (Ho 2007)

The 4-D Phasing projects provided quantifiable benefits including the reduction in construction duration by 19% on one renovation project and in another, optimizing an 8.5 year schedule to 5.5 years by identifying viable new swing space. Qualitatively, the 4-D phasing improved coordination between tenant agencies and GSA during pre-bid conferences (see Figure 2-16).

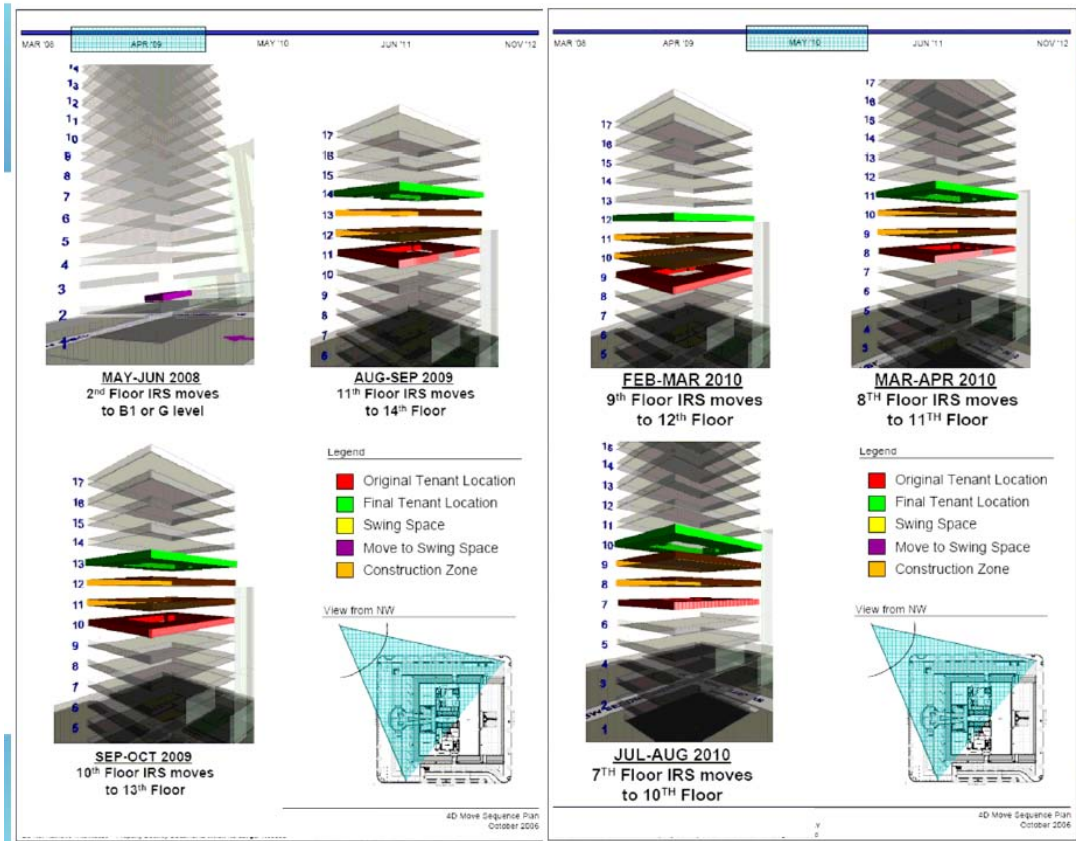
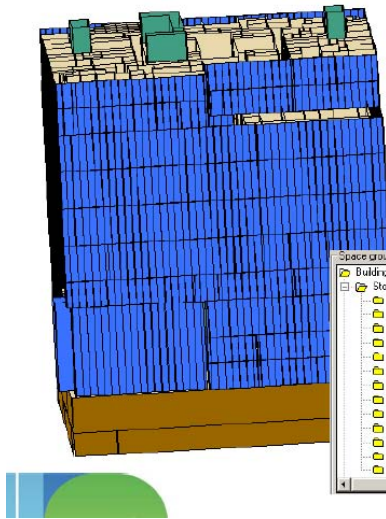
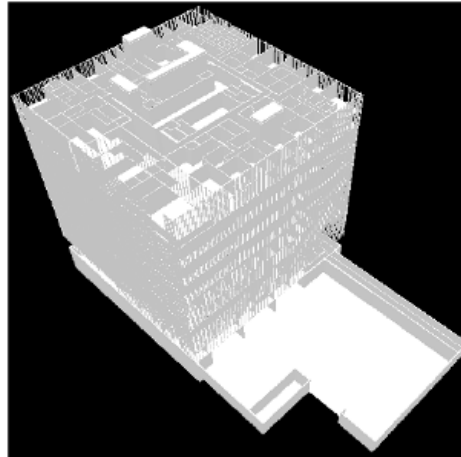


Figure 2-16. GSA: Example of 4-D Phasing improving visualization and planning for temporary tenant housing during renovation of IRS facility (Ho 2007)

Regarding energy performance evaluation, the GSA found that their current energy modeling practices tended to under-predict energy performance, and subsequently, they were not meeting their energy consumption reduction targets. BIM-based energy modeling approaches allowed for more automated transfer of information and predicted 30-50% higher energy

consumption than the traditional approach, so engineers were better able to pinpoint specific changes and inputs that would improve energy performance with great granularity and transparency in the process. Figure 2-17 shows the visualizations from the GSA pilot project, the 10-floor, 338,880 SF Salt Lake City Courthouse.

- Courthouse in Salt Lake City
- 338,880 sf
- 10 Floors
- Cubic Volume
- Heating: variable volume hot water with perimeter radiation
- Cooling: centrifugal chillers



Collaboration with academic institutions, research institutes and software developers. Organization is working with LBNL, NVE, and Olof Granlund in pilot applications.

Space groups		Spaces				
		Qty	Code	Name	m2	m3
Building						
	Storage					
	13 (Penthouse floor plan,) h=4.0 m	6	04036	Office (Chief Deputy US Marshal)	33.6	151.4
	12 (Tenth floor plan,) h=45.5 m	6	04038	Office (Computer Admin)	26.2	118.0
	11 (Ninth floor plan,) h=45.0 m	6	04075	Office (Exec Secretary)	16.8	75.7
	10 (Eighth floor plan,) h=38.7 m	6	04074	Office (Private Office)	16.8	75.7
	9 (Seventh floor plan,) h=32.4 m	6	04056	Office (Public Reception)	49.8	209.0
	8 (Sixth floor plan,) h=28.1 m	6	04078	Office (Supervisor Dept Marshals)	15.2	86.5
	7 (Fifth floor plan,) h=19.8 m	6	04083	Office (Supervisor Dept Marshals)	15.2	86.5
	6 (Fourth floor plan,) h=15.3 m	6	04031	Office (Supervisor Dept Marshals)	26.9	121.3
	5 (Third floor plan,) h=9.0 m	6	04077	Office (Supervisor Dept Marshals)	16.4	83.0
	4 (Second floor plan,) h=4.5 m	6	04076	Office (US Marshal)	50.5	227.2
	3 (Ground floor plan,) h=0.0 m	6	04071	Office (Visiting Agent)	20.5	92.3
	2 (Basement floor plan,) h=-6.0 m	6	04072	Office (VITSEC Office)	16.8	75.7
	1 (Subbasement floor plan,) h=-5.9 m	6	01001	Open office (Deputies)	442.2	198...
		6	04049	Open office (Deputies)	26.9	120.9

Figure 2-17. GSA: Energy Performance Pilot Project screen captures (Ho 2007)

The final category of pilot projects was those that focused on circulation validation. The sole project highlighted here is the Department of Justice/Administrative Offices of the U.S. Courts.

The GSA thought that automating the process saved time, improved accuracy, led to better

security and more reliable results. They were most interested in pursuing more efforts to ensure improved measures of safety for complex facilities like this court house project where there are competing security interests. This includes protecting judges, the public, prisoners from other prisoners, and even prisoners from the public. Similar to their partnership with Stanford’s CIFE on the 4-D phasing jobs, the GSA partnered with Georgia Tech and Solibri on their circulation validation efforts, which they found to be a very successful partnership (Figure 2-18).

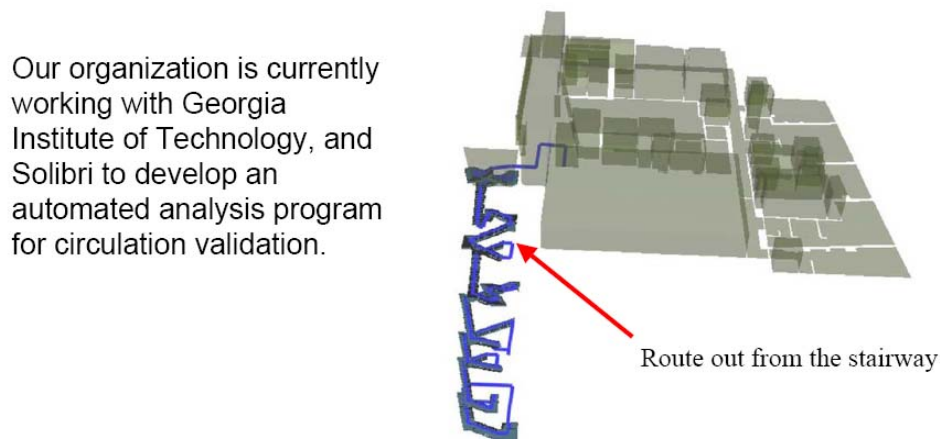


Figure 2-18. GSA: “Circulation Validations: Collaboration/Expertise” (Ho 2007)

The U.S. Army Corps of Engineers

Another large owner implementing BIM is the U.S. Army Corps of Engineers (USACE). Lieutenant General (LTG) Carl A. Strock, former USACE Headquarters (HQ) Commander and Chief of Engineers, ushered in the initiative called the “performance management system (PMS)” in Fiscal Year (FY) 2002 (Strock 2006). Because this research involves evaluating performance according to metrics or KPIs, it is therefore important to mention this USACE productivity initiative that seeks to integrate strategic and operational performance (Figure 2-19).

USACE Metrics: The Consolidated Command Guidance (CCG) program

The metrics (or KPIs) that the USACE uses to rate how well they are performing according to the PMS are called the “Consolidated Command Guidance (CCG) metrics.” The USACE

evaluates their own performance internally on hundreds of metrics, from human resources to logistics. Included in this long list of metrics is a category called, “Military Programs.” As of FY 2007, there are now 20 different metrics tracked in the Military Programs category and Numbers 1-12 are listed below because they deal specifically with the metrics of interest in the construction phase of the facility lifecycle (Note: 13-20 primarily deal with environmental concerns not directly affiliated with construction, such as remediation):

- MP-1. Program Execution – Forecast of Construction Awards
- MP-2. HQ Project Current Working Estimate (CWE) to Programmed Amount (PA) Ratio
- MP-3. Final Design Release by Customer
- MP-4. Ready to Advertise (RTA)
- MP-5. Initial Design Release by Customer
- MP-6. Construction Project Cost Growth
- MP-7. Project Construction Contract Time Growth
- MP-8. Project Beneficial Occupancy Date (BOD) Time Growth
- MP-9. Project Construction Timeline (Construction Duration)
- MP-10. Project Financial Closeout
- MP-11. In-House Design Percentage
- MP-12. Sustainable Design and Development (SDD)

Narrowing the field even further, the primary CCG metrics listed in the USACE construction administrator’s automated management application, called the Resident Management System (RMS) are metrics MP-6 through MP-10. From the RMS, geographically disparate construction managers or contract administrators can add data or query Corps databases for real-time status

updates on any of the active or completed projects in the USACE. Status is reported back in the following, simplified fashion:

- Green: CCG metric has met or is meeting the goal
- Amber: CCG metric has not met the goal by a slight margin
- Red: CCG metric has not been met and is not close to being met

The report from RMS querying all on-going projects for all Program Years, metrics MP-6 and MP-7 for the USACE are Amber with 91% for MP-6 and Red for MP-7 with a 76% rating (Figure 2-19).

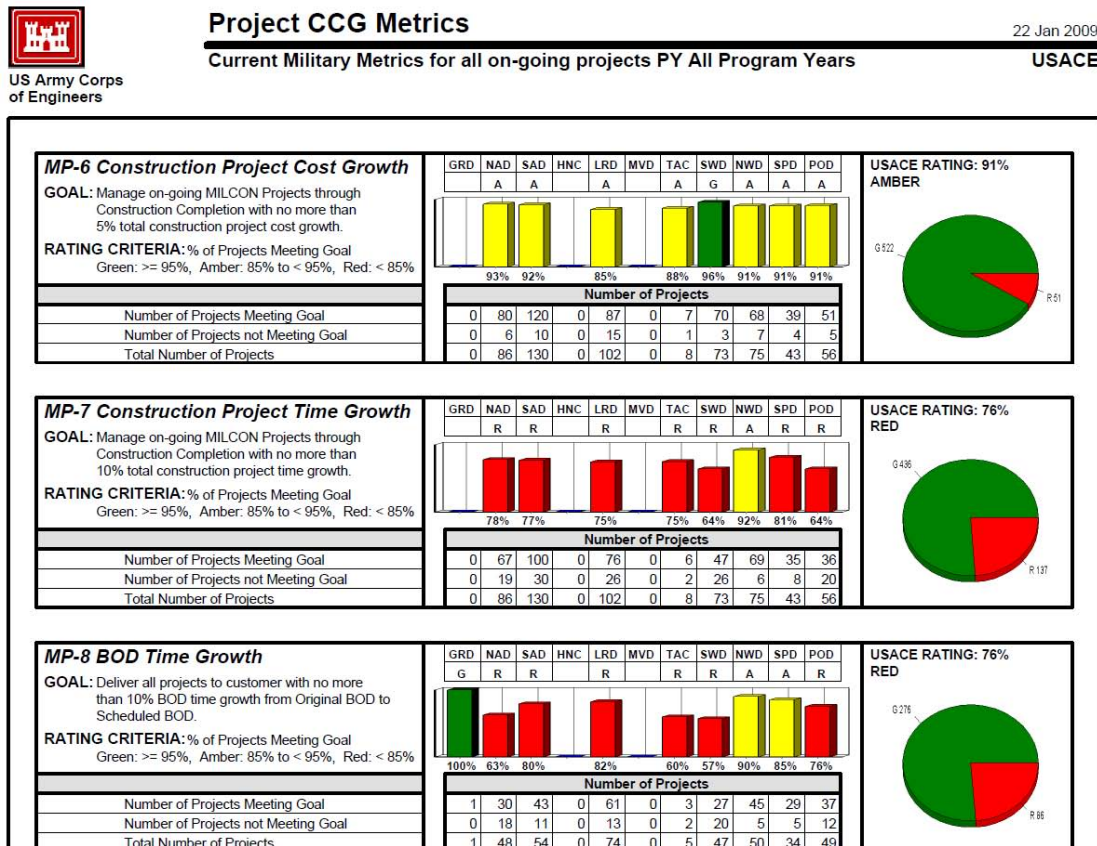


Figure 2-19. Project CCG Metrics, Corps-wide, as of January 22, 2009

For each specific metric and their accompanying, specific goals, projects can only meet or not meet the goal. However, for the regional Districts, or their higher sub-regional headquarters

called Divisions which consist of multiple Districts, the metric is “expressed as a percentage of the sum total of number of on-going projects in program years (PYs) 02-06 meeting the Cost Growth goal” (Strock 2006). Then the average sum total when dealing with an entire District or Division is broken out into the green, amber, red ratings. For each metric, the performance level and the windows of opportunity for achieving a “green” rating vary accordingly. For example, for MP-6 “Construction Project Cost Growth,” the goal is to “manage on-going MILCON Project construction through contract completion with no more than 5% total project cost growth” (Strock 2006). Accordingly, for a single project to achieve a green rating would require that the project’s cost could grow no more than 5% for the “sum of all construction cost growth from Military Construction (MILCON) funded contracts executing a project” (Strock 2006). If it did not meet this goal, the project would simply be classified as “did not meet goal.” However, collectively, an amber rating would be achieved for 85-95% of the projects meeting the cost growth goal and a red rating would be applied for below 85% of the collective projects meeting the goal.

As evidenced in the example in Figure 2-19, the Army is not meeting their goals. In fact, as of the date that report was queried on January 22, 2009, the USACE was red in four of the five metrics tracked in RMS, and, only achieved an amber rating in the last remaining non-red metric.

Clearly a change is needed and the army hopes to change this current level of performance. Strategically, the current initiative to meet the demands of the Department of Defense and the primary driver of all recent Army organizational changes can be attributed to “Army Transformation.” A program that piggybacks on Army transformation to support the infrastructure requirements dictated by Army Transformation is called “MILCON

Transformation.” It is MILCON Transformation that drives most of the actions, and especially the recent initiatives towards change in the Army Corps of Engineers.

MILCON Transformation

From former USACE HQ Commander and Chief of Engineers, Lieutenant General (LTG) Carl A. Strock, MILCON Transformation can be attributed to Deputy Assistant Secretary of the Army (Installations & Housing) Joseph W. Whitaker. In November 2004, Secretary Whitaker directed the Corps of Engineers to develop a strategy and implementation plan in support of Army Transformation to provide the Army the ability to establish, reuse/re-purpose facilities with minimum lead-time, leverage private industry standards and practices, and reduce acquisition/lifecycle costs. His direction recognized the urgent need for a massive, multi-year construction program to provide new facilities. The initiative developed in response to Mr. Whitaker’s task assignment is now known as MILCON Transformation and is an important element of the Army’s Business Transformation. This strategy was worked out in partnership among the Corps of Engineers, the Office of the Assistant Chief of Staff for Installation Management, the Installation Management Agency, private industry and Mr. Whitaker’s office. Key elements include standardization in acquisition processes, standardization of the design of facilities and expanded opportunities for use of alternative construction methods such as manufactured building solutions (Strock 2007).

With the sheer size and massive budget for the work that the USACE oversees, MILCON Transformation is poised to have far reaching implications. The USACE’s FY 08 Military Construction budget was \$18.3 Billion with \$7.7B for Army MILCON, \$1.6B for Air Force MILCON, \$.74B for the Global War On Terror (GWOT), \$1.9B for DOD Construction, \$2.2B Engineering and Design, \$1.7B for Host Nation construction, \$412M for Research and Development (R&D), and \$523 M for other assorted programs. These projects included

worldwide traditional MILCON projects such as Ranges, Barracks, Housing, Maintenance Facilities, Operations Facilities, Training Facilities plus National Missile Defense, Chemical Demilitarization, Foreign Military Sales, and work on Host Nation Construction Management and Oversight in places like Germany, Japan and Korea (Temple 2007).

MILCON Transformation includes a “disciplined emphasis on standardized facilities” and is designed to provide soldiers with quality, sustainable facilities less expensively, in less time and on-time to allow the Army to meet its transformational schedules. Specifically, the Corps plans on 15% less cost on projects and 30% quicker time tables. With MILCON Transformation as the driver, the USACE has moved towards focusing on BIM as an answer to ameliorating past inefficiencies in design and construction. In turn, the USACE has focused a great deal of effort on implementing BIM. This comes from their formally promulgated mission and vision regarding BIM, ERDC TR-06-10, “Building Information Modeling (BIM): *A Road Map for Implementation To Support MILCON Transformation and Civil Works Projects within the U.S. Army Corps of Engineers*” or simply the “USACE BIM Road Map” as it has been called informally.

The USACE BIM Road Map

The BIM Road Map is a 96-page guide and requirements listing for successful BIM implementation in the Army Corps of Engineers, a summary of its contents is included herein. The USACE BIM Road Map is a product jointly executed by the CADD/GIS Technology Center, Construction Engineering Research Laboratory (CERL), and Engineering Research and Development Center (ERDC). While the BIM Road Map addresses many areas of possible contribution, the primary impetus for pursuing BIM, according to the authors, is to “drive down costs and delivery time” (Brucker et al. 2006). According to BIM Road Map contributor and Seattle District CAD/BIM Manager, Van Woods, (who managed one of the real world BIM

projects highlighted in the document) “driving down costs and delivery time” specifically meant that the USACE wanted to achieve economies of scale for repeatedly designing the same types of buildings, as well as in reducing the average 18-month time from award to ground-breaking that the Corps was experiencing. As seen in the title, the BIM Road Map was an attempt to support “MILCON Transformation” within the USACE. Also in the name of support for MILCON Transformation, the Army published a memorandum from Brigadier General (BG) Merdith W.B. Temple, the Director of Military Programs, on March 06, 2006 regarding “Realignment/Establishment of Centers of Standardization (COS), FY-06” (Temple 2006).

In this memorandum, General Temple broke with the traditionally regionalized Division and District areas of expertise and established centers of standardization that would serve as design authorities for 42 different types of facilities in different Districts across the CONUS and even in Hawaii. The traditional model was for the Corps to focus on all MILCON and Civil Works projects within their region and contract out 75% of the work to contractors while retaining 25% of the design work in house. Now, under the joint COS and USACE BIM Road Map guidance, the 42 facility types will be designed via a BIM approach and altered to fit site conditions at each District. More importantly, each COS will establish regional Indefinite Quantity (IDIQ) contracts that will administer “services associated with assigned facility types.” This means that firms who “win” the original design solicitations for the BIMs for these 42 jobs will in essence have a contractual lock on the design services **every** time that building is modified and built in any USACE District in the United States, and that each District that serves as a COS will have an IDIQ to provide millions, and possibly billions, of dollars in services to construct these facilities across the United States. Quite simply the impact is staggering.

However, the USACE BIM Road Map is a step towards alleviating those fears by clearly spelling out lessons learned and best practices for Districts to follow when formulating their in-house or contract-led BIM efforts. Based on design work accomplished in the Seattle and Louisville Districts, the USACE BIM Road Map discusses the strength of BIM, as well as how best to implement it through a discussion of requirements, and both short term and long term strategic goals. Possibly the most beneficial to the technical or tactical level BIM implementer are the Appendices which discuss the goals in depth, the specific implementation plan, “dataset evolution instructions” (file structure library recommendation), organizational recommendations, contract language, oversight and implementation guidance for working A-Es, personnel position descriptions, and other related roles and responsibilities. All in all the BIM Road Map would be beneficial to any BIM neophyte and is both concise and thorough in a way that most other documents of its kind have not achieved.

Of particular interest are A-E firms’ technological requirements (i.e. software packages) when it comes to BIM. The USACE BIM Road Map addresses these concerns specifically by saying, “USACE will maximize use of available products and training. Districts may use existing purchasing agreements (Enterprise Licensing Agreements [ELA]) to minimize the cost of implementing BIM” (2006). Additionally, in the section, “Customer Technology Requirements” the document reads, “As in the past, when a District has a customer that has a requirement for BIM models that work in non-ELA software, the district should plan to conduct training in that non-ELA software’s BIM technology” (2006). Specifically, in the most frequent case, where an A-E firm or owner primarily use Autodesk software, rather than Bentley’s TriForma applications, the Road Map reads, “if the District foresees some customers requesting Autodesk BIM models of their COS facility type, they should prepare to maintain both Bentley

and Autodesk BIMs until reliable interoperability between the BIM packages is achieved” (2006). However, all other cases direct that the USACE will develop BIM models in the Bentley TriForma format. However, rather than letting the software debate stifle or limit production, at least the USACE has created policy that attempts to handle it as well as possible and is looking towards improving the process on a strategic level, as opposed to being mired in the technical details.

USACE Road Map Timeline

For the USACE to fulfill their vision as stated in the USACE BIM Road Map, “USACE will be a leader in using BIM to improve delivery and management of facilities for the nation,” they have laid out a timeline for achieving increasing levels of maturity within their program. Their timeline is broken into four phases with the following indicators for success aligned with each phase:

- 2008: Initial Operating Capability (IOC) with eight USACE Centers of Standardization productive in BIM
- 2010: 90% Compliant with NBIMS and all districts productive in accordance with NBIMS
- 2012: NBIMS used for all projects as part of contract advertisement, award, and submittals
- 2020: Leverage NBIMS data for substantial reduction in cost and time of constructed facilities

The USACE has created indicators that are both ambitious and realistic. By phasing their strategy, they have avoided the trap of “over promising” benefits that the technology cannot deliver. This also allows time for the culture within the USACE to change and to gradually phase in BIM in the best, most practical way in a traditional spiral fashion, synonymous with success in IT implementation.

In addition to the four phases, the USACE BIM Road Map includes seven “Milestones” for tracking their progress along the time continuum.

As seen in Figure 2-20, the BIM Road Map has organized the four indicators mentioned above into the following seven milestones (Figure 2-20):

- 4 COS trained in BIM
- Remaining 4 COS Trained in BIM
- Non-COS Districts Trained in BIM
- 8 Standard Facilities in BIM Repository
- 90% Compliance with NBIMS
- All Districts using BIM
- NBIMS Used on all projects

Appendix A outlines six “goals” that build on the four phases and seven milestones discussed above. These include:

- Goal 1: Establish Metrics To Use for Measuring Process Improvement
- Goal 2: Establish Initial Operating Capability for BIM No Later than 2008
- Goal 3: Establish Facility Life-Cycle Interoperability No Later than 2010
- Goal 4: Achieve Full Operational Capability Using NBIMS Based e-Commerce No Later than 2012
- Goal 5: Use NBIMS in Asset Management and O&M of Facilities no Later than 2012
- Goal 6: Leverage NBIMS To Automate Life Cycle Tasks No Later than 2020

USACE BIM Road Map Appendixes

The Army BIM Road Map’s Appendix B has 18 sections discussing tactical level implementation concerns targeted at mid level managers at the district level. It reads like a

“BIM for Dummies” guide might possibly read in that it focuses on specific, actionable steps for establishing a successful BIM program. Written in the first person, inclusive “we” approach, Appendix B serves not only as an instructional, but persuasive document to help USACE practitioners achieve successful transformation towards BIM-centric operations. Specific items of interest include recommendations for the BIM implementation team as well as requirements and salary ranges for the BIM modeling team once the program is established.

The Army BIM Road Map’s Appendix C addresses concerns about “dataset evolution instructions.” This means that is primarily focuses on the most technical portion of modeling, data input and how that changes over a project. Consequently, this appendix references technical guidance such as “Technical Report 01-6, September 2001 A/E/C CADD Standard, Release 2.0.”

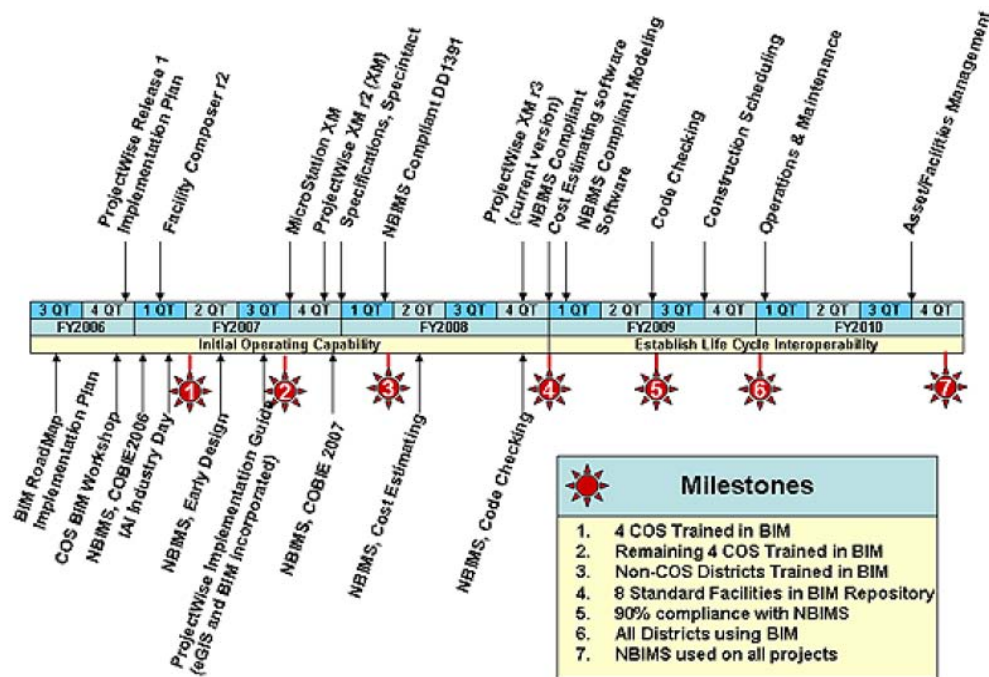


Figure 2-20. USACE BIM Road Map: Short-term Plan for implementing BIM with Milestones (Brucker et al. 2006)

This section also provides a graphic as seen in Figure 2-21 that helps managers visualize the cyclic process and nature of dataset evolution.

11. Data Set Evolution Flowchart

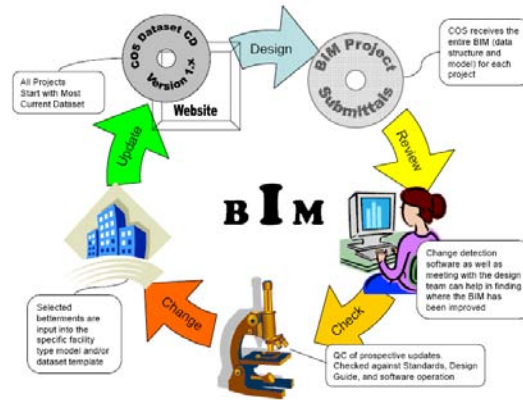


Figure 2-21. USACE BIM Road Map: Data set evolution graphic (Brucker et al. 2006)

The Army BIM Road Map’s Appendix D discusses specific concerns related to modeling workflow within the “BIM Pit” design team discussed earlier in the body of the document. This section references the Louisville District’s modeling workflow diagram shown in Figure 2-21.

Figure 2-22 is important because it shows that the end goal is still the traditional Construction Documents (CDs) including floor plans, sections, elevations, etc., but it also addresses the iconoclastic approach to modeling the building virtually in order to arrive at the desired end state. One added benefit of the new, BIM approach is the ability to accomplish interference checks as discussed in the Road Map. The document advises modelers to use “...Bentley Navigator together with Bentley’s Interference Manager. It is used to locate problems in the model where two objects are occupying the same physical space” (USACE 2006). Lastly, it also addresses the continued need for traditional media such as CDs and lists the required specific drawing requirements with further descriptions about what to include and how to include the information from the model in the drawings.

The Army BIM Road Map’s Appendix E, “A/E Contract Language” and Appendix F, “District Oversight and A-E BIM Implementation Guidance” are currently blank. Hopefully, the

USACE will populate these portions with boilerplate contract language and guidance for all 42 COS districts can use when soliciting for a BIM for their standard facility types, because this would be invaluable in helping expedite the RFP drafting process for this work.

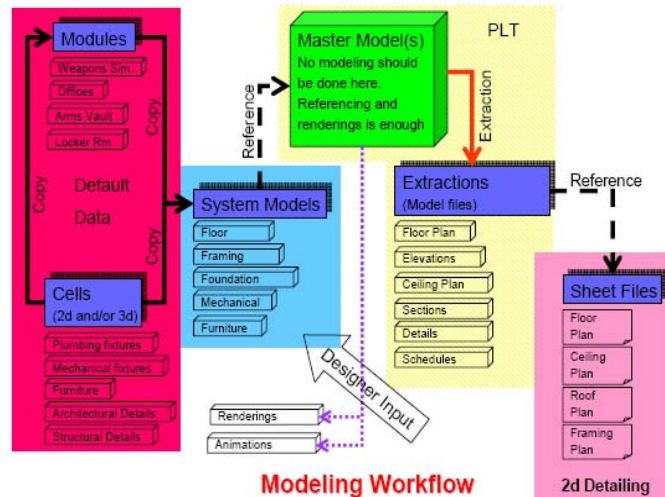


Figure 2-22. USCAE BIM Road Map: Example workflow used by Louisville BIM design team (Brucker et al. 2006)

The Army BIM Road Map’s Appendix G lists specific language for soliciting for a new position description (PD) for a “Civil Engineering Technician” as used at the Louisville District. In line with most other standard government PDs, it discusses portions of time that the individual will spend on certain tasks. This particular position description addresses database management 25%, project execution 30%, training 20%, and program management 25%.

The Army BIM Road Map’s Appendix H is comprised entirely of the FY 06 COS memo as discussed earlier in this section and Appendix I, “BIM Related Roles and Responsibilities” consists of a listing of contacts predominantly in the USACE that can help individuals provide guidance on implementing BIM.

In all, the USACE BIM Road Map is a highly valuable piece of work because of its ability to convey large amount of pertinent information in succinct ways. The document has a metaphorical “finger on the pulse” of the community and addresses nearly all the major questions currently posed about BIM in the AECO industry. It is important to note that the USACE BIM Road Map is not the only document addressing the use of BIM in the Army. Additionally, there are other supporting documents that address specific BIM concerns, such as this recent Engineering and Construction Bulletin number 2006-15 linked from the whole building design guide (WBDG) dated December 26, 2006 (USACE ECB 2006). This evidence supports the fact that BIM has support not only from labs such as ERDC, but that the leadership supports BIM use in the day to day processes of the Corps on all projects. This specific letter focuses on what format BIM deliverables will take in order to be interoperable and compliant with geospatial data, such as “coordinate systems, projections, and datum” being defined in the data’s metadata (USACE ECB 2006). In all, the Army has the tools in place in order to have a very substantial BIM program in the near future.

USACE BIM in the field

However, the BIM Road Map and WBDG are not static documents, but living testament to the mission and execution plans for the USACE. In accordance with the direction in the BIM Road Map, the Corps held a five week training/coaching effort. According to said Sandy Wood, a U.S. Army Engineering and Support Center mechanical engineer overseeing the BIM training, “We were tasked with learning the new software and applying it to a medium child development center project. Since BIM contains mechanical, electrical, structural and architectural components, we brought in employees from all four disciplines for the training” (Takash 2007). Wood went on to say, “Change orders usually account for 8 to 12 percent of the cost in a typical design project. A design done with BIM has been proven to reduce change orders to as little as 2

percent of the construction costs. In large dollar projects, this could easily add up to millions of dollars in savings” (Takash 2007). While Wood’s source for “proving” change order reduction in the construction phase of projects designed with BIM-compliant software is not substantiated, the claim is one that is representative of the feeling most organizations have who are transitioning to BIM. That is, there are hopes for construction phase effects from design phase changes. However, to this point, little work has been done to substantiate these claims.

As the USACE moves from adoption to implementation of BIM, one of their primary proponents thinks that Facility Management (FM) is a future, unexplored niche for BIM. Lee Ezell of the Mason and Hanger Group out of Lexington, KY is mentioned in Chapter 4 for his contributions to the Louisville District in helping them to start their BIM program for the Army Reserve Program Office to address desired improvements in the design phase... However, he also recently wrote an article included in the *The Military Engineer*, the official journal of the Society of American Military Engineers (SAME) entitled, “BIM for FM,” where he discusses the benefits of BIM in the O&M phase. In his article, Ezell notes that while BIM has “revamped building design” it also has added benefits of: enhanced design through better coordination, improved imagery to spend more time on design and less on contract documentation, and BIM software reporting features that aid facility managers to better maintain their equipment (Ezell 2007).

