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The Business Value of BIM in North America Multi-Year Trend Analysis and User Ratings (2007–2012)

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The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007–2012)

SmartMarket Report

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McGraw Hill CONSTRUCTION

About McGraw-Hill Construction

McGraw-Hill Construction (MHC), part of McGraw-Hill, connects people, projects and products across the design and construction industry, serving owners, architects, engineers, general contractors, subcontractors, building product manufacturers, suppliers, dealers, distributors, and adjacent markets.

A reliable and trusted source for more than a century, MHC has remained North America's leading provider of construction project and product information, plans and specifications, industry news, market research, and industry trends and forecasts. In recent years, MHC has emerged as an industry leader in the critical areas of sustainability and interoperability as well.

In print, online, and through events, MHC offers a variety of tools, applications, and resources that embed in the workflow of our customers, providing them with the information and intelligence they need to be more productive, successful, and competitive.

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Introduction

In 2007, because of the devoted following building information modeling (BIM) had gained in a relatively short time, McGraw-Hill Construction predicted that BIM would reach a tipping point in North America in 2008, even though industry-wide adoption at the time was only 28%. **Now, in 2012, 71% of architects, engineers, contractors and owners report they have become engaged with BIM on their projects, a 75% growth surge over five years.**

In 2009, seeing the dramatic adoption underway by contractors, especially among trades leveraging BIM for virtual coordination and prefabrication, McGraw-Hill Construction predicted that 2010 would be "The Year of the Contractor" in BIM. Trailing architects at the time (49% compared to 58% for architects), **contractors now lead all firm types with a 74% adoption rate, four percentage points ahead of architects.**

Engineers, who had seemed the least convinced of BIM's value in 2009, with only one-in-four involved, still struggle with issues of content and technical analysis. However, they have closed the adoption gap significantly, with 67% now reporting participation, especially among mechanical, electrical, plumbing and structural disciplines.

All of this points to one thing: **BIM, an innovative approach to design and construction for pioneering early adopters**

just a few years ago, is now taking its place firmly in the mainstream of the North American construction industry. And it is maturing, much like other major technology-oriented processes. Today, BIM has emerging standards and best practices, growing attention from professional organizations and an increasingly skilled user base incorporating its functionality into daily workflows. BIM also helps drive innovation by expanding its use to new tasks and integrating its rich data with many other vital technology tools.

In addition to updating our previous research on BIM adoption, implementation and value in North America, McGraw-Hill Construction has for the first time:

- **Included user ratings on over fifty BIM activities and processes.**
- **Developed four indexes (Engagement, Frequency, Value and Difficulty) that will provide a baseline of the current status of BIM in greater detail, help track its future growth, and better isolate and understand the unique dynamics of individual BIM users, activities and processes.**

We want to acknowledge the support of our sponsors who enabled McGraw-Hill Construction to conduct this research and make it available to the global construction industry.



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Stephen A. Jones leads McGraw-Hill Construction's (MHC) initiatives in BIM and integrated project delivery, as well as developing alliance relationships for technology and content. Active in numerous industry organizations, he frequently speaks at events around the world about the business impact of emerging technologies and trends. Before joining MHC, Jones was a vice president with Primavera Systems (now Oracle), a leading provider of project management software. Prior to that, he spent 19 years in creative, marketing

and management roles with design firms, most recently as a Principal and Board of Directors member with Burt Hill (now Stantec), a large, global architectural and engineering firm. Jones holds an M.B.A. from Wharton and a B.A. from Johns Hopkins.

Harvey M. Bernstein, F.ASCE, LEED AP has been a leader in the engineering and construction industry for over 30 years. Currently, he has lead responsibilities for MHC's market research group, including MHC's

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Council and as co-chair of the National Building Museum's Industry Council for the Built Environment. He is a visiting professor with the University of Reading's School of Construction Management and Engineering in England, where he also serves on their Innovative Construction Research Centre Advisory Board. Bernstein has an M.B.A. from Loyola College, an M.S. in engineering from Princeton University and a B.S. in civil engineering from the New Jersey Institute of Technology.

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Executive Summary

Commitment to BIM in North America Surges

from 2007 to 2012 despite the Challenging Economy

Overall BIM adoption and implementation levels have increased significantly, with the more deeply engaged users enjoying greater benefits and stepping up their plans for future investments.

BIM Adoption

BIM USERS

Industry-wide adoption of BIM surged from 28% in 2007 to 71% in 2012. Contractors (74%) have surpassed architects (70%) and engineers (67%) are close to parity with the two other groups.

Regional differences also narrowed, and though the Western U.S. still leads at 77%, the formerly lagging Northeastern U.S. jumped from 38% in 2009 to 66% in 2012. Other U.S. regions and Canada remain close to the growing national average.

Size matters in BIM adoption: **About 90% of large and medium-to-large organizations are engaged with BIM, compared to less than half (49%) of small ones.**

BIM NON-USERS

Although there are fewer non-users, more of them are hardening their resistance, especially among non-using architects where 38% say they will not use BIM.

Growth in Implementation and Expertise

All BIM users report that more of their projects involve BIM, and they are forecasting even greater implementation of it over the next two years: **58% of current users plan to deploy BIM on most of their projects by 2014, more than doubling the 2009 level.**

BIM expertise increased from 2009 to 2012, with the ranks of advanced and expert users growing 33% and 20% respectively. The 41% drop in beginners is likely a combination of economic constraints on hiring new users and recent adopters developing skills more quickly.

There are also more highly experienced BIM users in the industry: **Half (49%) of 2012 BIM users have five or more years' experience, twice the proportion of 2009.**

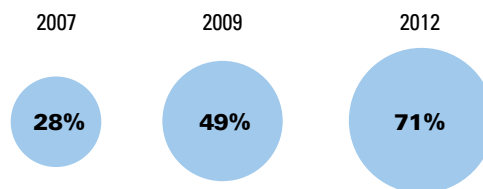
BIM Benefits, ROI and Investments

BENEFITS

The following BIM benefits that grew most between 2009 and 2012 are ones that take longer to validate as credible and repeatable, indicating a greater maturity of BIM as a

Levels of BIM Adoption in North America

Source: McGraw-Hill Construction, 2012



driver of sustainable business benefits:

- **Increased profits increased more than any other BIM benefit.**
- **Maintaining repeat business with past clients, which requires completed projects, outpaced marketing new business to new clients, a benefit that can be done right after adopting.**
- **The most engaged users enjoyed far larger increases in BIM benefits.**

ROI

Almost two thirds (62%) of all BIM users' perceive positive ROI, although not evenly across firm types or BIM engagement levels (a weighted metric of implementation, skill and experience levels developed for this *SmartMarket Report*).

- **74% of the contractors report a positive ROI compared to only 37% of engineers.**
- **ROI correlates strongly with BIM engagement level, rewarding companies with higher skill, experience and implementation levels.**

BIM INVESTMENTS

Users are favoring BIM investments that improve collaborative processes over ones in technology, especially among contractors, aligning well with their increasingly integrated role on BIM projects.

Highly engaged firms are most committed to BIM investments, demonstrating that despite their already significant levels of skill, experience and implementation, they see more value available.

User Ratings of BIM Activities and Processes

In the 2012 research, BIM users rated the frequency, value and difficulty of over 50 BIM activities and processes. By applying weighted indexes to each parameter, the resulting indexes reveal where users are finding the greatest value and challenges with BIM. The activities were grouped into three areas: Design, Construction and Processes. Below are key findings from those areas.

DESIGN

Design is the longest-standing application of BIM. Therefore, users report relatively high frequency and value with low difficulty for design-related BIM activities. The exception are its use for some emerging areas of technical analysis, especially related to engineered systems.

- **Modeling the building envelope by architects is the most frequently used BIM design activity and has a very high value index with only moderate difficulty.**
- **Analyzing mechanical system performance by mechanical engineers rates as the most difficult design activity, with a resulting low frequency.**
- **Structural analysis rates among the most difficult activities, but also has very high frequency and value indexes, indicating a critical need for the industry to address ways to make it easier.**

CONSTRUCTION

Construction-related activities are more recent applications of BIM. Therefore, in general they are less mature.

