CASE STUDIES IN BIM IMPLEMENTATION FOR PROGRAMMING OF HEALTHCARE FACILITIES

SUBMITTED: August 2007
REVISED: February 2008
PUBLISHED: June 2008
EDITORS: T. Olofsson, G. Lee & C. Eastman

Russell Manning, Graduate Student,
The Pennsylvania State University, University Park, PA, 16802;
e-mail: russmanning@psu.edu

John I. Messner, Assistant Professor of Architectural Engineering,
The Pennsylvania State University, 104 Engineering Unit A, University Park, PA 16802;
e-mail: jmessner@engr.psu.edu

SUMMARY: Building Information Modeling (BIM) continues to evolve and grow along with their respective application in practice. One of the key advantages of BIM is that is facilitates the development of detailed information and analysis much earlier in the building process to improve decision making and reduce downstream changes. The increases in cost of construction and combined complexity inherent in healthcare construction projects provides an opportunity to harness the strengths of BIM, and provide much more detailed information early in the development of a healthcare construction project. These case studies present evidence of benefits of BIM upstream in the project lifecycle – such as the programming stage.

Two healthcare related projects which implemented BIM in the programming phase are presented in this paper. One project is a trauma hospital in a developing country in conflict, and the other is a medical research laboratory in the United States. Each had unique circumstances, but also similarities which help to identify the strengths and challenges of BIM implementation in healthcare projects regardless of the individual projects' differences. The paper reviews the application of the BIM modeling process for each project. The benefits and challenges from the process used, and the results found are presented. Challenges included data transfer bottlenecks and apprehension due to a lack of knowledge of parametric tools in general. Benefits included visualization, time saved relative to concept updates, and quantity takeoffs.

Some basic framing of the strategic implementation of BIM on a construction project are discussed.

KEYWORDS: Healthcare, planning, design, construction, parametric design, BIM.

1. BIM INTRODUCTION

There is increasing momentum within the architectural, engineering and construction (AEC) industry to adopt BIM practices on projects. However there is a wide variety of usage and disagreement over how to utilize BIM tools. Challenges in the AEC industry are helping to increase the interest throughout to find tools that enable quicker more effective ways to program, develop, design, build and effectively manage our facilities.

The use of BIM on projects allows for information to be pushed upstream in the design development to include planning and programming. This added detail allows planners, designers and builders to better coordinate details and information amongst the multiple parties involved in the process (Klotz and Horman, 2006) of developing and executing construction projects. One of the key elements of the processes utilized is to empower understanding and communication among the participants. (Curtis et al., 1992) Each participant has unique and valuable information and skills to contribute (Table 1). However, the challenge lies in bringing these knowledge bases together and carrying information from one stage to the next. (Mogge, 2004) The building industry is intrinsically fragmented (Arbulu and Tommelein, 2003) and is often polluted with duplication of efforts that do not add value to the end product. (NIST, 2002)

Table 1: Project Lifecycle Knowledge Base

Stage / Knowledge Focus — Entity	Planning: Master Planning (Needs & Purpose)	Design: Advanced Technical Knowledge	Construction: Building Knowledge (General / Broad)	Construction: Detailed Building Knowledge (Specific / Depth)	Operation: Operations
Owner / Developer	Highest	*Limited*	*Some*		Highest
Designers (Arch. & Eng.)	*Some*	Highest	*Some*		*Limited*
Builder (CM & GC)	*Limited*	*Some*	Highest	*Limited*	*Limited*
Builder (Specialty Trades)		*Some*	*Some*	Highest	Highest

In many aspects BIM provides a tool which enables the realization of concepts of concurrent engineering, matrix organizational approaches, or integrated delivery mythologies. (Bogus et al., 2005, Jaafari, 1997) The data rich environment offered in BIM tools provides an opportunity to address these challenges with their implementation. However, the utilization of every BIM option available is not always the right application for every project or its respective stages. Organizational changes required in the utilization of BIM also provide hurdles in opposition to the successful utilization of BIM tools. (Ashcraft, 2006) The successful implementation of BIM tools could largely be attributed to how well the tool features implemented are aligned with the goals and objectives intended to be reaped by using BIM in the first place. (Halfawy and Froese, 2005) The use of BIM also provides the increased opportunity for owners, designers and builders to collaboratively coordinate the overall supply chain of the building process which is a key element in optimizing its value stream. (Jones and Womack, 2002)

The two projects presented in this paper are both healthcare projects. The research is based on data collected over a year and a half year period in which architectural BIM authoring tools were utilized for the planning and programming stages of two healthcare related facilities. The first was a new 8,920 gross square meters (gsm) expeditionary hospital in an area of conflict in the Middle East. The second is a renovation for an occupied 6,220 gsm medical research facility in the north-eastern United States. The data collected focuses on how the owner utilized BIM tools to help their internal project development during the planning and programming stages of the project. Each project while unique had similarities in their application of BIM tools, but also each presented it own unique challenges.