USACE BIM in FM: The COBIE initiative

In addition to better mechanical design through BIM, Ezell’s (2007) primary argument for BIM as an FM enabler is that it is possible to generate user-friendly spreadsheets that can be used to maintain equipment. This idea already has roots in the COBIE effort, or the Army’s attempt to automate the handover and commissioning of a facility for Facility Managers. COBIE stands for Construction Operations Building Information Exchange and is an initiative

spearheaded by Dr. William “Bill” East out of the Engineering Research and Development Center (ERDC) financed by USACE and located at the Civil Engineering and Research Laboratory (CERL) in Champaign-Urbana, Illinois. According to the National BIM Standard Project Fact Sheet, COBIE’s objective is to “create both an IFC reference standard supporting the direct software information exchange and a spreadsheet that can be used to capture COBIE data for both renovation and capital projects” (Brodt and East 2006). To date, COBIE has been fielded in test cases in the Seattle District into contract language, as well as at NASA on some renovation projects. Additionally, Robert Bradford of Burns & McDonnell provided the COBIE team from ERDC with the first COBIE file that provides a nearly complete example of COBIE "design" and construction "installation" information. While the Burns and McDonnell effort did not provide a complete project handover deliverable as is required in the Department of State, Corps of Engineers, and GSA contracts, it is the first publicly available COBIE data that has been prepared.

At the end of July, 2008, the COBIE initiative made a massive leap to the forefront of the industry’s focus on tying BIM to FM. Titled the “BIM Information Exchange Demonstration,” and sponsored by the Federal Facilities Council, buildingSMART Alliance, and USACE at the National Academies of Science in Washington, D.C., the event’s purpose was to “demonstrate the results of an emerging requirements-based process that allows subject matter experts [to] define contracted information exchanges” (East 2008). The live demonstrations conducted using commercial software and downloadable add-on products showed that three contracted information exchanges, the Spatial Compliance Information Exchange (SCIE), Coordination View Information Exchange (CVIE), and Construction Operations Building Information Exchange (COBIE) could replace current paper or e-paper deliverables. Focusing on the COBIE

demonstration, each software vendor conducted live demonstrations showing how the required data was exported from their software. Then, the final files were passed through a “file checker” program to test the quality and completeness of the exchange.

Company	System	Focus	Route	SCIE	CVIE	COBIE
				Space areas	IFC Proxies	C/T ratio
Onuma	OPS	Planning	direct	net only	n/a ¹	22.6
Bentley	Architect	BIM Design	via IFC	yes	2	4.1
AutoDesk	Revit	BIM Design	direct	yes	n/a ¹	0.5
AutoDesk	Revit	BIM Design	via IFC	yes	1820	5.5
Nemetschek	Vectorworks	BIM Design	via IFC	none	0	1.0
Project Blueprint	CodeBook/ Room Data	2-D Design	direct	none	n/a ¹	4.3

¹ software not tested against this requirement.

Company	System	Focus	Route	COBIE Quality
				10 least effort
Onuma	OPS	Planning	direct	9
Bentley	Architect	BIM Design	via IFC	8
AutoDesk	Revit	BIM Design	direct	4
AutoDesk	Revit	BIM Design	via IFC	6
Nemetschek	Vectorworks	BIM Design	via IFC	7
Project Blueprint	CodeBook/ Room Data	2-D Design	direct	5

Figure 2-23. Comprehensive and rank order results from FFC, bSA, and USACE “BIM Information Exchange Demonstration” in July 2008 (East 2008)

The results were slightly “controversial” because the product with the most market share (Revit) scored the lowest in the course of the test. Additionally, there was no standardized facility or level of design, so some software vendors argued that others had used more simple designs or that their more complex designs used objects without interoperable IFC representations yet (e.g. fire sprinkler heads). All in all, the results can be seen in their comprehensive and rank order format in Figure 2-23. In all, the US Army is leading federal

government owners when it comes to driving transformation through BIM implementation. As is evident in their robust planning, organizational change, and research efforts, BIM has a strong foothold in their current and future operations.

The U.S. Coast Guard


The United States Coast Guard's (USCG) approach to BIM is entirely different than the USACE approach. Whereas the USACE approach is to help streamline their operations and enhance their COS approach, the USCG viewed BIM as an opportunity to aid their expansion. When the Coast Guard moved under the Department of Homeland Security in 2002 due to the "new" perceived threat of terrorist acts on United States soil as evidenced in the attacks of September 11, 2001, the USCG's operations tempo level grew accordingly. Associated with this increase in operations were entirely new missions that the USCG did not have prior to 2002. Specifically, the new USCG mission to provide deep water surveillance brought with it the need for 35 unique sector command centers (SCCs). In a testimonial lauding the USCG's primary consultant for services in their BIM imitative, Onuma, Inc., J. M. Brockus, Lieutenant Commander, Chief, North Team, US Coast Guard, commented, "Onuma, Inc. helped create a BIM tool that greatly assists with the design and construction processes of Sector Command Centers. This tool allows consistent programming nationwide and rapid decision making for development of budgets and staffing levels. The success of this BIM tool paved the way for its expansion into whole building programming site planning, and design to support off-cycle crews for the Coast Guard's newest Deepwater National Security Cutters" (Onuma 2007).

Highlighted in the August, 2007 article, "Architect Creates Design Synthesis Software," the Onuma Planning System (OPS) was described as allowing "integration of vast amounts of information" (Tardif 2007). Coupled with Tardif's praise, Onuma's OPS application and

services for the USCG and Open Geospatial Consortium (OGC) received the highest scores on the NBIMS Interactive Capability Maturity Model (I-CMM). The I-CMM is a tool that was created by the NBIMS Testing Team in the fall of 2006 to answer the same question posed in research question #2 in this research, “What types of information can be leveraged in a BIM approach and to what degree?”

Described in NBIMS Chapter 4, Section 4.2, the NBIMS I-CMM is an interactive version of the static excel maturity matrix originally created by NBIMS Executive Chair, Mr. Deke Smith, FAIA. Before the NBIMS was published at the end of 2007, the I-CMM was validated in the summer of 2007 by using it to evaluate the 2007 American Institute of Architects (AIA) Technology in Practice (TAP) BIM Award Winners. After the team used a “double blind” approach and discovered scores that were only between 1-5% different, the tool experienced minor modifications before adoption and subsequent inclusion in the final NBIMS publication (McCuen and Suermann 2007). Figures 2-24 and 2-25 show the NBIMS Interactive-Capability Maturity Model score card for each submission respectively.

TODAY:		October 15, 2007	
© NIBS 2007			
The Interactive BIM Capability Maturity Model			
Area of Interest	Weighted Importance	Choose your perceived maturity level	Credit
<i>Data Richness</i>	84%	Limited Knowledge Management	7.6
<i>Life-cycle Views</i>	84%	Includes Operations & Warranty	5.9
<i>ITIL Maturity Assessment</i>	90%	Limited Integration	6.3
<i>Roles or Disciplines</i>	90%	Partial Ops & Sustainment Supported	6.3
<i>Business Process</i>	91%	Some BP Collect&Maint In Real Time	8.2
<i>Timeliness/ Response</i>	91%	Limited Real Time Access From BIM	7.3
<i>Delivery Method</i>	92%	Netcentric SOA Role Based CAC	9.2
<i>Graphical Information</i>	93%	nD - Time & Cost	9.3
<i>Spatial Capability</i>	94%	Part of a limited GIS	6.6
<i>Information Accuracy</i>	95%	Computed Ground Truth w/Full Metrics	9.5
<i>Interoperability/ IFC Support</i>	96%	All Info Uses IFC's For Interoperability	9.6
TOTAL			85.7
Certification Level			Gold






Figure 2-24. OPS I-CMM Score for USCG 2007 AIA-TAP BIM Award

TODAY:	October 15, 2007		
© NIBS 2007	The Interactive BIM Capability Maturity Model		
	Area of Interest	Weighted Importance	Choose your perceived maturity level
	<i>Data Richness</i>	84%	Limited Knowledge Management
	<i>Life-cycle Views</i>	84%	Supports External Efforts
	<i>ITIL Maturity Assessment</i>	90%	Limited Integration
	<i>Roles or Disciplines</i>	90%	Internal and External Roles Supported
	<i>Business Process</i>	91%	All BP Collect&Maint In Real Time
	<i>Timeliness/ Response</i>	91%	Real Time Access w/ Live Feeds
	<i>Delivery Method</i>	92%	Netcentric SOA Role Based CAC
	<i>Graphical Information</i>	93%	4D - Add Time
	<i>Spatial Capability</i>	94%	Integrated into GIS w/ Full Info Flow
	<i>Information Accuracy</i>	95%	Computed Ground Truth w/Full Metrics
<i>Interoperability/ IFC Support</i>	96%	All Info Uses IFC's For Interoperability	
		TOTAL	95.5
		Certification Level	<i>Platinum</i>

Figure 2-25. OPS I-CMM Score for work with Open Geospatial Consortium (OGS) for 2007 AIA-TAP BIM Award

According to Tardif, “Onuma’s solution is a software tool—the Onuma Planning System™ (OPS)—that enables project teams to amass and synthesize programmatic information far more quickly than is possible with any current method” (Tardif 2007). When asked to summarize his tool in one sentence, Tardif goes on to say that Onuma replied, “It allows you to test a lot of decisions early on and bump into problems early so that you can go in another direction” (Tardif 2007). Figure 2-26 shows a stylized screen capture of the OPS tool.

Specifically for the USCG, in the words of David Hammond, RLA, Chief, SFCAM Division Commandant, USCG, “The integration of BIM, geospatial data, real property data and mission requirements supports the need of a common operational picture for the USCG. This common operational picture can be real time tactical information as well as longer term strategic information, which was enabled by the architect’s use of BIM (Hammond 2007). In Hammond’s briefing to the National Academy of Sciences Government/Industry Day October 31, 2006, he stated that BIM was not a technological aid to existing operations, but instead an identified IT-enabler used in the course of organizational change and reengineered processes (Hammond 2006).



Figure 2-26. Various, Integrated Information Conglomerated through OPS (Hammond 2007)

In the USCG’s self-titled “IT-enabled enterprise framework” they moved away from building centric and project focused approaches in favor of a portfolio-based, business process linked to strategic outcomes. They integrated their individual asset portfolios such as buildings, cutters, aircraft, logistics, IT and HR and instead sought continuous horizontal flow across the organization (Hammond 2006).

In order to evaluate their progress on their organizational transformation, the USCG set distinct, measurable goals including the following:

- Moving from a locally focused sub-optimized facility engineering perspective to an enterprise-wide asset and portfolio management organization focused on managing \$7.5B in plant replacement value (PRV)
- Achieving 17% to 33% in recurring savings in annual services delivery
- Achieving CFO Act Audit Certification (Sarbanes/Oxley)

The answer to this was a focus on horizontal cross-functional alignment (Figure 2-27). Cross-functional management recognizes that process must be treated as a strategic corporate

priority, competition is won by treating all parts of the organization as a single unified whole, and critical cross-functional shore infrastructure process must be managed by process managers. In turn, the USCG moved their focus to linking and aligning their process with daily tactical activities and agency-wide strategic outcomes (Figure 2-27 and 2-28).



Figure 2-27. USCG Organizational Transformation to Horizontal Cross-Functional Alignment (Hammond 2007)

Bringing the business philosophy back to IT approaches, the USCG combined a BIM approach with their existing Geospatial Information Systems (GIS) strategy to manage the information that helped them align with their operational requirements, infrastructure capability, and organizational needs in an application called the Capital Asset Management Portal (CAMP) (Figure 2-29 and 2-32).

This portal gives them access to an enterprise-wide aggregated database and graphics used for both portfolio management/historical data applications as well as scenario-based business case development and an automated planning tool for real time mission readiness. (Hammond 2007).

Process Alignment

- Link and align daily tactical activities to agency-wide strategic outcomes.



Value Chain

- Link facility capabilities to operational requirements: **our customers**;
- Link operational capabilities to mission requirements
- Link mission capabilities to public demand for goods/services: **our customer's customer**.



Figure 2-28. USCG Process Reengineering to Vertical Value Chain Alignment (Hammond 2007)

CAMP uses, and provides access to, geo-rectified raster information like Google Earth Keyhole Markup Language (kml) data, floor plans and space utilization information like ArchiCAD/XML files, and planning functionality through the Onuma Planning System (OPS) which works with tabular data and provides visual representations of facility planning via Sketch up. The USCG has demonstrated the functionality of CAMP through routine business processes such as integrated planning for physical reorganization or design charrettes for new construction requirements.

Additionally, another area where the USCG is ahead of many of its peers is its focus on using BIM not only in the design phase, but as a tool to manage and leverage legacy data for day-to-day operations and maintenance of their facilities. In fact, the USCG proudly promulgates that they are the only owner with 100% of their real property stored in individual and portfolio-wide BIMs. In order to accomplish this, they created “BIM-blobs” for all their

existing facilities and are gradually adding data to the blobs as mission requirements dictate and time allows (Figure 2-30).

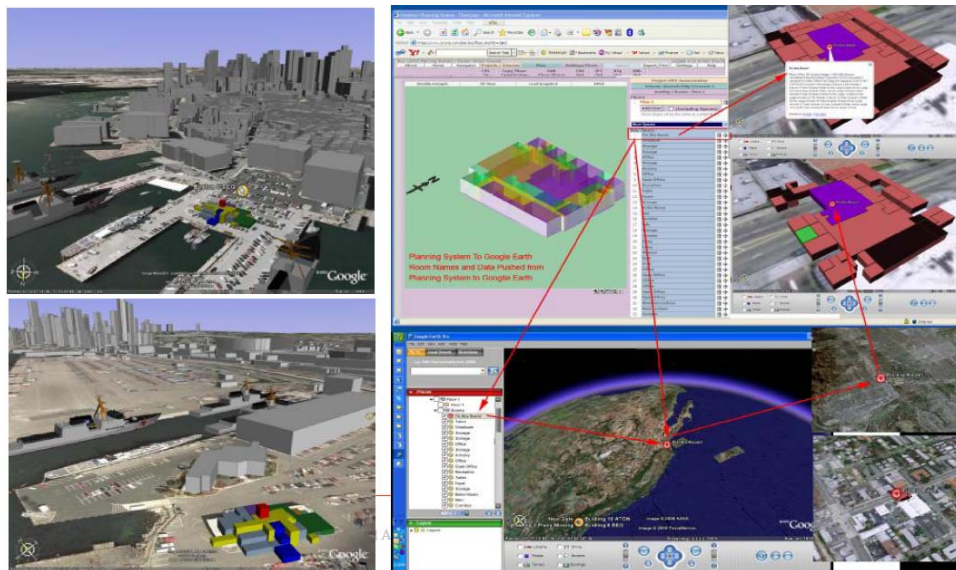


Figure 2-29. USCG CAMP Application: Various screen shots of integrated geospatial and facility level views (Hammond 2007)

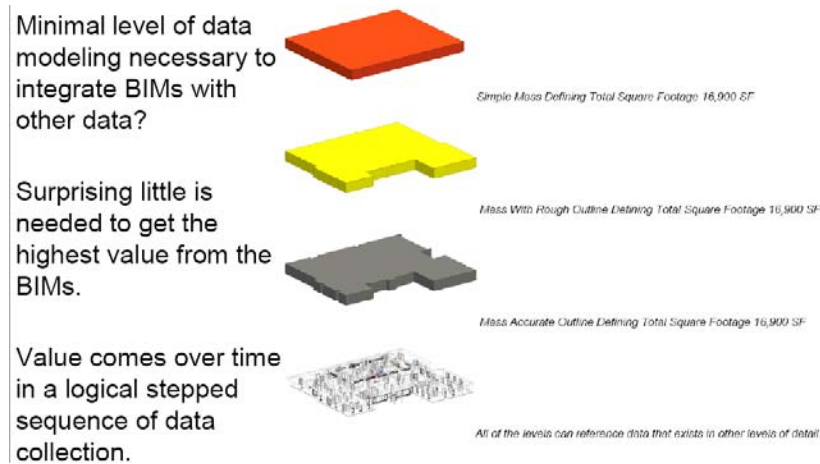


Figure 2-30. USCG Stepped Strategy of Data Collection and Modeling (Hammond 2007)

One area where the USCG is similar to the USACE is their adoption of “boilerplate” designs for standardized facility types. While not as archaic as the “kit of parts” post offices of the late 20th century, they do represent a definite philosophical shift from the idea that all

buildings are “unique works of art.” While some may think that this would be contrary to traditional architects’ views of architecture, this was not the case. Rather, the USCG received national acclaim as the 2007 AIA TAP BIM Award Winner in the Design/Delivery Process Category for BIMs. As the primary consultant to the USCG in their BIM initiative, Kimon Onuma’s submission for the award more than adequately summarizes the USCG approach:

“As architects and planners we solved the need of the projects and created a process for collaborating with the client in a way that integrated data and maximized value for the full lifecycle. Also as software developers we connected the dots, using data and knowledge efficiently thus leaving more time for creativity in design. The by-product is a more sustainable process of collaboration and better stewardship of building information for the client. The architectural charrette was turned inside out. Each session accumulated knowledge of the group, built upon the last, and unified decision making. All decisions were captured in the web enabled BIM. This process created a virtual ongoing process and unified all the projects in real time. Critical decisions can be made very early on in design and captured for the full life cycle of the project. New workflows were defined and data exchanges made possible. The integrated practice was made possible using interoperable standards defined Industry Foundation Classes (IFC) and Open Geospatial Consortium (OGC).” (Onuma 2007)

The primary project included designing one 3,500 SF SCC and repeating the process for the 35 unique SCCs with one methodology which included a BIM server with access for multiple users to view and edit sub-sets or entire models on multiple project sites in real time (Onuma 2007). Ironically, the SCCs even used a “kit of parts” mentality – but only where it “made sense.” This approach was primarily used on the internal configurations for command and control portions of the SCCs. Logically, optimization through standardization could best be achieved at the micro level of human interaction in the command center. In stark contrast, the building models themselves were highly customized to meet the needs of the geographically disparate and climatologically diverse individual SCCs themselves through direct input from the users (Figure 2-31).

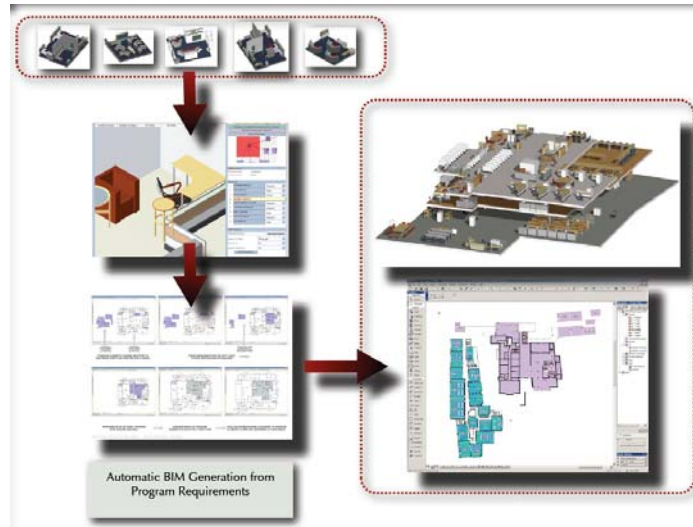


Figure 2-31. Onuma Planning Systems, Inc.: “Automatic BIM Generation from Program Requirements” from multiple users via the web (Hammond 2007)

In Onuma’s words, “Users began creating [a] BIM as a by-product of the process. Data was accessible in real time through a web interface to all in the process, not just BIM experts, but architects, engineering, owners, and others. The input and decisions were supported through the web . . . Whether at milestones during the process or at the processes’ culmination; senior level planners could perform reporting, see visual output of their coordination, or even visualize the results of their work through overlaid renderings via key-hole markup language (KML) files in Google Earth (Onuma 2007).

In all, the USCG’s recent strategic level efforts to transform their organizational climate and improve their value chain have resulted in tactical level business processes that are light years ahead of the industry. Their recognition as the AIA 2007 BIM Award winner for Design/Delivery Process Innovation may not be matched by any traditional firm or owner for years to come. However, what is most important to learn from the USCG case study in BIM is not the specific tool or even data output, but the prominence that the technology took as an

enabler for organizational transformation. True technological success will always and only be found in close proximity of truly successful leadership.

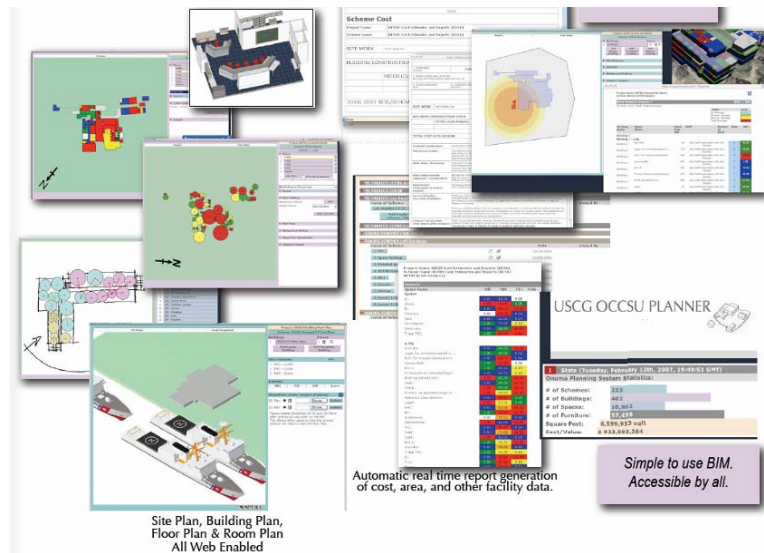


Figure 2-32. Onuma Planning Systems, Inc.: Multiple Benefits from CAMP with abilities for reporting, geospatial awareness, and coordination (Hammond 2007)

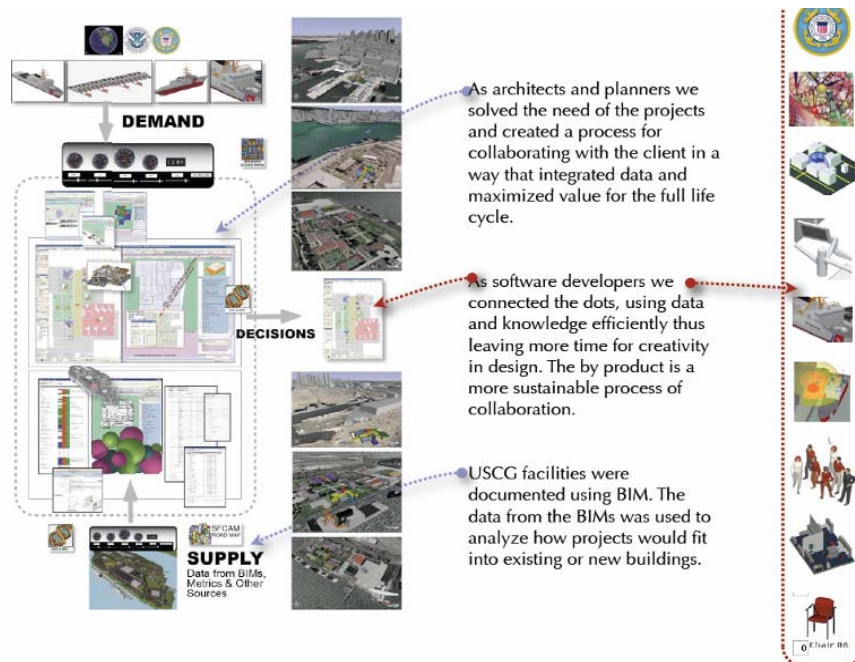


Figure 2-33. Onuma Planning Systems, Inc.: New Forms of Collaboration and/or Partnering as architects, software developers, and real estate manage (Hammond 2007)

The U.S. Air Force

The U.S. Air Force move towards Building Information Modeling came later than the U.S. Army Corps of Engineers. Instead, the U.S. Air Force's primary focus was on asset management in the form of improving their geospatial mapping products and capabilities from the year 2000 until the present day.

GeoBase: the USAF initiative to manage geospatial installation data

Some visionary mapping experts tried to field GIS maps in relative isolation at different Air Force bases, but with limited and varied success. It was not until Air Force general officers collectively saw the benefits of GIS in October of 2000 that the Air Force fully embraced the idea that there was a much better way to mapping. In May 2001, after the culmination of the aforementioned Colonel Brian Cullis's research at the Air University's Air War College, the Air Force Chief of Staff formally instructed Air Force installations to adopt Cullis's "GeoBase" Initiative, the Air Force all encompassing term for implementing GIS to aid in expeditionary and garrison operations. Now, only five years later in 2006, current base mapping standards set forth by the Headquarters Air Force GeoIntegration Office (HAF/GIO) dictate that Air Force installations use high resolution (usually 1 meter or better resolution) panchromatic raster imagery to serve as the basis for highly accurate (sub centimeter) installation maps. While there are many cultural, educational, and financial impediments inhibiting any large scale technological change, the Air Force and the DoD have been successful in adopting and furthering GIS, possibly more than any other entity involved in GIS today. With the aftermath of September 11th, and military deployments to many new locations in tense political climates, GIS has served as a force multiplier for DoD personnel. The DoD no longer avoids GIS, but instead, thrives on the benefits of wide scale implementation and standardization.

Drilling down from the macro level data that these highly accurate maps provide, the DoD now faces another challenge – to make their facilities’ data as rich and robust as their installation map data. The daunting task of devising a process to standardize the decentralized execution of the DoD’s technological applications has already been overcome in the arena of standardizing DoD’s approach to digital mapmaking in the Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE). SDSFIE are graphic and non-graphic standards for GIS implementations within the DoD and provide a standardized grouping of geographically referenced (i.e., geospatial) features (USACE WES 2006). Just as a librarian may use the Dewey Decimal or Library of Congress Systems to organize millions of works of literature into a finite number of groupings, the SDSFIE serve as a guide for DoD map makers to properly catalog the myriad of geospatial data available at any DoD installation or deployed location. With the bulk of military personnel serving in positions for limited periods of time, the SDSFIE serve to ensure that all maps military members work with are all “created equally.” This same thought process and methodology could (and should) be applied to data stored in a BIM, so that all personnel who work with the data would have a basis for understanding how to retrieve, use, and edit the data.

The USAF metric initiative for MILCON excellence: “Ribbon Cutter Metrics”

In the beginning of Fiscal Year (FY) 2001, the USAF initiated a program to try to reward productivity improvement in their MILCON program through recognition tied to metrics called “Dirtkicker metrics.” After undergoing a name change for FY09, the program became known as the “Ribbon Cutter” metrics and awards. This program is beneficial to the USAF for measuring their construction excellence from a strategic level. The USAF approach is very similar to the USACE approach in that it uses high level metrics such as cost growth, time growth, and financial closeout to monitor the performance of their MILCON projects. One area where the

USAF approach contrasts with the USACE approach is that they go a step further from just documenting the “delta” and use the Major Commands’ (MAJCOMs) performance as values in an equation that result in recognizing stellar performance.

This is how the winner is calculated. First, MAJCOMs are divided into two groups: small and large. Then, MAJCOMs can receive award points in four main areas: design, award, construction, and financial closure. These four categories are further broken down into subcategories as presented in Figure 2-34.

			Weight	Calculation Type
Design				
Use of Prior Yr P&D Funds			1	Program Goal: Pass or Fail
Design Authorization			1	% Projects that meet Gal
Design Completion			1	% Projects that meet Goal
Award				
President's Budget (PB) Projects			1	% Projects that meet Goal
Congressional Insert (CI) Projects			1	% Projects that meet Goal
Current Working Estimate (CWE)/Programmed Amount (PA) Ratio *			.5	Program Goal: Pass or Fail
Construction				
Cost Growth			1	% Projects that meet Goal
Schedule Growth			1	% Projects that meet Goal
Construction Timeline			1.5	% Projects that meet Goal
Financial Closure				
Timely Closeout			2	% Projects that meet Goal
TOTAL				Average % of all Goals

Figure 2-34. FY09 “Ribbon Cutter” Criteria Categories and Subcategories (Shibaro 2005)

To normalize scores, the total score is calculated as an average percentage of all competing categories using the weights as listed in Figure 2-34. In this way, MAJCOMs are not rewarded or penalized for not having anything to report in certain subcategories.

In all, there are awards for both the large and small MAJCOM with the highest percentage score, as well as the most improved large and small MAJCOM. However, MAJCOMs cannot

win both the overall award and the most improved award, nor can they win the most improved award in two consecutive years. Lastly, the most improved award will only go to the MAJCOM with highest positive percentage improvement over the previous fiscal year.

The USAF Dirtkicker Awards are on the right track: through a pragmatic, strategic, and quantitative rewards system, they are fostering a culture of construction excellence that strives for continuous improvement.

Dynamic Prototyping

In order to ensure continuous improvement in line with technology like BIM, the U.S. Air Force Center for the Engineering and the Environment (AFCEE) experienced several events that turned their “potential” BIM energy into “kinetic” energy in the spring of 2008. Most importantly, the Chief of the Design Branch, Mr. Gene Mesick, was successful in securing seed funding to field a pilot project to testing the USAF concept, “Dynamic Prototyping.” Dynamic Prototyping moves forward from standardized design types and standards included in the USAF section of the WBDG to create parametric 3-D geometry of the tabular information espoused in the in the guide. For instance, rather than talking about the standard functions contained in a Fire Station or Flight Simulator, there would exist “BIM legos” that could be assembled into a final building design more rapidly.

Work is underway to integrate Dynamic Prototyping into the U.S. Air Force Business Process Reengineering and transformation efforts under the evolving Agile Installation Management (AIM) initiative.

CENTCOMM HQ, MacDill Air Force Base, Florida: USAF BIM pioneer

In the summer of 2008, Lt Col Jay “Jim” Beam of HQ CENTCOMM at MacDill AFB in Tampa, Florida promulgated his vision for the future of their \$65M new headquarters building.

After accomplishing the “twin” JICCEN building in the fall of 2008, design began on the CENTCOM building (Figure 2-35).



Figure 2-35. New JICCEN facility and future HQ CENTCOMM facility location on MacDill Air Force Base, Florida (Beam 2008)

Wanting to avoid making the same mistakes again, Lt Col Beam wanted to turn the CENTCOM project into a flagship project that moved MacDill in the right direction. Because of this desire and before the design was completed, the project was specified as a LEED-Silver or better project, a BIM-based project able to handle changing user requirements and providing superior visualization abilities for General Officers, as well as a COBIE deliverable upon handover for superior FM capabilities. As of September, 2008, the project was going to be designed in Revit Structure and Revit Architecture, with MEP in AutoCAD MEP 2008 and integrated into the model in Navisworks. Additionally, the model was to be used for the LEED

process and structural analysis. Lastly, and most unique about the project, the BIM data was to be used in conjunction with building handover and commissioning data in order to make an extremely robust database available in Autodesk’s FM Desktop or NavisWorks FM application for this facility. Working with the USACE ERDC, CERL, Mobile District, AFCEE, the University of Florida, and Burns & McDonnell (the A/E), Lt Col Beam is still working to meet his vision.

The U.S. Navy

The Naval Facilities Engineering Command or simply NAVFAC is the primary stakeholder and BIM proponent in the U.S. Navy. Their initial BIM effort is aptly labeled a “grass roots effort.” At the time of publication, an enterprise-wide or portfolio BIM information management approach is beginning to materialize in the Navy the way it has in the Army and the Coast Guard. In fact, a 2007 web search for BIM-related work in the U.S. Navy yields little results except for a pilot project from Mr. Alex Viana of Naval Facilities Engineering Command (NAVFAC) at the Engineering Service Center. However, this project was unique in that it crossed a difficult boundary: from geospatial to building information model. Mr. Viana’s project set out to describe a step by step process to produce virtual 3-D waterfront facility models (Figure 2-36) of the Navy’s built environment from existing facility data (Viana 2007).

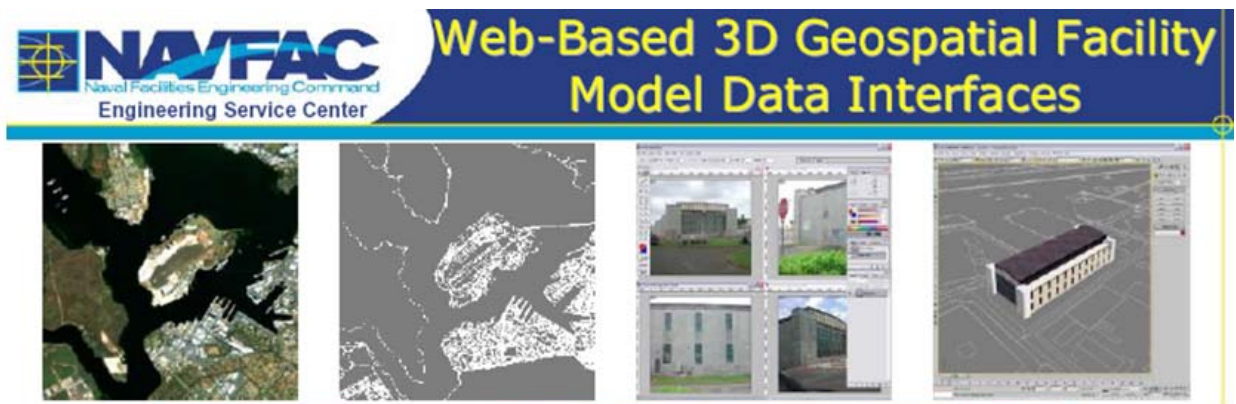


Figure 2-36. Samples of NAVFAC’s Web-based 3-D Geospatial Facility Model Data Interfaces

Also, a leading Jacksonville-based design-build firm, The Haskell Company, used Revit to design a U.S Navy Training facility in Virginia. However, “the company’s engineers and architects are trained as needed for specific projects, so only a dozen of Haskell’s design professional are really proficient in BIM” (Van Housen 2008).

However, in 2008, after talking to the most recent BIM Manager for the USN, Dean McCarns, the USN’s current approach to BIM is much more strategic in nature than the grass roots efforts described above. Because of the highly entrenched facility management databases in the USN, their BIM approach will seek to find the proper use of their existing information and where to best capitalize on information exchanges. In particular, one item of note for the USN is that they feel that “pilot projects are wastes of money and cause more confusion than they’re worth” (McCarns 2008). Therefore, they are progressing cautiously and are planning not to fully unveil their plan for five years.

Conclusion

BIM is rapidly becoming the standard for transforming the way facilities are programmed, designed, built, operated, and disposed and disassembled. The federal government is one of the leading owners driving the transformation.