- **Spatial coordination tops value and frequency ratings for preconstruction activities, benefiting all members of the project team.**
- **Constructability analysis and job site planning/logistics are contractors' top uses, demonstrating their innovation in applying BIM.**
- **All users report struggling with 4D and 5D.**

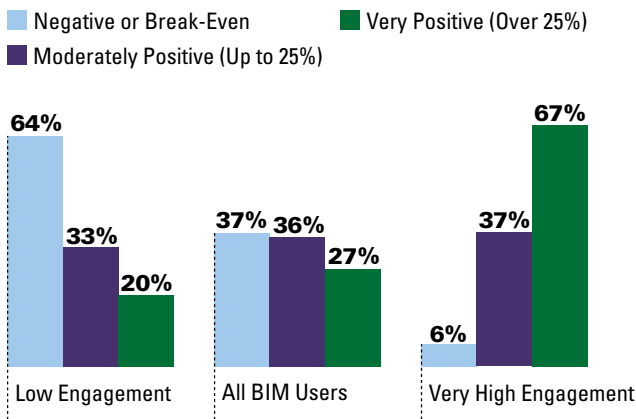
PROCESSES

BIM processes are the ways companies and teams leverage BIM to bring value to projects, including collaborative modeling and model-sharing, Integrated Project Delivery, BIM-generated visualization to expedite review and approval cycles, and using BIM for close-out and facilities management processes.

- **The highest level of model-sharing activity is taking place among contractors and fabricators, further indicating the growing BIM leadership from this sector.**
- **Most owners, architects and engineers give good ratings to accuracy, completeness and quality of models they receive from others. Contractors are less positive.**

BIM ROI for Users by Level of Engagement

Source: McGraw-Hill Construction, 2012



Conclusions and Recommendations

BIM Maturity

As a technology matures, its adoption reaches a plateau. The research shows this is happening with BIM, especially among architects, its oldest user segment, where 38% of current non-users state they intend never to use BIM. We believe adoption will stabilize at about 90% of the North American market, with the remainder seeing BIM as not relevant to their role, specialty or project type.

BIM-Engaged Contractors Poised for Industry Leadership

Contractors lead adoption and ROI, show high levels of BIM engagement, invest the most in training and actively share models. They are also innovating construction-related applications of modeling far beyond design representation. We believe this trend will continue, and, with the rise of integrated project delivery models and the aggregation of multiple skill sets in larger organizations, contractors that are highly engaged with BIM could rise to the central leadership role on major projects in our industry.

Recommendations

ARCHITECTS

- **Embrace the Level of Development initiative and project contracting methods that define consistent inter-party deliverables and protect their liability.** This will enable them to more fully engage and respond to the industry need for increased model sharing, something architects do least frequently today.
- **Focus on longer term benefits that are increasingly being validated, such as productivity and repeat business.** This will help architects improve ROI, which is a benefit this research indicates architects do not receive at the same level in the short term compared to contractors.

ENGINEERS

- **Drive deeper engagement in BIM, which correlates directly with better ROI.** This will help engineers close the gap in ROI benefits that architects and contractors are enjoying.
- **Demand content from manufacturers that is more searchable and able to be indexed.** This will help engineers improve their productivity and reduce investment costs.

- **Support and expand use of BIM for technical analysis.** Engineers rate using BIM for these activities to be highly valuable, but it is difficult, which is contributing to low use of BIM for this analysis by engineers today. However, as more routine analysis continues to be automated, these skills are critical for engineers to maintain relevance.

CONTRACTORS

- **Increase awareness among non-users, one-in-five of whom still do not understand BIM.**
- **Deepen engagement with BIM.** Contractors have slightly higher adoption of BIM, but only half the engagement level of architects.

OWNERS

- **Prepare a BIM execution plan with the project team.** Templates are readily available online and will provide critical guidance for a successful BIM project.
- **More actively involve facilities management staff in BIM design and drive the BIM deliverable for turnover.**

TECHNOLOGY PROVIDERS

- **Examine the user ratings of Frequency/Value/Difficulty for BIM processes and activities to guide future development activities, especially where users rate high value, yet show low frequency because of difficulty, such as:**
 - **Contractors:** Using BIM for labor and cost estimating, and integration of BIM with project management, cost management and accounting applications
 - **Engineers:** Conducting certain technical analyses
 - **Architects:** Leveraging BIM for sustainable design.

NON-USERS

- **Use the research findings to set appropriate expectations for getting started with BIM.**
- **Look to BIM users at higher levels to help establish goals for the path forward.**

Data: BIM Adoption and Value

Introduction to BIM Adoption and Value Data Sections

New technologies gain traction when their benefits are meaningful and sustainable for users. This is especially true with business solutions, which usually require process change, often involving multiple value chain members.

In 2007 McGraw-Hill Construction identified Building Information Modeling (BIM) as a potentially transformational approach to design and construction, requiring technology adoption and implementation, as well as encouraging substantial changes to the project delivery process. Although the adoption rate was relatively low (28%), all users planned to increase their level of implementation. This led us to predict BIM would reach its tipping point in 2008; not that all projects would be modeled, but that we were not going back. BIM was here to stay.

Since that time we have been tracking the global progress of BIM through research, with a particular focus on the business value of its benefits and the reasons for resistance among non-users. In 2009 we published the *The Business Value of BIM: Getting Building Information Modeling to the Bottom Line SmartMarket Report*, the first comprehensive study of BIM in North America. It showed adoption had grown to 49% and provided detailed analysis of a number of important trends, including:

- The degree to which various company types were receiving specific business benefits from BIM
- Which project and business factors influenced the value of BIM
- How broadly users were implementing BIM, what investments they were making in their BIM programs and their predictions for future expansion of both
- Non-users' perceptions of BIM activity by others in their markets, their reasons for resisting and what they needed to drive serious consideration of adoption

Subsequent *SmartMarket Reports* examined the use of BIM for sustainable design and construction (*Green BIM*, 2010); its adoption, implementation and value overseas (*BIM in Europe* in 2010, *BIM in Korea* in 2012); and segment-specific usage (*BIM for Infrastructure*, 2012).

This study, *The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings*:

- Updates the research on adoption, implementation, business drivers and non-user attitudes from the 2009 study, and looks ahead with two-year forecasts.
- Provides new data on user ratings of BIM activities and processes, giving a first-hand view of the challenges and successes users are experiencing with day-to-day use of BIM in their organizations.

Key Findings in the BIM Adoption and Value Data Section

ADOPTION AND IMPLEMENTATION

- Industry adoption has surged from 28% in 2007, 49% in 2009 and 71% in 2012.
- Contractors' BIM adoption rate of 74% surpasses the formerly dominant architects who are now at 70%.
- 91% of large companies are engaged with BIM versus only 49% of small organizations.

BENEFITS

- Increased profits was the BIM benefit that increased most in value to users from 2009 to 2012.
- Leveraging BIM for business development shifted as a top benefit in 2012 and maintaining repeat business became more critical than pursuing new clients.
- Improved interoperability and functionality of BIM software are the top two BIM improvements all users believe would improve their BIM value, both in 2009 and 2012.

ROI

- 62% of BIM users perceive positive ROI in 2012.
- ROI correlates strongly with BIM engagement level, rewarding companies with higher skill, experience and implementation levels.
- Improved productivity ranks as the top metric users believe would improve their BIM ROI.

INVESTMENTS

- Developing collaborative BIM processes is predicted to be the most important area of BIM investment in 2014.
- Communications infrastructure to improve model sharing is an important emerging need for 2014 investment.

NON-USERS

- Although non-users dropped from 51% of the industry in 2009 to only 29% in 2012, more of them are hardening their resistance, especially among non-using architects where 38% say they will not use BIM.

The BIM Engagement Index

Each user is engaged with BIM in a unique way. The BIM Engagement Index quantifies that with a numerical score for each respondent. The score is derived from the following data:

- **Experience:** The number of years the respondent has been using BIM
- **Expertise:** The level each respondent selected as best representing their personal skill with BIM
- **Implementation:** The percentage of projects being done in BIM by the respondent's firm.

These responses are weighted to reflect the increasing influence of more experience, skill or implementation. For more information on the weighting used for each category, please see the table at top right.

The range of resulting BIM Engagement Index scores (from 1 to 27 points) is divided into four tiers that reflect increasing levels of BIM engagement ("E-Level"). See the table at the bottom of the page for a description of the four tiers.

- The very high E-Level users are those at the top of all three categories (over 5 years' experience, expert skill level and over 60% BIM implementation). They represent 13% of all respondents.
- The remaining BIM Engagement Index scores are divided evenly to create the three other E-Levels.

How BIM Engagement is Used to Analyze Data in this Report

In addition to presenting the data by firm type, responses are also frequently filtered by very high and low E-Levels, providing valuable perspectives from highly engaged BIM users and those still in early stages of engagement.

- The current attitudes and behavior of very high E-Level users often indicate the BIM trends that the rest of the industry will be following in the near future.
- The experiences of low E-Level users represent reasonable expectations for non-users who choose to adopt BIM.

