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Building Information Modeling (BIM): Case Studies and Return-on-Investment Analysis

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Abstract
Building Information Modeling (BIM) is considered as one of the most promising developments in the AEC industry. It helps architects, engineers and constructors to visualize what is to be built in a simulated environment and aids in identifying potential design, construction or operational issues. Recent studies have indicated that BIM is certainly viable and offers many realizable advantages over traditional CAD systems. Though a wealth of information on BIM benefits is available in the recent trade, commercial and technical journals, very few studies have attempted to present data on the time and cost benefits which can be realized through BIM. This paper, via three case studies, presents the quantitative data to illustrate the cost and time savings achieved by developing and using building information models at the various project life cycle phases. In addition, using the data collected from 10 projects, the BIM Return on Investment (ROI) is calculated. It is found that the average BIM ROI on these projects was 634% which depicts its potential economic benefits.

Keywords
Building Information Modeling (BIM), Virtual Design and Construction (VDC), Cost-benefit analysis, Return-on-investment analysis, BIM value

1. Introduction

Building Information Modeling (BIM) is quickly gaining traction in the Architecture, Engineering and Construction (AEC) industry. BIM represents the development and use of a computer-generated model to simulate the planning, design, construction and operation of a facility (Azhar *et al.,* 2008a). The resulting integrated model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility (Associated General Contractors of America, 2005).

After years of development and experimentation, BIM is brining swift transformative change in the current project delivery and management processes. Research shows that users see clear benefits of BIM and they are responding by deepening their use of the BIM technology. A recent survey of 82 architects, 101 engineers, 80 contractors, and 39 owners (total sample size of 302) in the U.S. yielded the following findings (Young *et al.*, 2008):

- 82% of BIM users believe that BIM has a very positive impact on their company's productivity.
- 79% of BIM users indicated that the use of BIM improved project outcomes such as fewer RFIs and field coordination problems.

- Two third of users mentioned that BIM has had at least a moderate impact on their external project practices.
- 62% of BIM users plan to use it on more than 30% of their projects in 2009.

Kunz and Giligan (2007) conducted a questionnaire survey to determine the value from BIM use and factors that contribute to success. The main findings of their study are as follows:

- The use of BIM is significantly increased across all phases of design and construction during the last one year.
- BIM users represent all segments of the design and construction industry and they operate throughout the U.S.
- The major application areas of BIM are, construction documents development, conceptual design support and pre-project planning services.
- The use of BIM lowers overall risk distributed with a similar contract structure.
- At present, most companies use BIM for 3D/4D clash detections and for planning and visualization services.
- The use of BIM leads to increased productivity, better engagement of project staff and reduced contingencies.

In the above mentioned surveys and similar other studies (CRC Construction Innovation, 2007; Dean, 2007; Woo, 2007), the majority of AEC industry participants indicated that BIM technology is beneficial and results in time and cost savings. However, very few studies have attempted to present data on the actual time and cost benefits (e.g. decreased project cost, increased productivity or reduced project delivery time) which can be realized by implementing BIM. This paper, via three case studies, presents the quantitative data to illustrate the cost and time savings achieved by developing and using building information models at the various project life cycle phases. At the end, using data collected from 10 projects, the BIM Return on Investment (ROI) is calculated and major findings are briefly discussed.