2. THE HEALTHCARE INDUSTRY AND BIM

The benefits of BIM in relationship to optimizing value stream is no less critical in the current healthcare construction boom (Carpenter, 2004) with increasing resource costs such as steel and copper. As factors impacting healthcare construction converge increasing the challenges to successfully controlling cost and time on these projects, owners are reaching out to embrace tools and methods which they may not have commonly used before (CURT, 2004). The current healthcare boom is driven by multiple factors ranging from population shifts within the U.S., aging facilities which no longer meet modern operational practices and efficiencies to significant shifts in building code requirements such as CA SB 1953 in California relating to seismic requirements (Carpenter, 2004). This previous healthcare construction boom occurred in the U.S. during the 1960's and 1970's, when design-bid-build (DBB) delivery systems were the norm (Sanvido and Konchar, 1999, Carpenter, 2004).

If collectively the healthcare industry (owners, planners, designers and contractors) can optimize the current process to effectively reduce costs by even a minimum of one percent, there is a potential to save $100's of millions in facility capital investments currently planned. One percent alone in California's projected 10-year healthcare facility capital investment would save approximately $300M (Dauner, 2004). In reviewing various healthcare owner published building programs, their programs are in many cases significantly increasing. One healthcare owner's published program costs over the next 10 years have risen from approximately $9 billion stated in 2004 to $21 billion dollars today. While the data does not clearly delineate the reason for the program increases (e.g., additional planned construction, increased material costs, labor limitations), it further reinforces the scale of the healthcare market currently. Nationally, the implications of healthcare funds being used inefficiently mean that entire healthcare centers and facilities, which are needed, will be financially unobtainable.

From 2002 to 2003 there was a 10.7% increase in construction spending on hospitals across the U.S. Additionally, there was a 15% spending increase for medical office buildings during the same period (Census, 2003). According to the US Census Bureau (2003), the total hospital construction market segment was almost $14 billion annually. One of the contributing factors discussed above is the shifting population in the United States. (Figure 1) These shifts, with the exception of the major metropolitan areas, are generally from north-east to the south-west.

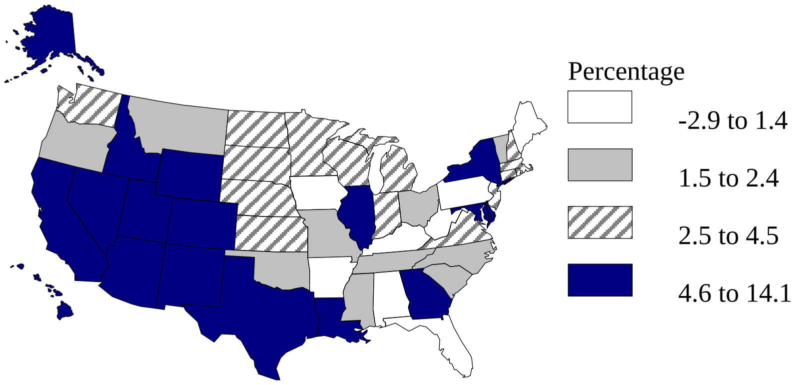


Figure 1. Projected Average Annual Rate for Natural Population Increases per 1,000, 1995-2025 (Census, 2003)

The Construction Users Roundtable (CURT) directed the Architectural/Engineering (AE) Productivity Committee to assess the ways to curtail increasing cost and time overruns in the in AEC industry. The key elements sited in the report were (1) owner leadership, (2) integrated project structure, (3) open information sharing, and (4) virtual building information modelling. (CURT, 2004)

There are many reasons why BIM may be particularly beneficial in healthcare. These include:

- Facility layout is important to minimize the potential for disease transference;
- Complex mechanical, electrical and plumbing (MEP) designs require geometric coordination;
- Engineering simulation models are important for lighting, energy analysis, delighting, and indoor air quality;
- Accurate facility as-built information can be critical to future renovations; and
- Healthcare owners are challenged with budget limitations so accurate design and construction information is important.