Points Used to Calculate Engagement Index

Source: McGraw-Hill Construction, 2012

Experience		Expertise		Implementation	
1 year	1 point	Beginner	1 point	Light (Under 15%)	1 point
2 years	2 points	Moderate	3 points	Moderate (15% to 30%)	3 points
3 years	3 points	Advanced	6 points	Heavy (31% to 60%)	5 points
4 years	4 points	Expert	10 points	Very Heavy (Over 60%)	8 points
5 years	5 points				
Over 5 years	9 points				

Classification of Firms into Engagement Levels

Source: McGraw-Hill Construction, 2012

Tiers of BIM Engagement (E-Level)	Range of Scores for Each E-Level	Percent of All Respondents in Each E-Level
Very High	27	13%
High	19 to 26	24%
Medium	11 to 18	32%
Low	3 to 10	31%

BIM Adoption

The results of McGraw-Hill Construction research on BIM from 2007, 2009 and 2012 clearly show the dramatic expansion of BIM adoption in North America over that period.

- **Adoption between 2007 and 2009 expanded by 75%.**
- **Despite the severe economic downturn between 2009 and 2012, the number of firms reporting engagement with BIM grew by 45%.**

This trend tangibly demonstrates the powerful value proposition of BIM to a broad range of companies across the construction industry. Counteracting the instinct to cut back during a recession, a quarter of the industry invested in a more efficient and productive future by embracing the technologies and processes of BIM.

Variation by Region

The differences between major regions found in 2009 research have lessened dramatically in 2012.

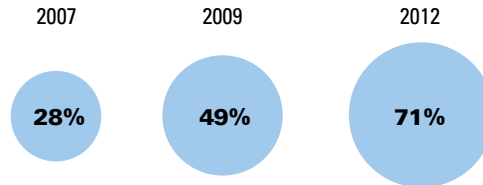
- **The West still leads all regions with an overall BIM adoption rate of 77%, up from 56% in 2009 and well above the national average.**
- **2009 Northeast regional adoption (38%) was significantly lower than the national average of 49%. Though still lagging in 2012, at 66%, the region grew the most from 2009 to 2012.**
- **The Midwest and South are still slightly above and slightly below average respectively, and Canada remains essentially at average.**

The range between the highest and lowest adopting regions dropped from a gap of eighteen percentage points in 2009 to only a differential of eleven in 2012, and it is likely to continue to reduce in the future. However, this difference may be affected by regional dynamics of economic recovery. Overall, this narrowing demonstrates that BIM adoption is becoming more widespread industry-wide.

Much of the growth across regions is likely spurred by the relatively large amount of health care work going on nationally, a project type particularly well suited to BIM because of its benefits of collaboration; spatial coordination; mechanical, electrical and plumbing (MEP) prefabrication; constructability review; and visualization that more effectively engage a wide variety of stakeholders. (For an example, refer to the case study on Sutter Medical Center on page 34).

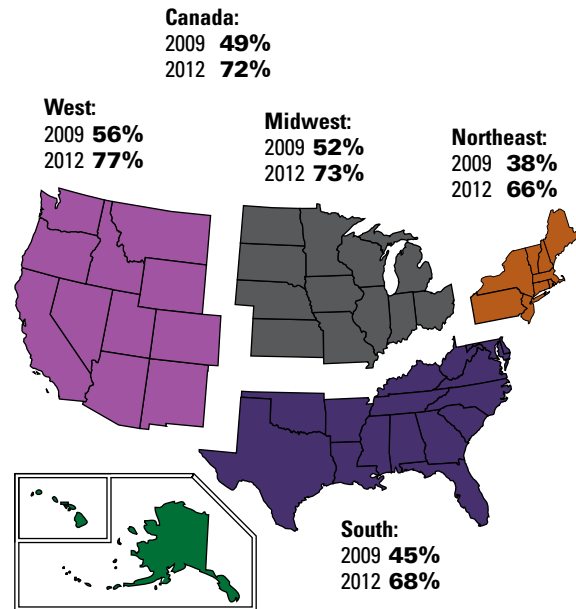
Levels of BIM Adoption in North America

Source: McGraw-Hill Construction, 2012



BIM Use in North America

Source: McGraw-Hill Construction, 2012



Variation by Player

Architects, engineers and contractors are close to reaching equal levels of adoption in 2012.

- **Contractors (74%) surpassed architects (70%) to lead adoption by firm type in 2012.**
- **Engineers, the lowest adopters in 2009, had the greatest increase, rising from 42% in 2009 to 67% in 2012.** Mechanical engineers lead their peers with 83% reporting engagement with BIM, followed by electrical at 77%.

The tangibility of BIM's benefits to contractors is driving their lead in adoption. The recent surge by engineers will help encourage software companies to expand and improve the technical analysis capabilities of their tools. (See page 44 for more information.)

Variation by Firm Size

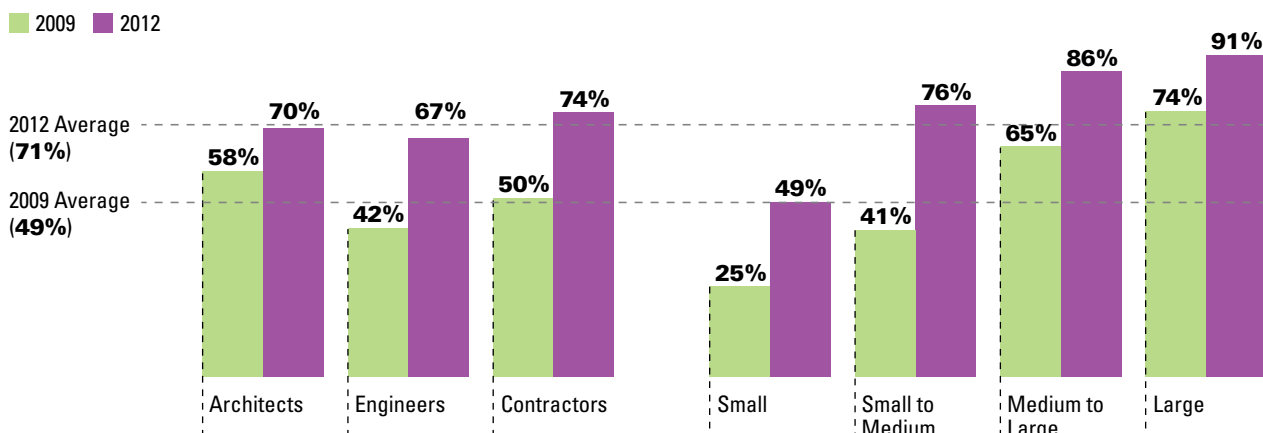
The size of an organization has the biggest influence on the likelihood that it has adopted BIM.

- **91% of large companies are engaged with BIM in 2012, up from 74% in 2009. In both years, this group was significantly higher than average.**
- **Medium-to-large firms, also consistent above-average adopters, grew from 65% in 2009 to 86% in 2012.**
- **The small-to-medium group soared from a below-average of 41% in 2009 to 76% in 2012.**
- **Only 49% of small organizations report 2012 BIM involvement, in spite of doubling their adoption since 2009.** This puts smaller organizations at a competitive disadvantage in serving the needs of increasingly BIM-aware clients.

Larger organizations generally benefit from greater resources and experience in implementing new technologies and standardizing business processes to optimize them. As a result, they are better positioned to be proactive about adopting BIM, evaluating its effectiveness, and rolling it out across their organizations in a managed program.

BIM Adoption by Type and Size of Firm (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Importance of BIM Capability for Project Team Selection

BIM capability is beginning to exert a greater influence on the process of evaluating companies for project teams. A significant 81% take it into account at some level when making project team selections.

A majority (52%) of BIM users encourage BIM capability from the companies they consider for their teams, and about a quarter (28%) requires other companies to be BIM-capable. This is expected to increase as the benefits of BIM continue to be recognized and the reduction in team productivity from non-compliant members becomes more visible.

Importance of BIM Capability for Project Team Selection

Source: McGraw-Hill Construction, 2012

Importance of BIM Capability for Project Team Selection	All BIM Users
We Require Companies be Experienced in BIM.	28%
We Encourage BIM Expertise, But Do Not Require It.	52%
BIM Expertise Does Not Affect Our Decisions.	19%

BIM Implementation Levels

BIM implementation levels demonstrate the evolution of BIM use from 2009 to 2012. In 2009, the highest concentrations were at the two extreme levels:

- **The largest group (35%) was light users, experimenting with BIM to determine if they could generate meaningful value from it.**
- **The next largest group (27%) was the very heavy users, already convinced of its value and committing to BIM use.**

In 2012, the two extremes are still the most populated tiers, but their positions are reversed.