CHAPTER 3 METHODOLOGY

Research Impetus

In 2008, gross spending in the U.S. construction industry was estimated to be \$1.28 trillion. According to the National BIM Standard, sixty percent (60%) or \$600 billion of this spending was most likely waste from inefficiencies caused by information sharing deficiencies or rework (NBIMS 2008). Internationally, the construction industry is one of the largest industries in the world. Other large, international industries such as aviation, manufacturing, and travel have enjoyed productivity increases through Information Technology (IT) business re-engineering. More importantly, re-engineering efforts have yielded **productivity gains** through simulation, web technology, and information standards use. Conversely, the US construction industry demonstrated a significant **productivity decline** since 1964 (Figure 3-1). There are many theories regarding the causes for this trend, however, one work in particular has received the most attention. The 2004 National Institute of Standards and Technology (NIST) documented a probable loss of \$15.8 Billion annually due to interoperability problems associated with current technological approaches used in the industry. This study fueled the efforts of the already ongoing work of the International Alliance for Interoperability (IAI), a group of internationally affiliated members of the Architecture, Engineering, Construction, and Operations (AECO) community. More importantly, it brought the issue to the forefront for the American AECO community, who were up to this point, primarily unaware of this important issue. The collective, international approach to solving this problem was the IAI-sponsored, and now known as the “buildingSMART™ initiative,” and it focuses attention on a two pronged solution:

- Standardize the way information is transmitted, received, and stored electronically through Industry Foundation Classes (IFCs) and chronologically through Information Delivery Manuals (IDMs)
- Build on standardized processes and increase the amount of technology used currently in the facility lifecycle to adopt the information exchanges and greater visualization afforded by a Building Information Modeling (BIM) approach

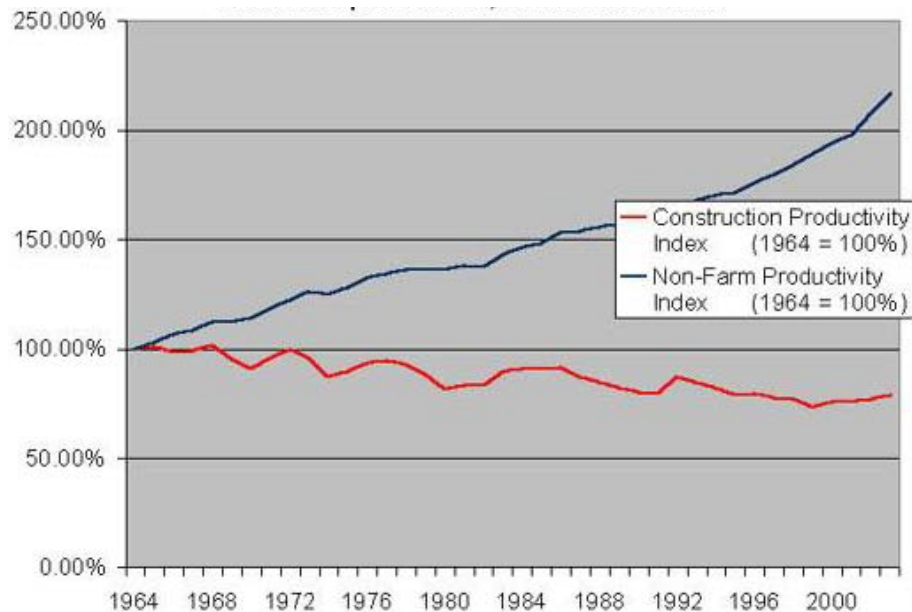


Figure 3-1. Construction & Non-Farm Labor Productivity Index (1964-2003). (Constant \$ of contracts / workhours of hourly workers) (Source: U.S. Department of Commerce, Bureau of Labor Statistics)

Historically, the AECO industry’s efforts to implement and support better information flow between stakeholders with existing CAD systems have focused primarily upon format and output versus open information and workflows (i.e. a paper centric versus a process centric viewpoint.) BIM is a different transition than the move to CAD because CAD did not significantly alter business processes, but simply increased the speed at which centuries-old traditional tasks were completed through electronic means. This was comprised of digitizing a well-known 2D-based design and paper-centric project delivery system (Livingston 2007). Even so, the transition to CAD was not merely a simple undertaking. This was primarily due to the

information standardization needs and business structures not being in place to maximize CAD until the National CAD Standard reached widespread implementation, which has only recently occurred. Therefore, CAD ultimately became a sub-optimized application that BIM is now addressing (NBIMS, 2007). BIM represents the hopes that industry stakeholders thought CAD was going to bring to fruition, but there is little, or possibly none at all, data that suggest these “hopes” are merited. Therefore, this research proposes to collect and interpret empirical data on the current leaders in applying BIM methodology, federal construction projects.

As it is well known in the construction industry “the success or failure of every construction project can be measured in terms of four variables: cost, time, quality, and safety” (Adrian 1995). This study will take this idea a step further and attempt to see if BIM has any tangible effects on the leading Key Performance Indicators (KPIs) (Cox et al. 2003) used to measure construction success.

The leading KPIs used in this research were gleaned from a study by Cox et al. (2003) that surveyed a wide range of construction companies with 166 total responses to determine management’s perception of construction KPIs. KPIs are defined as “compilations of data measures used to assess the performance of a construction operation.” The research noted that six primary KPIs were “reported as being most useful by every segment of the construction industry involved”. Therefore, this research only measures impacts according to these six KPIs described in greater detail later in this chapter.

Methodology

Overview

This research proposes to accomplish research in four phases. These four phases will be aligned with a process originally created by United States Air Force Colonel John Boyd. 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. The OODA Loop will be used here to structure the methodology for the data collection portion of this research. Boyd developed the theory 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 theory into a grand strategy with benefits to anyone who needs to pragmatically and quickly process information.

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 fastest tempo possible. However, in this research, it will be used to make the best, not necessarily the fastest, choices about the proper items to collect and investigate Through Boyd's OODA Loop; this research will be structured in four phases aligned with the ideas of *observation, orientation, decision, and action* (Figure 3-2).

Research Phase I: Observation

At the beginning of Phase I in 2006, BIM was 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

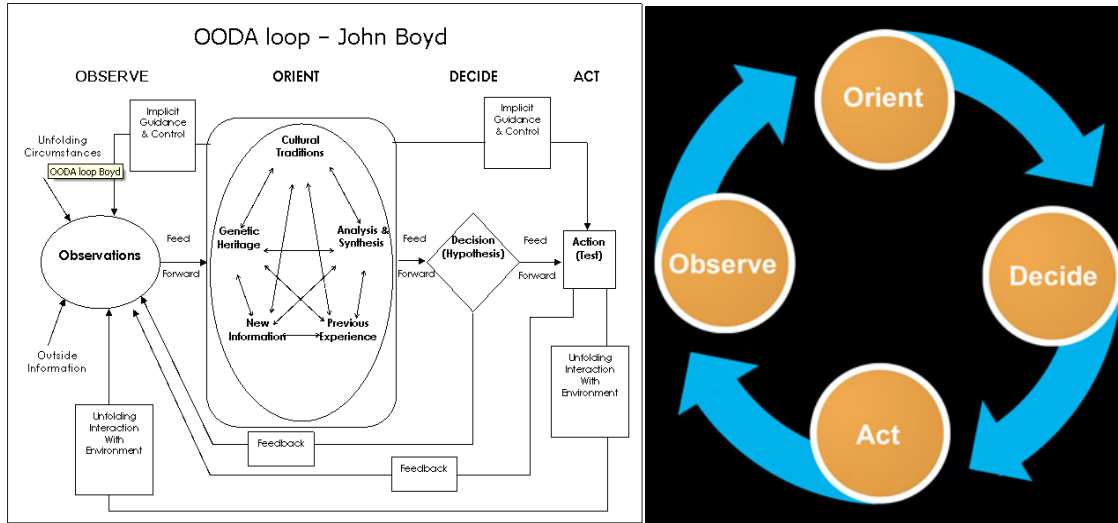


Figure 3-2. Col John Boyd, USAF (Ret.), “OODA Loop” (Observation, Orientation, Decision, Action). Detailed and Simplified.

software and that only 10% of the firms were using the software for billable work. But, by the end of 2008, the McGraw-Hill Smart Market Report on BIM and Interoperability reported that 62% of users surveyed indicated that they will be using BIM on over 30% of their projects in 2009 (Gudgel 2008). However, with little empirical data regarding BIM’s application and use in 2006, a qualitative survey was administered to garner initial data about practitioners’ perceptions about the effects of BIM on construction key performance indicators (KPIs) in addition to the traditional review of literature in the field. 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 a web-based 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.

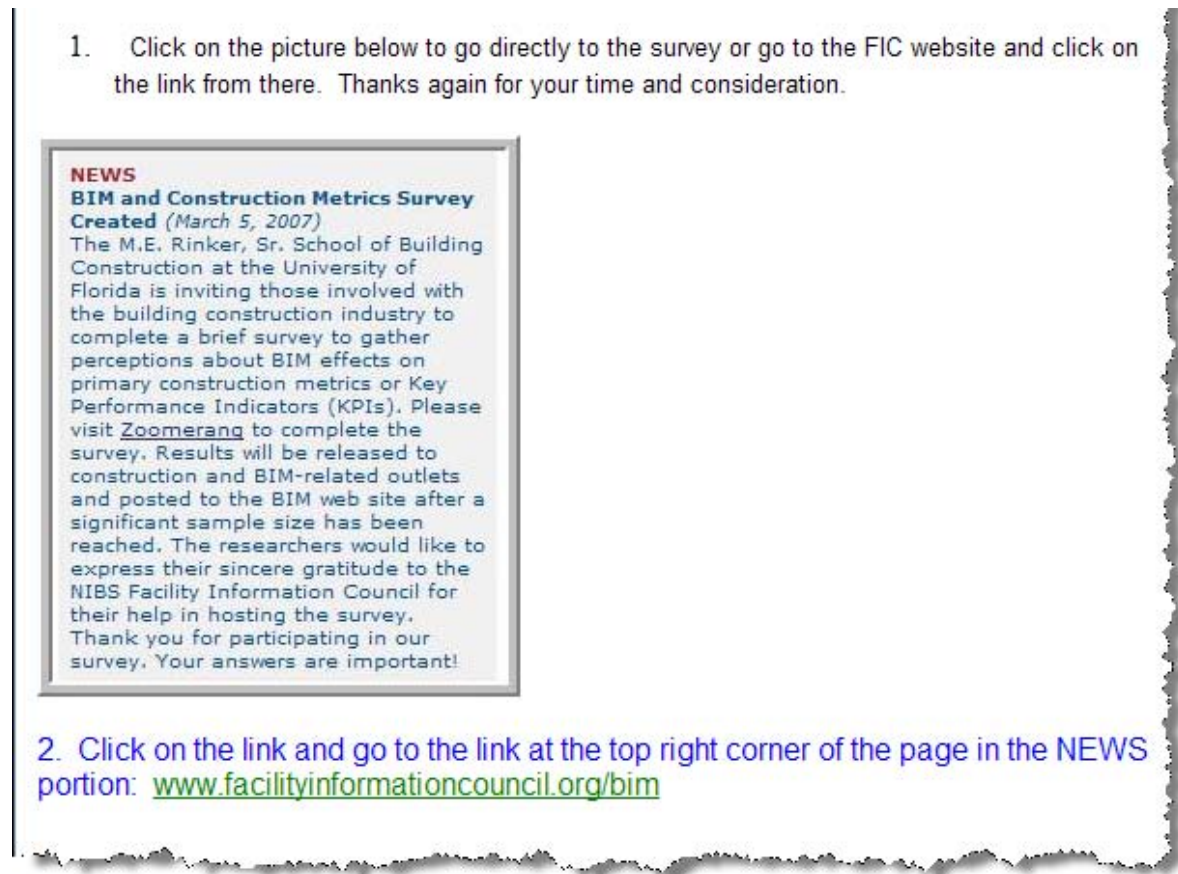


Figure 3-3. Excerpt from first email to FIC listserv notifying the launch of the survey. (Note: Notice the excerpt from the FIC website inside the email)

Survey Iterations #1 and #2: Web-based

Three iterations of a similar survey were launched for the purpose of collecting targeted respondents perceptions about impact of BIM on construction KPIs. This section will discuss all three iterations of the survey and describe the logistics of how each survey was drafted, fielded, and closed out. Results can be found in the chapter four, “Results.”

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. In order to garner maximum participation from existing and new members, the survey 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 (Figure 3-4).

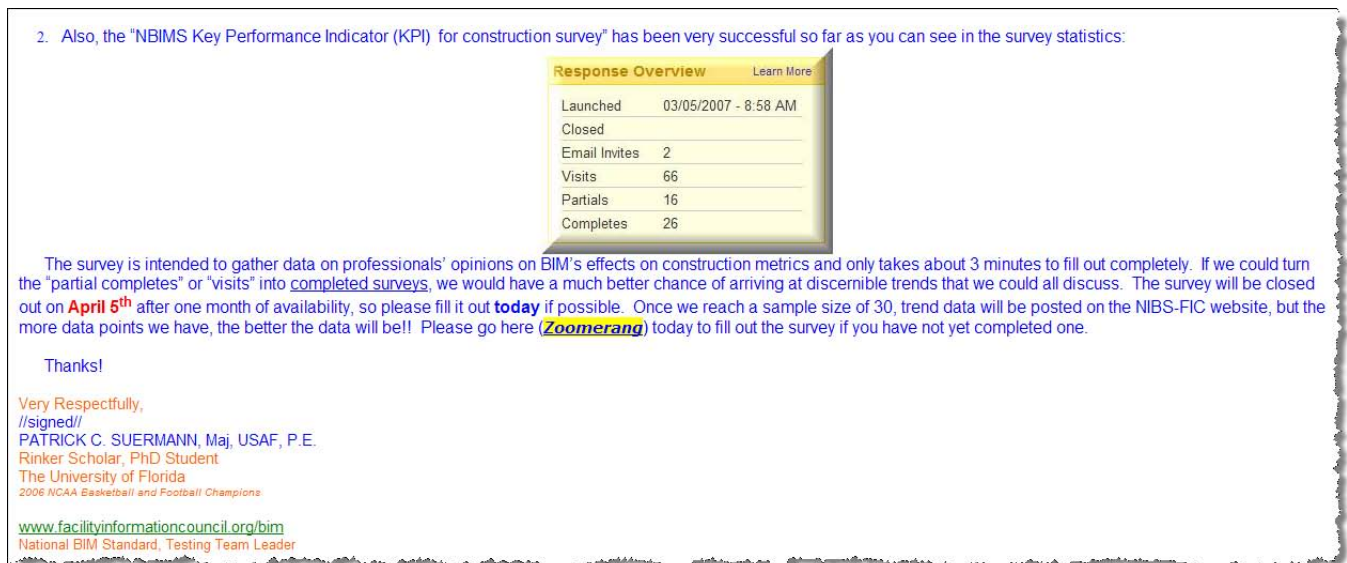


Figure 3-4. Excerpt from reminder email to FIC listserv for people to complete the survey

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 (Figure 3-4). The second method of garnering qualified respondents was to advertise the survey on the NIBS FIC website (at that time, but has since been moved to the

buildingSMART Alliance webpage), <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.

Through this methodology, the survey was administered to a sort of “Delphi Panel” of expert practitioners who are highly knowledgeable in BIM. After assessing their input, it can be compared to the second iteration of the survey, a version that sought to garner as many inputs as possible from across the AECO industry. First the original survey was edited according to input as recommended by respondents in the first iteration of the survey. The only two noticeable changes were

- Including a new organizational role for academic professionals
- Rewording the impact choices on some of the KPI responses to be more clear about what was a negative or positive response
- Adding more possible definitions to the final question about which definition most suited the respondent’s perceived definition of BIM

This final edit was made because it was deemed necessary in order to determine if different organizational roles had perceptions that collectively differed from other organizational roles, as well as the goal of adding more possible “distracters” from the originally limited set of possible answers. Then, a press release about the survey was drafted and submitted to the following media outlets or organizations with varying levels of advertising or success (Figure 3-5):

- 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

April 30, 2007

Contact: Patrick C. Suermann, P.E, 719-964-6289 or 352-273-1176, suermann@ufl.edu

Building Information Modeling (BIM) Effects on Construction Key Performance Indicators (KPIs) Survey Launched

Gainesville, FL—The University of Florida’s M.E. Rinker, Sr. School of Building Construction, in conjunction with the Facility Information Council (FIC) of the National Institute of Building Sciences (NIBS), launched a survey today welcoming all members of the building industry to voice their opinions regarding the effect of building information modeling (BIM) on construction.

The survey can be completed quickly (it has only 16 questions). The questions have been structured in such a way that the resulting data should reveal tangible and significant trends concerning where BIM has the most effect in construction. To take the survey now, please click on the following link: [BIM Construction KPI Survey](#). This survey will document practitioners’ perceptions of the impact of BIM on the construction phase of the facility lifecycle using six metrics or Key Performance Indicators (KPIs) commonly-used in the construction industry. After documenting a large number of practitioners’ opinions, further research can more readily focus on collecting specific, quantitative data to confirm or contradict these perceptions.

The researchers express their sincere gratitude to the University of Florida’s M.E. Rinker, Sr. School of Building Construction and the NIBS-FIC for their help in drafting and fielding this survey.

Figure 3-5. Iteration #2 of the survey went out with a standardized press release to a myriad of organizations and media outlets

The survey then also appeared in areas that must have been secondary media outlets to the organizations or media outlets listed above, because the press release also showed up in places that were not directly contacted by the researcher, such as the Builder’s Association Newsletter in Chicago, Illinois.

Survey Specifics

The survey was divided into four sections (Figure 3-6):

- 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 (Figure 3-7). 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).



BIM Effects on Construction Key Performance Indicators/Metrics

This survey is being conducted by the University of Florida's M.E. Rinker, Sr. School of Building Construction. By completing this survey, you are consenting to the answers being published in research, however, all sensitive information provided will be strictly confidential. There are no risks, benefits, or compensation to you for participating in the study. For questions about your rights as a research participant, please contact the UFIRB office at irb2@ufl.edu or 352-392-0433. Your participation is completely voluntary and you may withdraw your consent to participate at any time without penalty. If you have any other questions regarding this survey instrument, please contact the researchers: Patrick Suermann or Doctor Raymond Issa at 352-273-1176. The researchers would like to express their sincere gratitude to the NIBS Facility Information Council for their help in drafting and fielding this survey, as well as hosting the information and analysis once complete. Also, thank YOU in advance for your contribution to this study. Your answers are important!

The survey follows this overall format:

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

Why Use Demographic Questions?

- *To determine how well this survey captures the target audience.*
Knowing the demographic information of the target audience, we will be able to compare the survey results against what is currently known about the total population.

Figure 3-6. Survey Introduction and overview

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 (2007) Omniclass Table 34 for organizational roles (Figure 3-8 and 3-9).

PART I: Basic Demographic Information

The next questions are for classification purposes only. They will only be used to group your answers with others like yourself.

1 Please indicate your gender.

- Male
- Female

2 Please select the category that includes your age.



3 What best describes your level of education?

- High school graduate or equivalent
- Some college
- Associate degree
- Bachelor's degree
- Graduate or professional degree
- Prefer not to answer

4 What are the annual revenues of your company/organization?



5 In which state do you live?



Figure 3-7. Part I: Basic Demographic Information

6 * **Organizational Role:** Please choose the information that most closely matches the top level description of the position 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.



Figure 3-8. Part I: Basic Demographic Information, cont.

7 If you chose DESIGN on page 2, please enter your specific position from the dropdown menu



Figure 3-9. Part I: Basic Demographic Information, cont. (Note: Question 6 was set up with Zoomerang's "skip logic" so that people's customized organizational role answer would direct them to their correct specific position question and dropdown menu in question 7)

Part II of the survey served as the beginning of the primary data collection instrument (Figure 3-10). 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

PART II: BIM Effects on Key Performance Indicators (KPIs)
 With respect to Building Information Modeling (BIM), please rate your perception of BIM's impact on the following list of six construction KPIs.

8 ***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	Lessens	No Effect	Improves	Maximizes
1	2	3	4	5

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

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

10 ***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	Lessens LOST MANHOURS	No Effect	Increases LOST MANHOURS	Greatly Increases LOST MANHOURS
1	2	3	4	5

11 ***Cost:** Cost variance in actual costs to budgeted costs

1 Max Variance (\$ Lost)	2 Worsens	3 No Effect	4 Improves	5 Max Variance (\$ Saved)	N/A
General Conditions					
1	2	3	4	5	
Structural					
1	2	3	4	5	
Mechanical, Electrical, Plumbing					
1	2	3	4	5	
Finishes					
1	2	3	4	5	
Overall					
1	2	3	4	5	

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

Max Variance (Late)	Worsens	No Effect	Improves	Max Variance (Early)
1	2	3	4	5

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

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

SUBMIT →

Figure 3-10. Part II: BIM Effects on KPIs

The next question, #15, asked for the same perception about BIM’s impact on “dollars per unit” (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 Var:(\$ Lost)	Worsens	No Effect	Improves	Max Var:(\$ 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 Elim. 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 equaling no effect to 10 showing the most improvement (Figure 3-11)

14 *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.

1 2 3 4 5 6 7 8 9 10

On-Time Completion

1 2 3 4 5 6 7 8 9 10

Cost

1 2 3 4 5 6 7 8 9 10

\$/Unit

1 2 3 4 5 6 7 8 9 10

Quality Control / Rework

1 2 3 4 5 6 7 8 9 10

Safety

1 2 3 4 5 6 7 8 9 10

Units/MH

1 2 3 4 5 6 7 8 9 10




Figure 3-11. Part III: Ranking KPIs

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 (Figure 3-12). The other choices included:

- BIM is 3-D 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

15 **PART IV:** Please write any comments in the space provided below concerning BIM and key performance indicators. If you feel we have failed to address any key performance indicators which affect BIM, please let us know. Any feedback will be greatly appreciated. If you desire to be contacted in response to your comments, please include your preferred contact method and contact information.

16 ***Summary:** The following choices represent opinions expressed in recent editorials and publications. Which of these three 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
- 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
- Don't know

Thank you for your time and answers!

M. E. Rinker, Sr.
School of Building Construction

SUBMIT

Figure 3-12. Part IV: Free Response, Summary, and "Thank You" screen capture

Survey Iteration #3: BIM4Builders™ Conference Attendees

The third iteration of the survey was based of the same goal to determine respondents' perceptions about where BIM impacted construction. However, this iteration of the survey was different in its execution. A hard copy version of the survey was given to the BIM4Builders™ Conference attendees on check-in for the May 2008 Conference. Therefore, the survey was issued approximately one year after the first two iterations of the survey. Also, in order to ensure respondents were capable of completing the survey in an expedient manner, the hard copy survey was edited to fit on one page.

The original sample of the hard copy survey can be found in Appendix B. The survey consisted three sections. The first asked simple questions about basic demographic information. The second asked respondents to rank the same six KPIs on a scale from 1-10, and the third asked respondents to choose the BIM definition that was closest to their own.

Research Phase II: Orientation

Phase II includes reducing the survey data collected in Phase I and will test the primary research hypothesis by conducting research on-site at two U.S. Army Corps of Engineers Districts. 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 General Services Administration (GSA), Army Corps of Engineers (USACE), and United States Coast Guard (USCG) demonstrate that they are exceeding typical industry BIM adoption with a much higher adoption rate. However, despite recent promulgation of BIM procedures in documents like the GSA BIM Guide Series and USACE BIM Roadmap, there is little empirical evidence documented regarding BIM's impact on the construction phase of the

facility lifecycle. Therefore, this research proposes to evaluate BIM effects on federal construction projects according to the KPI metrics evaluated in the survey (Table 2-1).

Research Phase III: Decision

After interviewing the key stakeholders at locations where pilot BIM projects have been accomplished, the research will move forward by establishing a model to statistically assess and analyze the data from the pilot projects (variable) compared to data of similar construction projects in size and scope (control population). Phase III will include revisions and changes to the data collection model applied to a greater cross section of construction projects. Phase III also entails comparing the data garnered in Phases I and II regarding perceptions compared to the statistical data in Phase III. This would be accomplished by using data collected and maintained by research bodies such as the USACE Civil Engineering Resident Management System (RMS) administrators. Lastly, the data will be analyzed to determine if trends exist that demonstrate statistically significant differences in productivity or performance according to generally accepted practices.

Table 2-1. Key Performance Indicator (KPI) Metrics and their associated measurement values

KPI Metric	Measurement Value
Quality Control	Percent Rework in \$ of total project cost
On time Completion	Overall Project Duration Variance
Cost	Percent Cost Variance
Safety	Lost Man Hours due to injury
\$/Unit	\$/Square Foot
Units/Manhour	Square Foot/Manhour

The specific locations where on-site research will be accomplished are:

- U.S. Army Corps of Engineers, Seattle District
- U.S. Army Corps of Engineers, Louisville District
- U.S. Coast Guard Group, Charleston, South Carolina

Research Phase IV: Action

In Phase IV, after the bulk of the data collection, the lessons learned from conducting the embedded research will be applied to a further revised methodology recommended for future case study data collection. Additionally, observed trends will be discussed in the research analysis portion of this document and recommendations for consumption and implementation by federal entities and construction firms will be made as to best business practices that yield the most productivity improvements. In this way, the research will act on the lessons learned, fulfilling the OODA Loop. Probable further work will include establishing a user-friendly way for the U.S. Army Corps of Engineers or other owners to integrate this analysis method into their construction project management portfolio.

CHAPTER 4 RESULTS

Phase I: “Observe”

Introduction

Building Information Modeling 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 was little empirical data regarding BIM application, use, or benefits in 2006. Therefore, in addition to the typical review of literature in the field, three iterations of a qualitative survey was administered to garner initial data about practitioners’ perceptions about the effects of BIM on construction key performance indicators (KPIs) from 2007 to 2008. This survey data was used to determine current BIM practices and perceptions to formulate additional research hypotheses for use in Phase II. The web-based survey garnered 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/Man-hour 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.

Survey #1

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. In order to garner maximum participation from existing and new members, the survey 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 at that time (Note: the website has been changed to <http://www.buildingsmartalliancefacilityinformationcouncil.org/nbimsbim>), <http://www.buildingsmartalliance.org>, 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.

Part I: "Basic Demographic Information"

Figures 4-1 through 4-3 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.

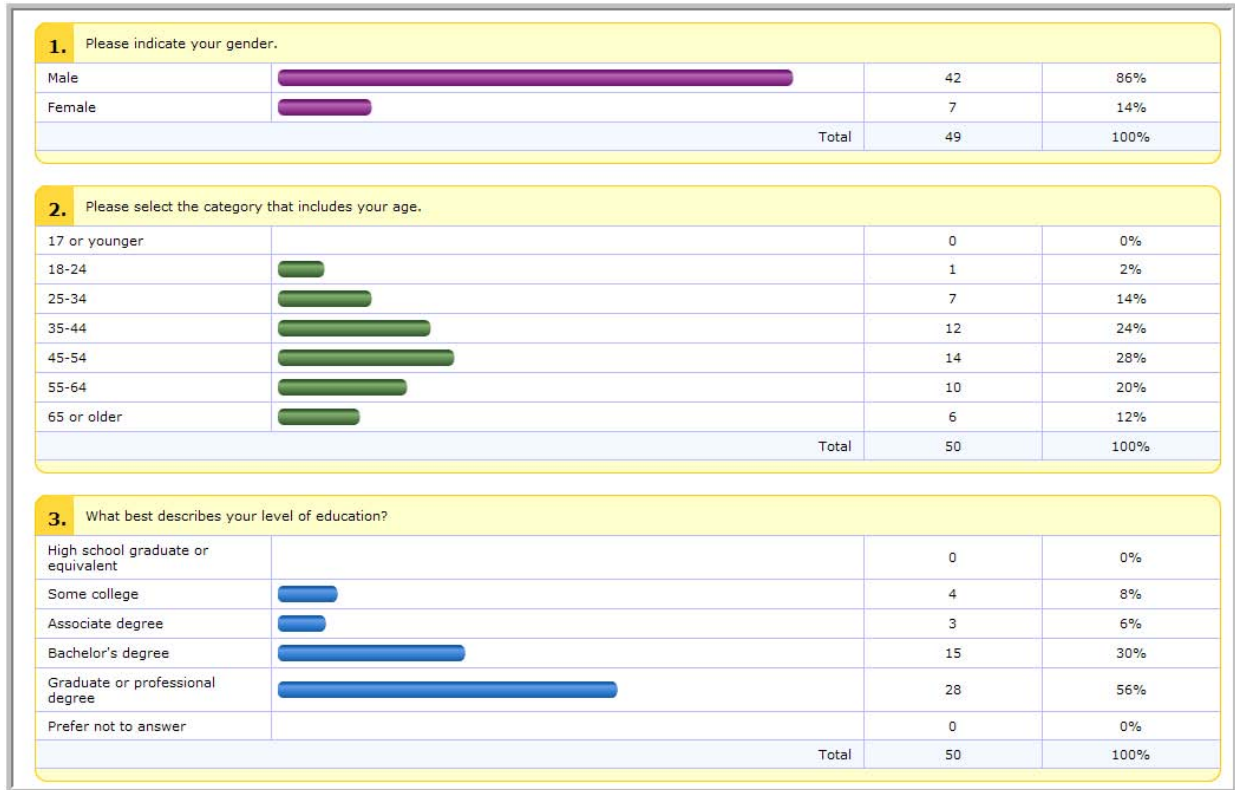


Figure 4-1. Survey #1 screen capture of the results to survey questions 1-3

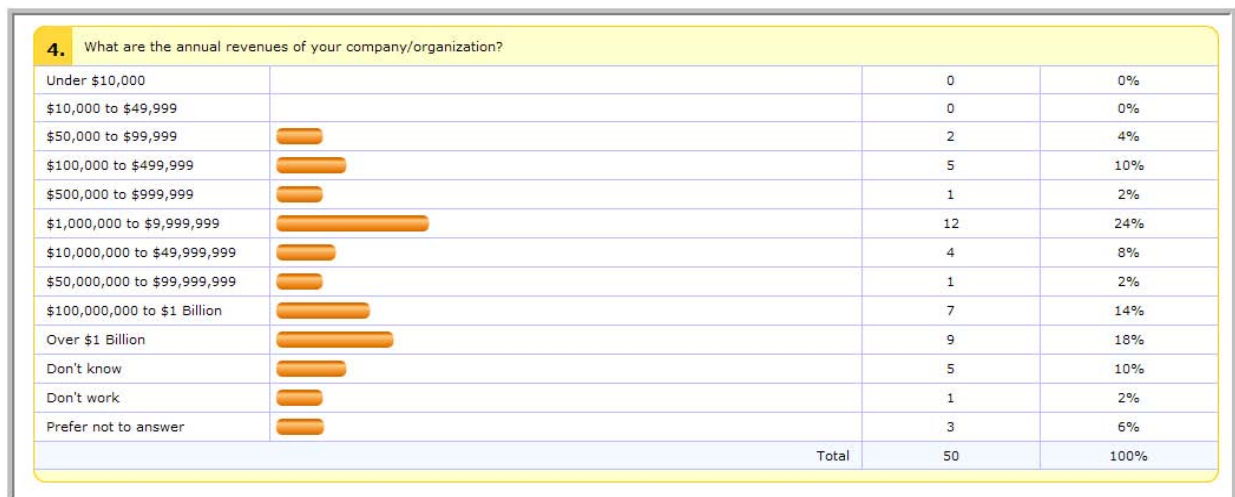


Figure 4-2. Survey #1 Screen capture of the results to question 4

The 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.







6. Organizational Role: Please choose the information that most closely matches the top level description of the position 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.)		15	30%
Planning Roles: (Owner, Planner, etc.)		3	6%
Design Roles: (Architect, Engineer, etc.)		22	44%
Procurement Roles: (Product Rep., Buyer, etc.)		0	0%
Execution Roles: (Contractor, etc.)		2	4%
Utilization Roles: (Facility Mgr, etc.)		2	4%
Support Roles: (Lawyer, Consultant, Intern, etc.)		6	12%
Total		50	100%

Figure 4-3. Survey #1 Screen capture of the results to question 6 – Top level description of organizational role

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

Part II: “BIM Effects on 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 (see Figure 4-4).

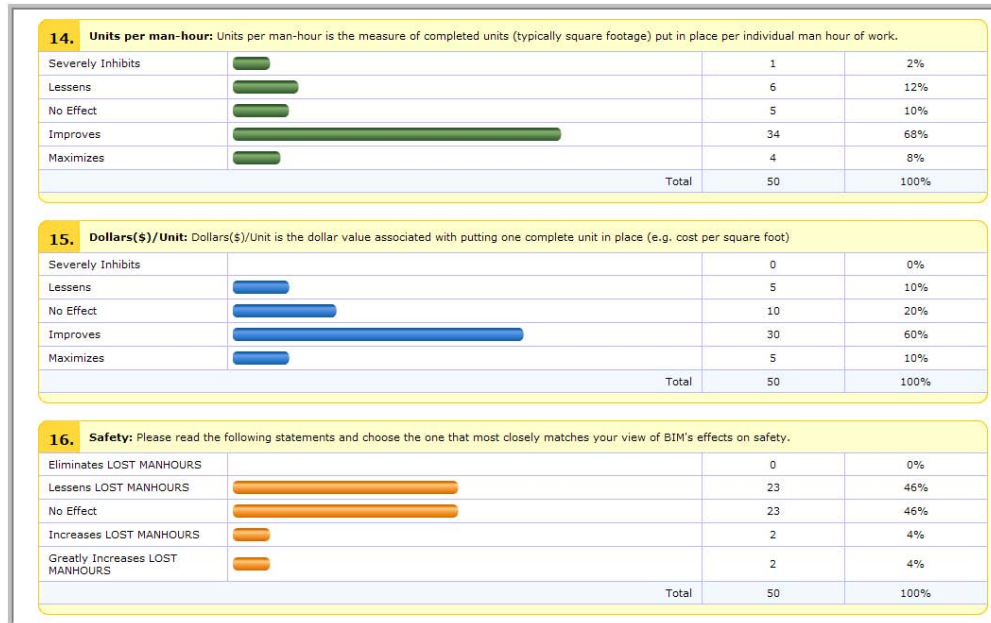


Figure 4-4. Survey #1 screen capture of the various results to first three KPIs: Units per man-hour, Dollars/Unit, and Safety

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 4-4 and 4-5.

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%).

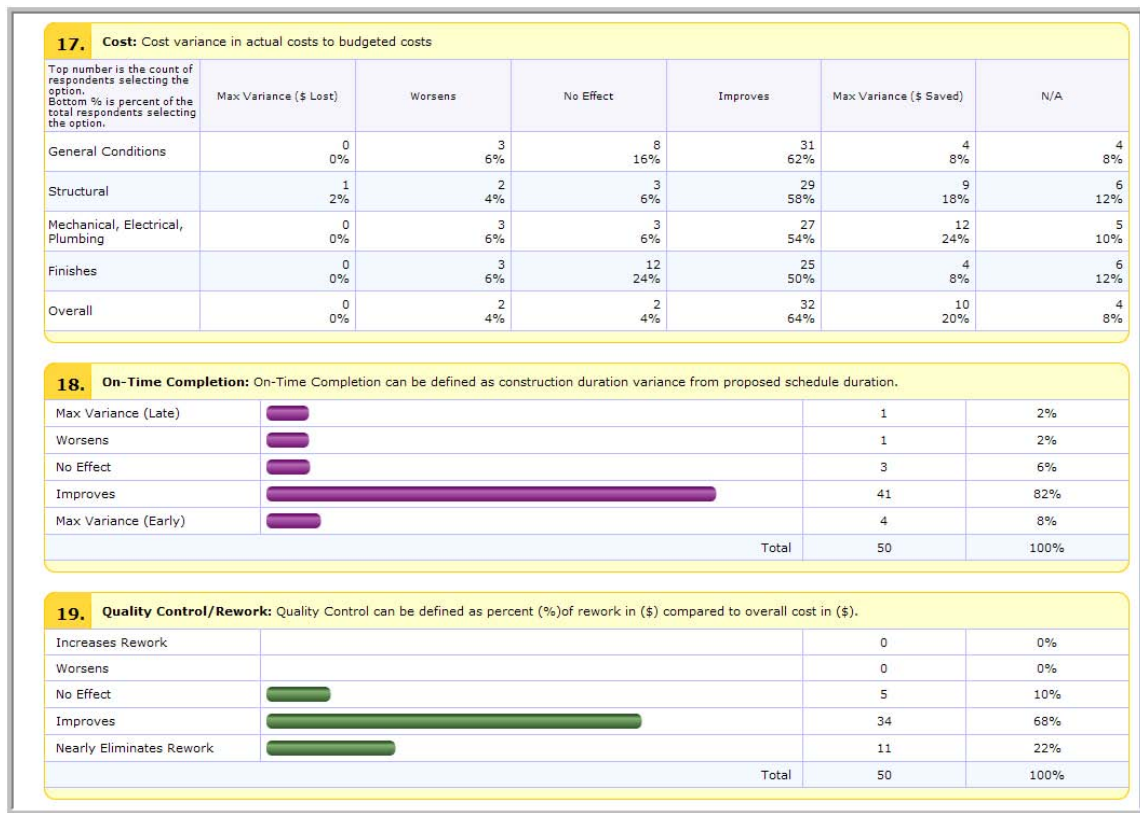


Figure 4-5. Survey #1 screen capture of results to last three KPIs: Cost, On-Time Completion, and Quality Control/Rework

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.