3. DATA COLLECTION

The data collection methodology for this case study research was through review of BIM models used on the projects combined with interviews with various parties involved in the process for each project. The lead author was actively involved in both case study projects during their planning and programming stages. The data is based on a two year window of time.

The expeditionary hospital case study data was collected from the time period starting from the beginning of the complete re-design effort to realign the proposed facility with changing mission requirements through substantial completion. This period spanned approximately 18 months. The facility was conceptualized as a fully modular building addition to an existing structure. The medical research laboratory (MRL) data was collected from programming and planning initiation at the corporate level through issuance of a request for proposal (RFP) development. The MRL was conceptualized as total building renovation, and the period examined spanned a period of 5 months.

The hospital and MRL projects used Autodesk Revit®, versions 9.1 and Architecture 2008 respectively for the development of a conceptual BIM. The first project, the expeditionary hospital, had parties involved in the Middle East, U.S. and Germany. Users, owners and expected suppliers were located in the Middle East, while contracting was handled from Europe and supporting technical subject mater experts were located in the U.S. Various approval agencies were located in all three locations. The second project, MRL, was located in the U.S. Facility users, owner, project contracting and expected builders were located in multiple states within the U.S. Specifically related to Case Study 2 (MRL) a post programming survey was conducted of the project delivery team (PDT). The PDT members were asked several questions about their perception of the value for using BIM during the programming phase. In response to statements, the members were asked to rate their agreement on a five point Likert scale ranging from “strongly disagree” to “strongly agree.” Table 3includes some selected questions from the questionnaire administered to the PDT.

4. CASE STUDIES

4.1 Case Study 1: Expeditionary Hospital Facility

4.1.1 Overview

The 8,920 gsm hospital project had originally been programmed as a modular and fixed facility hybrid solution, and functionally and operationally designed as a standard North American regional medical center with a 50+ year life expectancy. The original project had gone through conceptual development, programming, approval, contracting, and designed to approximately a 10%-15% level in the design development stage. It took approximately 3 years to get to this level with the contract for a design-build (DB) delivery having been awarded in the last 7 months of the 3 year period, meaning programming, conceptualization, approval, and contracting took approximately 29 months. The original RFP for the first plan went out with a detailed conceptual 2D design completed by the owner in-house. The detailed design consisted of double line plan drawings with much of the room medical equipment shown in 2D block representations and equipment numbers that related to a proprietary medical space and equipment planning database. The majority of the 29 month effort was developed in the U.S. by the planning group with limited final user input up to the point of the contract award. The conceptual drawings were being updated until the project was awarded. The end user’s had their first major interface with the U.S. based planning group after the first contract award and prior to the project kickoff meeting with the DB contractor. This meeting was a two day blitz to familiarize the users with the program developed by the planning group and collect the user’s concerns. Much time was spent on emphasizing that while it may have been the first interface the user’s had with the actual concept development team, the project was awarded and there was little opportunity to adjust the awarded plan.

This awarded plan was eventually cancelled 7 months after award for multiple reasons. Reasons which included a functional disconnect between the continental U.S. designed plan and the realities of operations and functional mission of the facility on the ground, and the projected delays associated with the contract awarded. The decision was made by the owner to redesign the first attempt to better match the functional and operational realities of the facility on the ground and to go with a total modular facility concept with an approximate 10 year life expectancy. This second concept, based on three other similar facilities built in the region over the previous 12 months, was expected to cost approximately 17% of the original awarded facility and take approximately 2 months to award, 6 months to construction, and 2 months to assemble on a prepared site. This left approximately two and a half months for conceptual redesign efforts in preparation for the RFP and contracting steps. One of the critical constraints of the new design was to maintain the original concept approved room sizes for the various room usage types.

4.1.2 Design and Documentation with Architectural BIM Tools

This short suspense meant that a different approach needed to be taken in developing the new conceptual layouts. Only one person on the team had ever used BIM tools before and that was limited to 16 hours of introductory training 10 months earlier. The original 2D plan drawings, completed by a seasoned CAD architect, took total drawing hours estimated at over 350 hours of work spread over approximately 24 months. The re-design using Autodesk Revit® took approximately 214 hours of design time over 44 days. The redesign was done on the ground in the Middle East and in collaboration with user groups with reviews from the continental U.S. based planning team and input from the contracting office in Europe. In at least 39% less CAD time the team had more conceptual design details than the previous three years of effort had been able to produce.