- **Very heavy users are now by far the largest group (39%), demonstrating the growing commitment to BIM by firms that have adopted it.**
- **Light users are the next largest (24%), representing the large number of firms that adopted BIM between 2009 and 2012, many of whom are still in the early stages of implementation.**

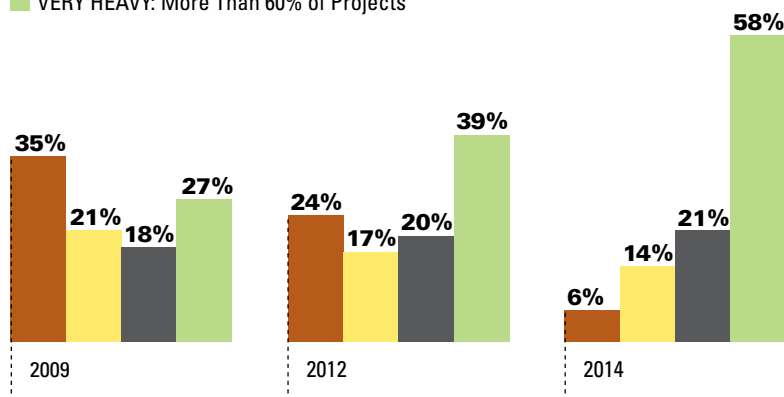
The forecast for 2014 implementation shows growing commitment.

- **By 2014, 58% of firms predict they will be at a very heavy level of BIM implementation, increasing from 39% in 2012 and 27% in 2009.**
- **Conversely, the percentage remaining at light usage dwindles to 6%, meaning 94% of current users intend to make a serious commitment to BIM.**

BIM Implementation Levels (2009–2014)

Source: McGraw-Hill Construction, 2012

- **LIGHT:** Less Than 15% of Projects
- **MEDIUM:** 15% to 30% of Projects
- **HEAVY:** 31% to 60% of Projects
- **VERY HEAVY:** More Than 60% of Projects



BIM Adoption and Value: Adoption

BIM Implementation Levels CONTINUED

THE BUSINESS VALUE OF BIM IN NORTH AMERICA: MULTI-YEAR TREND ANALYSIS AND USER RATINGS (2007-2012) DATA

Variation by Player

ARCHITECTS

Architects have consistently been the most very heavy BIM users due to the length of time they have been involved with BIM. They are projected to reach an industry-topping level of 75% at that intensity in 2014.

ENGINEERS

Engineers reported the least adoption of BIM in 2009 (42%), so they had more light users (41%) than other categories. However, in keeping with their surge in BIM adoption from 2009 to 2012 (see page 10), light usage is projected to drop to 12% by 2014, and over two-thirds (69%) predict being at heavy (26%) or very heavy (43%) use levels by 2014.

CONTRACTORS

Contractors, who now lead the industry in overall BIM adoption (see page 10), also show the most dramatic changes in implementation from 2009 to 2014:

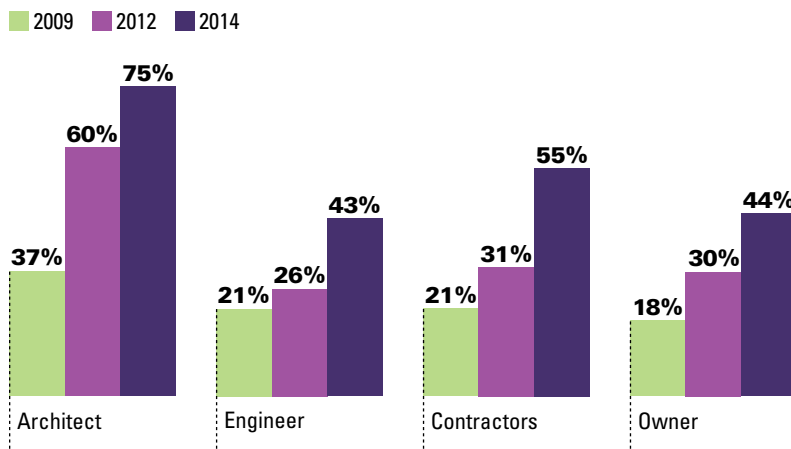
- The ranks of very heavy users will almost triple from 21% in 2009 to 55% in 2014.
- Light users drop from over one-third (37%) in 2009 to only 6% in 2014.
- Over 80% say they will be at heavy (27%) or very heavy (55%) implementation levels by 2014.

OWNERS

Owners topped the light user category in 2009 and 2012 at over 40% each time, but only 7% of the 2012 research respondents believe they will still be at that level in 2014, and 44% of them predict they will be at a very high level of implementation by 2014.

Percentage of Players Using BIM on More Than 60% of Their Projects

Source: McGraw-Hill Construction, 2012



BIM Expertise Level

BIM expertise is growing among North American users, with advanced and expert categories showing healthy increases.

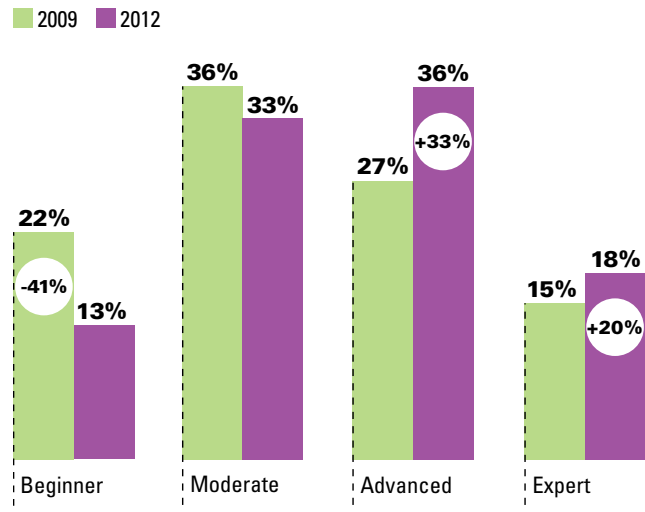
However, the economy is showing its effect by the relatively low number of beginners. With adoption increased from 49% in 2009 to 71% in 2012, there should be a large number of beginners in the population of BIM users. The large scale reductions in workforce that many firms have implemented has likely reduced the number of available younger staff, typically the ones who are initially assigned to engage with BIM.

Variation by Player

- **Contractors had the highest number of expert users in 2009 and 2012**, consistent with their surge in adoption.
- **Over 50% of owners admit to being beginners in 2009 and 2012**, consistent with their role as consumers of the products of the BIM process.
- **Even though their adoption surged from 2009 to 2012, engineers' population of beginners is lower than any other firm-type at only 7%**, reflecting either a lack of hiring or a strong learning curve.

BIM Expertise Level by Player (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Years of Experience Using BIM

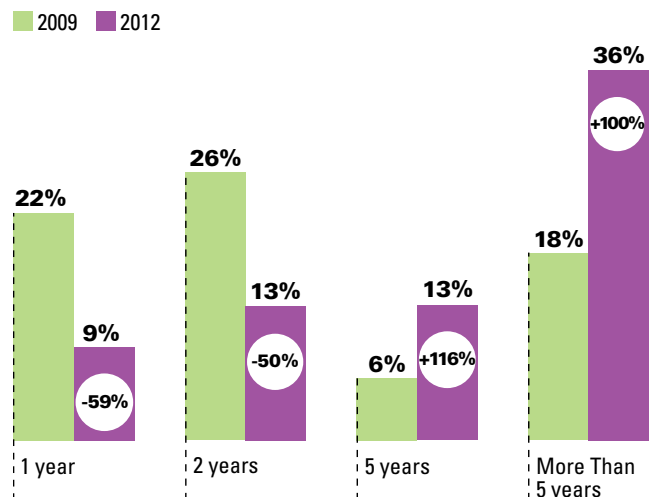
Although the percentage of highly experienced BIM users (having five or more years' experience) doubled from 2009 to 2012, the converse drop in the number of one- and two-year users probably also reflects the lack of incoming professionals due to the economy.

- **In 2009, the one- and two-year experience groups together represented almost half (48%) of all BIM users.**
- **In 2012, these groups account for only 22%. In fact it takes combining the one-, two-, three- and four-year experience groups in 2012 to reach a halfway mark.**
- **By contrast, those with one to four years of experience combined accounted for over three quarters (76%) of BIM users in 2009.**

This 2012 research confirms an expected steady advance of the 2009 users into higher tiers of experience, but the shortfall of new users filling the ranks behind them is more likely due to the economy than a negative industry attitude towards BIM.