2. Case Studies

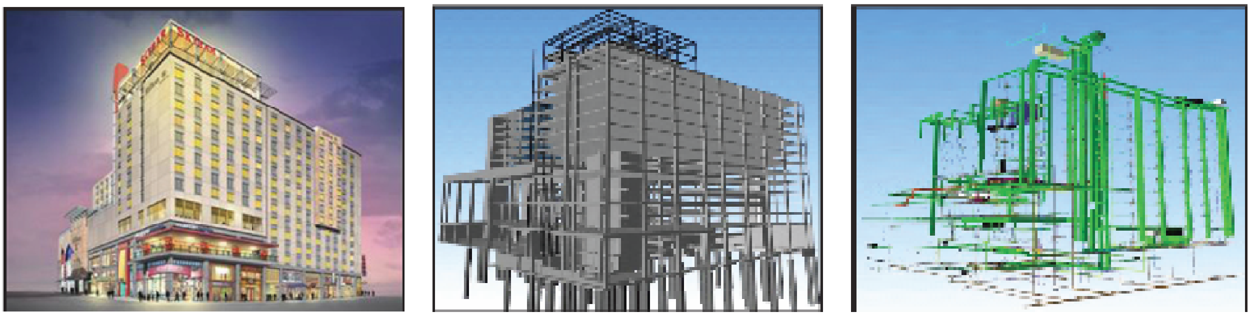
In this section, three case studies are presented to illustrate the cost and time savings achieved by implementing BIM in the project planning, design, preconstruction and construction phases. All the data reported in this section are collected from Holder Construction Company (HCC), a mid-size general contracting company based in Atlanta, Georgia. HCC is a market leader in the Southeast U.S. regarding the use of BIM technology and won the Associated General Contractors of America (AGC) National BIM award in 2007.

2.1 Case Study 1: Aquarium Hilton Garden Inn, Atlanta, Georgia

The Aquarium Hilton Garden Inn project comprise of a mixed-use hotel, retail shops and a parking deck. The brief project details are as follows:

Project scope: \$46M, 484,000 SF hotel and parking structure
Delivery method: Construction management at risk
Contract type: Guaranteed maximum price
Design assist: GC and subcontractors on board at design definition phase
BIM scope: Design coordination, clash detection, and work sequencing
BIM cost to project: \$90,000 - 0.2% of project budget (\$40,000 paid by owner)
Cost benefit: Over \$200,000 attributed to elimination of clashes
Schedule benefit: 1143 hours saved

Although the project had not been initially designed using BIM software by the design team, beginning in the Design Development (DD) phase HCC led the project team to develop architectural, structural and MEP models of the proposed facility using Autodesk Revit™ system as shown in Figure 1. These models were created using detail level information from subcontractors based on drawings from the designers.



(a) Architectural Model (b) Structural Model (c) Plumbing Model

Figure 1: Building Information Models for Aquarium Hilton Garden Inn, Atlanta
(Courtesy of: Holder Construction Company, Atlanta, GA)

After the initial visualization uses, HCC began to utilize these models for clash detection analysis. This BIM application enabled the contractor to identify potential collisions or clashes between various structural and mechanical systems. During the Design Development (DD) phase, 55 clashes were identified which resulted in a cost avoidance of $124,500. Just this stage alone yielded a net savings of $34,500 based on the original Building Information Models development cost of $90,000. At the Construction Documents (CD) phase, the model was updated and resolved collisions were tracked. Each critical clash was shared with the design team via the model viewer and a numbered collision log with a record of individual images of each collision per the architectural or structural discipline. The collision cost savings values were based on estimates for making design change or field modifications had the collision not been detected earlier and clash would have needed to be addressed in the field. Over 590 clashes were detected before the actual construction began. The overall cost savings based on the 590 collisions detected throughout the project were estimated as $801,565 as shown in Table 1. For calculating net cost savings, a conservative approach is adopted by assuming that 75% of the identified collisions could be detected through conventional practices (e.g. Sequential Composite Overlay Process using light tables) before actual construction begins. Thus the net adjusted cost savings could be roughly considered as $200,392.

During the construction phase, subcontractors also made use of these models for various installations. Finally, HCC's commitment to updating the model to reflect as-built conditions provided the owner a digital 3D model of the building and its various systems to help aid Operation and Maintenance (O&M) procedures down the road.

In nutshell, the Aquarium Hilton Garden Inn project realized some excellent benefits through the utilization of BIM technology and certainly exceeded the expectations of the owner and other project team members. The cost benefits to the owner were significant and the unknown costs that were avoided through collaboration, visualization, understanding, and identifying conflicts early will never be known. After this project, the architect is now using BIM on all projects, the owner is using BIM for sales and marketing presentations, and the general contractor is using BIM on over 20 projects while adopting new software platforms and expanding BIM capabilities and expertise (Azhar *et al.*, 2008b).