Figure 2 Departmental Adjacency Study

The re-design plans included plan views, sectional views, simple color delineated departmental adjacency plans (see Figure 2), 3D views from the various locations in the facility, a visual fly-through of a typical trauma patient from the ER through surgery and recovery to the intermediate care ward, mechanical pressurization requirements by room were indicated visually on the floor plans using color schemes. Additionally the model used color schemes to indicate individual room floor and ceiling materials, correlated color temperature (CCT) requirements, floor minimum structural strengths, and fire alarm zoning. The space allocations were computed automatically and sorted by department with less than 30 minutes of table set up time and virtually no calculations or updating required as the concept for the new plan evolved. The earlier 2D effort had only been completely validated against the authorized program once during the three years of the evolving conceptual design. Due to the amount of time required to validate the authorized space program to that of the non-BIM design, it was only spot checked to ensure a relative compliance. This illustrates some of the value of the data driven architectural BIM, specifically the ability to easily develop multiple views and the ability to query accurate information from the model.

Due to previous expeditionary modular hospital projects, the team knew that there were certain items that slowed the vendors/contractors from turning around working cost estimates. These included items such as door, window, electrical and data type and quantities. The BIM model allowed this to be accurately calculated and updated automatically as the concept developed. As an example Table 2 illustrates simple, but critical coordination information, that was easily calculated and updated in the parametric tool without LISP® or other coding required. The first design effort did not allow for this level of collaboration. The reason was that the planning team, using non-parametric design tools, did not want to invest the considerable time required to manually calculate and re-calculate the quantities nor the responsibility or assume the liability if the manual calculations were incorrect. Using non-parametric design tools this reservation is fully understandable; however these limitations resulted in a real road-block to collaborative efforts. With the parametric design tools, the labor intensive manual calculation and re-calculation were eliminated, and the conceptual planning effort could focus more time on ensuring the correct electrical and communications needs were identified in conceptual plans to meet the user needs. It is also interesting to note that the initial concept design effort performed in 2D CAD on the project met understandable resistance to changes, because of the cascading work effort required to propagate those detailed changes throughout the 2D drawings and associated schedules. This again was a realistic barrier to collaboration within the owner's team itself. These propagation of information challenges were almost entirely eliminated in the full re-design effort using parametric design tools; eliminating the internal collaboration barrier; and opening the path for more direct end user input into the concept designs developed.

Table 2 Electrical Fixture Schedule

Description	*Count*
110v/60Hz 15A on dedicated circuit	14
110v/60Hz 20A on dedicated circuit	3
110v/60Hz 40A on dedicated circuit	5
110v/60Hz Duplex Outlet	931
220v/50Hz 15A on dedicated circuit	8
220v/50Hz 20A on dedicated circuit	9
220v/50Hz 30A on dedicated circuit	7
220v/50Hz Duplex Outlet	610
220v/50Hz Hot Water on dedicated circuit	37
Tel/Data Boxes	260
Single Floor Outlet	19
Data Boxes Type II	7

4.1.3 BIM Implementation Benefits

Common benefits are explained in more detail in the BIM Values and Challenges section below. However, there were some benefits specific to Case Study 1.