Part III: “Ranking 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 4-5 and 4-6. Figure 4-4 and 4-5 show the percentages of favorable responses and their frequency.

20. 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	1 2%	0 0%	1 2%	1 2%	4 8%	10 20%	15 30%	10 20%	8 16%	0 0%
On-Time Completion	0 0%	0 0%	0 0%	2 4%	4 8%	5 10%	13 26%	15 30%	7 14%	4 8%
Safety	0 0%	0 0%	0 0%	2 4%	21 42%	5 10%	14 28%	7 14%	1 2%	0 0%
Cost	1 2%	0 0%	1 2%	0 0%	8 16%	3 6%	14 28%	14 28%	5 10%	4 8%
\$/Unit	0 0%	1 2%	1 2%	2 4%	6 12%	7 14%	17 34%	9 18%	5 10%	2 4%
Quality Control / Rework	0 0%	0 0%	0 0%	0 0%	3 6%	4 8%	13 26%	14 28%	9 18%	7 14%

Figure 4-6. Survey #1 screen capture of Ranking KPI responses

Part IV: “Comments”

A few of the most representative comments made by the respondents are listed here or all comments are included in Figure 4-7:

#	Response
1	Thanks for putting this together. But I think there are some issues here that could have been addressed differently. First, though I am an architect, my company provides software for the BIM process, but you don't have a category for that. Second, it wasn't really clear that the survey was about what we THINK BIM will do or what it IS doing. If BIM can evolve into a Knowledge Management tool for Architects, I think it has a chance for wide adoption. If it comes to be perceived as benefiting only the Owner and Contractor, then Architects will have no reason to adopt it. There are many parties that have to be on board for BIM to be successful and I think surveys such as yours and initiatives such as NBIMS and buildSmart would be better served by developing a solid framework for BIM (software, mfg participation, etc.) from the bottom up rather than working from the top down. Since my company, Architectural Data Systems (.com) is in the thick of this, I would welcome a call to discuss and help you in any way I can. 914-232-0128 (NY) Chuck Williams, CEO ADS
2	Hi Patrick. The last two survey parts are all construction related, and not specific to the role I picked, i.e. design. Thus I picked "no affect - or 5" in an attempt to stay neutral, but am not so sure this is a good answer either. Not applicable would be more accurate for my role, but it wasn't an option except for one subpart. We are still in the midst of producing construction drawings on our first BIM project. So our experience is very limited to this point, and still in the learning curve, especially since the project has numerous different wall systems and volumes. This makes for many different wall-to-wall and wall-to-floor/roof intersection types. Making these intersections clean takes the most time. I thought I'd take the survey anyway to lend support for your efforts. TB Chicago tblattner@dplusp.com
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.
4	There needs to be data concerning the difficulty or ease converting a firm to the BIM paradigm. Education, software usability, management decisions, simulation, etc.
5	Question # 11 implies that having a large amount saved over budget is a positive performance indicator. In my view BIM allows a more accurate budget estimate essentially minimizing the difference between budget and actual cost. Question #12 poses a similar concern since BIM also provides more accurate construction sequence and timing information.
6	Greatly enhances constructability, eliminates interferences and improves productivity. Need to improve interoperability across the supply chain
7	The questions that are being asked are of the type that a A/E would ask. You may want to look at asking that questions that builder, vendor, or trade contractor would ask.
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 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.
9	I expect BIM will facilitate getting buildings which more closely meet the needs of users and other stakeholders, and testing and maintaining compliance with requirements throughout the life cycle.
10	Learning curves depends on complexity of project types and size undertaken. Smaller firms will have greater financial burden to undertake BIM early in development, but like CAD, entry price will drop and enable all to jump in.
11	sprasad@dplusp.com
12	It is still a new enough process for me that I don't have a good feel for my responses.
13	More KPIs: Reduction in Claims, Improved public outreach/agency coordination, More sustainable structures
14	Answers reflect the fact that the use of BIM is in its infancy. Improvements should be seen as BIM gains more acceptance.
15	I feel your survey is fatally flawed with ambiguous questions. If you lower the cost per SF is that "lessens" the cost or does that "improve" the value?
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 coordinations are reduced.
17	While BIM a goal to strive for and is relevant to certain projects - the fractured nature of the A/E/C industry means that it will be a long time before BIM has a significant overall effect on the industry
18	The elimination of or collapsing of separate tasks into a unified workflow
19	Quantification of reduced O&M costs is essential. harry.singh@woolpert.com

Figure 4-7. Survey #1 screen capture of “Free Responses”

- 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 [is] 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

Summary

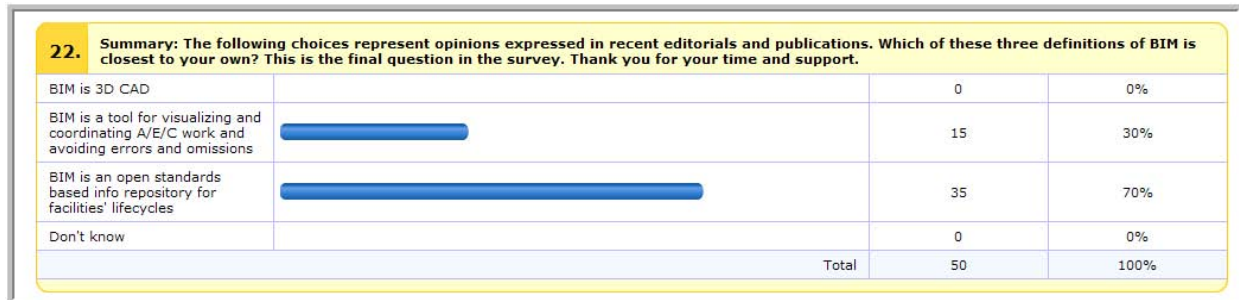


Figure 4-8. Survey #1 screen capture of Summary question, “Which of these three definitions of BIM is closest to your own?”

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 3-D CAD.” Therefore, none of the responses were eliminated from the data pool. As shown in Figure 4-8, 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 30% 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 by 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."

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. For more information about the formulation or advertisement of the survey, see the methodology in Chapter 2. However, 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.

Part I: "Basic Demographic Information"

Figures 4-9 through 4-11 show the data gathered through the Zoomerang online survey, or

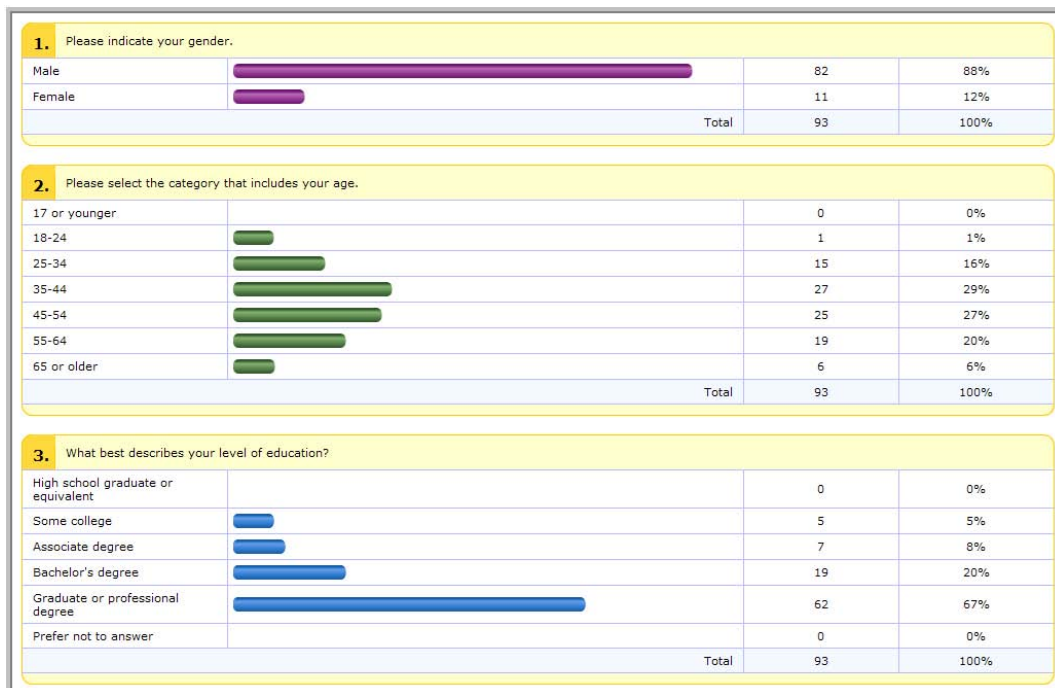


Figure 4-9. Survey #2 screen capture of the results to survey questions 1-3

data analysis derived from the data in the survey. Regarding gender, 88% of the respondents were male and 12% were female. Differing from the NBIMS Survey, this survey had more respondents in the 25-34 and 35-44 age groups, 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. The age data of the respondents shows that the mode response was the 35-44 year olds

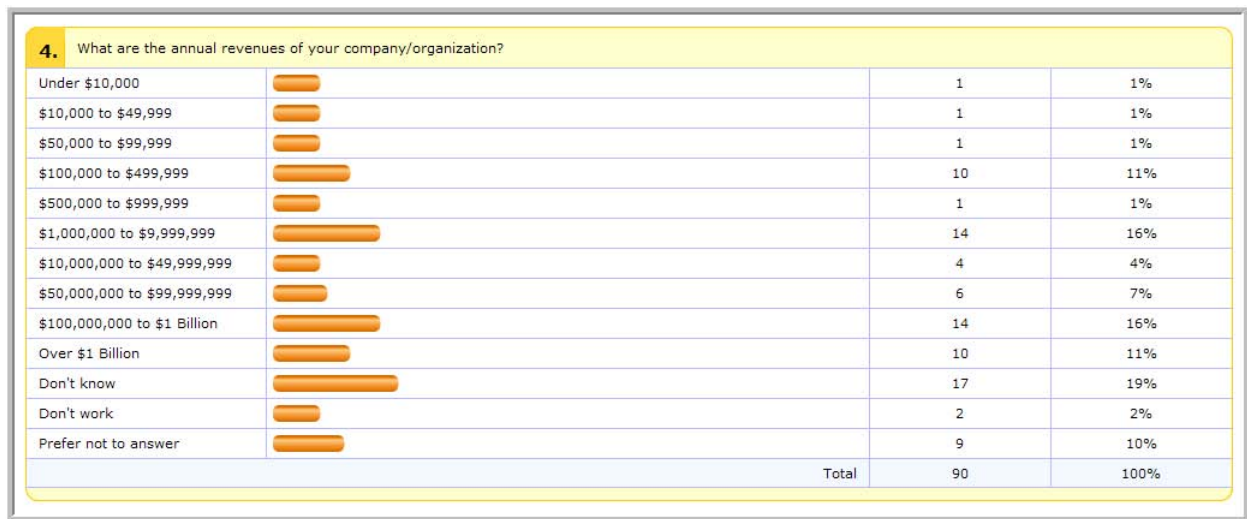


Figure 4-10. Survey #2 Screen capture of the results to Question 4

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.

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 position 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%

Figure 4-11. Survey #2 Screen capture of the results to question 6 – Top level description of organizational role

Part II: “BIM Effects on 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 (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” had the same frequency of favorable answers.

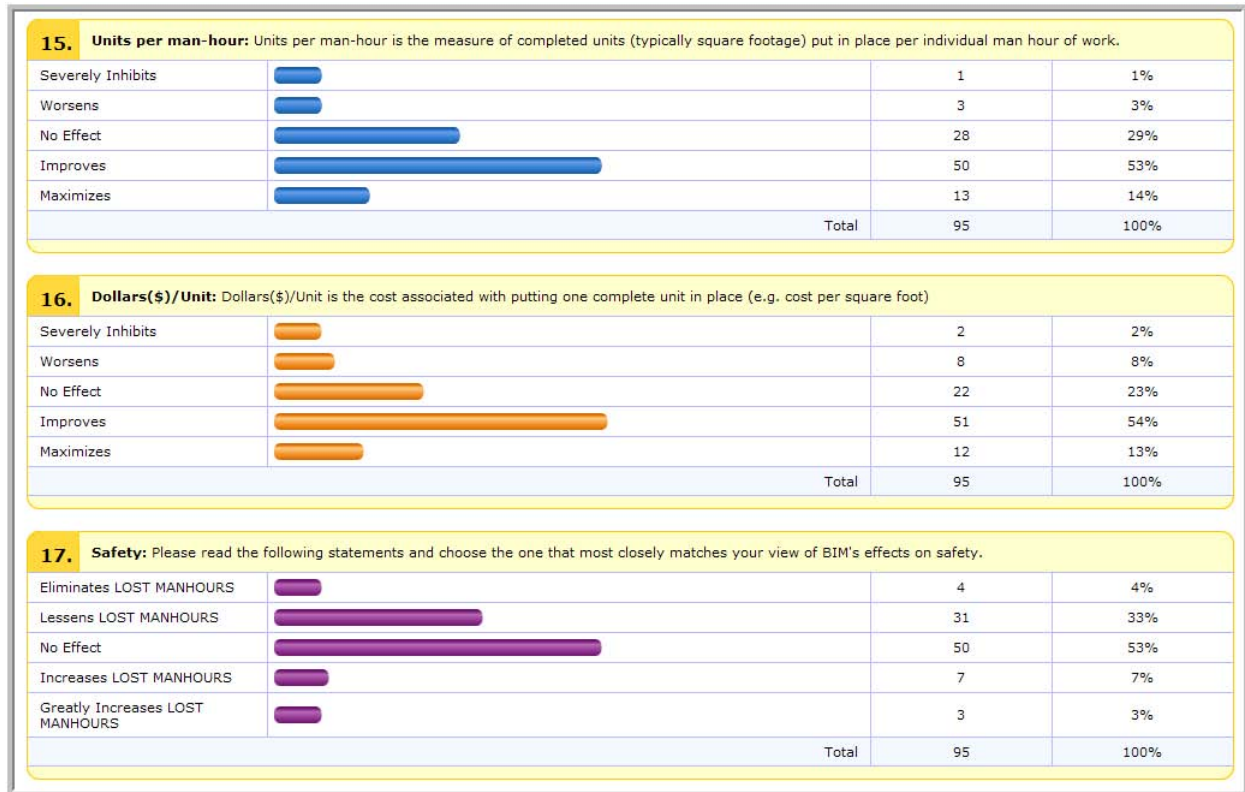


Figure 4-12. Survey #2 screen capture of the various results to first three KPIs: Units per man-hour, Dollars/Unit, and Safety

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).

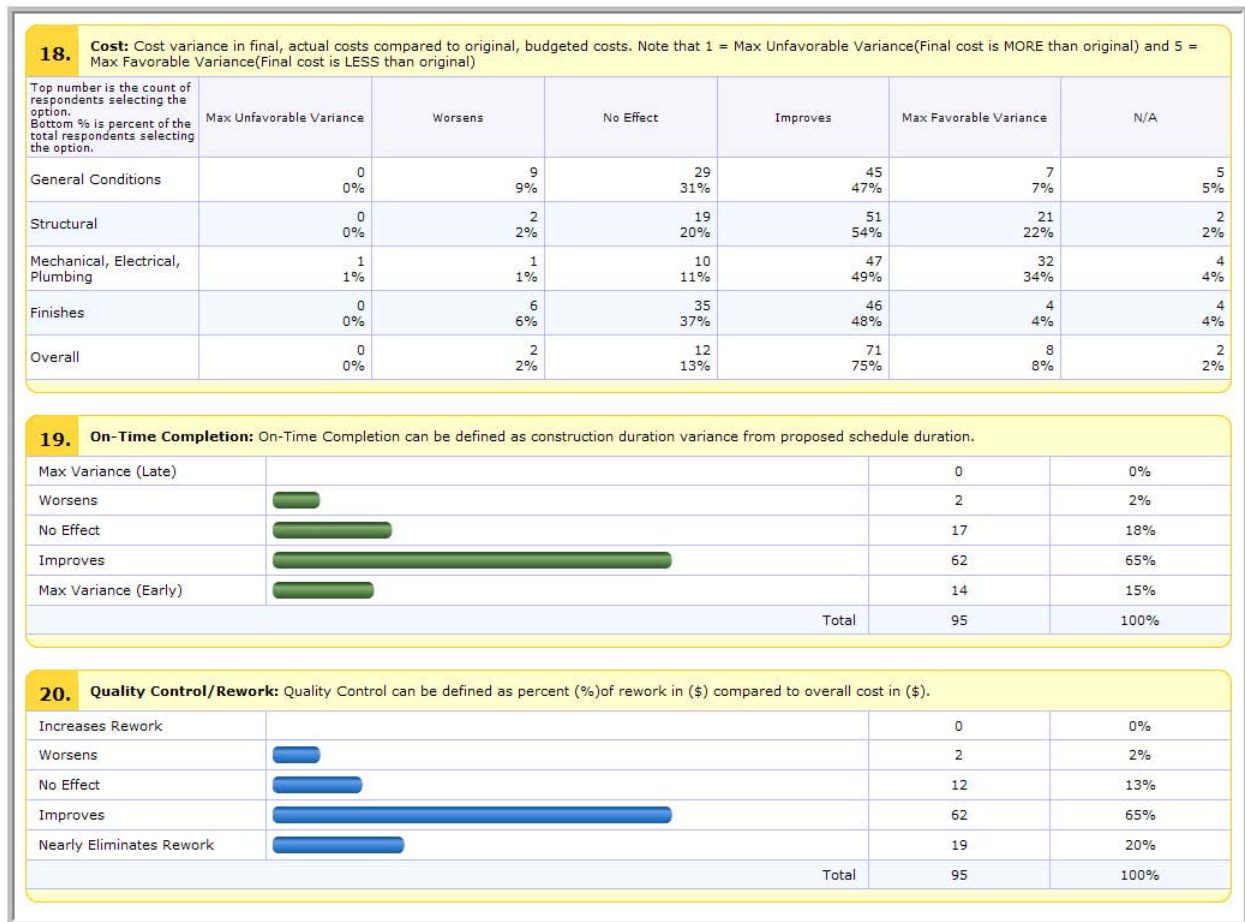


Figure 4-13. Survey #2 screen capture of results to last three KPIs: Cost, On-Time Completion, and Quality Control/Rework

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.

Part III: “Ranking 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 (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%

Figure 4-14. 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.

Part IV: “Free Answer”

A few of the most representative comments made by the respondents are listed below:

- 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 3-D 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 3-D 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 intersting [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.

Summary

The final 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 a general contractor's virtual approach to planning site logistics." Therefore, none of the responses were eliminated from the data pool. However it is important to note 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. Figure 4-15 shows a complete list of these responses:

#	Response
1	all of the above (except Don't know)
2	50 characters is not enough - see #16
3	is a digital 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

Figure 4-15. Survey #2 BIM Definition Free Response Answers

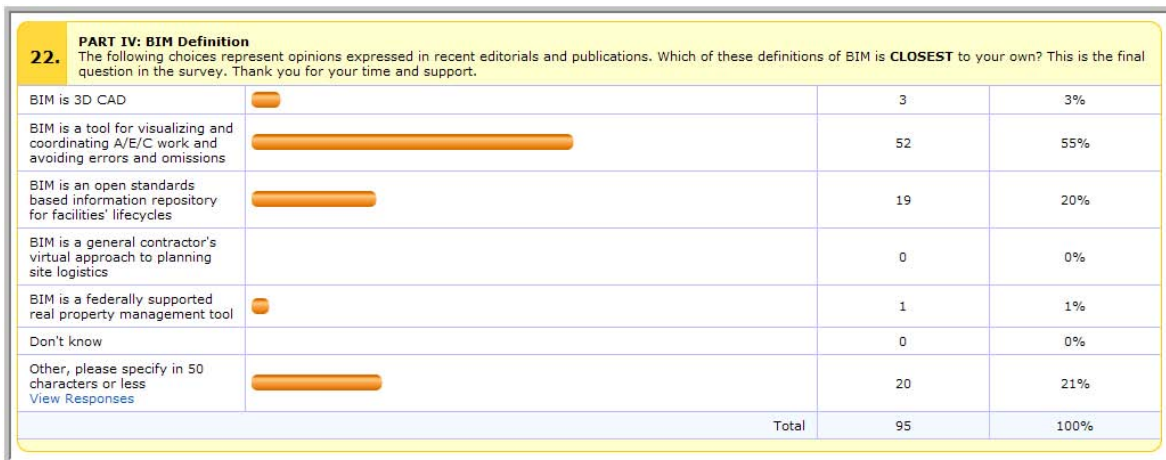


Figure 4-16. Survey #2 screen capture of Summary question

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
- Opined that Cost is benefitted more by BIM in Survey #2
- Greater disagreement on the definition of BIM in Survey #2

Survey #3

Survey iteration #3 (Appendix B-1) was issued on May 11, 2008 as conference attendees checked into the BIM4Builders™ event in Gainesville, Florida. 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.

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 the respondents’ 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 \$100 Million (Figure 4-17). The various organizational roles of the respondents were evenly distributed across management, design, academic, and other fields.

Variable	Categories	Percentage Comparisons Between BIM Definition Categories & Survey Variables								% total
		1. BIM is an open standards 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	%	
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%

Figure 4-17. Compilation of Demographic and BIM Definition Data from Survey #1, 2, and 3. (Note: Most frequent responses are highlighted/yellow.)

Part II: “Ranking Key Performance Indicators”

Similarly, all the 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 4-18, 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	%
Gender	Male	47	26.6%	130	73.4%	31	17.5%	146	82.5%	83	46.9%	94	53.1%
	Female	1	4.5%	21	95.5%	1	4.5%	21	95.5%	7	31.8%	15	68.2%
Age	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%
	55 & Older	13	28.3%	33	71.7%	10	21.7%	36	78.3%	27	58.7%	19	41.3%
Education	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%
	Other	7	25.9%	20	74.1%	4	14.8%	23	85.2%	13	48.1%	14	51.9%
Revenue	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%
	\$1b & over	5	15.2%	28	84.8%	4	12.1%	29	87.9%	16	48.5%	17	51.5%
Role	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%
	Other	13	19.1%	55	80.9%	9	13.2%	59	86.8%	31	45.6%	37	54.4%
Survey Group	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%
	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	6			3	3		1	6	

Variable	Categories	Cost				Quality				Unit Cost			
		Inhibits		Improves		Inhibits		Improves		Inhibits		Improves	
		N	%	N	%	N	%	N	%	N	%	N	%
Gender	Male	26	14.7%	151	85.3%	22	12.4%	155	87.6%	38	21.5%	139	78.5%
	Female	4	18.2%	18	81.8%	0	0.0%	22	100.0%	3	13.6%	19	86.4%
Age	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%
	55 & Older	11	23.9%	35	76.1%	10	21.7%	36	78.3%	12	26.1%	34	73.9%
Education	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%
	Other	3	11.1%	24	88.9%	3	11.1%	24	88.9%	6	22.2%	21	77.8%
Revenue	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%
	\$1b & over	3	9.1%	30	90.9%	1	3.0%	32	97.0%	4	12.1%	29	87.9%
Role	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%
	Other	5	7.4%	63	92.6%	3	4.4%	65	95.6%	10	14.7%	58	85.3%
Survey Group	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%
	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	

Figure 4-18. 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)

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 4-17 in a different way and representing it as shown in Figure 4-19 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 BIM.

Variable	Categories	Percentage Comparisons Between BIM Definition Categories & Survey Variables								
		1. BIM is an open standards 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		% total
		N	%	N	%	N	%	N	%	
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%

Figure 4-19. 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.)

Phase II: “Orient”

In Phase II, the information gleaned from the survey was used to orient research towards focusing on determining tangible impacts on real world construction projects in multiple organizations including: The U.S. Army Corps of Engineers Districts in Seattle, and Louisville, as well as the U.S. Coast Guard, NESU Charleston, SC. These organizations were targeted because of their advanced implementation of BIM in standardized ways in the federal government. Research at each location involved reviewing qualitative and quantitative data regarding the impact BIM had on organizations, technology, and construction in relation to the six primary KPIs referenced throughout this document.

U.S. Army Corps of Engineers – Northwestern Division (CENWD), Seattle District (NWS)

Introduction

On-site research was conducted at NWS from July 9-20, 2007. The primary sponsors for the research from within the Seattle District were Mr. Van Woods, CAD/BIM Manager, and Mr. John Herem, Chief, Contract Administration Section in the Construction Division and RMS Steering Committee Representative, CENWD/NWS. The BIM project targeted for analysis was titled in accordance with standard MILCON programming convention and entitled “W912DW-06-C-0007 NA FY06 Jackson Ave Whole Brks Renewal PH I,” an Enlisted Unaccompanied Personnel Housing (UPH) Barracks project built on Fort Lewis near Tacoma, Washington. There were four unique building footprints and seven instances of them. Data collection centered on learning about qualitative and quantitative information about this project and all similar and recent UPH projects. The qualitative information came mainly from interviews with District leadership and the Seattle project team. The quantitative data came entirely from the USACE contract management database, the Resident Management System (RMS) used by the District. As a side note, all military facilities are classified according to pre-defined facility use

codes called “category codes.” This type of UPH or barracks facility’s category code is 72111. Therefore, RMS queries were isolated to recent construction projects available from FY02-06 with construction predominantly consisting of category code 72111 usable SF. The rest of this section will elaborate on the qualitative (interview) data as well as the quantitative (database) metric data.

Qualitative data

USACE mainly executes 75% of its MILCON work through contracted out A-E services in traditional design-bid-build or design-build project delivery vehicles. Therefore, the remainder, or 25% of their work is retained in-house in order to maintain expertise and design skills. These projects are then bid and constructed after in-house design is complete. The project that the Seattle District accomplished via a BIM approach was conducted well before the BIM Road Map was published. The reason for this is that the current Seattle District’s CAD/BIM Manager was previously an embedded researcher in the District on loan from CERL. BIM Manager, Mr. Van Woods, persuaded leadership to agree to test a BIM approach on three in-house design projects. It was his hope that after three projects, the learning curve and process change would take hold and then designers and engineers would actually prefer to use BIM, rather than traditional means and methods.

The first project designed in house via a BIM approach was the project “W912DW-06-C-0007 NA FY06 Jackson Ave Whole Brks Renewal PH I,” which was designed in the fall of 2005 for FY 06 construction at Fort Lewis. This is important chronologically because it also occurred simultaneously with the Corps response to Hurricane Katrina, which took several members of the project team for this project to New Orleans or other command-directed locations to help with the aftermath of the devastating hurricane. Additionally, as a side note, although the project was supposed to be the first attempt at the planned three-project test bed, no other MILCON projects

have been accomplished via a BIM approach to date, due to the current freeze on designs with the pending implementation of the Centers of Standardization (COS) plan (See Appendix A-1 for an internal USACE memorandum regarding the COS program). However, progress has been made on trying BIM on civil works projects that include industrial construction like locks and dams. Lastly, it is also important to note that when the team decided to initiate a BIM approach on this project, several other large scale initiatives were also imposed/attempted at the same time.

These included:

- A cost savings initiative that consisted of switching to Type V, timber construction from steel.
- A sustainable initiative that consisted of attempting to achieve LEED-Silver certification.
- A “units of measure” initiative towards attempted “metrification” of federal government projects.

It is of great importance to note that while the first two initiatives above were adopted by all following barracks projects with respect to material type and all projects with respect to sustainability, no other project at the Seattle District has been designed or managed with SI units since this one.

Because of these unique facets above, it would appear that there would be so many challenges on this job that it should demonstrate **significant** differences from traditional projects both qualitatively and quantitatively (i.e. cost and time overruns). However, while there were certainly many items discussed in the interviews that classify this project as “challenging,” the project’s quantitative data show that it was typical of nearly all other recent barracks projects accomplished. When talking to the designers and BIM support team who were exposed to the pilot project, “W912DW-06-C-0007 NA FY06 Jackson Ave Whole Brks Renewal PH I,” there was one recurring theme. That theme was that BIM provides a lot of promise, but that the cultural and training hurdles necessary for overcoming transition to the new process were more

difficult than predicted. Like many other organizations, the Corps is in the middle of re-engineering their information management approach and has rolled out multiple IT applications in various stages of maturity (See Figure 4-20).

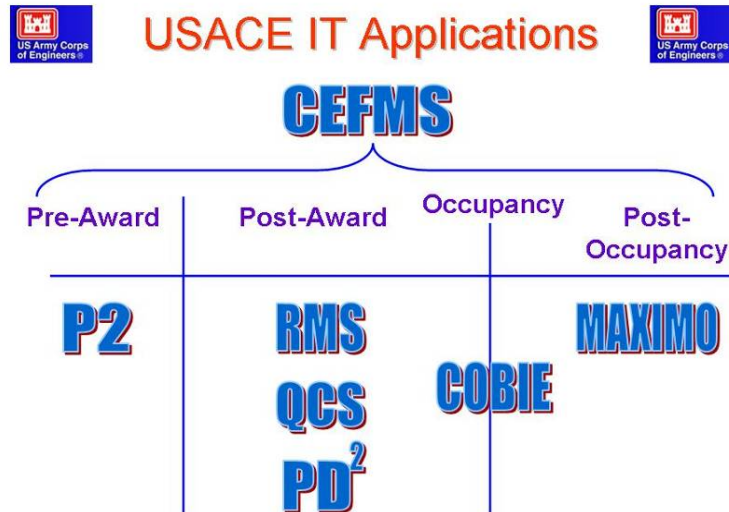


Figure 4-20. U.S. Army Corps of Engineers Information Technology Applications across the Facility Lifecycle

The rest of this section will focus on a background discussion concerning USACE organizational and technological transformation.

Organizationally, the USACE has been involved in three major programs involving organizational change:

- Centers of Standardization (COS) causing movement from 25% in-house design to nearly 100% RFP to outside A-E firms
- A-76 outsourcing study for Information Management IMO (i.e. IT) services staff
- Project Management Business Process (PMBP) according to ICC tenets of successful construction management

First, the USACE moved to a concept of operations called the Centers of Standardization in FY06. More information about this can be found in Chapter 3. Also, the USACE recently

outsourced nearly all IT staff in an A-76 study that awarded a services contract to Lockheed to address their IT or Information Management Office (IMO) needs. As seen in Figure 4-20, the USACE has employed multiple software platforms across the facility lifecycle and in turn automated many of the project management data routinely created, collected, and leveraged in the facility lifecycle. Technologically, the following serves as a description of each IT application and their intended use:

CEEIS: The Corps of Engineers Enterprise Infrastructure Services program provides the management and services for the Corps network. The CEEIS web page listing their products and services is at <https://www.ceeis.usace.army.mil/>. This is the portal or clearing house for all the tools below. When users have rights to use the software platforms below, they have access to the various applications through this “one stop shop.”

CEFMS: The Corps of Engineers Financial Management System is the overarching system that follows the project from inception on because it deals with financial information. Separately, P2 is an automated information system (AIS) to effectively manage all programs and projects in the U.S. Army Corps of Engineers. Its functions include the capability to scope, develop and track critical path networks, assign resource estimates, compare estimated costs to actual costs, perform earned value analysis, and maintain a historical record of a project. P2, as a project and programs management tool, provides structure and support to the Corps corporate, regional, and district-level and project management business processes. Additionally, P2 provides for a corporate database utilized for decision support capability, utilizing on-line analytical processing (OLAP) tools to display Corps management information in various views and to generate customized reports. P2 is a commercial off the shelf (COTS) solution. The application is a 3-tier architecture interface accessible through a web browser on the client. It is

the sole Project Management Automated Information System (PM-AIS) or, as it is more commonly known, “P2” for the Corps. P2 is a major technological enhancement of the legacy system, PROMIS, already fielded. PROMIS was a significant leap forward in project management capability for the Corps. It integrated the business functions of multiple, redundant AIS into a single technology solution. It has proven effective in meeting its limited objectives. However, subsequent to the fielding of PROMIS, advances in technology have rendered the system incapable of fulfilling today’s requirement of programs and project management, resource management, virtual project team and regional business center concept.

RMS: The Resident Management System is the primary tool the Corps uses to manage the data for their ongoing construction projects.

COBIE: Construction Operations Building Information Exchange is the newly developed tool from the Construction Engineering Research Laboratory (CERL) at the Engineer Research and Design Center (ERDC) to automate the turnover process. The goals are two-fold: Minimize paper transmission and provide a launching point for attributing future intelligent BIMs with this important information.

FEM: Facilities and Equipment Maintenance is a Department of Defense migratory Computerized Maintenance Management System (CMMS). The Joint Logistics Systems Center (JLSC) developed the system to meet the needs of DoD maintenance organizations. This system was designated as a DoD migratory system in 1995. FEM is the Corps customization of MAXIMO Enterprise Base Systems (MRO Software, Inc.), which is a Commercial-Off-The-Shelf-System (COTS) package. The customization is provided to each service (Army, Navy, and Air Force) to fulfill unique mission requirements. FEM integrates several plant maintenance functions into a cost effective asset management program. It supports and consolidates

functions, such as capital depreciation, equipment preventative and corrective maintenance, equipment installation, facility modification, and equipment calibration into a single management environment. The functionality also envisions an integrated application that optimizes asset use through management of corrective and preventive equipment maintenance, asset calibration, inventory and property, and maintenance budget. It provides capability to track life cycle costs of all assets, thus providing real-time accountability. In terms of expected performance outcome, deployment of FEM will standardize the maintenance business process Corps-wide. In addition, implementing FEM should reduce spare parts consumption, material purchases, maintenance labor, contract costs, calibration labor, and capital equipment acquisition. It will replace local-unique applications at several field activities, as well as automate facility and equipment maintenance management at an estimated 80% of Corps facilities.