Table 1: Cost and Time Savings Achieved via Collision Detection Process
(Source: Holder Construction Company, Atlanta, GA)

Collision Phase	Collisions	Estimated Cost Avoided	Estimated Crew Hours		Coordination Date
100% Design Development Conflicts	55	$124,500	NIC		*June 30, 2006*
Construction (MEP Collisions)					
Basement	41	$21,211	50	hrs	*March 28, 2007*
Level 1	51	$34,714	79	hrs	*April 3, 2007*
Level 2	49	$23,250	57	hrs	*April 3, 2007*
Level 3	72	$40,187	86	hrs	*April12, 2007*
Level 4	28	$35,276	68	hrs	*May 14, 2007*
Level 5	42	$43,351	88	hrs	*May 29, 2007*
Level 6	70	$57,735	112	hrs	*June 19, 2007*
Level 7	83	$78,898	162	hrs	*April 12, 2007*
Level 8	29	$37,397	74	hrs	*July 3, 2007*
Level 9	30	$37,397	74	hrs	*July 3, 2007*
Level 10	31	$33,546	67	hrs	*July 5, 2007*
Level 11	30	$45,144	75	hrs	*July 5, 2007*
Level 12	28	$36,589	72	hrs	*July 5, 2007*
Level 13	34	$38,557	77	hrs	*July 13, 2007*
Level 14	1	$484	1	hrs	*July 13, 2007*
Level 15	1	$484	1	hrs	*July 13, 2007*
Subtotal Construction Labor	590	$564,220	1143	hrs	
20% MEP Material Value		$112,844			
Subtotal Cost Avoidance		**$801,565**			
Deduct 75% assumed resolved via conventional methods		($601,173)			
Net Adjusted Direct Cost Avoidance		**$200,392**			

2.2 Case Study 2: Savannah State University Building, Savannah, Georgia

This case study illustrates the use of BIM at the project planning phase to perform options analysis (value analysis) for selecting the most economical design. The project details are as follows:

Project: Higher Education Facility, Savannah State University, Savannah, Georgia
Cost: $12 Million
Project Delivery: CM-At-Risk / Guaranteed Maximum Price (GMP)
BIM scope: Planning, value analysis
BIM cost to project: $5,000
Cost benefit: $1,995,000

For this project, HCC coordinated with the architect and the owner at the Predesign phase to prepare Building Information Models of three different design options. For each option, the BIM-based cost estimates (using Innovaya™) were also prepared using three different cost scenarios (normal, mid-range and high range). The owner was able to walk-through all the virtual models to decide the best option which fits his requirements. Several collaborative 3D viewing sessions were arranged for this purpose. These collaborative viewing sessions also improved communications and trust between stakeholders and enabled rapid decision making early in the process. The entire process took 2 weeks and the owner achieved $1,995,000 cost savings at the Predesign stage by selecting the most economical design option. Figure 2 depicts the three design options while Figure 3 illustrates the project scope and budget options.