Years of Experience Using BIM (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Interview: Thought Leader



Patrick MacLeamy, FAIA, LEED AP

Chairman and Chief Executive Officer, HOK
Chairman, buildingSMART International

How did you get involved with BIM?

MACLEAMY: In 1995 a group of 12 companies in the U.S. got together. That was before the term “BIM” had come along. We just wanted a contractor to be able to take our data and use it instead of only having drawings. I went around Europe and East Asia soliciting more people’s interest in this, and we formed the International Alliance for Interoperability (IAI) as a little United Nations just for the building industry. We later changed our name to buildingSMART International and we now have chapters in 20-odd countries and a very robust technical group. We created the IFC [Industry Foundation Classes], an international standard for open data exchange in the building industry, which we later succeeded in getting formally adopted by ISO. And good things have continued to happen.

How has BIM impacted the construction industry?

MACLEAMY: [It has] cleared away a lot of the bureaucracy of getting a building built and replacing it with processes that are saving real time and money. For instance, instead of going all the way through working drawings, engineers are giving contractors a BIM model much earlier, which they can use for fabrication. We’re also seeing fewer RFIs [Requests for Information], which means more efficiency, more sureness, more speed of construction.

“I think there’s going to be a huge shake-out. Those who practice the old way are soon going to find themselves without work. Either change, get with this program, or go out of business.”

What are the most important current BIM needs to most effectively advance the industry?

MACLEAMY: Getting owners and manufacturers involved. Only a few owners understand the value proposition that they can get better buildings that operate better and give them more value over time through BIM. We turn really good buildings over to even sophisticated owners, who are not yet geared and software isn’t quite available yet, to operate a building optimally. People who make the products that we put into our buildings are becoming quite interested in highly filtered searches online that identify the right product for the right use in a model with all the technical details. We’re at the beginnings of that, but it could really take off.

How do you think BIM will change the industry over the next ten years?

MACLEAMY: I think there’s going to be a huge shake-out. Those who practice the old way are soon going to find themselves without work. Either change, get with this program, or go out of business.

Also, having full exchange of information is only part of the story. We

need a fundamental realignment of how architects, contractors, engineers and owners interact. Architects are going to have to develop new working relationships with contractors based on respect for what each brings to the project.

What are buildingSMART International’s future plans related to BIM?

MACLEAMY: I want buildingSMART International to transform the world of buildings. The UK government wants to transform its building industry and is adopting our ISO standard for their 2016 plan. The French product manufacturer’s association has approached us to help create a digital filter that allows anyone in the world to find any product in the building industry. This is a revolutionary time for us. Instead of being just pioneering and having to do it all by ourselves, other people are starting to take the initiative. ■

Metrics Measure the Value Gained from BIM

As they get more BIM projects completed, companies are now developing their own metrics to understand the benefits gained from BIM. Also, researchers are working on a bimSCORE to be applied industry-wide.

Given the potential investments and cultural shifts associated with BIM adoption, users have leaned on metrics to help them identify the technology's value. Initially, metrics were hard to come by, as users could only work from limited data. But over time, users have gained a wealth of information about the costs and benefits associated with BIM, helping users expand and refine the use of metrics.

Collaboration

As an earlier adopter of BIM, executives at J.C. Cannistraro, an MEP contractor based in Watertown, Mass., could sense that greater collaboration yielded better results but couldn't quantify it, says Michael Cannistraro, vice president of service

and engineering at J.C. Cannistraro. "We wanted to show owners the value in bringing the mechanical contractors early to help design our work to the budget," he says.

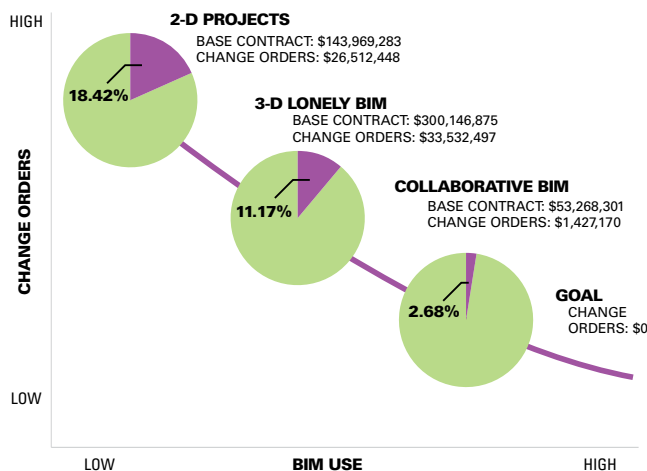
The company looked at change order costs on 408 projects completed between 2003 and 2009 with a total project value of \$558,858,574. To help drive its message, the company broke its projects into three groups:

- 2D projects [no BIM use]
- Lonely BIM [siload use of BIM]
- Collaborative BIM [multi-party BIM use]

The results showed how, in the big picture, BIM saves money as the team gets more collaborative. On its 2D projects, the firm saw 18.42% in additional change order costs from

its base contracts. On projects where J.C. Cannistraro used BIM in-house but did not collaborate, change order costs dropped to 11.7%. On its collaborative BIM projects, where they exchanged models and data with multiple parties, change order costs dropped significantly to 2.68%.

Cannistraro, who serves as on the BIM Committee for the Mechanical Contractors Association of America, says he hopes the findings resonate with others in the industry. "I try to explain to other mechanical contractors out there that once you get the immediate benefits of using BIM yourself, then you move to this collaborative approach and the benefits become more significant," he adds. "Everyone starts sharing, and everything starts to fire on all cylinders. That's what we wanted to show."



A study by J.C. Cannistraro of 408 projects Valued at \$559 million shows how, in the big picture, BIM saves money as the team gets more collaborative.

Targeted Measurement

Another early adopter, Mortenson Construction, has seen a steady evolution in its use of metrics. As the company has continually gathered data from projects over time, it has built a significant database that has allowed it to dig deeper into investigating the value proposition of BIM, says Derek Cunz, vice president and general manager at Mortenson Construction.

Cunz says that from 2000 to 2003, the company was focused on measuring the ROI for its initial investments in BIM. "We were trying to justify the spend," he recalls. "We

believed it would be positive for our business, but we had to prove it.”

Since 2007, Cunz says the company has refined its efforts, benchmarking similar projects, expanding the range of metrics it measures and targeting more specific uses of BIM.

“All of the low-hanging fruit that we justified in the past is now all standard operating procedure,” he says. “Things like modeling, clash detection, planning enclosure mock-ups are all a given [on projects]. Now we can use metrics to guide decisions about specific BIM uses on certain projects. So, on a project with a complex steel frame, we could look at how much we would save if we did a BIM-to-fabrication scenario and decide that it would be worth it.”

While Mortenson Construction can measure effectively against itself, Cunz says he looks forward to expanded and open sharing of metrics among other companies in the coming years, so it can gauge its performance on an industry level.

Industry Effort

To help add more industry perspective, researchers with the Center for Integrated Facility Engineering at Stanford University developed a metrics system called bimSCORE. The system benchmarks innovative practices and scores projects by rating their practices against those benchmarks.

Each project’s Virtual Design and Construction (VDC) Scorecard is broken into four main areas: planning, adoption, technology and performance. Each of those areas is subdivided into two or three additional “dimensions” such as quality or objectives. Another 20 measures feed into those dimensions.

Through its benchmarking, the team can score different practice areas based on a sophistication scale that starts at conventional [not leveraging VDC] and move up to typical [standard BIM use] then advanced [leveraging uses that a majority may not be doing] then best practice [among the best uses] and topping out at innovative [one of a kind].

Calvin Kam, CEO and founder of bimSCORE, says that by breaking the scoring into multiple pieces, a team gets a more complete picture of a project and can show projects where their BIM use may have excelled or been lacking.

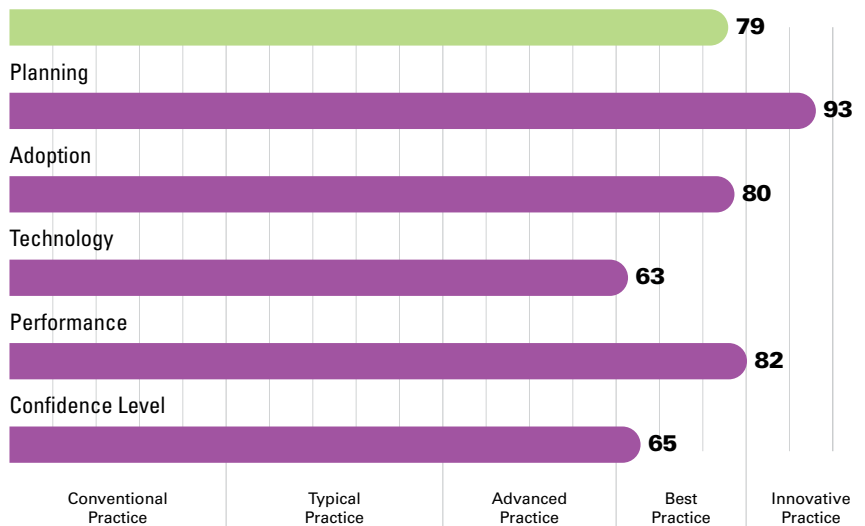
“It’s a great tool for showing an owner that maybe they had the right technology on a project but the wrong team,” he says. “Or maybe the planning was great, but then you didn’t follow through with performance. We provide the vocabulary to discuss this.”