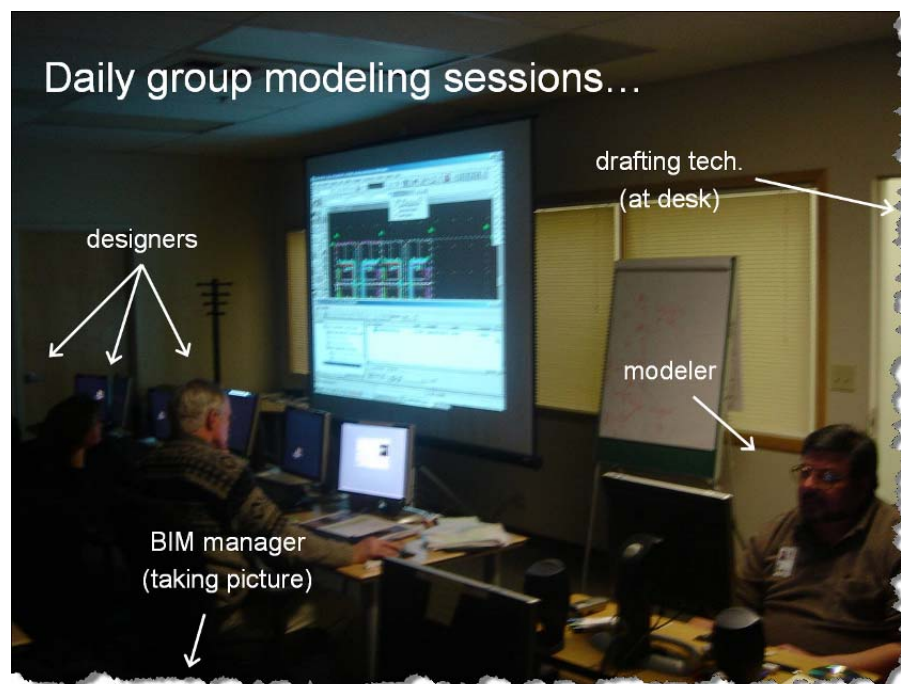


Figure 4-21. Seattle BIM PIT Approach (Source: Mr. Van Woods)

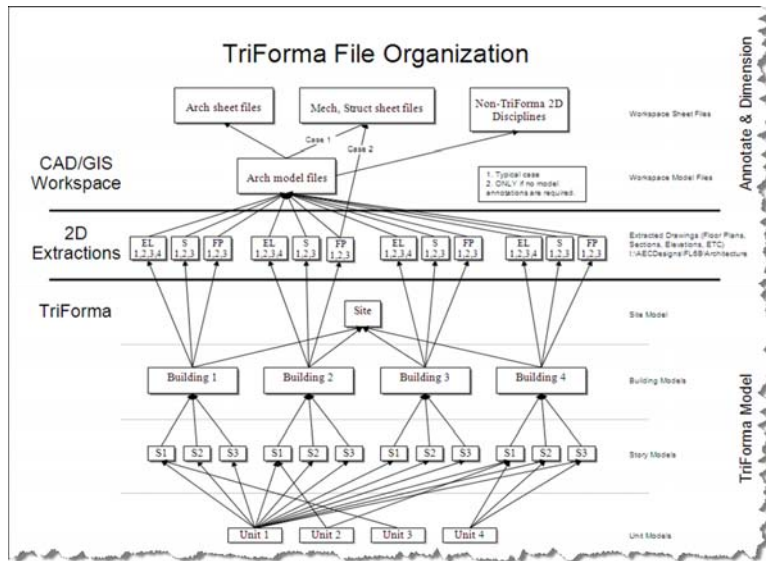


Figure 4-22. NWS’s TriForma File Organization (Source: Mr. Van Woods)

Seattle transitioned to an approach they call the BIM Process Initialization Team (PIT) where all the members of the design team received training one week that incorporated the project requiring design. Members were sequestered in one room and worked on real engineering and architectural requirements for the project throughout the training week. In the second week, members were “coached” by the trainer and BIM Manager to complete the design. Along with Louisville’s approach, this became model for all subsequent COSs.

The Seattle BIM team consisted of: Van Woods, BIM manager, Bruce Hale, Architects and Yolanda Melchert; Wayne Kutch, Structural Engineers; William Daniels and Anne Marie Moellenbrendt, Mechanical Engineers, and Jim Davis, Project Lead Technician and O Song Kwon, as Systems Engineer from the Far East District in Korea who helped Mr. Woods set up the work space environment. Figure 4-22 shows the Seattle BIM PIT work process according to tasks on the right side and file organization along the left side.

Interview data analysis

Now that most of the software approaches have been discussed, specific information can be discussed that came from interviews while conducting embedded research within the Seattle District from July 9-20 2007. Throughout the period of embedded research, formal or informal interviews were held with the following individuals:

- COL Michael McCormick, District Engineer
- MAJ Karl Jansen, Deputy Chief, Construction Branch
- Mr. Van Woods, BIM Initiator, CADD/BIM Manager
- Mr. John Herem, Chief, Contracting Branch
- Mr. Bruce Hale, R.A., Chief, Design Branch
- Mr. Thomas Poole, Senior Construction PM
- Mr. Tim Grube, Chief, Safety Branch
- Mr. John Brigance, Project PM
- Mr. James Davis, CADD/BIM Support/Designer
- Miss Adrienne Murphy, Engineering Intern, Contracting Branch
- Ms. Brenda Moriarty, Chief, Information Operations Management
- Ms. Carla Lafferty, Safety
- Mr. Stephen Pierce, Chief Cost Estimating
- Mr. Melquiades Bonicillo, Cost Estimator
- Mr. Martin Frisvold, Cost Estimator

Seattle interview #1: Bruce Hale

Bruce Hale, R.A., the Chief of the Design branch was interviewed on July 19, 2007 while driving back from a Society of American Military Engineers (SAME) luncheon and Fort Lewis construction tour where the BIM project was visited while at the 80% complete stage of

construction. Hale won the Corps-wide Award for “Architect of the Year” for 2006 in part because of his work with on the BIM job, FY06 Jackson Ave. Barracks. Hale demonstrated leadership, architectural design abilities, and technical savvy in bringing the barracks to fruition with a “contemporary feel, in a forested, campus like setting” (Hale 2007). However, Hale freely admits that the Jackson Ave. Barracks job was not optimal. Primarily, he points to the challenges stated earlier in this chapter including cost, sustainability, and metrification initiatives; but he also concedes that the technological component was extremely difficult. In turn, he had to demonstrate tremendous leadership acumen to train and aid his designers in a completely new software platform. In fact, at the 35% design review, some of the elevations used to convey design intent to the customers at Fort Lewis Department of Public Works (DPW) were even hand drawn.



Figure 4-23. Rendering and as-built photo of Jackson Ave. Barracks project. Notice uses of multiple software platforms. This rendering came from SketchUp (Woods and Solis 2007).

A great deal of the interview focused on shortcomings of the Bentley software. According to Hale, Bentley admitted that the barracks design “stumped” TriForma’s roof-making tool. Therefore, Jim Davis, a designer and CAD support team member, took three months to model

and re-model every truss and connection individually. Sadly, the pre-fabricated truss manufacturer whose services were used on the project did not use this data and instead they opted to use their own software and production capabilities, increasing the amount of unnecessary data creation. This example provides clear evidence supporting the need for a National BIM Standard.

Other challenges mentioned by Hale were a lack of a project-specific metric library of assemblies for things like doors and windows. Also, the design team was not trained in and did not like the rendering results they were obtaining in TriForma. Therefore, the team accomplished a mock-up for rendering purposes in Sketch-up, which is still the primary photograph, associated with the project for public relations purposes (See Figure 4-23).

Also, Hale goes on to say that “Early on, you had to decide what type of wall you were going to use. This was due to cutting sections and requiring the correct thickness with drywall, resilient channel, etc. At 35%, we had to determine exactly what the wall types would be (thickness, etc.) This was way too early to know this information” (Hale 2007). Also according to Hale, managing and defining the extractions was very difficult. Generating the extractions was not difficult, as an automated nightly update procedure was established. The real challenge was to get the database driven drawing generation approach to produce the exact output that was expected from high quality drafting conventions achieved previously through manual drafting.

Seattle interview #2: Van Woods

BIM Manager, Mr. Van Woods, asserted that the challenges noted in Mr. Hale’s interview are all normal “growing pains” associated with learning a new, complex system. Object definitions and drawing extraction management was specifically chosen by Mr. Woods to be managed by CADD/BIM Support staff rather than designers in order to ease the learning curve on the first project, but as a result the designers did not feel like they had enough control. He also

asserts that there is nothing wrong with the quality of the rendering system, but rather that it was a much lower priority above more valuable business process objectives of items like cost estimating, construction sequencing visualization, and interference detection. He feels there were certainly usability improvements that could be made to the system, but that most of the frustration was a result of software education-related rather than technological shortcoming by TriForma.

Issues that both Woods and Hale agree on include the use of the information from the model. Woods had several “pet projects” in mind that he wanted to test on the BIM job. These primarily included initiatives to leverage the INFORMATION part of the Building *Information* Model. Items like 4-D sequencing movies, quantity take-offs, and interference detection, were successful and became more than just pet projects, but reality. However, they were mostly relegated to “eye candy” for presentations on the project rather than really used by anyone outside the team. For example, both Hale and Woods lament that the estimators did not use either the quantity take-off (QTO) or estimate from the model. Instead, the estimators warned that they “trusted their experience over the BIM software.” When their estimates came in much higher than the initial government estimate (IGE), they came back to the designers to determine the cause. The primary reason was because the estimator had included one kitchen item (e.g. refrigerator, stove, sink, etc.) for every person in the 240-person barracks when in reality, there was only supposed to be one kitchen set for every two people. This is a problem that would have never occurred if using the BIM QTO as the basis for an accurate estimate.

Other functionality typically associated with a BIM approach includes window and door schedules and room tags. However, the design team did not use the model to create these, but instead created them by hand in annotation on the 2-D CDs.

Seattle interview #3: Thomas Poole

Mr. Thomas Poole, a senior military construction Program Manager has worked for the Corps for the past 19 years. Also, Poole was recently recognized as a “Modern Day Technology Leader” during 21st Annual Black Engineer of the Year Awards Conference held Feb 15-17 in Baltimore, Maryland (Overton 2007). In his opinion, he is a BIM proponent and he feels that it holds a lot of promise, but there is no clear direction on execution. He feels that the BIMs will be successfully completed to the 80% level as part of the COS effort, but that adapting the models in line with all the competing constraints like installation design guides, topological concerns, and other unknowns will make implementing BIM extremely difficult as envisioned.

In order to be successful, Poole feels that USACE needs to determine what the “undesigned 20%” will be as soon as possible and begin engineering those items, as well. Overall, he feels that the technology can handle it; it is the process that will be the challenge.

When asked where he stood on the spectrum of thinking every construction project is a unique piece of art and the other end of the spectrum where construction is no more than production, Poole said that he falls more towards the latter end of the spectrum and that the Corps needs to move in this direction, as well. He thinks we can get through expanded functionality in modularity similar to the job he did at Fort Lewis in 2005 where he and John Herem led the \$100M program that was designed and constructed in 11 months including renovation of 18 barracks and four dining facilities and installation of 450,000 SF of modular buildings. Poole also thought it was important to mention that the double edged sword of technology was the impact on the human component. “BIM is fundamentally changing the whole process. What about the trades, crafts, unions, etc?” Consequently, Poole was asked who wins, “Casey Jones or technology.” Poole said that Casey Jones would always win because of

experience but because Casey Jones relies on shortcuts, he needs technology to validate and verify his work.

Seattle interview #4: John Herem

Mr. John Herem, the USACE Construction Project Manager of the Year for 2005 and current Chief of the Contracting Branch of the Seattle District was also interviewed. Mr. Herem's expertise and knowledge were sought because of his expertise on RMS, but he was also a wealth of information regarding Project Management in the Corps. While interviewing Mr. Woods and Mr. Herem jointly, the recurring theme of the dialogue focused on a top-down method of project delivery. According to Mr. Hale, the organizational landscape within the USACE can be classified as "drastic" to "tumultuous," depending on who is interviewed. The overarching changes from the service-wide "Army transformation" have trickled down to the Corps of Engineers and driven a great number of changes as discussed in Chapter Three.

In a follow-up telephone interview on October 4, 2007 after the on-site interview in July, Mr. John Herem noted that the project was 91% complete, but behind schedule due to the following problems:

- Poor Construction Manager from the subcontractor who was different than the same CM used on other similar barracks projects at Fort Lewis
- The contractor failed to protect the wood resulting in mold remediation delays
- They (the contractor) poorly coordinated the trades which delayed installing mechanical equipment and made installing interior finish work more difficult
- They pre-fabricated the wood panels and they had to rework them when the doors and windows did not fit on site
- They pre-fabricated the roof trusses which caused extensive mechanical ductwork re-work.
- They had other mechanical chaise rework issues
- They did not use high quality carpenters and used residential carpenters, so they had a lot of framing trouble

- They started under manning the job when they started losing money.

When talking to Mr. Hale, the primary theme alluded to earlier was that, “BIM provides a lot of promise, but that the cultural and training hurdles necessary for overcoming transition to the new process were more difficult than predicted.” Due in large part to the lessons learned in Seattle and Louisville regarding training, the USACE and their BIM software partnered to establish a pedagogical approach to learning their BIM software that included 3-5 weeks of training, with a 1 week introduction to the software followed by 2-4 weeks of intense training where designers work together to apply newfound BIM knowledge to an Army Center of Standardization (COS) standard facility type. Therefore, all 8 geographically disparate COSs were trained by the end of FY07 with sound training plans that resulted in tangible benefits and real design drawings. A final challenge that Seattle uncovered was the lack of metric “assemblies” (or sample content) available in 2005. The design team was forced to convert or modify every assembly from imperial units to metric one-at-a-time, eliminating a benefit of BIM that is more prevalent today. Conversely, there are widely available project assembly data that can be used “off the shelf” in any project to rapidly advance the design phase.

Finally, after interviewing Mr. John Herem, the Chief of Contract Administration for Seattle District, he said that aesthetically, the BIM design on this project was embraced by the user. But from a contractual standpoint, it was “as good as any other design” when it came to the quality of the construction documents. Ultimately, he wished that the contractor would’ve had the knowledge and training to work with the virtual model rather than just the construction drawings; but since this was not the case, the project suffered significant construction management issues caused by the contractor that could’ve been avoided. In particular, there were structural and mechanical issues and scheduling/phasing difficulties that could have been avoided if the contractor was more active in using the model to visualize, and in turn, manage a

successful project. In the big picture, operating in a BIM environment leverages information to transform the building supply chain through open and interoperable information exchange, while contracts only stipulate legal minimums. In other words, “when you do things the way you always did them, you get what you always got.” Seattle found that operating in a BIM environment gave them an edge, but because of lack of buy-in, the contractor did not.

Capability Maturity Model (CMM) rating

As part of the NBIMS, Version 1.0, the NIBS FIC NBIMS Team established a model that evaluates the maturity of Building Information Models and serves as an awareness tool for turning qualitative analysis of information management into a quantitative number for great objectivity. The W912DW-06-C-000”7 NA FY06 Jackson Ave Whole Brks Renewal PH I” project was scored by the Seattle District BIM Manager and the research using the Interactive version of the CMM and it received a 38.2 score out of 100, for a “Minimum BIM” rating (Figure 4-24).

TODAY:		July 18, 2007		
© NIBS 2007	The Interactive BIM Capability Maturity Model			
	Area of Interest	Weighted Importance	Choose your perceived maturity level	Credit
	Data Richness	84%	Data Plus Expanded Information	4.2
	Life-cycle Views	84%	Planning & Design	1.7
	ITIL Maturity Assessment	90%	Limited Awareness	2.7
	Roles or Disciplines	90%	Two Roles Fully Supported	3.6
	Business Process	91%	Separate Processes Not Integrated	0.9
	Timeliness/ Response	91%	Limited Response Info Available In BIM	3.6
	Delivery Method	92%	Network Access w/ Full IA	3.7
	Graphical Information	93%	4D - Add Time	8.4
	Spatial Capability	94%	Part of a limited GIS	6.6
	Information Accuracy	95%	No Ground Truth	1.0
Interoperability/ IFC Support	96%	Forced Interoperability	1.9	
Credit Sum			38.2	
Maturity Level			Minimum BIM	

Figure 4-24. I-CMM score for Seattle BIM Project, “Jackson Ave. Whole Brks Renewal”

The areas where the BIM scored the highest were in the “Graphical Information” and “Spatial Capability” categories. This was due to the BIM’s successful 4-D simulation as well as

its geo-rectified location and inclusion in the District's GIS in a limited fashion. However, the BIM reflected the cross section of what most current BIM projects are: a slightly more complex 3-D version of the current sub-optimal 2-D drafting approach. This included a heavy reliance on preliminary design concept drawings done in 2-D first and then recreated them in 3-D in TriForma. Ironically, 2-D CAD extractions from the 3-D model were then required for the Construction Documents (CDs), so the end product was once again 2-D. Also, not all components of the building were modeled – most notably, portions of the structural plan. Finally, the BIM was not used in large-scale fashion (i.e. other than by designers) by anyone or anywhere other than to create traditional construction documents. This excludes constructability reviews by the contractor, O&M usage, emergency responder planning, or other typical applications envisioned for BIM models. Therefore, the Seattle District BIM had little more than standard information management practices compared to what would be used on any traditional design or construction project.

Quantitative data

Prior to arrival in Seattle and Louisville, computer security (COMPUSEC) tests were accomplished so that access to Corps' IT applications could be accessed. This included training and testing in Information Security (INFOSEC) and a training survey regarding Subversion and Espionage Directed Against the US Army (SAEDA). These tests were important because it is notable that the statistical data collected, analyzed and discussed here is not readily available on the web, and while not classified, the data is sensitive in consideration of future MILCON contracting considerations.

Quantitative data was gleaned from the Corps' RMS, the tool described at length earlier in this chapter. Specifically, the possibility of aligning the quantitative or statistical data comparison portion of the research with the Corps' internal metrics initiative, the Consolidated

Command Guidance (CCG) program, was considered. These CCG Reports provided a myriad of data regarding all civil and military construction projects in the NWS District.

The first step was to determine what metrics the Corps tracked that were the most similar to the six KPIs surveyed in the “Observation” Phase of this research. According to the “P2 Data Dictionary Update” According to internal Corps guidance for employees, the most critical metrics are those reported to higher authority through the USACE CCG metrics and are generally at the MILCON “Project” (i.e. Department of Defense (DD) Form 1391) level and use those milestones associated with:

- Construction Award or Obligation
- Interim design execution milestones such as RTA, Advertising/RFP and Bid Opening,
- Construction execution metrics relating to project level cost growth
- Construction time and BOD time growth.

Then, RMS was used to generate multiple reports for each project showing the data regarding these metrics. The raw report data and analysis of the results can be seen below.

The only project accomplished at the District via a BIM approach from design through construction was the “W912DW-06-C-0007 NA FY06 Jackson Ave Whole Brks Renewal” project. Therefore, reports were generated for this project and all other comparable Barracks Renewal and Construction projects dating from FY02-06. In this way, only similar projects were evaluated and the data pool was more manageable, having been filtered according to facility use code 72111, Enlisted Unaccompanied Personnel Housing (UPH) which Department of the Army Pamphlet 415-28 describes as a “building or portion thereof that meets or exceeds those minimum standards for assignment as housing for unaccompanied enlisted personnel or dormitory space for cadets at the U.S. Military Academy at West Point” (2006). According to

Appendix A, Parts I and II for Buildings and Support Facilities, “Unit Costs for the Army Facilities – Military Construction Program,” UPH barracks are usually about 99,500 SF. Because of MILCON Transformation (MT), a **15% reduction in the unit costs from the 2007 DoD Facilities Planning Guidance Costs have been already incorporated** into category code 72111 SF facilities for a cost per SF of \$166. Therefore, the normalized cost per square foot equals $\$166 \times 1.15$ or \$190.90 if the MT 15% reduction is not taken into account.

The initial concept of a detailed KPI by KPI comparison is listed below. Every attempt was made in order to evaluate only construction metrics that could be compared across the board for all six projects from FY02-06. After an exhaustive comparison of every detailed metric tracked in RMS, the following list represents the initial approach used to compare the pilot BIM project with the other similar projects completed in the Seattle District. Figure 4-25 is included to show the first iteration of statistical comparison.

Quality

In the survey, quality was defined as, “% of rework compared to overall cost.” While this may be a good metric for contractors on construction projects, it was not a metric evaluated by the Corps of Engineers. Therefore, the metrics that were viewed as the closest comparisons were:

- Punch List, Quality Assurance, #
- Punch List, Quality Control, #
- RFIs, #
- Changes, #
- Changes, \$
- Changes, Time (Days)
- Contingency, \$

- Contractor Claims, #
- Contractor Claims, \$
- Contractor Claims, Time (Days)

On-Time completion

In the survey, On-time completion was considered construction duration variance from proposed schedule duration.

- Time Growth, TOTAL, Completed and Signed, %
- Time Growth, TOTAL, Funded (Pending), %
- Time Growth, TOTAL, Unfunded (Pending), %
- Time Growth, Controllable, Completed and Signed, %
- Time Growth, Controllable, Funded (Pending), %
- Time Growth, Controllable, Unfunded (Pending), %

Units/manhour

In the survey, units per man-hour was defined as, “measure of completed units (typically square footage) put in place per individual man hour of work.”

- % Complete*TOTAL SF/Man-hours to Date
-

Cost

In the survey, cost was defined as, “variance in actual costs to budgeted costs.”

- Cost Growth, TOTAL, Completed and Signed, %
- Cost Growth, TOTAL, Funded (Pending), %
- Cost Growth, TOTAL, Unfunded (Pending), %
- Cost Growth, Controllable, Completed and Signed, %

- Cost Growth, Controllable, Funded (Pending), %
- Cost Growth, Controllable, Unfunded (Pending), %

Cost/SF

In the survey, Cost/SF was defined as, “the dollar value associated with putting one complete unit in place (e.g. cost per square foot).”

- Construction Cost for Cat Code 72111 Only/Square Feet for that Specific Cat Code as paid according to the CEFMS portion and reported in RMS
- Construction Cost for Barracks (Contractor Cost per SF as bid)
- Construction Cost for Barracks (Initial Government Estimate per SF as advertised)

Safety

In the survey, safety was defined as, “lost man-hours.”

- Exposure Hours (work hours)
- Accidents
- Lost Man-hours
- (Number of Lost Time Accidentsx200,000)/Hours Worked

06.C.0007 NA FY06 Jackson Ave Whole Brks Renewal PH I					
KPI	Corresponding RMS Metric	Value - Observed	Value - expected	Delta	Notes
Quality	Punch List, OA, #	0	51	-51	79% complete through Jun 2007
Quality	Punch List, QC, #	22	18.5	3.5	BOD 03 DEC 2007
Quality	RFIs, #	397	178.50	218.50	
Quality	Changes, #	66	64.17	1.83	
Quality	Changes, \$	\$596,386.77	\$1,760,618.82	-\$1,164,232.05	
Quality	Changes, Time (Days)	37	77.5	-40.5	
Quality	Contingency, \$	(\$112,659)	-\$19,395.00	-\$93,264.00	
Quality	Contractor Claims, #	5	1.67	3.33	
Quality	Contractor Claims, \$	\$286,610.99	\$315,082.72	-\$28,471.73	
Quality	Contractor Claims, Time (Days)	0	48.17	-48.17	
On-Time Completion	Time Growth, TOTAL, Compl and signed, %	6.90%	8.57%	-1.67%	
On-Time Completion	Time Growth, TOTAL, Funded (Pending), %	6.90%	10.23%	-3.33%	
On-Time Completion	Time Growth, TOTAL, Unfunded (Pending), %	6.90%	11.28%	-4.38%	
On-Time Completion	Time Growth, Controllable, Compl and signed, %	3.50%	4.63%	-1.13%	
On-Time Completion	Time Growth, Controllable, Funded (Pending), %	3.50%	6.30%	-2.80%	
On-Time Completion	Time Growth, Controllable, Unfunded (Pending), %	3.50%	7.35%	-3.85%	
Units/Manhour	% Complete/TOTAL SF/Manhours to date	0.396			
Cost	Cost Growth, TOTAL, Compl and signed, %	0.7%	4.03%	-3.33%	
Cost	Cost Growth, TOTAL, Funded (Pending), %	0.9%	4.28%	-3.38%	
Cost	Cost Growth, TOTAL, Unfunded (Pending), %	1.1%	4.45%	-3.35%	
Cost	Cost Growth, Controllable, Compl and signed, %	0.9%	2.30%	-1.40%	
Cost	Cost Growth, Controllable, Funded (Pending), %	1.1%	2.53%	-1.43%	
Cost	Cost Growth, Controllable, Unfunded (Pending), %	1.50%	2.58%	-1.08%	
\$/SF	Construction Cost for Cat Code 72111 Only/SF	\$237.80	\$195.67	\$42.13	72111=Enlisted Personnel Unaccompanied Personnel Housing (UPH)
\$/SF	Const. Cost for Barracks (Contractor=Obs/IGE=Expected)	\$232.00	\$162.00	\$70.00	Awarded Cost from Contractor/Initial Govt Estimate IAW cost est d
Safety	See Man-hour Calculations below TOTAL-->	218499			
	Jun-07	21625			1 Accident
	May-07	23351			1 Accident
	Apr-07	24247			1 Accident = 16 lost manhours

Figure 4-25. Statistical Information Collection sample created and accomplished in Seattle

Revised statistical approach

After determining that this process was not easily repeatable, nor as trustworthy as using the multi-level-verified CCG reports used by higher headquarters, Chapter 5 discusses the move towards using the Corps' internal CCG program as the primary means of collecting quantitative data to conduct the statistical comparison.

U.S. Army Corps of Engineers – Great Lakes and Ohio River Division (CELRD), Louisville District (LRL)

Introduction

Embedded research was conducted at the Louisville District from 23-27 JUL 07. The primary sponsor for the research from within the District was Mr. J. Wayne Stiles, CAD/BIM Manager. The pilot BIM project was titled in accordance with convention and entitled “W912QR-07-C-0037 Raleigh-Durham - ARC/OMS/Unh Storage,” an Army Reserve Center with an Organizational Maintenance Shop and Unheated Storage project built on land leased from North Carolina State University in Raleigh, North Carolina. Data collection centered on learning about qualitative and quantitative information about this project and all similar and recent ARC projects. The qualitative information came mainly from interviews with District leadership and the Louisville project team. The quantitative data came primarily from the USACE contract management database, the Resident Management System (RMS) used by the District. Just as the barracks job at Fort Lewis had a 72111 category code, this type of facility's category code is 17140. Because the District also constructs Armed Forces Reserve Centers (AFRCs) with the category code of 17141 which are nearly identical to ARCs, RMS queries were isolated to projects with these category codes 17140 and 17141. The rest of this section will elaborate on the qualitative (interview) data as well as the quantitative (database) metric data.

Qualitative data

The Louisville District (LRL) traced their BIM initiative to November 2005 when two ACSIM-AR contracted consultants, Al Frye and Lyle Bonham, visited LRL to represent their client, the Army Reserves. The impetus for the visit came from a problem that the Army Reserves (AR) and LRL shared. AR used a product called the Modular Design System (MDS) that was developed in the late 1980s at the recommendation of ACSIM-AR (Larry Cozine, personal communication, July 23, 2007). When it was no longer supported by Bentley and became obsolete due to incompatibility with software upgrades around 2005, AR and LRL identified BIM as a way to preserve the data embedded in MDS and allow the information to remain useful in a newer software platform. The AR previously developed standard room and room layout configurations for various AR unit types. In this way, MDS was used to take design charrettes to construction documents more quickly. When AR and LRL became dependent on MDS and could not utilize this data in the design phase without MDS, they realized the need to change their processes and their technology.

When Frye and Bonham, an A/E firm used by AR in the past, visited LRL, their main objective was to solve the problems surrounding MDS. Because of their knowledge about the industry's move towards BIM, they were convinced that BIM was the right path to pursue from a design standpoint as well as a technological perspective. At the recommendation and invitation of Frye and Bonham the Mason and Hanger Group presented their work to LRL during this workshop. Simultaneously, Mr. Van Woods, who was assigned to the Construction Engineering Research Laboratory (CERL) at the time and now at the Seattle District as discussed above, was also in attendance to present his work and perspective on BIM. Because of the impressive presentations by Lee Ezell of Mason and Hangar Group and Van Woods of CERL adopted the

enthusiasm Frye and Bonham shared for BIM, and LRL was persuaded to pursue BIM; ushering in a fundamental paradigm shift in how they designed their AR facilities.

Frye and Bonham knew that the decision to pursue BIM was not enough to create or sustain the program. Therefore they left LRL with three actionable requirements that began LRL's BIM "journey." First, they designated the Raleigh-Durham Army Reserve Center, which already had received funding and a flexible timetable for delivery to the clients, as the first pilot project. Second, LRL required a BIM mentor. LRL partnered with Lee Ezell and Eric Baker, who served as the mentors to LRL on technical and procedural issues, from the Mason and Hanger Group. Third, Frye and Bonham set a two year deadline in which the LRL team was to complete the design, solicit proposals, and award their first BIM pilot project.

Whereas Seattle started with no data of any kind, the Army Reserve's move to BIM began with importing and updating their knowledge base preserved in the databases of MDS, as well as lessons learned and system implementations from the Seattle District. At the same time, they set out to create the team that would successfully create the first BIM-based project from LRL. In developing their team, LRL hand-picked people who were open to change and had good communication skills. After initial attempts by individual design team members to achieve progress on their own proved ineffective in early 2006, LRL transitioned to an approach they call the BIM Process Initialization Team (PIT) where all the members of the design team received training one week that incorporated the project requiring design. Members were sequestered in one room and worked on real engineering and architectural requirements for the project throughout the training week. In the second week, members were "coached" by the trainer and BIM Manager to complete the design. In the words of Brian Huston, the BIM PIT consisted of 5-10 people whose position descriptions are described below. It was because of this accelerated,

integrated design effort that the Raleigh job was ready for solicitation and 100% designed approximately 8 months before the ACSIM-AR imposed deadline. As an aside, the team felt that BIM was the vehicle that drove the organizational change in order to accomplish better integrated design, whereas previous efforts amounted to little more than unrealized goals (Huston, personal communication, July 24, 2007).

Central to the BIM PIT was the BIM manager. In LRL's eyes, the BIM manager was the most significant member because that person must possess varying technical and team building skills in order to initiate and sustain the BIM approach. While they need not actually accomplish a large portion of the actual design work, this person needed to have a strong grasp of the district's design process and be able to work with new software with new file management standards but embrace legacy standards such as the Tri-Service CADD Standard for construction documents.

The Architect is also vital to the team as the person who accomplishes, and leads the team to accomplish, the design. The BIM Architect was required to learn new software and coach others on tips and techniques for success in the new software. This person had to be both a strong technician and be able to prepare drawing sets. The architect also aided the structural designer who used RAM steel and STAAD structural analysis packages to model the facility's structure in the Bentley TriForma Structural package (McConis 2006).

The rest of the team of BIM designers were required to apply their professional expertise to make engineering decisions and evaluate the implications that their designs had on other disciplines with more detailed analysis. These individuals needed to understand the geometry and connectivity of elements. Still, as with all design, engineering ability was far more

important than the ability to model in 3-D, but modeling successfully was still needed for project completion and communication of the design intent (McConis 2006).

LRL also utilized a Project Lead Technician who was responsible for all extractions to 2D from system models and drawing set completion. This person was also responsible for all file management within the project directory and worked with all disciplines to ensure 2D output was completed and standardized. This person worked intimately with the BIM manager to coordinate specific project dataset issues (McConis 2006).

The LRL BIM team consisted of: Brian Huston, BIM manager, Dan Hawk, Architect; Eric Fry and Jeremy Nichols, Structural Engineers; Brandon Martin, Mechanical Engineer, and Brad Allen, Project Lead Technician. Later, the necessity of Interior Design arose and Barbara Pfister joined the team. Larry Cozine, Chief of Design, was assigned to the position of Team Leader to facilitate successful design.

The Chief of Design, Cozine, followed the Project Management Business Process (PMBP) throughout the effort, providing the necessary processes for project delivery and effective quality management. The PMBP Manual ensures that USACE actions comply with the internationally recognized standard ISO 9001: 2000 Edition. Some key aspects of the Project Management Business Process are documented in the list below (McConis 2006)

- Quality Policy and Objectives
- Objectives and related measures
- Project Delivery Process Map
- Project Initiation and Planning
- Project Execution
- Project Closeout

- Project Operation
- Support Services
- Continuous Improvement
- Documents and Records

The PMBP is the fundamental driver of all USACE business processes. Project execution is a dynamic process of sequential and interrelated processes. The flowchart in Figure 4-26 shows a visual interpretation of the Project Delivery Process Map.

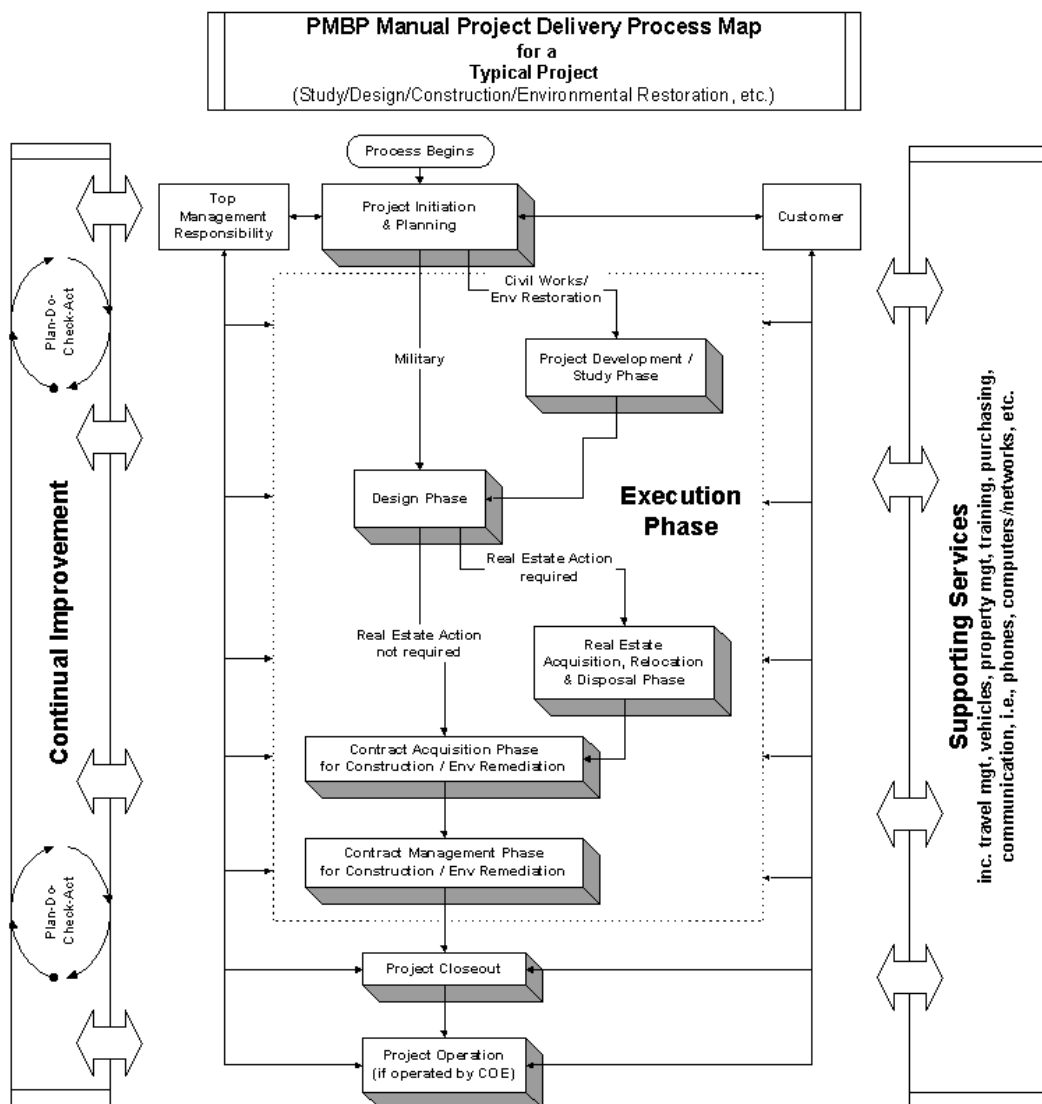


Figure 4-26. PMBP Manual Project Delivery Process Map for a Typical Project

As part of the PMBP, organizations need to create goals and objectives that assess not only deliverable productivity, but how that productivity is achieved. The LRL BIM team created the following goals and objectives for their BIM initiative:

- Goals and Objectives
- Facilitate the desires and needs of client
- Gain skill set for team members – Train the trainer
- Produce a quality design on schedule and on budget utilizing BIM.
- Create and maintain corporate dataset – should be building type specific

Once the design team was comfortable with their 100% design of the Raleigh-Durham ARC, they wanted to carry this knowledge over to establishing the 80% solution for all future ARCs and AFRCs that could be site-adapted for sites across the armed forces. In accordance with regulations, the AR historically maintained and followed stringent design criteria for facility construction. In addition to design guides, there were standards for apportionment such as criteria established regarding facility size, room types, room sizes, and supplied furniture just to name a few. However, without guides on how to accomplish the design with a BIM approach, there were challenges for LRL. The biggest challenge for LRL besides the learning curve for BIM CAD software use was determining what output would be generated from the model. The team was faced with many questions. If they were to model the building in a way that was intended to create traditional construction documents, then why follow the new approach? From another perspective, if they did not provide traditional construction drawings or plans, how would the contractor know how to interface with the model to build the building successfully? What liability issues existed for this new approach? Like NWS, LRL pursued modeling the building 100% and was more successful at modeling the structural portion of the facility. In

turn, this was inserted in RAM Structural analysis...while still creating traditional construction documents. This means that they also leveraged the model to produce automated and parametric schedules such as door, window and finish schedules (McConis 2006). Also, since they applied "accurender" material attributes to the facility, they were able to accomplish renderings inside TriForma rather than relying on SketchUp for their renderings and project visualization.