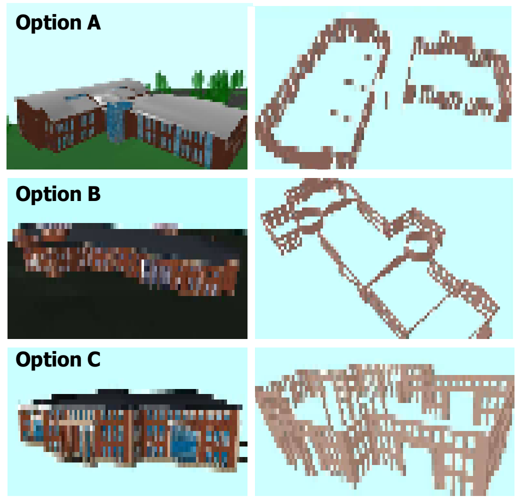
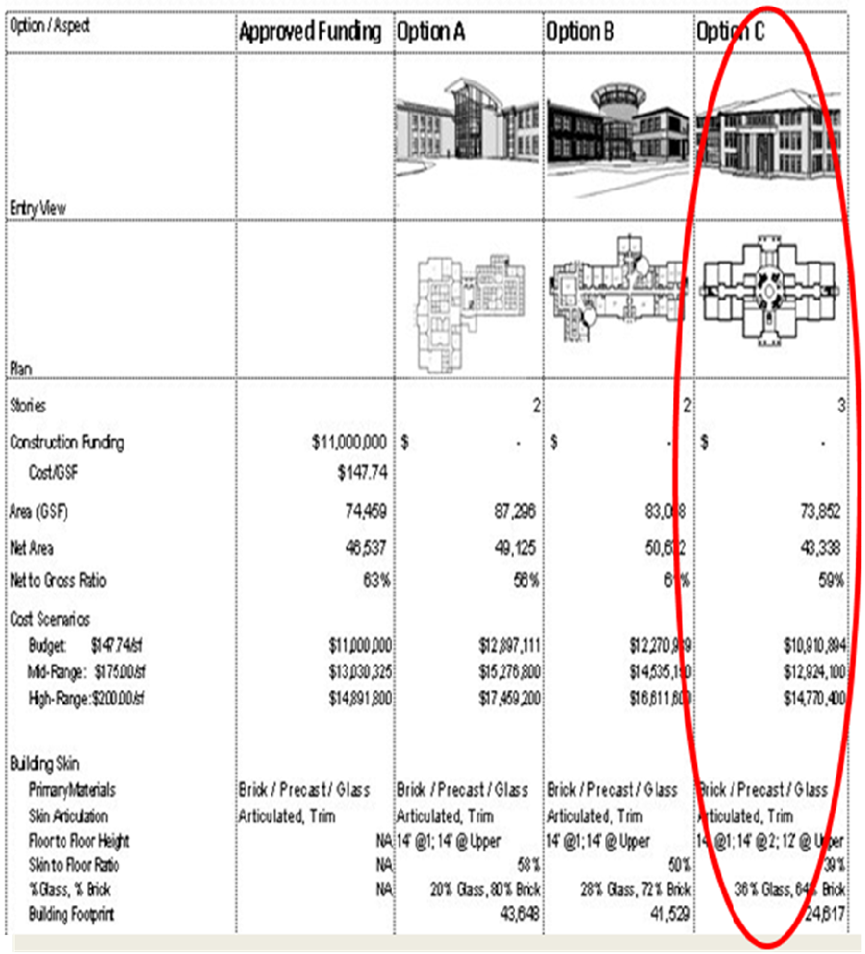


Figure 2: 3D Concept Models of the Savannah State Academic Building
(Courtesy of: Holder Construction Company, Atlanta, GA)



Option / Aspect	Approved Funding	Option A	Option B	Option C
Entry View				
Plan				
Stories		2	2	3
Construction Funding	$11,000,000	$ -	$ -	$ -
Cost/GSF	$147.74			
Area (GSF)	74,459	87,296	83,0[illegible]8	73,852
Net Area	46,537	49,125	50,6[illegible]2	43,338
Net to Gross Ratio	63%	56%	6[illegible]%	59%
Cost Scenarios				
Budget: $147.74/sf	$11,000,000	$12,897,111	$12,270,9[illegible]9	$10,910,894
Mid-Range: $175.00/sf	$13,030,325	$15,276,800	$14,535,1[illegible]0	$12,924,100
High-Range: $200.00/sf	$14,891,800	$17,459,200	$16,611,6[illegible]0	$14,770,400
Building Skin				
Primary Materials	Brick / Precast / Glass	Brick / Precast / Glass	Brick / Precast / Glass	Brick / Precast / Glass
Skin Articulation	Articulated, Trim	Articulated, Trim	Articulated, Trim	Articulated, Trim
Floor to Floor Height	NA	14' @1; 14' @ Upper	14' @1; 14' @ Upper	14' @1; 14' @2; 12' @ Upper
Skin to Floor Ratio	NA	58%	50%	39%
%Glass, % Brick	NA	20% Glass, 80% Brick	28% Glass, 72% Brick	36% Glass, 64% Brick
Building Footprint		43,648	41,529	24,617

Figure 3: Scope and Budget Options of the Savannah State Academic Building
(Courtesy of: Holder Construction Company, Atlanta, GA)

2.3 Case Study 3: The Mansion on Peachtree, Atlanta, Georgia

The Mansion on Peachtree is a five-star mixed-use hotel located in Atlanta, Georgia. The project details are as follows:

Cost: $111 Million
Schedule: 29 Months (Construction)
Project Delivery: CM-At-Risk / Guaranteed Maximum Price (GMP)
BIM scope: Planning, Construction Documentation
BIM cost to project: $1,440
Cost benefit: $15,000

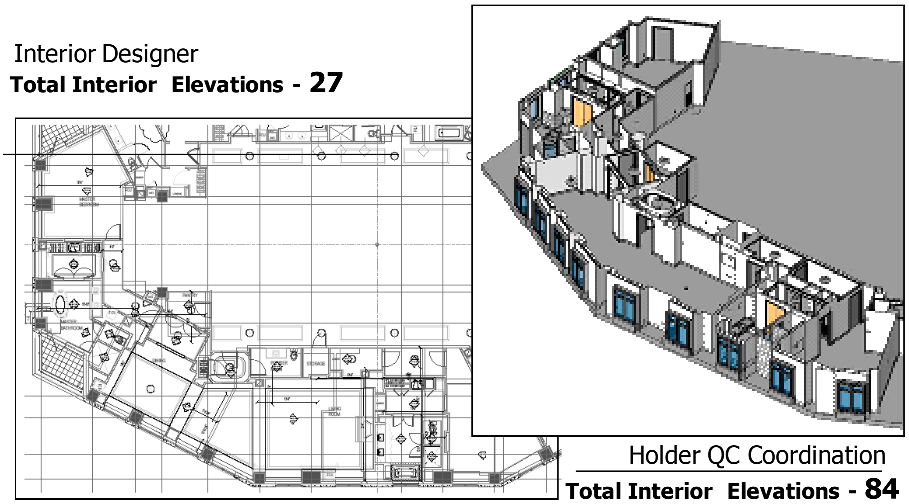
It was a fast-track project and the HCC identified the following issues at the Project Planning phase.

- Incomplete design and documents
- Multiple uncoordinated consultants
- Conflicting information
- Field construction ahead of design
- Constant design development
- Owner's scope changes

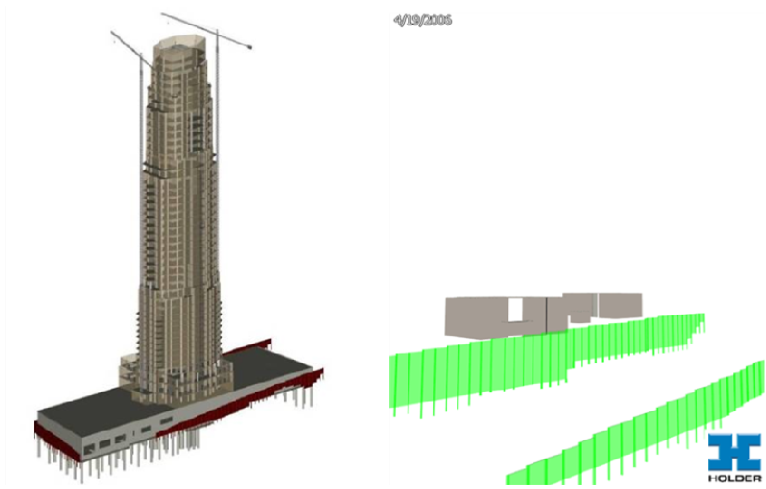
The biggest challenge for the general contractor (i.e. HCC) was how to maintain schedule and ensure quality with incomplete/uncoordinated design and minimize risk/rework. The project team decided to use BIM for project planning and coordination. First of all, contract documents were analyzed to flush out discrepancies and identify missing items. Then "Coordinated Shop Drawings" were prepared via model extractions. These shop drawings were reviewed with the design team to resolve any issues and to issue field use set to subcontractors for coordination and construction. The following paragraph illustrates how BIM helped to achieve these tasks.

Initially, the project designers presented two finishing options (brick v. precast) to the owner as shown in Figure 4. Via a BIM viewer software, the owner visually compared both options and selected the later one based on appearance and cost. Then based on project drawings, HCC prepared the 3D interior elevations to clarify interior details as illustrated in Figure 5a. If any component was found missing or conflicting with the other component, an RFI was issued to the designer to resolve this issue before construction. Finally, a 4D scheduling model was prepared (Figure 5b) to decide the construction sequence and align all the resources. Through these measures, the HCC was able to complete the project on time and within budget.