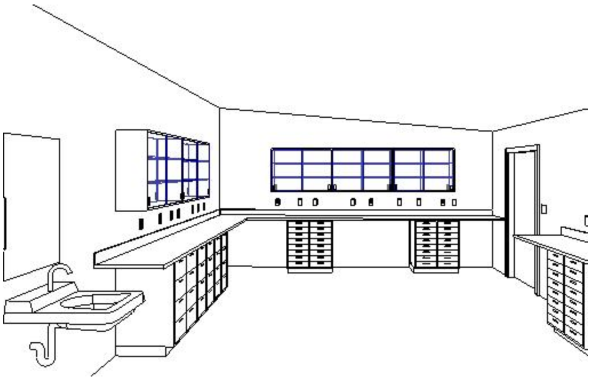
Some simple benefits of the parametric design tools were noted, and seen as critical time saving features which enabled more collaboration in the compressed schedule than would have been viable using the 2D non-parametric design tools. The first item noted was the ability to convert the drawings and dimensions between metric and imperial units in less than five minutes without any scaling or coding (e.g. LISP®) commands required. This was notable on this project because the majority of the planning team and users were used to imperial units, while the majority of the vendors/contractors were used to working in metric units. The contracting office in Europe insisted on publishing the drawings in metric units. The problem was largely overcome simply by the fact that the BIM could be easily switched back and forth between the two depending on who was viewing the model at the time (conversion took approximately 3 minutes in the BIM). Another simple feature of the parametric design tool was the ability for drawing set cross-references to be updated automatically. Basic updates to sections and isometric views relative to changes in the plan were time prohibitive in the first non-parametric effort at the expense of illustrative detail not being available to the extended user groups. The full re-design of the concept was published on 11x17 paper due to printing limitations of some of the owner and user review team in the Middle East. This lead to a concept drawing set of 54 pages, interlaced with multiple drawing sheet cross references (call-outs and sections). Without the parametric abilities of the Revit® design tool the amount of time required to update and verify cross-references for every concept update issued would have been days. Instead these updates were instantaneous and the BIM modeler spent less than 30 minutes just verifying the changes did not adversely affect drawing sheet layouts, before reissuing the updated concept drawings for review.

The use of the architectural BIM tool in concept planning also allowed the team to quickly express sectional and isometric details to the end users so the overall concept could be refined prior to contracting and articulated to the design-builder. This was especially valuable in the coordination of casework in the various spaces, an area that was noted as being a continual challenge for the owner on previous projects. The ability to implement this level of detail was in large part due to the efforts of the Woodwork Institute (www.wicnet.org) in developing freely available parametric casework families for use in Revit®. The planning team was able to develop concepts at a level of detail that could be easily adapted in working with the end users; and then translated to the vender/contractor. While the end product was not a 100% reflection of the architectural BIM, it was surprisingly close (see Figure 3 and Figure 4). The early efforts, and level of detail developed in the conceptual BIM planning, allowed time during the DB execution stage to be focused on additional details versus limited to trying to establish a common baseline. Casework modifications later were minimal and related to building type changes (from modular pre-fabrication to a pre-engineered steel structure).


2006 Schematic BIM Model


2007 Constructed Facility

Figure 3 Expeditionary Trauma Area


2006 Schematic BIM Model


2007 Constructed Facility

Figure 4 Casework Area

4.1.4 BIM Implementation Challenges

While there were many benefits to the project overall there were some challenges to taking full advantage of the parametric benefits of the BIM tools utilized. Not the least of which was a typical project bottleneck of drawing format transfer from one entity or project stage to another. The challenges are explained in more detail in the BIM Values and Challenges section below.

4.2 Case Study 2: Medical Research Lab (MRL)

The second project reviewed, the MRL, had a different occupancy, was a renovation of an existing building versus new construction, and limited to team members from the continental U.S. The architectural programming and planning for this project also used BIM tools for many of the same reasons. The MRL project was originally being addressed through a larger replacement facility project which due to various reasons was delayed by the owner for five or more years. The existing conditions of the MRL were plagued by failing building infrastructure and existing spaces which could not functionally support research being conducted. These circumstances lead to the development of a renovation project for the MRL. Again this project had a limited amount of time to be programmed, conceptually developed and combine this information into a coordinated phasing plan and scope of work (SOW) which could be issued with an Request for Proposals (RFP) under a Design-Build (DB) delivery approach within a seven month window. The team had multiple entities, both internal and external to the organization, that were going to be involved in the planning, programming, review, funding and contracting of the project.

The team decided to implement the use of BIM to help with basic planning of the project. First to figure out the existing space utilization through identifying which department owned which spaces, and clearly identify current room usage types. One of the challenges the planners had seen with facilities of this scale, occupied by multiple departments, and having years of modifications; is that the existing or available information that is typically provided to the design and construction contractors is out of date. Much of this erroneous information is propagated forward through the project, which leads to time and energy being lost in its resolution. The team decided to take advantage of some of the basic intelligence intrinsic to BIM tools and use that to (1) establish a baseline of space ownership agreed to by the departments prior to contracting, (2) use that model to clarify and update the current lab type and other space usages, (3) identify current square footages occupied by departments, (4) work through preliminary phase planning and generate discussion and thought processes on the operational impacts early, and (5) provide some basic 3D models of the current building for involved parties who knew little or nothing about the building.