Interview data analysis

- COL Raymond Midkiff, Commander, District Engineer
- J. Wayne Stiles, P.E., BIM Manager
- Ed Mathison, P.E., CADD Mgr, Engr Div
- Larry Cozine, Chief, Design Branch, Engr Div
- Gerard Edelen, Chief, Reserves Sect Engineering Mgmt Br, Engr Div
- Daniel Algeier, Project Mgr, AR Criteria, Reserve Proj Mgmt Br, Plng, Prgms & Proj Mgmt Div
- Dave Klinstiver, Acting Chief, Construction Div
- Brian Huston, Bentley Systems, Inc. (former LRL BIM Mgr)
- Kirk Daily, Project Mgr, AR Program, Reserve Proj Mgmt Br, Plng, Prgms & Proj Mgmt Div
- Shenita McConis, Junior Project Engineer, Plng, Prgms & Proj Mgmt Div
- Mark Real, Master Planner/Landscape Architect
- Donna Thompson, Master Planner/Landscape Architect
- C. Fred Grant, P.E., Chief, Reserve Proj Mgmt Br, Plng, Prgms & Proj Mgmt Div
- Rosemary Gilbertson, Chief, Engineering Division
- Denise Klingelsmith, Chief, Computer Svcs Branch, Information Mgmt Div
- Jeremy Nichols, P.E., Structural Engineer, Structural Design
- Jason Adwell, LRL Systems Administrator Pat Judd, Database Admin, Information Mgmt Division

- Wes Barber, Acting Chief, Quality Assurance Section, Construction Div
- Bruce Murray, Chief, Engr Div

Louisville interview #1: Larry Cozine

Interviews were conducted on site from July 23-27, 2007 while conducting embedded research at LRL. The first person formally interviewed was Mr. Larry Cozine, Chief of the Design Branch. Mr. Cozine made it clear that while he interfaced with the Reserve Support team (RST), he and his team members overlapped with the RST. Also, Mr. Cozine's position on the oversight committee for the COS initiative proved invaluable because of the information he was able to provide in the interview which is included here. Mr. Cozine helped launch the COS program due to his experience in centralizing work for the ACSIM-AR in Louisville in 1997.

According to Mr. Cozine, since 1997, each ARC was designed in Louisville through MDS and then the construction management was led by the regional USACE District where the construction occurred until FY 2006 when the policy was changed to have all construction managed out of LRL, as well. This meant that projects completed prior to FY06 lost visibility in RMS as they were converted to the District with the geographic authority. However, the usual rate of projects was maybe one or two a year, but with the most recent round of BRAC, there have been a great deal of new ARCs, approximately 16 currently accessible in P2 (Cozine, personal communication, July 23, 2007).

Later in the interview, Mr. Cozine summarized LRL's RST responsibilities into three requirements:

- **Project management:** typical things like customer interface, etc.
- **Construction oversight:** fairly new, real contracting authority and obligating funds, modifications and contract changes, so they only track money and the geographic regions do the day to day inspections that also do the RMS construction data

- **Technical team:** Quality Assurance of the customers' technical and functional requirements and providing tools, develop and maintain the standard RFP (update it and make changes as necessary) maintain all the technical criteria and conformance to Dep. Army requirements.

While the RST is unique to the Department of the Army, the model they established at LRL is being emulated in the COS program. Strategically, the project funding class of Military Construction Army Reserve (MCAR) is executed out of ACSIM-AR in Washington D.C. Because their operations are in a state of flux, it helps to have their facility needs met by LRL. This state of "flux" includes the fact that while they are run from DC, their Headquarters (HQ) is in Atlanta, but they are currently in the process of moving up under ACSIM which is moving to Fort Knox in Kentucky.

Differing from the RST, the COS initiative stemming from MT is different because it no longer focuses on geographic location as the predominating factor in program management. As a testament to the effect of globalization when drafting the COS plan, the team looked at companies like "Walgreen's, Kroger, and Wal-Mart, but did not follow any one model," according to Mr. Cozine (Cozine, personal communication, July 23, 2007). Because no single model fit the Army's requirements, the COS program created an entirely new approach that represented an amalgam of lessons learned from multiple case studies. In this way, the COS initiative includes installation-specific requirements such as design guidance, LEED design goals, and energy saving directives like EPAC-05. EPAC-05 is more stringent than LEED because it was a congressional mandate to cut energy consumption by 30% as of 2005. In this way, MT and the subsequent COS program was also an opportunity for HQ USACE to roll up many disparate, new mandates and approaches in one consolidated effort.

Specific lessons learned from case studies on companies like WAL-MART included construction strategies that hired general contractors (GCs) to complete work either globally,

regionally, or nationally in IDIQ contracts. With this approach, contractors' learning curves improve more quickly and their knowledge has continuity by using and reusing construction drawings. According to Mr. Cozine, "the repetition is an important aspect" (Cozine, personal communication, July 23, 2007).

How much repetition? Under the COS initiative, 42 standard facilities are designed to the 80% level, but that is actually the second step in the three-phase process. The first phase was to "embrace and gather industry initiatives" which included the case studies on organizations like Walgreen's, Kroger, and WAL-MART. Also under this phase, the team accomplished the often misunderstood term, "adapt-build." The term is often misunderstood because there is another, similar term known as "site-adapt." This is where designers take a design already designed off the shelf and reuse it. Standard BIMs will be site-adapted to their specific geographic locations, but according to Mr. Cozine, adapt-build means to incorporate innovations from industry into the USACE's new MT and COS building strategy and methodology. Examples include taking not only industry CM techniques, but innovations like pre-cast, tilt-up concrete construction or, Type 5 construction with modular roofs built on the ground and hoisted into place. Note that this latter approach was witnessed in the field at Fort Lewis.

Also during the adapt-build phase, the USACE COSs will start building BIMs. Because these initial BIMs will not be far enough along in construction to know any lessons learned from a constructability standpoint, the only product will be design build RFPs. However, all FY08 contracts for COS standard facility types will be IDIQ so they can get the same types of buildings built by the same contractors over and over again. These contractors will be able to bring in different abilities since they will be able to practice the job with incorporated. Starting in FY08 and through FY10, IDIQ contracts will be awarded to the same contractor who designed

the building model. Before FY08, HQ USACE awarded “C” contracts which are “onesy, twosy [sic] projects here and there accomplished design build” (Cozine, personal communication, July 23, 2007). The adapt build phase will expire in FY08, at which point the Corps will transition to the Prototyping phase where IDIQ firms will design the 41 different standard facility types to the 80% level and build the 100% solution across the United States.

While the COS program has merit, its authors still have their reservations. The COS initiative’s leaders “biggest fear,” according to Larry Cozine and echoed by members at the Seattle District, is what will happen when there are multiple IDIQ contractors on site at the same time. For example, rather than one GC building a set of Barracks, an operations facility, and dining facility all at one site, there would not be three GCs building the same three projects with three times the overhead and exponentially more difficult coordination with owners on installations. According to Mr. Cozine, his personally “biggest fear is that the one [contractor] that you have left – the site contractor – will hold up all the other contractors from executing the project” and create four contractors pointing fingers at the others (Cozine, personal communication, July 23, 2007). The expectation is that COSs will develop skills on how to handle challenges like these. Right now, all effort is focused on the perceived payback, reduced construction duration. Also, the hope is that all overhead costs will be billed under the site contract managed by the regional districts that will coordinate lay down areas, cranes, and the like.

When asked about the possibility of having the COS IDIQ contractor with the predominating amount of work managing the other COS IDIQ contractors as a modified Owner’s rep, Mr Cozine, said that this would NOT happen. Known as the “umbrella contractor” approach, the USACE would not pursue this approach because it would affect their small

business capacity and goals. IN fact, it is the USACE goal that as many as possible of the COS IDIQ projects will awarded to small businesses. Large scale needs and facilities like barracks will be awarded to big contractors. But because there are multiple versions of the 41 facility types, such as small, medium, and large versions of the same types of facility (e.g. chapels) one facility type could have multiple awarded IDIQs. This would allow small firms to build small chapels across the United States.

For the IDIQ solicitation starting in FY08, contractor deliverables will include only design concepts and construction management plans. Then, after awarded the IDIQ, it is expected that these small firms with minimal design capabilities will partner with A-E firms to create the needed BIM designs and as-builts after they win the IDIQ. This is also in place because there will be no seed money available for the teams who compete in the solicitations. For the next bid of the IDIQ in two to three years from the original wave of the COS standard facility types, (FY10-11), it is the responsibility of the COS to maintain. With the majority of the COS centers residing in the southeast, many of the “have-not” districts are eager for a redistribution of the COSs, but there is currently no known “refresh rate” or cycle time for changing the Centers of Standardization. Most COSs are currently in southeast because that is where almost all POM’ d construction will occur. With the guidance in the master plans promulgated under Army Transformation, installations like Forts Bragg, Bliss, Carson, Riley, Hood, and Campbell are getting the most troops, new missions, and in turn, construction.

When asked why all the beneficial information just described above was not “common knowledge” in the Corps, Mr Cozine’s answer was that it could be attributed to limited resources. “Because of the time and effort spent to help stand up the COSs, USACE has not had the availability to go out and explain to non-COS districts how this will work.” However, there

is a website that serves as a clearinghouse for all the SOPs regarding COS information that is managed by the Fort Worth District COS, so it is behind the Army firewall and only available to USACE employees, but it does exist (Cozine, personal communication, Jul 23, 2007).

When asked about how HQ USACE ran the most recent COS Selection process, Mr. Cozine answered that there was a competition. Under the old, existing COS program, districts were little more than informal “experts” on recurring facility types. When MT dictated that districts take formal responsibility for the 41 standard facility types, HQ USACE knew there needed to be a consistent, defensible process for deciding who would serve as the new COSs. The old COS approach was been spread out to a number of Districts for the last 15 years. Facility types were archaic and/or no longer constructed. Standards were outdated or not well maintained. Took the already existing program and concentrated it where the associated workload was the most heavily weighted criterion. For example, Operational Readiness Training Complexes (ORTCs), along with ARCs, went LRL. Fort Worth District (SWF) has the most barracks in the Army with all the installations in Texas, so they received the COS designation for barracks.

Louisville interview #2: Brian Huston

The next primary stakeholder in the BIM Program interviewed was Mr. Brian Huston. Now working for Bentley as a full time salaried employee, Huston spoke primarily during the interview about his role as the former LRL BIM Manager. However, one of his new tasks as a Bentley employee was to help conduct training in the spring and summer of 2007 at all eight COSs for two weeks at each COS District. This training cost HQ USACE \$86K for 16 weeks of training in total or a total of \$5,375 per week of training (Woods and Huston, compilation of personal conversations, July 2007).

According to Stiles and Huston, LRL attempted to have the CADD/GIS Center fund his travel to do the training while still a member of LRL, but was unsuccessful. The Center determined that neither Mr. Huston nor the Center staff could accomplish all this training because of the multiple discipline-specific training requirements. However, the Center did fund Mr. Huston (while he was working at LRL) to support the Center's development of a BIM Manager's Workshop (funded directly by HQ USACE) and the development of a BIM Road Map. The COS BIM training curriculum was established and funded months prior to Mr. Huston's decision to leave the USACE, but the end result is that all the people who needed to be trained are trained. Huston's past work on the pilot BIM project showed that he excelled at making the technological and cultural efforts necessary to shift LRL's paradigm towards a BIM approach. For example, Huston did not discuss this, but new data was discovered by reviewing the unclassified, but sensitive, contracting folder for the Raleigh-Durham project. Under Huston's direction, on December 15, 2006, LRL hosted a pre-award planning meeting near the job site in North Carolina that focused on educating the bidders on the LRL's BIM program, the difference between this design and typical designs, and the way to access the model. Nothing like this was accomplished in Seattle, and it represents an important part, the education component, of the unified effort needed to cement BIM in the AECO culture. Huston should be commended for his proactive and innovative approach.

However, with all the effort Huston exerted, it was disappointing that the RFIs indicated that none of the bidders or any of their employees ever viewed the BIM. In fact, the first RFI revealed and the subsequent government amendment #3 centered on correcting sheets 293, 298, 317, 322, 323, 324, 433, 435, and 436 of 454 total sheets which had gross errors (Gee, email dated December 27, 2006). According to current LRL BIM Manager, Wayne Stiles, RFI#1

caused them to admit that, “we had egg on our face after that one” (Stiles, personal conversation, July 26, 2007) but Stiles later pointed out that this was a design team error that could happen on any job, and was not caused by anything related to the new BIM process used on the job (Stiles, personal email, August 23, 2007).

However, setting the construction drawings errors aside, LRL showed great progress from their original start only a year earlier in 2005 when the project team started in MDS before they knew they determined that it was obsolete. According to Huston, AR decided to go to BIM because they wanted the goals accomplished in MDS to be re-iterated in BIM in a more interoperable way. “It was too expensive to keep porting all the MDLs and rebuilding all the code every time a new version of MicroStation came out” (Huston, personal conversation, July 24, 2007). AR did an evaluation of the BIM packages primarily based on an assessment accomplished by Ms. Beth Brucker (CERL), and the CADD/BIM Center who accomplished evaluations of Revit, Graphisoft and Bentley. According to Huston, in the summer of 2004, HQ USACE and AR decided to go with Bentley because of the different disciplines (e.g. MEP, Structural, Architectural) and the flexibility that Bentley gave them to work with their existing software that were mostly Bentley products. Huston admitted that this was third hand, verbal knowledge, and that he did not know why or how this decision was made, but remembered vividly that when he started, CERL told him that “his job was NOT to evaluate software” (Huston, personal conversation, July 24, 2007).

Huston served as the BIM and BIM PIT Manager over the design team consisting of Dan Hawk, Jeremy Nichols, Brad Allan, and Brandon Martin. They were initially tasked to design the project in BIM and develop a standard to use for the plan at the time to contract with the six IDIQ contractors to build all Army reserve centers. This was one contract with 6 firms which

later expired at unknown date which is why the Raleigh-Durham ARC was awarded as a one-time contract. Huston said that it was LRL's job to "build the knowledge base to mentor in house and A-E firms." With that in mind, LRL built the dataset and database within one year knowing that it would be the template for future ARCs across the United States. At this point, they had created their own model. However, after formal Bentley training paid half by ERDC and half from AR, they realized their dataset was the "weak link" so they nearly started over and utilized the approach implemented in the Seattle District configuration which made the workspace more project centric to have something to contract around and deliver back and forth, meaning that they changed the way the files were stored. This served as the impetus for the CADD-GIS Technology Center project to establish the BIM "corporate template dataset for design and construction" (Spangler, telephone communication, October 12, 2007) of which Mr. Van Woods is now the lead of the BIM SubCOP Workspace Team.

In paraphrased words from Huston, the workspace creates an independent configuration that can sit on a server with a small footprint. It does not interfere with anything else like other applications. It is self contained for greater control over things file storage QA/QC. Huston felt that this approach was more beneficial because the data can more easily be converted into Construction Documents (CDs).

Again, Frye and Bonham sought to create a BIM partnership with industry. AR hosted an AE Workshop APR 24-26th of 2007 in Louisville where the following companies attended: Mason and Hanger, RSP Architecture partnered with Ghafari, URS, Jacobs, CH2Mhill, HNTB Arch., Burgess and Niple, etc. In Hustons's view, they participated in training that was not effective at the beginning of LRL's BIM initiative. The beginner courses provided by Bentley proved to be an inefficient use of the team's time and efforts because it was too simplified for

their requirements. LRL then developed a training workshop modeled on Seattle's experience with having Bentley trainers becoming part of the project team and providing project-specific support and training which consisted of 2 weeks, as mentioned earlier in the chapter. While the first week was focused on technical training in TriForma tools, the second week was devoted to coaching the team to further develop real world design project.

After this second round of training, LRL initiated weekly modeling meetings where they would accomplish trouble shooting, tackle design issues and assign upcoming tasks. These meetings were run by architect, Dan Hawk, and BIM Manager, Brian Huston. Hawk and Huston worked together throughout the entire process as the champions of the program. Both felt this was a very good arrangement for tackling the issues surrounding the BIM initiative; because the BIM was started by engineers and designers, but it was managed by the BIM manager. Because ACSIM-AR allowed for an extended design schedule, the project allowed time for the extensive learning curve users faced when working in the new environment. This provided time for adjustments to the model and other initiatives. These include implementing Groove Virtual Office software and Bentley's ProjectWise for coordination of the project, which included managing meetings, tasks, and tracking the "data about the data." Groove Networks Inc. provided desktop workspace software powered by Mobile collaboration Services, to provide LRL a better way of working together online.

The PDT developed the model work flow by trial and error. The end result is shown in Figure 4-27.

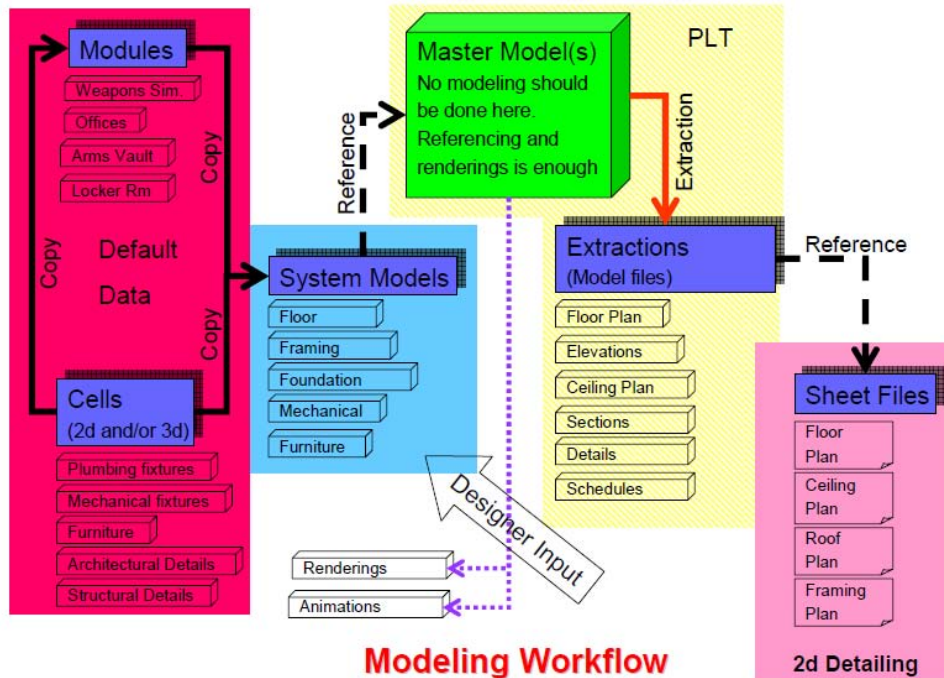


Figure 4-27. LRL Modeling Workflow (Brucker et al. 2006)

This consisted of breaking the work flow into three main areas. These areas were system models, where designers give input to the model; master model, where the lead technician referenced system models and created extractions; and the 2D extractions and sheets, where the detailing and annotation is completed. In a way, it was similar to traditional drawing, and paper space, but with a third dimension for managing the process of extracting data from the model into the required 2D output in the construction documents.

When Huston was asked if he thought that BIM had effects on construction, he said that, “we will have significant savings regarding RFIs due to collaboration and coordination improvements.” He also expects that the BIM PIT approach will decrease by 30-40%. His evidence supporting this claim was that when he asked the team how long it would take to design the Menasha project, they responded that it would not take the 11 months allotted, but instead 11 weeks.

Louisville interview #3: Shenita McConis

Another valuable interviewee was Shenita McConis. According to McConis, the model workflow LRL used began with pre-defined data known as “cells” and “modules” (McConis 2006). This ensured the data being manipulated represented only information that had been verified through the BIM Manager’s quality control process. Each module could be linked to a space or (room) from the Army Reserve design guide and came from the legacy data in MDS. BIM modules were standard rooms with 3-D space information complete with all interior components including furniture, lighting, ceiling grid, HVAC an exhaust systems. This information for each standard room was taken from the MDS data developed by the Army Reserve years earlier. The modules did not contain all of the data needed to create the BIM, but they were good starting points that ensured everything in the BIM was compliant with applicable CADD standards as well as the Design guide as soon as they were used. See Figure 4-28 for a listing of the types of modules used in the Raleigh-Durham ARC BIM.

Regarding “System Models,” designers used a specific tool known as “default data” for design creation. System models are at the heart of the BIM data set, because this is where the design is created; similar to the “model space” in traditional 2D drafting procedures. This is where most of the first week of the training workshop focused on educating the BIM design team. Another component of the workspace was the “Master Model.” From the system models, the project lead technician (PLT) created references that in turn created the Master Model. Then, the PLT ran extractions from the master model to create standard sheet files for construction documents. The PLT emphasized that any changes to the sheet file made the BIM obsolete. Therefore, he suggested to design team members that they make changes to the system models, and then re-run the extractions, rather than working in the extractions themselves. LRL was able to have TriForma produce more information for the CDs than NWS, who still, even with their

challenges, had about 90% from the extractions. LRL probably had more like 95% or more coming from extractions which is probably a good rule of thumb. An example is door schedules at LRL which were “drafted” in annotation at NWS.

	CODE	FUNCTION TITLE
1	ADS	Administrative Support
2	ARM	Armory
3	ASH	Assembly
4	BCR	Broadcast Room
5	BKR	Break Room
6	BTR	Battery Room
7	CHR	Chair Storage
8	CLS	Classroom
9	CLW	Controlled Waste Storage
10	CON	Conference Room
11	ELC	Electrical Room
12	FLM	Flammable Storage
13	FLO	Office Full Time Shared
14	FMS	Facility Maintenance Storage
15	FSO	Family Support Office
16	FTP	Office Full Time Private
17	GN1	Generic Room 1
18	GN2	Generic Room 2
19	GN3	Generic Room 3
20	ITC	Information Technology Closet
21	JNT	Janitor
22	KTH	Kitchen
23	LBS	Library Storage
24	LIB	Library
25	LRC	Learning Center
26	MEC	Mechanical Room
27	MLR	Mail Room
28	M-TLT-LOC-SHO	Men's Toilet, Locker and Shower
29	MTO	Office Maintenance Shared
30	MTP	Office Maintenance Private
31	M-W-HC-TLT	Men - Women - Handicap - Toilet
32	NOC	Network Operations Center
33	OSP	Supply Room
34	PHY	Physical Fitness
35	RRO	Recruiting/Retention Office
36	TEL	Telephone Equipment Room
37	TLR	Tool Room
38	TRS	Training Aid Storage
39	VLT	Arms Vault
40	W-TLT-LOC-SHO	Women's Toilet, Locker and Shower

Figure 4-28. Extracted Schedule from the LRL BIM showing various modules (rooms)

Another benefit of using the MDS data was the data contained in the furniture Library. Each of the standard rooms required specific furniture as defined by the Army Reserve with the use of MDS. Each piece of furniture was tagged with specific information, including name, type, size, and location and had a 2D representation linked to 3-D data for use in the model and extractions (Figure 4-29). The TriForma software used to accomplish the BIM design had the

capabilities to read this information due to its native link to the Bentley file format. In turn, LRL used the BIM to generate reports or schedules such as door and window schedules used in the creation of the construction documents.

This capability allowed designers to elicit accurate and up-to-date data quickly from the model. Figure 4-29 shows a list of the furniture types brought into the BIM from MDS and Figure 4-30 shows an example of the 3-D furniture geometry. With data like the room modules and furniture, the data evolved quickly. Huston labeled this phenomenon as “dataset evolution.” Figure 4-33 shows a graphic of the way LRL visualized dataset evolution for the ARC dataset. In order to contract for a specific dataset and the entire BIM, LRL must provide a starting point for the designer.

The pilot Raleigh project ARC (Figure 4-32) serves as the standard design for all future ARCs.

The following is a list of projects implemented through the BIM methodology at LRL:

- Raleigh Durham, NC USARC
- Homestead USAFR Lodging Facility
- Youngstown USAFR Lodging Facility
- Ft. McCoy USAR Warehouse
- Beaver Falls USAR
- Menasha USAR

Other Projects scheduled for design are the Niagara Falls USAR – Fire & Crash Rescue Station and Scott USAFR Center.

Furniture Types:
FILES AND STORAGES
STORAGE CABINETS
WARDROBE CABINETS
SEATING
TABLES
DESK UNITS
FITNESS EQUIPMENT
POWERED PANELS
NON-POWERED PANELS
POWER INFEEDS
POWER POLES
POWER RAILS
DUPLEX OUTLETS
WORK SURFACE TOPS
DESK SUPPORTS
RETURN DESK SUPPORTS
STANCHIONS
SYSTEM STORAGE
DESK ACCESSORIES
TASK LIGHTS

Figure 4-29. Furniture Types Imported from MDS and used in the LRL BIM

FURNITURE TAG: D4
DESCRIPTION: DESK UNIT TYPE 4
LEVEL NAME: I-SYST-FURN-D4
FILE NAME: _D4.DGN

Design By: BIM TEAM	Drawn By: S. McCONIS	Checked By: 	DESK UNITS	
Reviewed By:	Approved By:	US Army Corps of Engineers		
Date:	Scale: 3/8"=1'-0"	Drawing Code:	Sheet Ref. No. DESK UNITS_2	Sht 2 of ___

Figure 4-30. Example of 3-D furniture imported from MDS into BIM application

Army Reserve Dataset Evolution

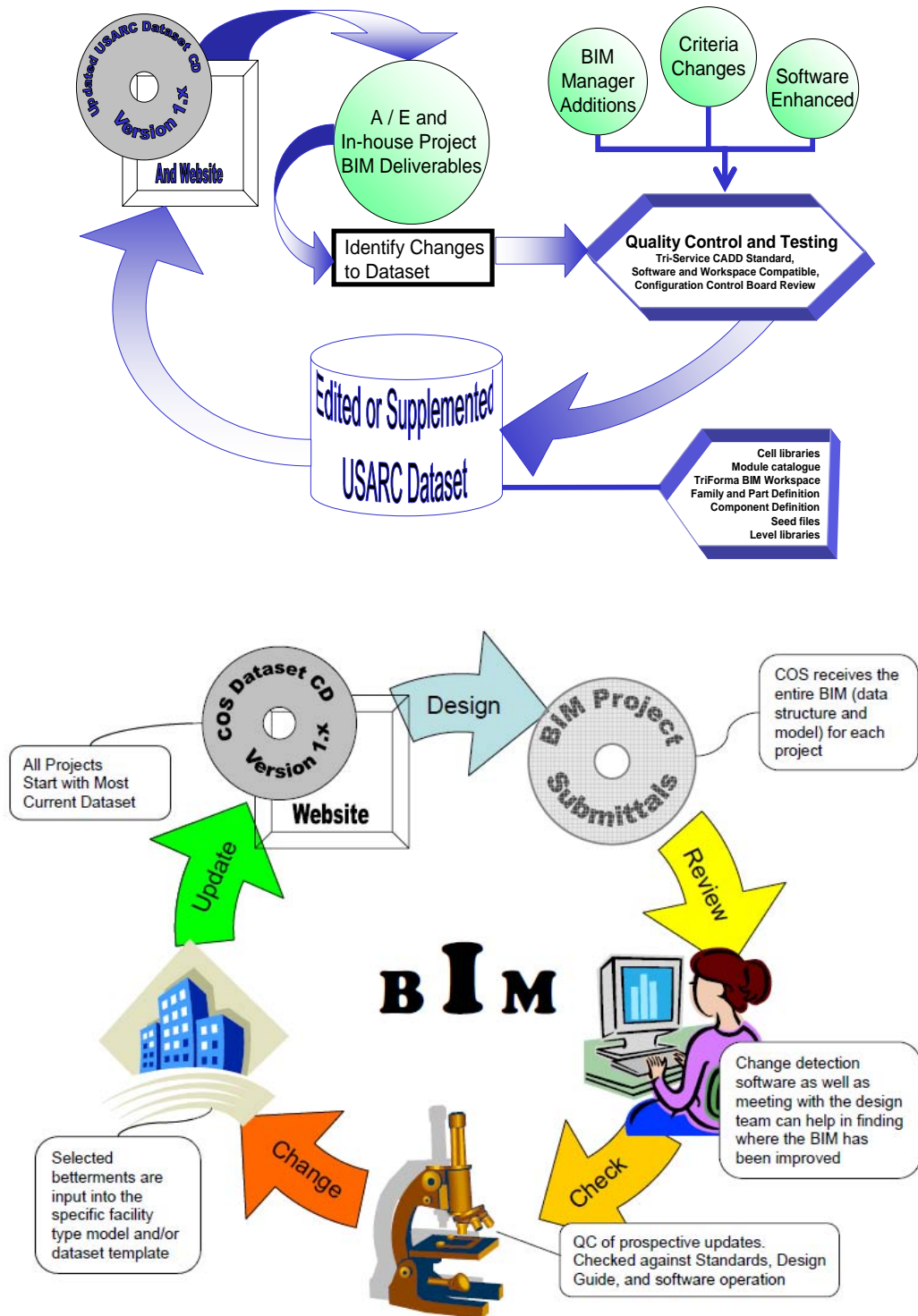


Figure 4-31. Army Reserve Dataset Evolution guidance and Finalized USACE-wide Dataset evolution guidance (McConis 2006) and (Brucker et al. 2006)

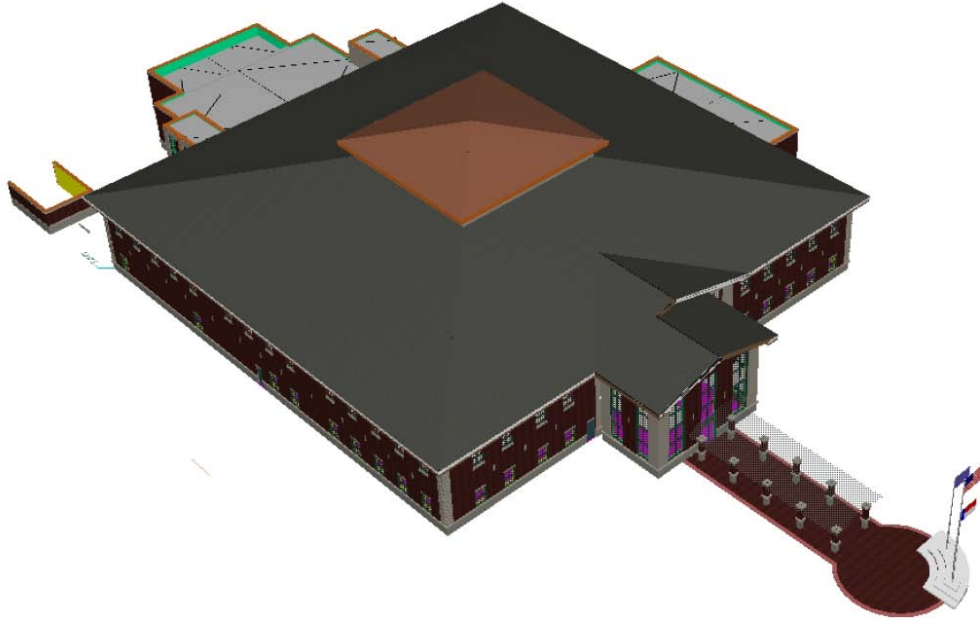


Figure 4-32. Rendering of LRL's first 3-D BIM, the Raleigh-Durham and subsequent standard ARC design

Louisville interview #4: Rosemary Gilbertson

On July 25, 2007, Chief of the Army and Air Force Design Section, Rosemary Gilbertson was interviewed simultaneously with her counterpart, BIM Manager, Wayne Stiles. The interview went well because Gilbertson had an executive level perspective of BIM whereas Stiles could provide a hands-perspective. When asked what changes BIM have created in their organization, Gilbertson focused on the process rather than the technology. She said that the current BIM design teams are "operating more like a team," meaning the architect gets designs started earlier than in the previous approach. Before, the project team did not come together to accomplish the design, but under the BIM PIT approach, the whole team comes together to accomplish the design. Gilbertson said that at the 30-50% design level, the great thing is that everyone is working in the virtual workspace. Instead of fixing problems after, the team is designing continuously together in the model. Gilbertson felt that the key was "forcing" the team to work together in the same virtual space, which in turn helped the design process

immensely. The disciplines “play” together much better (Gilbertson, personal communication, July 25, 2007).

Furthermore, regarding staffing, Gilbertson said that BIM teams need to be comprised of the “top of the line folks.” LRL chose the individuals who had a comfort level with the technology and “can do” attitude as opposed to the possibly the “more tenured” individuals. Above the design team, management needs to commit to supporting BIM 100% because their support was crucial for success to providing things like space for the BIM PIT, empowerment to accomplish the design, and scheduling the work.

When asked what implications BIM has on the construction phase, Gilbertson referenced their partnerships with A-E firms like Mason and Hanger. This revealed a perception that in-house designs on BIM do not have as large an impact on construction as the promise offered by design build contracts. This is because the BIM may “die” when transferring the information to GCs who may not use the same platform or have the same experience in BIM, showing and interoperability and education challenges. Gilbertson reiterated that since they started talking about BIM, they have heard more information from firms like Jacobs, CH2MHill, Black and Veatch, and Mason and Hanger who are glad to partner with the Corps and offer up their BIM content. Conversely, Gilbertson also noted that some A-E firms try to convince USACE that BIM-based designs will cost more. Gilbertson felt that owners need to say that if an A-E firm is going to use BIM, there should not be an extra fee, because firms have the knowledge and experience already. Whereas Gilbertson felt that LEED could possibly drive up costs due to added scope of work, BIM was different. BIM is a better way to design, so it should cost less, not more. LEED is actually a higher level of effort and more work so Gilbertson felt that it made sense to charge more for the design and the facility. In fact, Gilbertson went on to say that A-E

firms should be taking up to 10% off their total fee now that they are lowering liability insurance rates due to the reduced amount of errors and omissions provided through a BIM approach.

When asked “How will BIM change things?” Gilbertson replied that she hopes it will change the way they do business. She hopes that the technology will advance and that they keep up with it. The customer drove the train: the Army reserve. The next big challenge is getting the rest of their design staff trained and converting to BIM. They need to show their other customers the benefits. For example, they want to take it into more robust operations such as facility handover through the Construction Operations Building Information Exchange (COBIE) initiative coming out of ERDC (Gilbertson, personal communication, July 25, 2007).