Kam notes that one of the benefits of the system is that scores are dynamic, so they are not simply snapshots in time. As new innovations are introduced, benchmarks are adjusted. In theory, scored projects will see their scores drop over time as BIM use advances.

As of October 2012, the team had scored 57 projects in roughly two years. Over time, Kam predicts that the system could create an ample database of projects for comparing scores at multiple levels.

“This is something that can scale from individual projects to companies to regions to industries and even to countries,” he says. ■

Overall



Sutter Medical Center Castro Valley (see page 34) earned an overall bimSCORE of 79, registering high marks (93%) in the planning area for its innovative 11-party IPD method, while showing room for improvement in the technology area (63%).

Short- and Long-Term BIM Benefits

Some benefits of BIM can be experienced on a user's first few projects, such as reduced errors and omissions, rework and cycle time of workflows. Others require longer time frames to demonstrate their value, such as reduced cost, schedule and claims, or maintaining repeat business and increasing profits.

This 2012 research shows higher levels of importance for ten of the eleven BIM benefits rated compared to the 2009 results. Interestingly, the largest percentage increases occur with benefits that take longer to validate, reflecting the increasing length of time BIM has been in the market and the increasing maturity of BIM users in evaluating its benefits.

The top percentage gainers include:

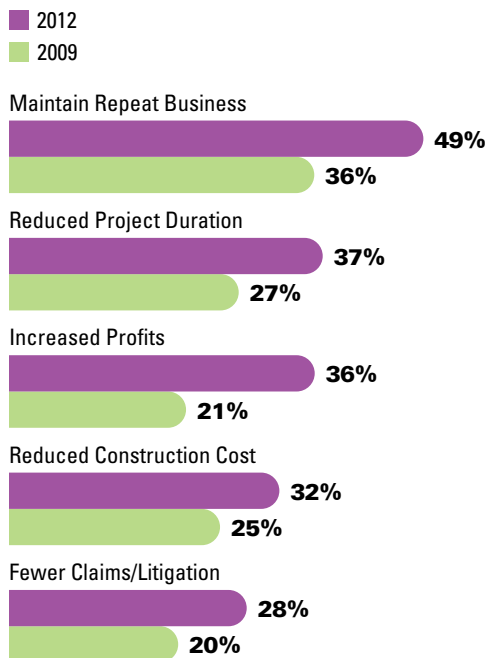
- **Increased Profits:** This rating expanded by 70%—from 21% and the next-to-last position in 2009 to 36% in 2012. This could drive use of BIM in the future—as BIM processes become more standardized and the

initial costs of adoption and implementation are amortized, firms using BIM have the ability to see a sustained impact on profitability.

- **Fewer Claims and Litigation:** Although still ranking low overall, this benefit grew by 40% from 2009, growing from 20% in 2009 to 28% in 2012. Relatively few BIM projects have reached completion (when the majority of claims and litigation appear), so evidence is still scant. However, this strong percentage increase indicates a growing belief that as more problems are avoided during construction and claims measurably diminish, this will be a reliable benefit.
- **Reducing Overall Project Duration:** This metric also requires a substantial number of completed projects in order to be validated, but if the trend of increased importance continues—growing from 27% in 2009 to 37% in 2012—reduced project duration will become a powerful ingredient of a quantifiable BIM benefit calculation.

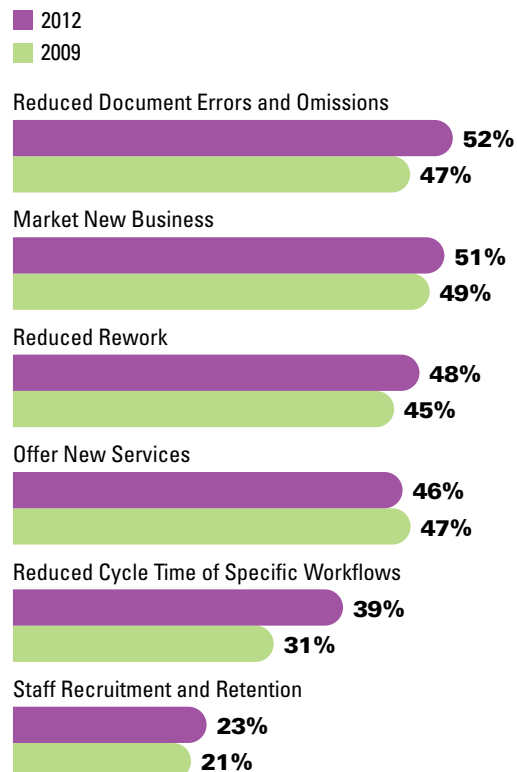
Long-Term BIM Benefits (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Short-Term BIM Benefits (2009 and 2012)

Source: McGraw-Hill Construction, 2012



BIM Adoption and Value: Benefits

Short- and Long-Term BIM Benefits CONTINUED

■ Maintaining Repeat Business with Past Clients:

Among the three highest-rated benefits related to business development, measuring BIMs impact on repeat business takes longer than leveraging BIM for marketing to new clients or offering new services. Its 36% growth from 2009—increasing from 36% in 2009 to 49% in 2012—confirms clients' increasing awareness of BIM value and its contribution to deepening client relationships.

Variation by E-Level

The accelerating importance of these long-term benefits is reinforced by their ratings from very high E-Level BIM users. This group's 2012 ratings more than double the industry-wide 2009 levels, and significantly outpace the overall 2012 numbers.

Among the other seven benefits rated:

- **Six of the seven benefits trended positively, and they should continue to do so as BIM use continues to mature and the benefits become more reliable and widespread.**
- **Leveraging BIM to offer new services had a very small decline, but not enough to be meaningful, especially considering that it earned a 56% rating with very high E-Level users.**

Percentage of BIM Users Who Consider Benefits of High/Very High Value (2009 to 2012)

Source: McGraw-Hill Construction, 2012

	2009 Rating by All BIM Users	2012 Rating by All BIM Users	2012 Rating by Very High E-Level BIM Users
Increased Profits	21%	36%	52%
Fewer Claims and Litigation	20%	28%	50%
Reducing Overall Project Duration	27%	37%	60%
Maintaining Repeat Business	36%	49%	58%

Top Business Benefits by Player

Although BIM is creating an increasing level of integration and sharing of common project objectives among the players, there are still distinct differences in how each player experiences BIM value.

Architects

Architects sharply increased the ratings of their top BIM benefits between 2009 and 2012:

- **The consistent leading benefit for architects in both 2009 and 2012 is reduced errors and omissions in documents** because it affects both risk and productivity related to their key project deliverable. The sharp growth shows that more architects are convinced of BIM's contribution to this mission-critical objective.
- **The second and third most important benefits fall in the business development category, with each showing about a 20% increase over 2009 levels**, demonstrating the increasing competitive advantage achieved from using BIM.
- **Reducing rework is a tangible outcome of the top-ranked benefit of reduced errors and omissions in documents**, again reducing risk and enhancing productivity.
- **Reducing Cycle Time of Specific Workflows improves productivity**, a focus for architects.

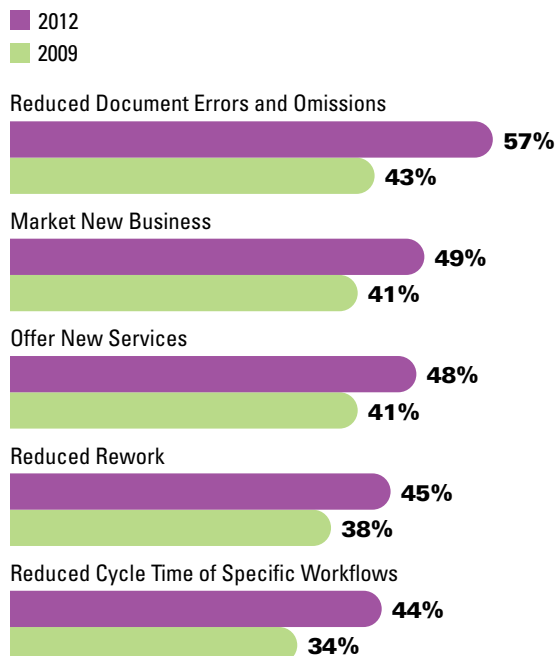
Engineers

Engineers were more reserved than architects in rating their top benefits, with the lead benefit only garnering a 50% response rate, and the others running significantly lower compared to the number of architect respondents. This probably reflects the generally lower ROI being experienced by engineers. (See page 24 for more information on BIM ROI reported by engineers.)