These basic goals were identified at the start of the programming and then the extent to which BIM was implemented followed the goals. The use of the tools allowed the programming team to coordinate collaboratively with the various user departments using simple color schemes to quickly represent ownership and usage type. The “room” or “space” intelligence of the BIM tool allowed the model to be concurrently updated to match the existing conditions and to quickly be adjusted based on user feedback as they reviewed plan views of their facility for the first time in many cases. Historically the owner lost one to two weeks of site investigation time once the AE was on board trying to establish accurate space utilization that all user divisions could agree upon. It was estimated based on previous projects, that this saved approximately 100+ man-hours of time previously expended through the contracted AE. This AE time was now focused on specifics of the future design and engineering for the renovated facility.

The modeling effort took 78.5 man-hours including all revisions, yielding approximately 20% savings in man-hours for the existing division and department space calculations – which was equivalent to approximately 62% cost savings. This increased cost savings is a result of different hourly rates and the learning curve required by the AE to understand the current operational practices and organizational divisions before working through the existing space utilization calculations.

The original objectives, though simple, were achieved, and it has positioned the team to use the established model in the future. Further the model will also be used to provide an accurate comparison of existing spaces to the renovated spaces.

The key project delivery team members (including user point of contact, multiple owner facility project staff, contract administration, project management, and the contracted design team) were surveyed at approximately four weeks into the contracted design effort. This included 11 total project delivery team (PDT) members. As expected the PDT’s experience with BIM ranged from no previous experience to multiple exposure and previous usage of BIM. The AE possessed the highest level of previous experience with BIM of all PDT members. The user group had never been exposed to BIM previously, and the owner facility members ranged from no experience to approximately 2 years of previous experience using BIM.

The value seen by the AE members of the PDT were understandably less than the owner facility engineers and user members, because of its primary usage during the programming (pre-design award) effort. The owner members of the PDT found the BIM most beneficial through increased understanding and confidence in the projects scope of work accurately representing the collective owner's project objectives. The PDT on average stated they "agreed" (with an average score of 4.2) that the BIM helped the owner clarify the scope of the project compared to earlier efforts where BIM was not used during programming. Table 3 includes some selected questions from the questionnaire administered to the PDT.

Table 3 Questionnaire Examples and Results

Question (from 1 – strongly disagree to 5 – strongly agree)	**Score**
The BIM helped visualize the facility to be repaired and put it into context with the scope of work (SOW).	4.3
The BIM increased my confidence in the SOW being clearly thought out.	4.8
The BIM made the project bidding process easier. *	4.0
I think using a BIM helped increase the chances of success on the project.	4.3
Using the BIM with decision makers made the discussions easier.	4.5

*The owner's facility and contracting members found this more valuable than the AE team. The owner PDT members surveyed rated this "strongly agreed" with an average score 5.0.

Of particular note was universal strong agreement by user, owner facility project and contracting members that the BIM helped explain the scope of work to decision makers in the owner's organization to secure approval for the needed capital investments. Further the PDT strongly agreed that the use of a BIM during programming eased the project approval process within their organization.

The PDT members were in strong agreement that future projects should include BIM in the programming phase. However, half the PDT members stated they need to gain a better understanding of what BIM can do to maximize the potential benefits. One unexpected result was the user's interest in the BIM itself. The user, while interacting mostly through Adobe Acrobat® output of the BIM, found the most usage of the BIM in transition (swing space) planning during renovation and operations planning. All members of the PDT strongly agreed that the visualization aspects of the BIM increased understanding during programming discussions.

5. BIM VALUES AND CHALLENGES

Common objectives existed for both of the medically related projects, even though one was an international project compared to continental U.S. and one focused on patient care spaces, while the other focused on tertiary patient environment laboratories, and one was new construction versus renovation and repair. Both projects utilized architectural BIM tools in conceptual development. Both projects looked at the goals or benefits they wanted or needed to obtain from using a digital model of the building and then utilized those features which achieved the objectives. While it was noted on both that there are other more powerful features of BIM that could have been utilized, the return on investment (time to learn and incorporate) did not align with the immediate benefits sought. With an incremental growth in the knowledge of the various BIM tools, additional benefits are likely to be found. However, it was demonstrated in these two examples that a complete skill set of all the available components of a BIM tool is not needed to achieve significant value added in using the basic components.