Louisville interview #5: Fred Grant

Also interviewed on July 25th was Fred Grant, Chief, Reserve Support Branch for LRL and CERL-PM-R. Grant began by discussing the history behind LRL’s relationship with Army Reserve. In 1994, LRL was assigned as the AR Program Mgr at the request of AR. IN 2004, that MOA was upgraded for LRL to serve as the construction agent for all Army Reserves. It was not until 2006 that LRL officially became the CM representatives for AR, as well. Right now the total FY 07 program for the reserve MCAR and BRAC is \$700M this year and a little less in 2008. Mr. Grant thought that this reflected that the AR is “a very satisfied customer for LRL.”

When asked about BIM, Mr. Grant said, “BIM is the next step in this progression...Spin into 3-D design, etc.” It was interesting to note that Louisville was forced to move to Tri-Forma when Bentley changed their platform and MDS no longer ran on the new platform.

When asked what he thought about the new COS approach, Mr. Grant replied that it will be a logistics challenge. According to Grant, LRL does “not have a cookie cutter approach.” They have small, medium, large facilities and their standard approach is “components.” Assembly

Hall designs, standard office areas, recruiting offices, classrooms, etc. With MDS, you assemble the building using those standards. It brought reflective ceiling plans, furniture layouts, floor plans, etc. This was “developed into BIM from MDS to do finishes, lighting schemes – you can now make virtually any size office. Lighting patterns, etc. This makes the modules virtual and modifiable.” Similarly, Gilbertson called this approach, “Standard components vs. standard buildings.”

In conclusion, the interviews at LRL were valuable in providing the background story on the transition to BIM within the LRL STAR team. While many of the cultural hurdles were similar to those faced in Seattle, this team differed in their technical approach because of their experience with the Modular Design System. As the traditional geographic barriers are eliminated in the COS approach, superior content and technical know-how like this should be established as a ‘best practice’ and be readily available to all Corps designers.

Capability Maturity Model (CMM) rating

As stated earlier in this chapter, the NBIMS, Version 1.0, established a model that evaluates the maturity of Building Information Models. This tool serves as an awareness tool for turning qualitative analysis of information management into a quantitative number for greater objectivity. The Raleigh-Durham BIM project was scored by two members of the original BIM team for the project, LRL BIM Manager, J. Wayne Stiles, P.E. and the structural engineer on the project, Jeremy Nichols, P.E. (Figure 4-33) and the researcher. Using the Interactive version of the CMM, the LRL Raleigh-Durham BIM project received a 40.2 score out of 100, for a “Minimum BIM” rating (Figure 4-34). This was very close to the NWS BIM I-CMM score of 38.2, with LRL receiving more points for harnessing the as-built data and applying the knowledge to future construction projects re-using the BIM geometry and data.



Figure 4-33. Photograph of researcher evaluating the ARC BIM according to the NBIMS I-CMM with LRL Mechanical Engineer, Jeremy Nichols; and current LRL BIM Manager, Wayne Stiles (Source: Hornback 2007)

July 26, 2007			
The Interactive BIM Capability Maturity Model			
Area of Interest	Weighted Importance	Choose your perceived maturity level	Credit
Data Richness	84%	Enhanced Data Set	2.5
Life-cycle Views	84%	Add Construction/ Supply	2.5
ITIL Maturity Assessment	90%	Limited Awareness	2.7
Roles or Disciplines	90%	Plan, Design & Construction Supported	5.4
Business Process	91%	Few Bus Processes Collect Info	1.8
Timeliness/ Response	91%	Most Response Info Available In BIM	4.6
Delivery Method	92%	Network Access w/ Full IA	3.7
Graphical Information	93%	3D - Intelligent Graphics	6.5
Spatial Capability	94%	Basic Spatial Location	1.9
Information Accuracy	95%	Full Ground Truth - Int Spaces	3.8
Interoperability/ IFC Support	96%	Most Info Transfers Between COTS	4.8
Credit Sum			40.2
Maturity Level			Minimum BIM

Figure 4-34. Capability Maturity Model Evaluation of LRL Raleigh-BIM Model July 26, 2007.

The area where the BIM scored the highest were in the “Graphical Information” and “Roles or Disciplines” categories. This was due to the BIM’s successful completion of 3-D intelligent graphics and roles supported in design, planning, and construction through their BIM PIT and carry over to their construction contractor, Bordeaux Construction in their contractual

language and education. However, overall the BIM was only two points higher than Seattle's first BIM project and it similarly reflected the cross section of what most current BIM projects are: a slightly more complex 3-D version of the current sub-optimal 2-D drafting approach. While their reliance on 2-D CAD was not as heavy as Seattle's their project also had 15 RFIs from solicitors primarily centered on questions about errors or omissions in their plans.

Compared to NWS, LRL relied more heavily on using extractions of the actual 3-D model in the Construction Documents (CDs) rather than the sub-optimal 2-D approach. Also, they modeled more of the facility, namely the structural portion. Lastly, while attempts were made to use the BIM was in a large scale fashion (i.e. other than for visual aids in presentations) it has not yet been used by the construction firm nor is it planned for being used in FM phase of the facility's lifecycle other than as-builts, which are required for this project. This BIM, like Seattle's, seems to have been focused nearly exclusively towards creating traditional construction documents. This excludes constructability reviews by the contractor, O&M usage, emergency responder planning, or other possible applications for BIM models. Therefore, both the Seattle and Louisville Districts BIMs had little more than standard information management practices compared to what would be used on any traditional design or construction project.

Quantitative data

This portion describes the technical data used to describe the construction phase of the Louisville District's first Building Information Modeling (BIM) project. With the subsequent MILCON Transformation Initiative, the Louisville District serves as the Army Reserve Center of Specialization (COS). Before the COS policy letter or BIM Road Map required that COSs use BIMs, the Army Reserve elected to use the Raleigh-Durham Army Reserve Center project as the pilot test for a Building Information Modeling (BIM) that would later serve as the basis for all other standardized models used to construct Army Reserve Centers. The facility consists of a

training building, operations and maintenance shop (OMS), Vehicle Maintenance, and an Unheated Storage facility. While the project had an initial government estimated construction cost of \$11.2 million, the final awarded cost to the GC, Bordeaux Construction Company, was \$13,014,501.00 due to escalations in steel costs. While the project had a “bid-bust” in its first solicitation, it was value engineered by reducing some of the curtain walls and windows and reauthorized for a higher programmed amount (McConis 2006).

The pilot project facility use category code was 17140, “Army Reserve Center Building” which Department of the Army Pamphlet 415-28 describes as a “building or complex that supports training and operations of U.S. Army Reserve (USAR) units” that usually houses assembly space, classrooms, locker rooms, weapons storage, and others as needed (2006). According to Appendix A, Parts I and II for Buildings and Support Facilities, “Unit Costs for the Army Facilities – Military Construction Program,” ARCs typically cost \$191 per square foot and are usually about 20,000 SF. Because they are also under the purview of LRL and after talking with facility programmers at the Louisville District, Armed Forces Reserve Centers (AFRCs) with facility use category code 17141 were also included. The description in DA PAM 415-28 is also nearly the same as for ARCs.

The quantitative data for ARCs and AFRCs came from a consolidated RMS query accomplished by Mr. William S. Reeser, P2 Coordinator for the Louisville District. The report generated projects from Program Years (PY) 2001-2007. Prior to 2006, all USAR projects were managed under the geographic jurisdiction of Districts across the country. After 2006, the Louisville District centralized construction management and RMS data entry under their LRL office. Therefore, the researcher needed to get clearance from every District in the United States to have read access to their RMS databases in order to gain access to this summarized and

reduced information below. All credit for this huge undertaking can be attributed to Ms. Brenda Moriarty, the Information Management Officer from the Seattle District.

The same statistical data determined in Seattle were used as a basis for data collection in Louisville. This included data from quality, on-time completion, etc. However, this proved even more difficult because there were many data items that were either missing, or not completed yet, or incorrect in RMS. Figure 4-35 gives more information on this initial statistical analysis approach

W912QR-07-C-0037 Raleigh-Durham - ARC/OMS/Unh Storage					
KPI	Corresponding RMS Metric	Value - Observed	Value - expected	Delta	
Quality	Punch List, QA, #		#REF!	#REF!	
Quality	Punch List, QC, #		#REF!	#REF!	
Quality	RFIs, #		#REF!	#REF!	
Quality	Changes, #		#REF!	#REF!	
Quality	Changes, \$		#REF!	#REF!	
Quality	Changes, Time (Days)		#REF!	#REF!	
Quality	Contingency Used, \$		#REF!	#REF!	
Quality	Contractor Claims, #		#REF!	#REF!	
Quality	Contractor Claims, \$		#REF!	#REF!	
Quality	Contractor Claims, Time (Days)		#REF!	#REF!	
On-Time Completion	Time Growth, TOTAL, Compl and signed, %		#REF!	#REF!	
On-Time Completion	Time Growth, TOTAL, Funded (Pending), %		#REF!	#REF!	
On-Time Completion	Time Growth, TOTAL, Unfunded (Pending), %		#REF!	#REF!	
On-Time Completion	Time Growth, Controllable, Compl and signed, %		#REF!	#REF!	
On-Time Completion	Time Growth, Controllable, Funded (Pending), %		#REF!	#REF!	
On-Time Completion	Time Growth, Controllable, Unfunded (Pending), %		#REF!	#REF!	
Units/Manhour	% Complete*TOTAL SF/Manhours to date		#REF!	#REF!	
Cost	Cost Growth, TOTAL, Compl and signed, %		#REF!	#REF!	
Cost	Cost Growth, TOTAL, Funded (Pending), %		#REF!	#REF!	
Cost	Cost Growth, TOTAL, Unfunded (Pending), %		#REF!	#REF!	
Cost	Cost Growth, Controllable, Compl and signed, %		#REF!	#REF!	
Cost	Cost Growth, Controllable, Funded (Pending), %		#REF!	#REF!	
Cost	Cost Growth, Controllable, Unfunded (Pending), %		#REF!	#REF!	
\$/SF	Construction Cost/SF	\$214.77	#REF!	#REF!	
\$/SF	Const. Cost for Barracks (Contractor=Obs/IGE=Expected)		#REF!	#REF!	
Safety	See Man-hour Calculations below TOTAL-->		#REF!	#REF!	

Figure 4-35. Initial Data Collection in Louisville less successful due to database reliability

U.S. Coast Guard—NESU, Charleston

A site visit to the U.S. Coast Guard, Naval engineering Support Unit (NESU) Charleston, SC was made on August 14-15, 2007 at the recommendation of Mr. David Hammond, from USCG HQ. Some basic information describing the installation and operations are included here from a

recent press release written by the Unit's Executive Officer (XO), Lieutenant Commander (LCDR) Kenneth D. Ivery.

Located in historic Charleston, SC on the Cooper River at the "Old Charleston Naval Base" is one of the most unique support operations in the Coast Guard. Operated by the 23 person staff at Naval Engineering Support Unit (NESU)/Maintenance Augmentation Team (MAT), Vessel Support Facility (VSF) provides port engineering and maintenance support to 25 cutters in three states, manages deep water mooring for two 378 foot cutters, a 225 foot buoy tender and two major National Oceanographic and Aeronautical Administration (NOAA) vessels.

Another aspect of VSF uniqueness is its responsibility as the landlord of 100-thousand square feet of office, shop and storage space. VSF supports 17 tenants including the Department of Justice (DOJ), Electronic Support Detachment (ESD) Charleston, CGIS, Southeast Regional Fisheries Training Center (SRFTC), NOAA, and twelve other Federal, State and Local agencies. In addition to performing the traditional NESU/MAT responsibilities, VSF performs facilities maintenance, shipping and receiving, logistics, port services, heavy equipment, and storage operations which more closely resemble an Integrated Support Command (ISC) than a NESU.

To accomplish these missions, VSF relies on a single Facilities Manager, Mr. George "Skip" Aldrich, in conjunction with the assistance of the 14 person MAT. VSF Charleston encompasses facilities management of four structures totaling more than 100-thousand square-feet and port operations for the 1350 foot long pier; homeport for five major vessels. Annually, VSF accommodates more than twenty-five visiting vessels from other U. S military services, commercial vessels, and foreign combatants. Operation of the pier and its maintenance is a demanding endeavor. Sustaining the structural integrity of the 200 pilings supporting the pier,

maintaining safe water depth through dredging and ensuring that utility services are properly distributed and marked requires constant diligence. VSF facilities manager and MAT also provides buoy on-load/offload support to the D7s largest AtoN asset, CGC OAK and oversaw the construction of a 6000 square-foot concrete buoy storage facility. Accomplishing these missions requires the commitment and dedication of a well trained and devoted port operations and facilities staff, the impetus for accomplishing this vital task comes from the dedicated men and women of VSF/MAT Charleston.

Classifying this responsibility as a collateral duty for MAT diminishes the importance of this vital operation and the extensive training, and expertise required to accomplish such important missions as ensuring the safe moorings of the Coast Guard largest Search and Rescue and Law Enforcement platforms, two 378-foot WHECs.

The research accomplished was due in part to Charleston's selection as one of the new locations for the USCG's new deep water capability and bed down of the new 425' Cutters.

CHAPTER 5 DISCUSSION

Phase III: “Decide”

Introduction

This chapter will discuss work done in the “Decide” portion of the Observe, Orient, **Decide**, Act Loop. The information gleaned in the observation phase in the surveys was used to focus data collection efforts at the U.S. Army Corps of Engineer districts. Furthermore, the data collected at the district levels was used to orient a finalized research methodology to determine trend analysis Corps-wide. Therefore, this chapter will discuss the follow-up work and analysis accomplished in this phase before writing analysis and future work for those managing construction in the USACE to “Act” upon and use in their mission to improve their construction procedures.

General Information on Statistical Modeling used in Construction

Successful prediction stems from accurate historical documentation. Sampling the data through key performance indicators (KPIs) therefore both describe past performance, as well as set benchmarks for predicting future performance. A review of existing construction productivity evaluation “best practices” found that leaders in the field of establishing KPIs for describing and predicting construction productivity primarily reside in the UK or Singapore. Additionally, the majority of research concerning construction KPIs occurs in these two regions. Furthermore, because of the multiple variables involved with assessing construction productivity, the predominant approach for modeling the quantitative evaluation of the impact of these multiple factors is through Artificial Neural Networks (ANN). However, this research decided to take a more traditional approach in the United States: benchmarking.

Benchmarking as a means for productivity improvement

In 2007, NIST's Building and Fire Research Laboratory (BFRL) researcher, Robert Chapman, stated that in light of the 2004 NIST study that served as an impetus for catalyzing widespread-BIM adoption, "Construction industry stakeholders need compelling metrics, tools, and data to support major investments in productivity enhancing technologies. The development of metrics, tools, and data is complicated because each measurement level (i.e., task, project, and industry) has many different analysis requirements" (Chapman 2007). The rest of this section will discuss task, project, and industry level benchmarking.

The U.S. Construction Industry Institute (CII) is also a research organization that has engaged in benchmarking and creating metrics for construction. However, like Means and other estimating services, their metrics are primarily task-based. With large organizations like the Bureau of Labor Statistics tracking metrics that are primarily industry-based, there are few, if any, metrics tracked on the project management level from the owner's perspective. The USACE Consolidated Command Guidance metrics are one of these few metrics that attempt to compare past or current performance to an expected norm.

Benchmarking and metrics in international construction research

It is interesting to note that NIST and the CII partnered in the summer of 2008 to establish a research team to create an approach for better collecting project management level metrics. James M. Turner, the deputy director of NIST told more than 500 owners at an August 5-7, 2008 meeting in Keystone, Colorado that NIST "launched a multiyear, collaborative research effort that aims to supply the measurement science needed to bring major gains in construction productivity" at the task and project levels (Tuchman 2008).

Furthermore, the idea of benchmarking construction metrics to improve productivity is not unique to the United States. The CSIRO of Australia and researchers in Hong Kong partnered to

research benchmarking as a means to avoid rework in a study in 1998. According to Love and his other authors, “the early management theorist Fredrick Taylor in 1915 concluded that the success of management is based upon their ability to become scientific where knowledge is characteristically acquired through systematic observation, experiment and deductive reasoning” (Love et al. 1998). The noted construction productivity expert, James J. Adrian contrasts Fredrick Taylor and his approach for measuring productivity called “Taylorism” with an alternative management approach popularized in Post World War II Japan, “Quality Circles” (Adrian 2004). Whereas Taylorism stemmed from operations research and breaks tasks down into their smallest pieces, Quality Circles (QC) attempt to reap the benefits of both Taylorism and Adrian’s term of “craftsmanship.”

For QCs to be effective, the supervisor forms sub-groups composed of specialists from diverse areas across the company or project to engage in continuous improvement. The goal is to act on specific problems with an interdisciplinary approach. This approach is a keystone of the very successful, but highly unpopular concept (in the United States military at least) total quality management (TQM). Similarly, Love revealed that, “Australian construction organizations have generally refrained from implementing quality management principles. As a result, little is known about the costs of poor quality and the impact it has on an organization’s performance and competitiveness” (Love et al. 1998).

Therefore, any recommended approach for monitoring productivity that is also practical or desirable enough to be implemented by a real world owner or construction organization should measure performance variables that are as simple as possible, in a method that is commensurately simple, but has the maximum level of impact. As a result, these variables should be the primary variables in construction of interest to an owner: **cost, time, and quality.**

More specific variables could be generated, but they should all focus on answering back to these three primary variables. Therefore, the research focused on existing means and methods that demonstrate successful productivity measurement.

The Resident Management System (RMS) and Consolidated RMS (C-RMS)

After the unsuccessful attempts to painstakingly collect 25 individual data points on each of the pilot BIM projects, it became clear that it would be important to simplify the process and align with current USACE operations. As discussed earlier, the Resident Management System and Consolidated –RMS which rolls up all geographically disparate RMS data across the United States, is entered in the database to determine project, and in turn portfolio, productivity. The manager of this system is Haskell Barker, who works at the C-RMS Center in Simi Valley California. Mr. Barker’s team has accomplished the laborious process of setting up the data management system, collecting the data, and executing the algorithms to harvest the enormous amount of data stored in the RMS. In this way, Mr. Barker turns data into information and eventually knowledge.

Establishing the baseline

In January of 2008, after a teleconference with Bruce Pastorini of the USACE Jacksonville District (SAJ), Steven Spangler of ERDC CADD/BIM Center and Haskell Barker of the C-RMS Center, the C-RMS Center established a toggle box for BIM and non-BIM projects in the user interface for Construction Managers across the USACE. Following this action, the known BIM projects were “marked” by the NWS and LRL pilot BIM teams (among others working on current BIM projects). Lastly, the C-RMS team performed a custom query where they generated a report of all the completed and in-progress Non-BIM projects that were of the same facility use category codes as the Barracks project and Reserve center, 72111 and 17140/17141, respectively. C-RMS sent this original information in PDF file format via email on February 27,

2008 and then again on the first of the month, starting in April of 2008 every month until February 1, 2009.

In turn, this data was converted to text and imported in MS Excel as a delimited text file. After extensive “cleanup,” and verification, the MS Excel workbooks were evaluated with traditional descriptive statistics (Appendix A). In this way, an expected baseline was established, but the process still was far from being something that could be easily repeatable by construction managers or District Engineers across the Corps.

Metrics for construction productivity—the USACE Consolidated Command Guidance (CCG) program

After the laborious, inefficient, and error-prone process of collecting (and sometimes calculating) 25 individual data areas on the individual BIM projects, it was apparent that this process was not repeatable and needed improvement. The noted historian, scientist and philosopher, Thomas Kuhn, said, “Very often the successful scientist must simultaneously display the characteristics of the traditionalist and of the iconoclast” (Kuhn 1962) Applying this quote, it became evident that it was important to use something that was not only statistically useful, but already integrated into the USACE culture and daily business processes. Therefore, it was important to leverage a traditional approach for an iconoclastic result. During embedded research it was noted that the USACE already had a “report card” for assessing performance through their Military Construction (MILCON) program in the form of the Consolidated Command Guidance (CCG) metrics MP-6 through MP-10. All districts are required to report their CCG status, which is forwarded to the Division level, which in turn are evaluated at the Headquarter level.

As it is well known in the construction industry and corroborated by Adrian (1995) “the success or failure of every construction project can be measured in terms of four variables: cost,

time, quality, and safety”. Similarly, these are aligned with the primary metrics that USACE uses to evaluate its own competency is the CCG program. The USACE CCGs attempt to compare past or current performance to an expected norm. There are a myriad of CCG metrics used to evaluate every phase of USACE work from design to sustainability, but there are five specific CCGs primarily used to evaluate construction productivity. These five CCGs are found in the USACE construction administrator’s automated management application, called the Resident Management System (RMS) are metrics MP-6 through MP-10. From the RMS, geographically disparate construction managers or contract administrators can add data or query USACE databases for real-time status updates on any of the active or completed projects in the USACE. Status is reported back in the following, simplified fashion:

- Green: CCG metric has met or is meeting the goal
- Amber: CCG metric has not met the goal by a slight margin
- Red: CCG metric has not been met and is not close to being met

Below are a list of each specific metrics and their accompanying goals, from the Honolulu District’s guidance (Won 2007):

- MP6: Construction Project Cost Growth
 - “Is the project’s current cost of construction within 5% of the awarded contract amount?”
- MP7: Construction Project Time Growth
 - “Is the project’s scheduled construction completion within 10% of the original contract duration?”
- MP8: Project Beneficial Occupancy Date Time Growth
 - “Is the project’s scheduled BOD within 10% of the original BOD?”
- MP9: Project Construction Timeline

- “Is the project’s overall delivery schedule within the timeline guidelines based on the PA amount?”
- MP10: Project Financial Closeout
 - “Is the project’s scheduled fiscal closeout within 12/15 months of BOD?”

When evaluating construction projects individually, each project can only “meet” or “not meet” the goal. However, for the regional Districts, or their higher sub-regional headquarters called “Divisions” (which consist of multiple, subordinate “Districts”), the metric is “expressed as a percentage of the sum total of number of on-going projects in program years (PYs) 02-06 meeting the Cost Growth goal” (Strock 2006). Then the average sum total when dealing with an entire District or Division is broken out into the green, amber, red ratings. For each metric, the performance level and the windows of opportunity for achieving a “green” rating vary accordingly. For example, for MP-6 “Construction Project Cost Growth,” the goal is to “manage on-going MILCON Project construction through contract completion with no more than 5% total project cost growth” (Strock 2006).

Therefore, for a single project to achieve a green rating would require that the project’s cost could grow no more than 5% for the “sum of all construction cost growth from Military Construction (MILCON) funded contracts executing a project” (Strock 2006). If it did not meet this goal, the project would simply be classified as “did not meet goal.” However, collectively, an amber rating would be achieved for 85-95% of the projects meeting the cost growth goal and a red rating would be applied for below 85% of the collective projects meeting the goal.

Therefore, in the figure showing the CCG report from RMS querying all on-going projects for all Program Years, metrics MP-6 and MP-7 for the USACE are Amber with 89% for MP-6 and Red for MP-7 with a 68% rating.

From the information shown in Figure 5-1, clearly the Army is not meeting their internal goals (Figure 5-1). In fact, as of the date that report was queried on September 8, 2008, the USACE was red in four of the five metrics tracked in RMS, and, as shown in the figure above, only achieved one amber rating. Evidently, a change is needed and the USACE hopes to change this current level of performance.

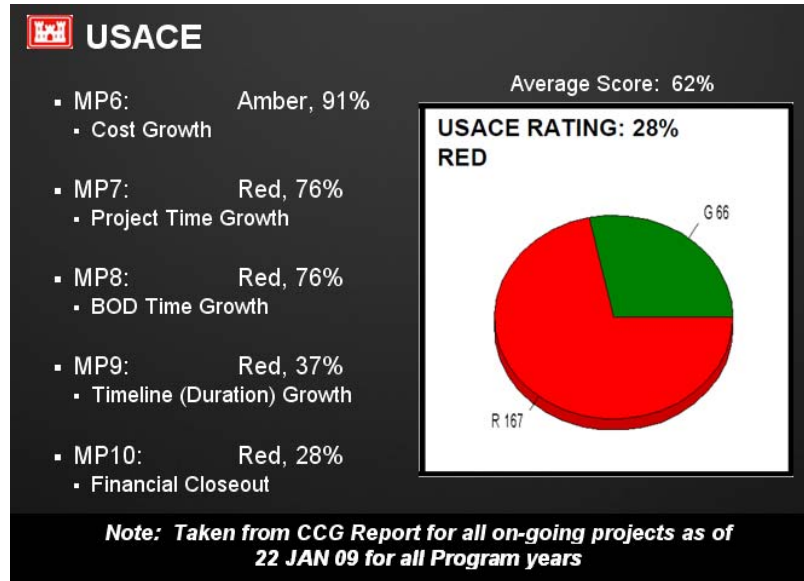


Figure 5-1. Summary USACE CCG Report, 22 JAN 09, showing range of 28%-91% meeting their metrics

CCG Critique

Before basing a more complex strategy off the existing one, it is important to evaluate the existing CCG program critically. The single biggest criticism of the CCG program is that there is no tie between some of the administratively “arbitrary” metrics and the information in the C-RMS. For example, the MP-10 metric requires that all construction projects are financially closed out within 12 months stateside and 15 months overseas. However, with only a 29% passing rate, this metric is not at all in line with what is actually occurring in the field. Intuitively, the metrics would be much improved if they were more realistic. This could be

accomplished by comparing project performance to historic benchmarks and then reward performance at the high end of the normal distribution while analyzing and assessing projects at the low end of the normal distribution. Right now, the CCG metric program only looks at negative variance from an otherwise arbitrary performance level.

Advantages: Applying Kuhn’s quote here about traditionalist versus iconoclastic characteristics, the CCGs are good *traditionalist* metrics for the *iconoclastic* technology (BIM) to demonstrate an impact on USACE construction because they are already part of the traditionalist USACE culture. In an organization with a linear chain of command like the military, it is crucial for the Engineer, Research and Design Center (ERDC) who is accomplishing BIM and construction research, to align their work with horizontally positioned organizations like the Army’s Districts who are accomplishing the “real work” or construction. Because USACE Headquarters (HQ) has already promulgated their support for CCGs MP6-10 and included them in the Resident Management System (RMS), it would be counterproductive to create new metrics (for the time being) to test BIM-based projects against. Therefore, leadership support and familiarity are the primary advantages of using the USACE’s CCGs to evaluate BIM’s impact on construction. Before BIM can demonstrate the type of impact that MILCON Transformation promises (like 15% cost savings and 30% time savings for 50 year facility lifecycles), it must first demonstrate projects that score 100% (green) compliance with existing USACE metrics like the CCGs.

Disadvantages: The CCGs, like many other construction evaluation means, are lagging indicators. Their only expectation is a negative/unfavorable variance from an expected level of success. Additionally, the expected levels of success are not always tied to real world project benchmarks or key performance indicator baselines, but instead arbitrary administrative marks,

especially in the case of MP9 and MP 10. Proper metrics should be compared to reliable historical data of real world projects, not arbitrary administrative policies. Additionally, initiatives to improve on these metrics should be tied to realistic, achievable goals that stem from strategic level goals for reaching return on investments for the specific initiative. Otherwise, the initiative will never demonstrate improvement and should not be undertaken.

CCG comparison and discussion

In order to collect the data on BIM-based projects versus non-BIM-based projects, the USACE Resident Management System (RMS) database administrators were contacted. They added a toggle box in the *Contract Description* area that allows users to note whether or not a project was considered “Building Information Model (BIM) Compliant” (Figure 5-2). In this way, known and future BIM projects could be easily differentiated for research purposes.

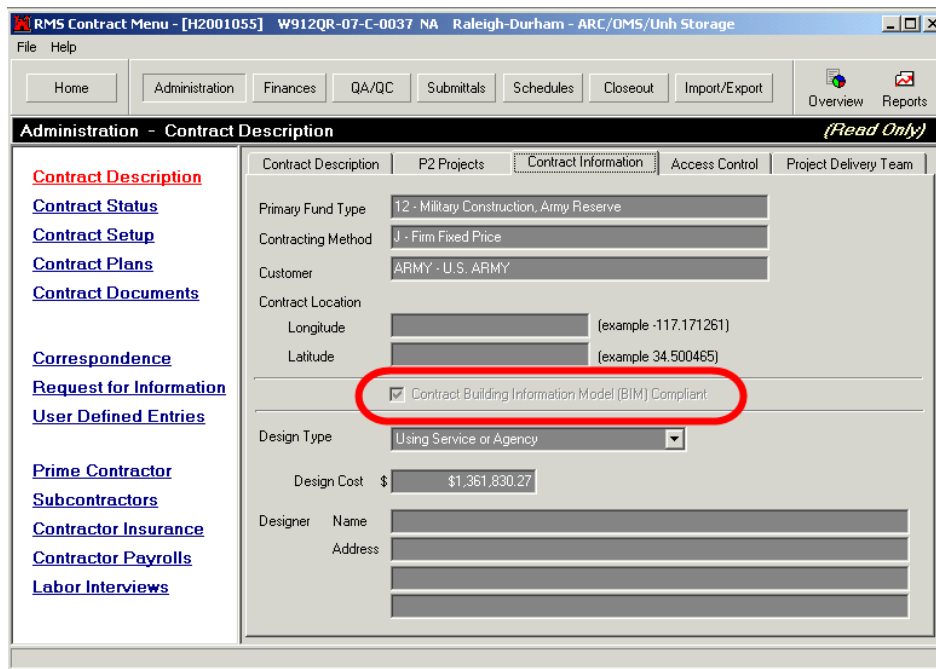


Figure 5-2. New “BIM Compliant” toggle box in Resident Management System (RMS) construction management database interface (Note: This is the BIM-compliant LRL pilot BIM project, so it demonstrates compliance but is not editable under this login’s security rights, and is therefore grayed out)

Next, data was extracted using the Consolidated RMS (C-RMS) database. In this query, projects with the barracks facility category code (72111) or Army/Armed Forces Reserve Center category code (17140/17141) were compared to the test bed BIM projects in Seattle and Louisville, respectively. All completed projects of the aforementioned facility category codes and meeting the requirements necessary to appear in a CCG report were generated. This yielded 57 individual projects completed from 2002-2009 in various locations around the United States. Of these 57 projects, two were thrown out because they were less than \$5M and were not comparable to either BIM-based project. Using the central limit theorem, the data was summarized and evaluated for 90% and 95% confidence intervals to describe two classes of projects that were comparable to the Seattle and Louisville projects. First, one class of projects indicative of the Army Reserve Centers was chosen with characteristics between \$5M and \$20M and had a 540 day duration expectation. Then, the second group was indicative of barracks or dormitory projects, consisting of projects over \$20M and a 730 day expected duration.

Comparing the BIM projects

Next, the two pilot BIM projects' metrics from Seattle and Louisville were compared to two control populations using the CCG metrics from all the similar, completed projects from the past using the student's t-test. The two pilot projects were then compared to the confidence interval data from the past completed projects. Results were accumulated individually by applying the same procedure to past projects CCG data and creating statistical norms through the Central Limit Theorem (CLT) approach.

This included calculating the mean, standard deviation, standard error and then 90% and 95% confidence intervals for the data based off the 90% and 95% Student's t values. Upon completion, the BIM-based projects were compared through simple, automated "IF" statements in the spreadsheet that labeled the result with one of three possible choices: "OUTSIDE-" (red),

“OUTSIDE+” (blue)”, or “INSIDE” (green). If the result was INSIDE, then the BIM-based value was within the CI for the given metric and typical of the control population. If the label was OUTSIDE+, then the BIM-based project’s performance was highly favorable (blue). If the label was OUTSIDE-, then the BIM-based project’s performance was highly unfavorable (red) and outside the CI. See Figure 5-3 for summary analysis and comparison colors for the LRL and NWS BIM project comparisons to the control population.