Figure 4: 3D Value Analysis for Visual Clarification (Courtesy: HCC, Atlanta)



(a) QC Coordination Shop Drawings and the Model



(b) 4D Phasing Model

Figure 5: Use of BIM for the Mansion on Peachtree Project (Courtesy: HCC, Atlanta)

3. BIM Return on Investment (ROI) Analysis

The Return on Investment (ROI) analysis is one of the many ways to evaluate a proposed investment. It compares the gain anticipated (or achieved) from an investment against the cost of the investment (i.e. ROI = Earning/Cost). ROI is typically used to evaluate many types of corporate investments, from R&D projects to training programs to fixed asset purchases (Autodesk, 2007).

A recent survey of AEC industry participants indicated that 48% of respondents are tracking BIM ROI at a moderate level or above ((Young *et al.*, 2008). It is also found that the initial system cost does not seem to be a problem. Doubling the system cost could only reduce the ROI by up to 20% (Autodesk, 2007). For this study, detailed cost data of 10 projects were acquired from HCC to perform the BIM ROI analysis. The results are shown in Table 2.

Table 2: BIM ROI Analysis
(Source: Holder Construction Company, Atlanta, GA)

Year	Cost ($M)	Project	BIM Scope*	BIM Cost ($)	Direct BIM Savings ($)	Net BIM Savings ($)	BIM ROI (%)
2005	30	Ashley Overlook	P/PC/CD	5,000	(135,000)	(130,000)	2600
2006	54	Progressive Data Center	F/CD/FM	120,000	(395,000)	(232,000)	140
2006	47	Raleigh Marriott	P/PC/VA	4,288	(500,000)	(495,712)	11560
2006	16	GSU Library	P/PC/CD	10,000	(74, 120)	(64,120)	640
2006	88	Mansion on Peachtree	P/CD	1,440	(15,000)	(6,850)	940
2007	47	Aquarium Hilton	F/D/PC/CD	90,000	(800,000)	(710,000)	780
2007	58	1515 Wynkoop	P/D/VA	3,800	(200,000)	(196,200)	5160
2007	82	HP Data Center	F/D/CD	20,000	(67,500)	(47,500)	240
2007	14	Savannah State	F/D/PC/VA/CD	5,000	(2,000,000)	(1,995,000)	39900
2007	32	NAU Sciences Lab	P/CD	1,000	(330,000)	(329,000)	32900
Total All Types				**260,528**	4,516,620	4,256,092	1633%
Totals w/o Planning/VA Phase				**247,440**	1,816,620	1,569,180	634%

* P: Planning, F: Feasibility analysis; D: Design; PC: Preconstruction Services; VA: Value analysis; CD: Construction documentation; FM: Facilities management

As evident from Table 2, the BIM ROI for different projects varies from 140% to 39900%. On the average, it is 1633% for all projects and 634% for projects without planning or value analysis phase. Due to the large data spread, it is hard to conclude a specific range for BIM ROI. The probable reason for this spread is varying scope of BIM in different projects. In some projects, BIM savings were measured using 'real' construction phase 'direct' collision detection cost avoidance, and in other projects, savings were computed using 'planning' or 'value analysis' phase cost avoidance. Also, note that none of these cost figures account for indirect, design, construction or owner administrative or other 'second wave' cost savings that were realized as a result of BIM implementation. Hence the actual BIM ROI can be far greater than reported here.

4. Concluding Remarks

Building Information Modeling (BIM) offers valuable benefits to users, helping drive expanding investment in the technology. Building performance and predictability of outcomes are greatly improved by adopting BIM. As the use of BIM accelerates, collaboration within project teams would increase, which will lead to improved profitability, reduced costs, better time management and improved customer/client relationships. As shown in this paper, average BIM ROI for projects under study was 634%, which clearly depicts its potential economic benefits. The ROI analysis shown in this paper is a preliminary one; a detailed analysis must include factors such as lifecycle value of BIM, initial cost of software purchase and staff training, productivity improvement at personnel and organizational level and increased repeat business.

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