The major benefit sighted were:

- Instant 3D visualization of spaces and alternatives that could quickly be evaluated by technical and non-technical staff alike;
- Sections, perspectives, plan views and quantity take offs could quickly (in many cases automatically) be updated to effectively ascertain potential costs;

- The parametric attributes allowed programming information to quickly be compiled for comparison to original authorization documents with a high degree of confidence in its accuracy. These comparisons under non-parametric design tools were largely assumed and only spot checked due to amount of time involved relative to updates.

The concept update time frame requirements went from what was typically weeks and months to days to meet projected schedules and decision processes. Traditional design tools absent of parametric characteristics simply could not support this turn around time with the limited staff available. One simple but illustrative example is in the design of an emergency room. As an example, various clinicians had significantly different ideas about how the emergency room layout could be optimized to more effectively meet trauma flow. Within sixteen hours the team was able to provide multiple conceptual 3D walkthroughs videos, and perspective views from alternative nursing station configurations for evaluation by the clinical staff and administration. This proved extremely valuable, because previous 2D discussions (including 2D CAD sketches and over 10 hand sketches of various alternatives), lasting hours, on the same subject were locked in circular arguments amongst staff. When the various parties saw the 3D solutions they were able to quickly evaluate pros and cons, resolving which direction to proceed in less than 30 minutes. Instantaneously, isometric views from various locations and adjusted for various staff physical heights could be presented to aid the decision making process.

There were also distinct challenges with using the BIM tools. The major challenges sited were:

- Data transfer from one project stage to another and internally during concept development reviews;
- Unfamiliarity with parametric concepts in general and;
- Lack of parametric objects/families.

These were typical bottlenecks often seen in transferring information contained in the model from one entity to another. While the tools allowed for the quick development of concepts, the information transfer across the team was mostly through Adobe Acrobat® output from CAD programs. This was due in part to a lack of consist CAD programs utilized amongst all the team members, some level of apprehension from members who were not familiar with parametric tools, and varied CAD skills amongst designers.

For the project in Case Study 1, much of the imbedded information was lost when the concept drawings were transferred to a contracting office, unfamiliar with BIM at the time, and using another CAD vender’s traditional 2D software. Specifically, the contracting office wanted to put the concept design out using their own CAD software. When the BIM was exported to a non-parametric tool many of the simple benefits described were lost. As a result, even though some elementary quantity take offs were used in collaboratively estimating costs during conceptual design, these schedules were pulled from the RFP package that went out for bid. Some isometric views, which could have aided potential contractors in understanding what was wanted by the customer, either did not transfer or transferred poorly and were pulled from the final RFP package.

As with Case Study 1, the use of the BIM developed in Case Study 2 was not heavily used by the AE in the future design phases. While the AE originally stated during the contracting process that they intended to use the model to help their effort, the AE switched the offices executing the project and failed to pass the existing BIM to the branch office. During a survey of the original BIM usage, the AE’s branch office was surprised to learn that there was a BIM for the existing building. This again highlights an industry challenge of communication. The AE office executing the design effort chose to model the building additions in a BIM. However, not aware of the existing building being in a BIM, they choose to design the renovation portions in standard 2D. The owner noted this was unfortunate, however the BIM in the programming still provided a positive return on effort without the additional benefits of it being carried forward for use by the AE.

One impediment noted on both projects was the limitation of available parametric objects from manufacturers. Each project sought to use parametric objects that were developed by venders familiar with the specifics of their respective products. While more manufacturers are developing families/objects/components the pool of these existing elements remains limited. Forums for manufactures and individual users exist on that web at www.bimworld.com and www.revitcity.com.

These challenges are not uncommon in daily practice, and ultimately, due to these challenges the BIM implementation was limited to conceptual design. However, while this information bottleneck occurred on these projects and may be unfortunate, it did not eliminate the value added by employing BIM tools. Programming, design conceptualization and team navigation through a rapid project conceptualization effort would have been significantly limited without the use of these tools. Additionally, many more man-hours than were available would have been required to develop the same level of information.

6. CONCLUSIONS

The healthcare AEC industry will continue to learn effective ways to plan, design, and execute projects using BIM. A full understanding of all aspects of BIM is not a requirement for implementation, nor to see tangible results. While the benefits are increasing with knowledge of BIM, there are still challenges.

The primary challenges found were (1) information transfer bottlenecks, (2) current lack of parametric content for significant project vender products, (3) unfamiliarity of BIM's breadth of ability and associated experience of application in programming, and (4) a lack of understanding of interoperability limitations and abilities.