Indicator	MP-6				MP-7					MP-8				MP-9 (540)		
	Award Amount Including Options	Mod Amount Excluding Options	Total Contract Amount	% Cost Growth (All Mods Excl Options)	Original Contract Duration (days)	Actual Cons duration (days)	% Time Growth Actual vs. Orig Duration	% Time Growth All Mods Excl Options	% Time Growth for User Changes	Duration from HTP to Original BOD (days)	Duration from HTP to Actual BOD (days)	Delta (days)	BOD %Time Growth	Target Duration to BOD (days)	Actual Duration to BOD (days)	Days Difference Actual Vs. Target Duration (days)
avg	\$10,709,146	\$393,684	\$11,102,831	4.07%	652	691	6.70%	11.99%	2.07%	679	704	25	3.663%	540	662	122
dev	\$4,464,578	\$434,966	\$4,541,464	4.63%	112.82	164.98	22.15%	14.89%	6.34%	123.79	187.14	155.49	0.23	0.00	195.81	195.81
std dev of the mean	1193209	116250	1213757	0.012	30	44	0.059	0.040	0.017	32	48	40	0	0	54	54
Degrees of Freedom	14	14	14	14	14	14	14	14	14	14	15	15	15	13	13	13
95% t value	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.131	2.131	2.131	2.131	2.160	2.160	2.160
90% t value	1.761	1.761	1.761	1.761	1.761	1.761	1.761	1.761	1.761	1.753	1.753	1.753	1.753	1.771	1.771	1.771
95% interval value	2559178.12	249330.63	2603250.36	0.027	64.671	94.572	12.696%	8.536%	3.632%	68.129	102.992	85.574	12.78%	0.000	117.324	117.32
90% interval value	2101610.55	204751.63	2137802.90	0.022	53.108	77.663	10.426%	7.010%	2.962%	56.034	84.708	70.362	10.51%	0.000	96.175	96.17
95% CV	0.24	0.63	0.23	0.85	0.10	0.14	1.89	0.71	1.75	0.10	0.15	3.44	3.49	0.00	0.18	0.96
90% CV	0.20	0.52	0.19	0.54	0.08	0.11	1.56	0.58	1.44	0.08	0.12	2.83	2.87	0.00	0.15	0.79
95% Low	\$8,149,968	\$144,254	\$8,499,580	1%	567.60	596.63	-6%	3%	-2%	610.87	600.88	-60.70	-9.12%	540.00	544.39	4.39
95% High	\$13,268,324	\$643,015	\$13,706,081	7%	716.94	785.77	19%	21%	6%	747.13	806.67	110.45	16.44%	540.00	779.04	239.04
90% Low	\$8,607,536	\$188,933	\$8,965,028	1.89%	599.16	613.54	-3.73%	4.98%	-0.91%	622.97	619.17	-45.51	-6.85%	540.00	565.54	25.54
90% High	\$12,810,757	\$598,436	\$13,240,634	6.25%	705.37	788.96	17.13%	19.00%	5.06%	735.03	788.58	95.26	14.17%	540.00	757.89	217.89
Sample Size (.15 CV)	36	250	34	265	6	12	2234	316	1909	7	14	7890	8114	0	18	537
Sample Size (.15 CV)	24	168	23	179	4	8	1507	213	1287	5	10	5337	5488	0	12	381
BIM	MP-6				MP-7					MP-8				MP-9 (540)		
Louisville	\$13,029,912	\$366,748	\$13,396,660	2.80%	540	629	16.50%	16.50%	2.80%	580	640	60	10.30%	540	640	100
Comparison (95%)	INSIDE	INSIDE	INSIDE	INSIDE	OUTSIDE+	INSIDE	INSIDE	INSIDE	INSIDE	OUTSIDE+	INSIDE	INSIDE	INSIDE	INSIDE	INSIDE	INSIDE
Comparison (90%)	OUTSIDE-	INSIDE	OUTSIDE-	INSIDE	OUTSIDE+	INSIDE	INSIDE	INSIDE	INSIDE	OUTSIDE+	INSIDE	INSIDE	INSIDE	INSIDE	INSIDE	INSIDE
Indicator	MP-6				MP-7					MP-8				MP-9 (730)		
	Award Amount Including Options	Mod Amount Excluding Options	Total Contract Amount	% Cost Growth (All Mods Excl Options)	Original Contract Duration (days)	Actual Cons duration (days)	% Time Growth Actual vs. Orig Duration	% Time Growth All Mods Excl Options	% Time Growth for User Changes	Duration from HTP to Original BOD (days)	Duration from HTP to Actual BOD (days)	Delta (days)	BOD %Time Growth	Target Duration to BOD (days)	Actual Duration to BOD (days)	Days Difference Actual Vs. Target Duration (days)
avg	\$42,246,619	\$980,725	\$43,227,344	3.71%	713	837	20.04%	12.64%	0.17%	812	840	80	9.852%	730	869	139
dev	\$59,390,292	\$2,130,719	\$60,645,945	12.44%	251.19	290.51	27.79%	18.88%	0.63%	307.58	312.10	389.73	0.23	0.00	294.47	294.47
std dev of the mean	9164121	328777	9357872	0.019	39	45	0.043	0.029	0.001	51	51	64	0	0	52	52
Degrees of Freedom	42	42	42	42	42	42	42	42	42	42	37	37	37	32	32	32
95% t value	2.018	2.018	2.018	2.018	2.018	2.018	2.018	2.018	2.018	2.026	2.026	2.026	2.026	2.037	2.037	2.037
90% t value	1.682	1.682	1.682	1.682	1.682	1.682	1.682	1.682	1.682	1.687	1.687	1.687	1.687	1.694	1.694	1.694
95% interval value	18493944.60	663498.89	18884950.33	0.039	78.218	90.464	8.655%	5.880%	0.196%	102.458	103.960	129.820	7.58%	0.000	106.033	106.03
90% interval value	15413614.85	552987.29	15739495.62	0.032	65.190	75.396	7.213%	4.900%	0.163%	85.311	86.562	108.093	6.31%	0.000	88.177	88.18
95% CV	0.44	0.68	0.44	1.05	0.11	0.11	0.43	0.47	1.17	0.13	0.12	1.62	0.77	0.00	0.12	0.76
90% CV	0.35	0.56	0.36	0.87	0.09	0.09	0.36	0.39	0.98	0.11	0.10	1.35	0.64	0.00	0.10	0.64
95% Low	\$23,752,674	\$317,227	\$24,342,393	0%	635.06	748.19	11%	7%	0%	709.86	735.75	49.79	2.27%	730.00	762.63	32.63
95% High	\$60,740,563	\$1,644,224	\$62,112,295	8%	791.50	927.12	28%	19%	0%	914.77	943.67	209.65	17.43%	730.00	974.70	244.70
90% Low	\$26,533,004	\$427,736	\$27,487,849	0.49%	648.09	761.25	18.38%	7.74%	0.08%	727.01	753.15	-28.07	-3.54%	730.00	780.49	50.49
90% High	\$57,660,234	\$1,533,713	\$58,966,840	6.93%	778.47	912.05	27.26%	17.54%	0.33%	897.63	926.27	188.12	16.17%	730.00	956.84	226.84
Sample Size (.15 CV)	358	854	356	2040	22	22	348	404	2557	26	25	4327	974	0	21	832
Sample Size (.15 CV)	248	593	247	1417	16	15	242	281	1778	18	17	3000	676	0	15	575
BIM	MP-6				MP-7					MP-8				MP-9 (730)		
Seattle	\$45,707,000	\$749,631	\$46,456,631	1.60%	540	721	33.50%	33.50%	0.00%	630	743	113	17.94%	730	743	13
Comparison (95%)	INSIDE	INSIDE	INSIDE	INSIDE	OUTSIDE+	OUTSIDE+	OUTSIDE-	OUTSIDE-	INSIDE	OUTSIDE+	INSIDE	INSIDE	INSIDE	OUTSIDE-	INSIDE	OUTSIDE-
Comparison (90%)	INSIDE	INSIDE	INSIDE	INSIDE	OUTSIDE+	OUTSIDE+	OUTSIDE-	OUTSIDE-	OUTSIDE+	OUTSIDE+	INSIDE	INSIDE	OUTSIDE-	INSIDE	OUTSIDE-	OUTSIDE-

Figure 5-3. Unabridged results from Central Limit Theorem Comparison of BIM-based pilot projects to control population of similar facility use category code. (Note: red is highly unfavorable, green is within the expected range, and blue represents highly favorable. Also, note there is no clear trend regarding the BIM-based results)

In summary, the “scores” of the two pilot projects were very different. The Louisville project scored favorably (blue) in two categories: “expected contract duration” and “duration from NTP to BOD.” However, it also scored unfavorably (for the 90% CI) on two categories

dealing with cost: “award amount” and “total contract amount.” In every other area, the Louisville BIM project was unremarkable, scoring within the 90% and 95% confidence intervals for expected values.

	CI	OUTSIDE	INSIDE	OUTSIDE
Louisville	95%	0%	88%	13%
	90%	13%	75%	13%
	CI	OUTSIDE	INSIDE	OUTSIDE
Seattle	95%	19%	50%	31%
	90%	19%	38%	44%

Figure 5-4. Summary of BIM-based project results when compared to 90% and 95% Confidence Intervals (CI) of the control population of similar construction projects

The Seattle BIM project scored unfavorably in three categories dealing with time: “% time growth compared to expected (for mods and options)” and “BOD % time growth.” However, it should be noted that if the Seattle District had used an expected duration in line with projects of similar dollar value (730 days for projects over \$20M) they would have scored in either the blue or green zones across the board. Instead, they were overly optimistic about the expected duration of this project and estimated duration of only 540 days. Most telling, however, is that the Seattle project (despite delays due to new LEED considerations, technology, and later mold) still finished in the blue region for an actual overall duration of only 743 days. Both this value and the minor 13-day-time-growth on duration were favorably outside the 90 and 95% CIs for projects of similar scope and type. Figure 5-4 shows a summary breakdown by percentage of how each pilot BIM project scored compared to their individual control populations.

Discussion – Louisville BIM project

In addition to the statistics discussed here, it is important to close the loop on the qualitative elements of how the BIM-based design impacted the construction process for each pilot BIM facilities. Unlike the Seattle BIM project, the Louisville project's construction was managed by an office other than the district where it was designed. The Raleigh ARC's construction was managed by a Resident Engineer from the Seymour Johnson AFB Resident Office of the Savannah District, Mr. Stephen T. Blanchard, P.E. In a telephone interview on November 13, 2008 at 1409 hours, Mr Blanchard had several important points to note about the BIM-based project's construction.

When asked if he knew it was a BIM-project, Mr. Blanchard acknowledged that his staff knew, but it was Louisville's first and his office's first. He felt that, "It was kind of a learning process for them [LRL]." But as far as the construction management was concerned, "we have had minimal differences compared to regular projects." Since the end product was a set of plans, their staff and contractor used the BIM-based design the same way they would for any project. One notable difference in cost and effort towards the end of the project was that his office was compelled to get a "specialized" A/E to do the as-builts. The contractor, Bordeaux, went to a specialized sub-contractor to accomplish this bid item from the initial solicitation. According to Blanchard, it cost more approximately \$35K for the BIM-based as-builts compared to the typical \$5-10K for the same service on a traditional project. This is **substantially** (3-7 times) more expensive than traditional means and need to be considered on future projects in the holistic view of cost for the entire project's design.

Unfortunately, there were many missed opportunities on this project compared to noted advantages of most BIM-based projects in industry. LRL did not, nor Mr. Blanchard's office, use any unique visualization approach, like camera shots, 3-D sections, or perspectives to help

aid in construction or constructability. Nor did LRL or Mr. Blanchard's team use any conflict detection software. Consequently, his team had "a lot of mechanical issues" as well as structural issues with the light gauge truss system. He thought that this could be due to the truss manufacturer changing the truss layout from what was originally designed. To counteract the problems, the contractor added some structural steel in its place after approval from the structural engineer.

As a COS project, this ARC design will be built many more times in the coming years, so it is important to document all these changes and have a process for knowledge management to complete the information loop back to the LRL BIM design team and future construction managers.

Another benefit promised by BIM-based projects is improved handover through a COBIE deliverable. LRL has been working with Army Reserve Command to plan the handover to the user so they can use it in their day-to-day maintenance items. Mr. Blanchard said his office had "no guidance" on what types of information to put back into the overpriced as-builts.

Regarding non-BIM specific items such as change orders and RFIs, there were "significantly more mod[ification]s and changes than on normal projects" according to Mr. Blanchard. From his perspective, Mr. Blanchard thought that the LRL design team was still learning the BIM modeling process and did not have enough time to go back and check their finish schedules, color schedules, "a lot of loose ends were 'left loose' on this project." Also, he was not sure if this knowledge or information will carry forward to other BIM-based designs over and above what is documented in the RMS database.

When asked about the time growth this project experienced, Mr. Blanchard said that a 67 day time extension was granted for design errors; 45 days attributed to building changes with the

structure – roof, sheathing, brick lintels and one was a weather delay, or an admin delay.

Regarding cost growth, this was “mainly due to changes to the building (33 contract changes to date – 7 or 8 have been site work, rest interior)” which Blanchard noted was unusually high for a project with this scope. He said that “a few were pretty substantial, but most were small (less than \$10K) and several were credit modifications such as design calling for things not needed to get credit back and within budget.” Some specific areas of changes include the structural steel which was an \$80K change, and another “big one” was the parking lot: The LRL “prescriptive specification” called for placing a type of stone that did not work in North Carolina because when the contractor attempted to crush the granite stone, it did not get crushed, “just moved around.” This delayed the exterior paving up for several months while going “around and around” on what to use for the drainage layer. LRL’s geotechnical engineers eventually had to travel to Raleigh to witness a trial run and deleted the granite drainage layer for \$60K. The team then replaced it with a aggregated base course (ABC) which was more typical for the area.

There were also nine (9) additional modifications pending as of the date of the telephone interview. The USACE owed the contractor time for mechanical and HVAC changes for designing and installing a hood over the range in the kitchen of the facility. It is important to note that this violated code and was never included in the original BIM-based design.

In summary, the LRL project exhibited many opportunities for improvement on future design and construction projects for Army Reserve Centers. To the USACE’s credit, however, the experiences on this project would have been typical on any project and rather than losing them in the vacuum of singular, unique projects, this information can be captured, modeled, and improved for future design and construction management. Subsequently, this information and lessons learned can be used the next time this project is built at another ARC location. This is

what the COS initiative intended to accomplish, and as evidenced by this pilot project, it is sorely needed.

Discussion – Seattle BIM project

When comparing the Seattle BIM-based project to the control population, the words of the Contract Manager, John Herem, come to mind, “Seattle found that operating in a BIM environment gave them an edge, but because of lack of buy-in, the contractor did not.” The technological benefit of the BIM-based was never realized by the contractor, who faced many problems once on site including interferences as well as weather and mold delays due to their administration of the project and approach with the unusual material type of Heavy (Type V) Timber construction in the Pacific Northwest. Conversely, had they taken advantage of the virtual building model, it is likely that some of their problems could have been avoided.

Further statistical analysis

After completing the initial series of tests based on the students’ t-test, further analysis was accomplished to determine if the tests completed could be used with confidence to report the noted trends. For most primary tests central to MP6-9 in the Army Reserve Center control population, the “n” or sample size was very close (within a few integers of) the preferred sample size calculations for a 15% Coefficient of Variance. For example, for MP-6, the n was 15 and the preferred sample size was either 36 for the 95% CI or 24 for the 90% CI. However, with respect to the barracks projects, there was much more variance in the control population. While there was a fair “n” sample size of 42, the preferred sample size calculation resulted in 358 for a 95% CI or 248 for a 90% CI. Therefore, there either needs to be more data (higher n) or the data needs to be further subdivided so that there is less variance among the projects in the sample.

Results

Overall, both the Seattle and Louisville BIM-based projects had some statistically significant (when compared to the control populations in this research) differences with the typical barracks or reserve center facility projects. However, without a clear trend, this information does not substantiate the overwhelmingly positive data collected earlier in the research through practitioner surveys regarding key performance indicators. Strangely enough, the Seattle-based BIM project, which demonstrated the stochastic nature of typical construction projects, due to common construction management problems like time growth due to HVAC interferences, weather, and mold showed little impact from its supposed technologically superior BIM design. In fact it surpassed its peer projects for overall duration of similar sized projects.

The hypothesis for this research was that there is a positive correlation between a BIM-based approach and construction management productivity. Through qualitative means (interviews) and quantitative means, (statistical analysis) the BIM-based projects did, in fact, demonstrate varying levels of positive impact. However, with the limited sample size and scope of the control population, this data should only be used to establish correlation and not causation. As indicated by the Seattle project, more complex models would be required to account for the myriad of variables that exist in the design and construction facility lifecycle like mold or other factors. In addition, much more data would have to be collected in order to make any claims about BIM-based designs causing construction productivity gains.

Discussion

The business case and argument for the USACE to adopt this benchmarking approach is compelling. Currently, their internal metrics, the Consolidated Command Guidance (CCG) program has no way of determining if their innovation will yield any significant results on a portfolio-wide level in line with their goals. In the Corps' move to breakdown the geographic

boundaries and focus on optimizing construction by facility type, they need an approach that establishes statistically sound confidence intervals to allow them to know what to expect, reward/emulate those projects that surpass their expectations, and evaluate/document those projects that fall short of their expectations.

It is recommended that the USACE adopt a procedure to allow for the use of their meticulously collected data for documenting benchmarks whereby similar projects of type, cost, and duration are compared. Administratively-driven metrics are of little value and fail to reward superior performance and only document the existence of inferior performance.

Before identifying new metrics that mitigate the disadvantages in the CCGs, it is recommended that the USACE follow the model established by the Construction Industry Institute in their “benchmarking productivity metrics” initiative. This would include placing more emphasis on USACE construction managers completing their existing construction management database, RMS to provide USACE with reliable, historical project data. Then, the USACE should use this enormous amount of data to establish baseline data for construction of different facility types, geographic performance, seasonal construction performance, etc. In this way, the USACE would have a reliable “starting point” for creating new metrics to assess construction management efficiency, and could possibly use a re-tooled version of the same CCGs that still focus on cost and time to deliver a quality project. Namely, in the short term, the MILCON Transformation goal of 15% project cost savings and 30% quicker durations could be used as metrics in the method described in the answer to the next question below.

Similar to the methodology espoused by Brunso and Siddiqi’s (2003) the USACE should use its historical project data in RMS to generate benchmarks and comparative metrics from the historical data. Projects would be organized data collections according to facility use codes,

geographic regions, and seasonal weather considerations. The data should exhibit a normal distribution for cost and time metrics according to all of the ways described above. Projects outside a specified confidence interval (CI) (such as a 95% CI) of the normal distribution would be analyzed to determine contributing factors for success or failure. In this way, initiatives could be undertaken based off the real world data in turn compared to the historical database to evaluate the initiatives' ability to demonstrate tangible performance benefits. If the initiatives demonstrated a historical improvement, their new data points could be linearly extrapolated into the future to predict upcoming norms. BIM, along with other MILCON Transformation initiatives like modularity or the Centers of Standardization (COS) initiatives could also be assessed. Gradually, the data would evolve from static reporting to real-time access on all projects worldwide to help decision makers at any point in the facility lifecycle from inception onward.

Both the Louisville and Seattle pilot BIM projects demonstrated favorable and unfavorable statistically significant effects in the construction phase of their lifecycles when compared to a control dataset of similar projects. While the evidence supports the hypothesis, there is no definitive trend – either positive or negative – that can be attributed to BIM aiding construction productivity.

Research Questions

- Does a Building Information Modeling (BIM) approach in the design phase have an impact on the construction phase?

In Phase I, survey respondent data showed that there was a perception that BIM had a positive impact on the construction phase of the facility lifecycle. In Phase II, interviews and case study analysis revealed that participants and stakeholders in pilot BIM projects thought there were both favorable and unfavorable impacts on the construction phase. In Phase III,

statistical analysis showed evidence that confirmed the hypothesis: employing BIM in the facility lifecycle yielded a statistically significant effect on the construction phase in the two pilot projects studied, but there was no trend indicating BIM causes favorable advances in construction productivity.

- If so, how does BIM affect construction?

The surveys demonstrated industry stakeholders' perceptions about where BIM most likely helps construction. The top three KPIs perceived as most benefitted by BIM were: quality, cost, and schedule. In the course of on-site research and interviews with BIM designers and managers, there was a myriad of positive BIM effects on construction including: improved coordination, increased design confidence, conflict detection, and simplified phasing. There were also negative effects including: capital and time for software procurement and training, necessary organizational changes to optimize BIM process, CD creation, contracting concerns and questions. However, the pilot projects from 2005 were meant to “unearth” these challenges and the Army set about solving them during the BIM process. Lastly, while the statistical analysis shows that the BIM projects experienced statistically significant performance values compared to the control data set, there was no trend indicated and more research would need to be accomplished in order to demonstrate causation.

- What types of information can be leveraged in a BIM approach and to what degree?

What began as a personal research question took on a life of its own. The second research question was answered in a parallel research effort in conjunction with the National BIM Standard Testing Team. The end product, the Interactive Capability Maturity Model (I-CMM) is now the National Standard for evaluating BIM maturity and is used to define what threshold constitutes a “Minimum BIM” at one end of the spectrum; as well as visionary BIM experts who are achieving maximum levels of information management success. The I-CMM has also

garnered interest from the AIA TAP Community of Practice, the International Conference on Computing in Civil and Building Engineering (ICCCBE), and online newsletters like AECbytes through either companion research efforts or accepted publications.

- To what degree does BIM affect construction?

As stated earlier, there are many anecdotal examples in industry of specific problems that BIM designers and managers encounter in which BIM either helps them overcome design challenges or pose new challenges for integrating workflow, but in order to provide statistical support a longitudinal data collection and comparison needs to take place over a long period of time with a large sample size.

- How do owners determine whether investments in improved technology (BIM) result in measureable benefit?

As referenced earlier, CII and NIST both advocate a “scientific approach” where benchmarks and careful productivity measurements will show whether or not introducing variables yield results. While the Army has the CCGs and the USAF has their Ribbon Cutter metrics, these only measure performance or improvements compared to administrative mandates and are not capable of demonstrating productivity improvement correlation or causation attributable to the introduction of a variable in the facility workflow. In fact, there were no documented programs in place at the test locations where owners have implemented a scientific method for assessing changes in their construction productivity in relation to introduced variables. Chapter 6 will discuss how to apply the benchmarking approach used in this research for successful productivity measurement in the U.S. Army and Air Force to start measuring the “R” in “ROI.”

Industry-wide, BIM ROI has come to the forefront as a primary consideration. Published in November 2008, the McGraw-Hill 2008 Smart Market Report on BIM targeted ROI as a

primary concern (Figure 5-5). In the report, 48% of the BIM experts surveyed said they were tracking BIM ROI “at a moderate level or above” (Gudgel 2008). From the two highlighted firms in case studies PCL and Holder, the initial ROI was “300 to 500% on projects where BIM was used” (Gudgel 2008). A follow-up survey of AGC BIM Forum members in November of 2008, found that the average perception of ROI on BIM to be between 11% and 30%.

Measuring the Value of BIM

Survey results indicate that 48% of respondents are tracking BIM return on investment (ROI) at a moderate level or above. Results from companies who are actively tracking BIM return on investment (ROI) (see PCL Construction Case Study and Holder Construction interview) are showing **initial BIM ROIs of 300 to 500% on projects where BIM was used.**

A follow up McGraw-Hill Construction online survey of AGC BIM Forum members (November 2008) found that the average perception of ROI on BIM to be between 1% and 30%. However, **those making the effort to measure ROI perceive a higher value.** Among those that do measure it, almost one third report an ROI greater than 100%, with several greater than 1,000%. Thus measuring ROI establishes greater benefit of BIM than mere intuition suggests.

Some of the most important aspects of BIM ROI being measured by firms include:

- Improved project outcomes such as fewer RFIs and field coordination problems (79%)
- Better communication because of 3D visualization (79%)
- Positive impact on winning projects (66%)

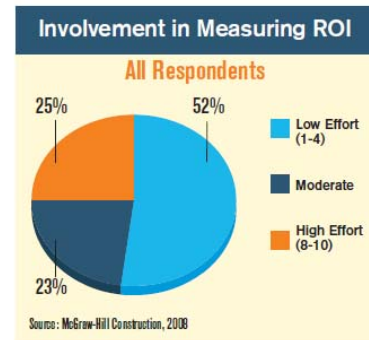


Figure 5-5. ROI: Measuring the Value of BIM (Gudgel 2008)

CHAPTER 6 FUTURE WORK

Phase IV: “Act”

Future Research

There are several things that were unable to be accomplished in the course of this research or that could have been executed differently. It is advisable for future researchers to take this into account if they pursue similar research building on the results here. The overarching component lacking in this research was evaluation of ROI related to BIM. ROI could have been addressed in the surveys, interviews, and lastly in the statistical data analysis, and would have been extremely beneficial to owners who are deciding on how best to invest in BIM and when they can expect to see their investments bear fruit.

Rather than focusing on clerical or minor improvements that could have been made in the previous three phases of research (observe, orient, and decide) since they have already been noted through open answered comments in the survey and interviews, it is more beneficial to focus on what types of future work could be supported by using the tool recommended here.

The benefit of the benchmarking approach is that it answers the basest of scientific questions, “is there a difference when something has been changed?” Therefore, the benchmarking tool could be applied to nearly any variable that may affect construction productivity either directly or indirectly. This includes sustainability measures, modularity, pre-fabrication, construction automation (robotics), radio-frequency identification, virtual reality, sensors, or nearly any other current initiative in the AECO industry. Similarly, the tool is applicable across categories like industrial, private, public, commercial, medical, and residential construction industries. This tool should be used any time unbiased comparison data is required to help decision makers determine benefits from innovation.

A Simple Plan for Implementing Benchmarking to Evaluate MILCON Productivity Improvement in the U.S. Army and U.S. Air Force

Because the need exists currently, it is also beneficial to discuss how owners like the ones studied here (the DoD) could benefit from employing this tool. The U.S. Army and U.S. Air Force already collect a great deal of information related to measuring their productivity. However, their current use of this information is sub-optimizing the potential analysis of this data. By only using the data as lagging information to determine variance from expected administrative requirements, the services are missing out on using the data as a benchmarking process to improve current, and predict future, productivity.

The benefit of this proposal is that it requires very little change in the most difficult portion of the process – collecting the data. Instead, this proposal focuses on what to do with the data once it is collected.

Step 1

The first step necessary is to ensure all construction managers are entering the data fully and completely in a standardized fashion. The database is only as strong as its weakest entry and can only analyze what it contains. In other words, “Garbage In, Garbage Out – but at least make sure the garbage gets in there!” One way to ensure data entry is to align the contract management databases with existing overarching interfaces such as the P2 financial system which is already required for progress payments. Decreasing duplicative data entry yields benefits of greater data accuracy as well as compliance with entry requirements.

Step 2

Once the data is assembled in an ODBC or Oracle database, provide all data under one queryable “key code” like Project Number or Contract Order. After that, all project fields under this key code should be available for analysis similar to that found in a MS Excel pivot table

approach. This would entail an interface that could handle massive amounts of data but serve up only the construction performance values the PM needs: namely time and cost metrics.

Step 3

Step 3 involves a process whereby the data is aggregated and analyzed using the student's t function to retrieve a bell curve for the past performance values of all queried projects. In turn, this could provide the expected mean, variance, and range of values that the PM accomplishing the query could expect on a current project or predict for future work.

Step 4

Step 4 entails setting goals for improvement and documenting “lessons learned” and “best practices” from past projects in a Community of Practice, online knowledge base, or similar application. These would be “tagged” for users and would automatically be emailed to PMs when beginning work on projects of similar scope, size, or use. Gradually, mean productivity values (such as cost/SF) would be reduced and durations would decrease asymptotically until there was less variation among standardized projects of similar category codes. This would replace gross overstatements like “30% reductions” with a plan for discovering truly optimized performance through thoughtful management, similar to the manufacturing industry.

Also, with real-time access to reliable DoD-wide construction cost and time data, it would eliminate requirements for buying outside estimating services like the following applications currently used in the DoD: Parametric Cost Estimating Software (PACES), Military Cost Assistance and Estimating Software (MCASES), or more common RS Means cost estimating guides. By eliminating these goods and services contracts, the DoD could save millions of dollars annually. Also, since the stakeholders would be limited to using only their own entered data, it stands to reason that there would be a greater level of care when entering or querying the cost and time data to make more reliable estimates.

Recommendations for Future Study or Implementation

The old sub-optimized CM by geographic location perpetuated by the Army Corps and USAF is no longer acceptable; as was demonstrated in the recent re-alignment of the Centers of Standardization in the Corps and MILCON management at AFCEE in the USAF. However, just as in the past, most MILCON work is focused on organizing the 1391 process to formally request money from Congress to fund projects.

Now the same amount of work needs to be in place in order to ensure that the military acts as good stewards with the taxpayers' dollars and that Congress is rewarding excellence in line with national objectives. Therefore the new vision of DoD MILCON management should be aligned with the Facility Use Category Codes used in the programming phase. This aligns with the reorganization and focus on facility types - no longer geographic location - in the MILCON and asset management transformation efforts.

Under this new model, every construction manager would know the mean, median, and mode construction durations and performance metrics for each facility type and this would be included on the 1391 for funding from Congress. When the contract would be awarded, it would be under an IDIQ (unit price) or Target Guaranteed Maximum Price (TGMP) that would have added incentives for meeting or exceeding established benchmarks. These would all be tied to the established performance metrics.

All the tools to accomplish this vision are already in place. While it would not be simple, it would be important to bring together disparate databases to "talk" to each other via the key code of facility use cat code as the field that universally bridges the gap across geographic location. For example, web-enabling a combination of PACES/MCASES, P2, and RMS/CRMS would create a powerful application that would control the money and Const Mgmt data for a facility throughout its lifecycle. Benefits for POMs, fiscal planning, problem shooting, and most

importantly -- aligning the DoD MILCON program across the services with what is important to construction managers across the industry – time, cost, and quality – and then rewarding those who partner on this path to success.

Benefits of Implementation

Strategically, the construction industry needs to improve productivity through greater investment in research, but this will only come after successful benchmarking initiatives as discussed in studies similar to those by NIST’s Chapman described earlier. Some possible benefits from this type of research will include interoperability among software applications that can provide direct benefits like those demonstrated in the aviation and automotive industries. Here, organizations have demonstrated productivity gains through manufacturing improvements such as reduced mock-ups, increased global collaboration, and O&M improvements.

Operationally, the drivers (owners) of the construction industry have the least amount of benchmarking initiatives for evaluating construction productivity. This seems counterintuitive because owners are the ones funding construction, but to date there have been few actions that demand construction productivity improvement from an owner perspective, at least in the United States. Here in the U.S., the buildingSMART™ Alliance Internationally, the buildingSmart initiative is calling for a \$600B reduction in construction costs through productivity improvements by 2020, and they feel it is conservative. This is a mandate that should be embodied in owner initiatives to benchmark their construction productivity levels and then set goals that can contribute to making the buildingSMART™ initiative goal a reality.

Tactically, initiatives like the CII’s project supported by FIATECH consisting of benchmarking and metrics for task-level construction needs to achieve greater involvement and wider scope from industrial work to commercial and residential construction segments.

Final Conclusion

From starting this research in the spring of 2006 until the conclusion in spring of 2009, BIM has begun the massive spiral development discussed in the NBIMS published exactly half way through this research. In all, BIM adoption will be mirror the theory of evolution. Species will survive through either sudden or gradual changes and the change is inevitable. As design constraints increase, and collaboration becomes more important, BIM is the AECO industry's answer to interoperable information exchange to improve the facility lifecycle.

APPENDIX A
USACE REALIGNMENT/ESTABLISHMENT OF CENTERS OF STANDARDIZATION



DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF:

MAR 08 2006

CECW-CE (1110)

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Realignment/Establishment of Centers of Standardization (COS), FY-06

1. Army Transformation and MILCON Transformation will have a profound impact on the way USACE COS and military districts will execute MILCON in FY-06 and beyond. MILCON Transformation will rely increasingly on design-build acquisition and will result in larger projects in some areas of the country and less in-house design. COS will be involved increasingly in the planning, programming and execution of their designated facility types.
2. To meet these challenges HQUSACE has elected to redistribute the COS. The enclosures show the facility assignments and define expanded duties of the COS. Although specific Corps Districts are identified, MSC can and should consider use of regional resources to support COS duties and responsibilities as deemed most effective and efficient.
3. Each MSC will acknowledge and accept their revised COS assignments by providing a Project Management Plan (PMP) to the Points of Contact thirty days from the date on this memorandum. PMP will address how the COS proposes to meet the duties listed on the enclosure with respect to their assigned facility types. Include in-house and contract support, staffing requirements and proposed costs.
4. FY-06 will be a transition year for the assignments. Full capability in reassignments will be effective with the MILCON Transformation instructions issued for FY-07.
5. HQUSACE (CECW-CE-D) will host a COS workshop within fifteen (15) days of receipt of MSC COS PMP for discussion of duties, responsibilities and expectations. Points of Contact for this action are Albert Young, telephone (202) 761-7419 or Frank A. Norcross, AIA, HIDA, telephone (202) 761-7500.

Encls

*This way ahead will
make us more effective
providers of technical
services while helping
us sustain our core
technical competencies
through our RBCs and COSs.*

MERDITH W.B. TEMPLE
Brigadier General, USA
Director of Military Programs

Figure A-1. Realignment/Establishment of Centers of Standardization (COS), FY-06

APPENDIX B
SURVEY ITERATION #3: BIM4BUILDERS™ HARD COPY SURVEY

BIM Effects on Construction Key Performance Indicators Quick Survey



Survey results will be presented on Tuesday and compared to the perceptions of other industry professionals

PART I: Basic Demographic Information

1. Gender: Male Female

2. Age: 17 or younger 18-24 25-34 35-44 45-54 55-64 65+

3. Education: High school graduate or equivalent Some College Associate degree Bachelor's degree
 Graduate or professional degree Prefer not to answer

4. Annual Company/Organization Revenue: Under \$10,000 \$10,000 - \$49,999 \$50,000 - \$99,999
 \$100,000 - \$499,999 \$500,000 - \$999,999 \$1,000,000 - \$9,999,999
 \$10,000,000 - \$49,999,999 \$50,000,000 - \$99,999,999 \$100,000,000 to \$1 Billion
 Over \$1 Billion

5. Organization Role: Please Select the category that that most closely matches the top level description of the position you fill the majority of the time in your professional life.

<input type="checkbox"/> Utilization Roles: (Facility Mgr, etc)	<input type="checkbox"/> Support Roles: (Lawyer, Consultant, Intern, etc)
<input type="checkbox"/> Execution Roles (Contractor, etc)	<input type="checkbox"/> Design Roles: (Architect, Engineer, etc)
<input type="checkbox"/> Planning Roles (Owner, Planner, etc)	<input type="checkbox"/> Academic Roles (Professor, Researcher, etc)
<input type="checkbox"/> Management (CEO, VP, etc)	<input type="checkbox"/> Procurement Roles: (Product Rep, Buyer, etc)
<input type="checkbox"/> Suppliers/Vendor	<input type="checkbox"/> Software Programmer

PART II: Ranking Key Performance Indicators: Please rank the key performance indicators according to your perception of how well BIM improves the given Key Performance Indicators metric with 10 showing the most improvement, 5 showing no effect, and 1 showing that BIM inhibits the given Key Performance Indicators.

1. Output Per Man Hour: defined as the measure of completed units (typically square footage) per individual work man hour	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9	<input type="checkbox"/> 10
inhibits				neutral						improves
2. On-Time Completion: defined as construction duration variance from proposed schedule duration	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9	<input type="checkbox"/> 10
inhibits				neutral						improves
3. Safety: defined as the minimizing injuries on construction projects	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9	<input type="checkbox"/> 10
inhibits				neutral						improves
4. Cost: defined as the cost variance in final, actual cost compared to original, budgeted cost	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9	<input type="checkbox"/> 10
inhibits				neutral						improves
5. Unit Cost (\$/Unit): defined as the cost associated with putting one complete unit in place (e.g. cost per square foot)	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9	<input type="checkbox"/> 10
inhibits				neutral						improves
6. Quality Control/Rework: defined as percent (%) of rework in (\$) compared to overall cost in (\$)	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9	<input type="checkbox"/> 10
inhibits				neutral						improves

PART III: BIM Definition: The following choices represent opinions expressed in recent editorials and publications. Which of these definitions of BIM is CLOSEST to your own?

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 information repository for facilities' lifecycles

BIM is a general contractor's virtual approach to planning site logistics

BIM is a federally supported real property management tool

Don't know

Other, please specify:

Thank you for your time and support!

Figure B-1. "BIM Effects on Construction Key Performance Indicators Quick Survey"

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BIOGRAPHICAL SKETCH

Upon graduation from high school, Major Suermann received a Presidential appointment to the United States Air Force Academy in Colorado. As a Second Class Cadet (junior), he was selected for the exchange program to the United States Military Academy at West Point, New York. Before graduation from the Air Force Academy, he earned his soaring wings, completed Air Force Freefall Basic Parachutist School, Army Reconnaissance Commando (RECONDO) Small Unit Tactics School, and Army Air Assault School. He graduated with a Bachelor's of Science degree in civil engineering and was commissioned a Second Lieutenant in May of 1997.

Major Suermann's active duty Air Force assignments have included Charleston Air Force Base (AFB), South Carolina in the 437th Civil Engineer Squadron (CES) as an environmental engineer and SABER (Simplified Acquisition of Base Engineering Requirements) Chief. In January 1999, he served as a combat design engineer at Eskan Village, Riyadh, Saudi Arabia. In April 2000, he transitioned to duty overseas in the 36th CES, Andersen AFB, Guam. Here he became the Chief of GeoIntegration and Base Development after attending PACAF's GeoBase Immersion Training Program. Upon completion of his tour in Guam, he served on the Reserve Officer Training Corps (ROTC) Detachment 805 staff, Texas A&M University, for a short time before earning his Master's of Science degree in Construction Management from the Langford College of Architecture in August of 2003. In the fall of 2003, he became a Civil Engineering Instructor and later Assistant Professor at the Air Force Academy in the Department of Civil and Environmental Engineering (DFCE). Major Suermann received several notable awards during his time at the Air Force Academy including the 2004 DFCE Company Grade Officer of the Year, the 2005 Augustus M. Minton Award for Outstanding Air Force Civil Engineer Article of the year for the Air Force at large, and the 2006 DFCE Outstanding Academy Educator (OAE) award as the most outstanding professor in the Civil and Environmental Engineering

Department. While attending the University of Florida, Major Suermann was honored as the Air Force winner for the National Society of Professional Engineer's Professional Engineer of the Year Award for 2009.

Major Suermann is an active member of the Society of American Military Engineers, the American Society of Civil Engineers, and the Associated Schools of Construction. Major Suermann attended the University of Florida through sponsorships funded by the Air Force Institute of Technology Civilian Institution (AFIT/CI) Program and the M.E. Rinker, Sr. Foundation as the inaugural Rinker Scholar. He is married to a former Naval Lieutenant and Registered Nurse, the former Megan Diane Kouns of Houston, TX. They have three beautiful and gifted children, Andrew James, Isabelle Murphy, and Jack O'Connell.