- **The three top benefits are directly related to business development, led by maintaining repeat business with clients, which grew by 43% between 2009 and 2012—rising from only 35% in 2009 to 50% in 2012.** Since engineers are often retained by other professionals as consultants, this focus on repeat client development is critical to ongoing business health.
- **The higher percentage of engineers citing reduced errors and omissions in documents and reducing rework, although showing slight decreases from 2009 levels, reflects the impact of these factors on risk and productivity, similar to the architects surveyed.**

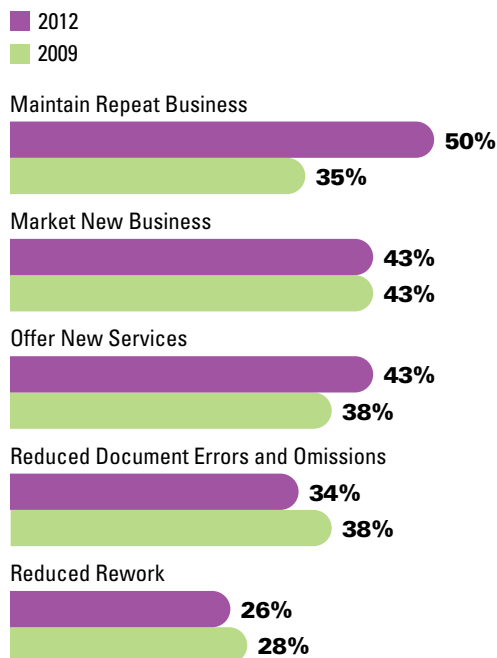
Top BIM Benefits for Architects (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Top BIM Benefits for Engineers (2009 and 2012)

Source: McGraw-Hill Construction, 2012



BIM Adoption and Value: Benefits

Top Business Benefits by Player CONTINUED

Contractors

Because contractors focus heavily on their progress at the job site, any new process or technology will be judged in that light. Thus, it is no surprise that BIM benefits that directly impact job site productivity represent four of the top five most valuable for contractors.

- **Reducing rework is selected by the highest percentage of contractors**, indicating that most are seeing this benefit on their projects. Rework is a leading cause of cost and schedule overruns, which have a negative impact on repeat business and may even generate claims. The wide recognition of BIM's ability to reduce rework contributes strongly to its value proposition with contractors.
- **Reducing overall project duration had the highest percentage increase in importance from 2009, jumping from 32% in 2009 to 53% in 2012—a growth of 66%.** The strong increase suggests that contractors are getting this benefit consistently on projects.
- **Reduced errors and omissions in documents remains the third most important benefit**, presumably because of its direct connection to the issue of reducing rework.
- **The power of BIM for business development remains strongly represented in contractors' top benefits.** Maintaining repeat business with clients increased from 42% in 2009 to 54% in 2012. It is a very tangible metric given that contractors are brought back by satisfied clients to perform more BIM projects. And even though marketing new business to new clients slid from first to second place among all benefits, it is still important to 56%.

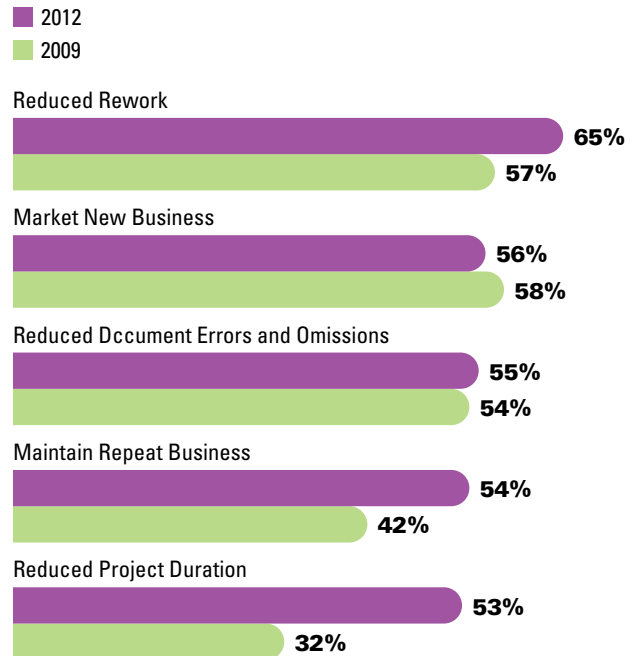
Owners

Owners focus on the ultimate success of the project, so their most important BIM benefits match those needs. Architects, engineers and contractors should consider the voice of the owner about the BIM benefits that provide them the greatest value.

- **The largest percentage of owners consider reduced errors and omissions in documents a key BIM benefit because it can prevent numerous problems from occurring on their projects.** In fact, the percentage of owners who consider this benefit important increased from 43% in 2009 to 61% in 2012. It was also selected by more owners than any other player as an important benefit.
- **BIM's ability to reduce in rework, cost, schedule and claims finish out the list of the top benefits for owners**, each of which directly impacts the success of the project.

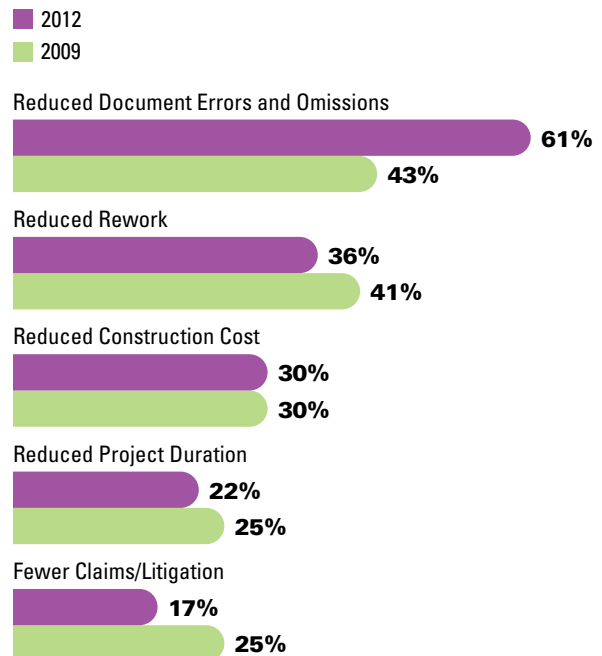
Top BIM Benefits for Contractors (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Top BIM Benefits for Owners (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Factors That Impact BIM Benefits

In their evaluation of factors that, if improved, would impact their ability to benefit from BIM, a higher percentage of BIM users in 2009 consider these to have a high or very high impact compared to those in 2012. In 2009, some factors were selected by over 70% as being of high or very high importance, but in 2012 respondents reveal less urgency, suggesting that users may feel more in control in an increasingly BIM-friendly environment.

The biggest percentage drops from 2009 to 2012 relate to BIM resources.

- **The need for more internal staff with BIM skills dropped 28%, and more external firms with BIM skills fell by 38%.**
- **Ranking last among the fifteen factors, more available outsourced modeling skills reduced by half. (Note, only the top ten important factors are shown.)**

These findings do not represent diminishing importance of these resources. Instead, they more likely indicate the growth in available internal and reliable external BIM resources, so their scarcity is less of an obstacle to achieving value from BIM.