Challenges where individuals or companies who have established their CAD efforts in traditional non-parametric tools, and are adverse to change. Challenges to understanding BIM and therein missteps in aligning objective benefits with how BIM is implement on a project. Challenges also remain with erroneous perceptions by some design firms that BIM is a service which is of limited benefit to the designers (Ashcraft, 2006), versus understanding the many efficiencies BIM provides to a designer or planner. The traditional bottlenecks of information remain, transfer from one project stage to another still exist. However the incentive to address these bottlenecks is greater, because of the exponential amount of information present in a BIM.

As demonstrated by the two projects reviewed, even with known challenges that may limit the use of a BIM tool to its maximum extent, the incremental value added is still beneficial and empowering to the AEC team. In the cases presented the focus was on how owners might utilize the tools at the concept development stages, even before a designer or contractor are brought onboard. The user was able to identify the benefits sought from the implementation of BIM tools and then focus their usage to achieve those objectives. Further the cases indicated that even with the learning curve using the product provided more detail, accuracy and collaboration than traditional non-parametric design tools allowed, all in less time. While not an initial goal when implementing BIM, the tool was noted as the means by which roadblocks to collaboration were lessened.

The primary benefits of using BIM during the programming efforts on healthcare projects is (1) rapid visualization, (2) increasing information available to support decisions upstream in the project development process, (3) rapid and accurate updating of changes common through the conceptual development, (4) reduction of man-hours required to establish reliable space programs (5) increased communication across the total project development team (users, designers, capital allocation decision makers, contracting entities, and contractors), and (6) increased confidence in completeness of scope developed in programming to be carried forward.

Healthcare is a complex and critical AEC market segment with many challenges. BIM tools can increase the effectiveness with which owners, designer, and builders effectively and efficiently develop and execute these projects. The case studies presented demonstrate tangible benefits to incremental implementation of BIM during programming efforts with or without further downstream design or construction utilization of BIM.

7. REFERENCES

ARBULU, R. & TOMMELEIN, I. (2003) Value Stream Analysis of a Re-Engineered Construction Supply Chain. Building Research and Information, 31, 161-171.

ASHCRAFT, H. W. J. (2006) Building Information Modelling: Electronic Collaboration in Conflict with Traditional Project Delivery. Construction Litigation Reporter, July-August, 335-348.

BOGUS, S. M., MOLENAAR, K. R. & DIEKMANN, J. E. (2005) Concurrent Engineering Approach to Reducing Design Delivery Time. Journal of Construction Engineering and Management, 131.

CARPENTER, D. (2004) Behind the Boom, What's Driving Hospital Construction? Health Facilities Management, May, 13-18.

CENSUS, U. S. (2003) U.S. Census 2003 - Construction Data. IN PPL-47, P. D. (Ed.), United States Census Bureau.

CURT (2004) Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation. IN COMMITTEE, A. E. P. (Ed.) WP-1202. Construction Users Roundtable (CURT).

CURTIS, B., KELLNER, M. & OVER, J. (1992) Process Modelling. Communications of the ACM, 39.

DAUNER, C. D. (2004) Hospital Seismic Compliance - A Framework for Responsible Action to Earthquake Readiness. Special Report. California Healthcare Association (CHA).

HALFAWY, M. & FROESE, T. (2005) Building Integrated Architecture/Engineering/Construction Systems Using Smart Objects: Methodology and Implementation. Journal of Computing in Civil Engineering, 19, 172-181.

JAAFARI, A. (1997) Concurrent Construction and Life Cycle Project Management. Journal Construction Engineering and Management, 123.

JONES, D. & WOMACK, J. (2002) Seeing the Whole: Mapping the Extended Value Stream, Brookline, MA, The Lean Enterprise Institute.

KLOTZ, L. & HORMAN, M. (2006) A Lean Modeling Protocol for Evaluating Green Project Delivery. Lean Construction Journal, Submitted for Review 5/2006.

MOGGE, J. (2004) Breaking Through the 1st Cost Barriers of Sustainable Planning, Design and Construction. Atlanta, Georgia, Georgia Institute of Technology (GT).

NIST (2002) Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry. IN ECONOMICS, O. O. A. (Ed.), National Institute of Standards.

SANVIDO, V. E. & KONCHAR, M. (1999) Selecting Project Delivery Systems, State College, PA, Project Delivery Institute.

This paper is available electronically at http://itcon.fagg.uni-lj.si/~itcon/index.htm