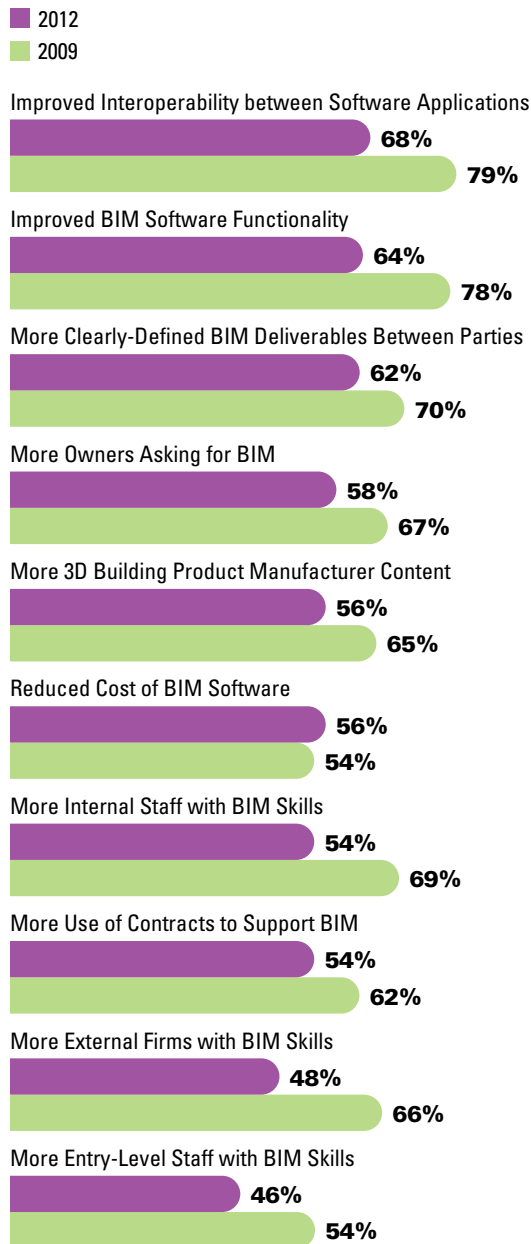
Technology-related factors rank first and second both years, though with reduced intensity in 2012. Users are still faced with file-exchange issues and challenges applying existing software to meet needs such as technical analysis (see page 44 for more information). In addition, some top reasons cited by non-users for not adopting BIM are functionality that do not relate to their needs and lack of interoperability with CAD. Emerging standards initiatives for data, exchange and deliverables plus improved Application Programming Interfaces (API) for authoring tools will help address the interoperability concerns. Software companies are also working to expand functionality and improve ease-of-use.

Another technology factor, reduced cost of BIM software, is the only one that grew over the period, moving up to #6 in the 2012 importance rankings. A persistent issue throughout the research, the economy is certainly adding more pressure to this need.

Two business-related issues also make the top ten. More clearly defined BIM deliverables between parties and more use of contracts to support BIM decreased somewhat in intensity for 2012, but indicate a persistent challenge that a number of industry organizations are actively trying to address, including AIA (BIM Agreement), AGC (Consensus Docs), Charles Pankow Foundation (BIM Execution Plan) and the BIMForum (Level of Development).

Most Important Factors for Increasing BIM Benefits (2009 and 2012)

Source: McGraw-Hill Construction, 2012



More 3D building product manufacturer-specific content, ranking fifth in 2012, may owe its reduced intensity to greater activity by manufacturers to have content created and distributed, and more sites from which it is available.

Variation by Player of the Most Important Factor

When asked to identify the single most important factor, users' selections crystallize the drivers of BIM business value for each group.

ARCHITECTS

Their top response is more owners asking for BIM.

Architects already have high levels of adoption, implementation and expertise; what they need is demand.

ENGINEERS

Their top response is improved functionality of BIM

software. Engineers have had to adapt to software that was primarily developed for architectural design, so they are eager for tools, processes and content more tailored to their needs.

CONTRACTORS

Their top response is more clearly defined BIM

deliverables between partners. Contractors—downstream from BIM design processes and increasingly adding to or creating new models, especially among the trades—need clarity between those who author and those who receive models.

OWNERS

Their top response is more clearly defined BIM deliver-

ables between partners. Owners also need well-defined deliverables between parties, not only because that will reduce risk and improve outcomes on their projects, but because they are also increasingly responsible for developing contracts and BIM execution plans that rely on clear definitions linked to established standards.

Perceived ROI for BIM

Although there is no industry-standard method to calculate the return on investment (ROI) for BIM, most users have a perception of the degree to which they are receiving value for the time, money and effort they have invested. These research results suggest that the apparent similarity between the 2009 and 2012 findings about the perceived ROI of BIM mask interesting forces at work.

Existing users naturally improve their ROI over time as their skills and experience increase, and they amortize the initial costs over more projects. However, the percentage of total users reporting over 50% ROI appears flat from 2009 to 2012.

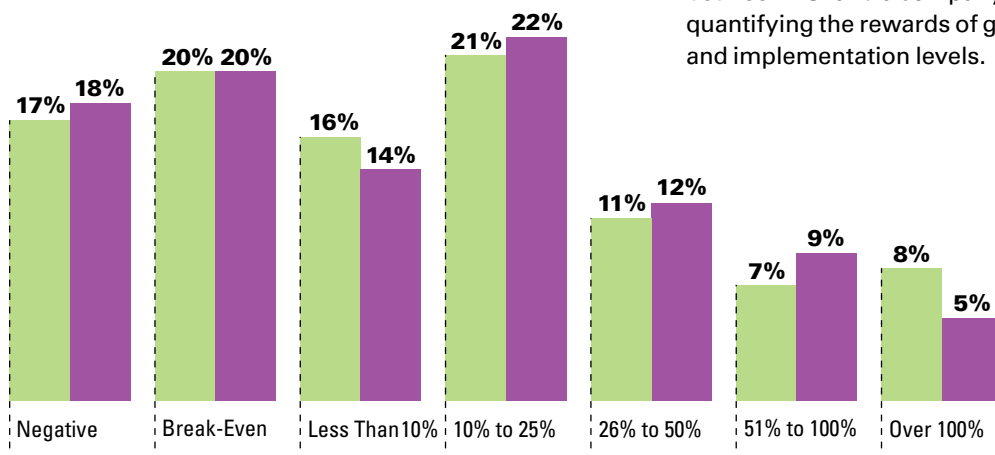
Meanwhile, the total pool of BIM users has expanded from 49% of the industry to 71% between 2009 and 2012, raising the percentage of newer users whose ROI is typically negative or quite low in their early years. However, the lower portions of the ROI spectrum also appear flat.

Thus, it is possible that these two forces are offsetting each other, so while the actual number of users experiencing higher ROI is growing, the overall size of the population is also increasing, keeping their percentage of the total essentially flat. Likewise, the positions in the lower tiers that are being vacated by the advancing users are being back-filled by just enough new entrants to keep all the proportions roughly equivalent.

BIM ROI (2009 to 2012)

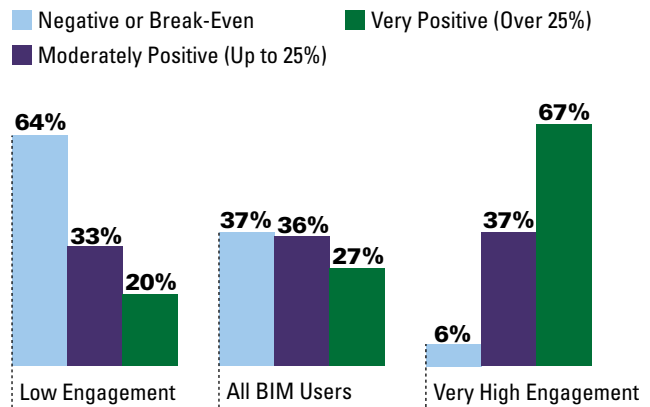
Source: McGraw-Hill Construction, 2012

2009 2012



BIM ROI for Users by Level of Engagement

Source: McGraw-Hill Construction, 2012



Variation by Engagement (E-Level)

Dividing the total user population into three basic tiers of ROI, a very clear picture emerges by comparing the results of those with low and very high BIM engagement levels:

- About a third of each group is receiving moderately positive ROI (up to 25%).
- The very high engagement users dominate the very positive range, with 67% reporting of ROI over 25%, compared to only 20% of low E-Level users.
- Nearly two thirds (64%) of low engagement users are in the negative or break-even range, compared to only 6% of high E-Level users rating their ROI at these levels.

This analysis demonstrates the powerful relationship between ROI and a company's level of BIM engagement, quantifying the rewards of greater BIM experience, skill and implementation levels.

Variation by Player

ARCHITECTS

Architects are the most mature group of BIM users, and their BIM ROI reflects their experience. The percentage getting very positive ROI has risen:

- The number claiming negative or break-even has dropped.
- A consistent proportion (about 30%) report moderately positive ROI in both periods.

This makes sense because the existing users are advancing, and the influx of new adopters between 2009 and 2012 have been able to take advantage of the relatively advanced state of architectural BIM and get to break-even (or beyond) fairly quickly.

ENGINEERS

The sharp increase of engineers with negative or break-even ROI is clearly the impact of their very large influx of new adopters (25% have one or two years experience).

The drop in moderately positive ROI users is also likely due to the large number of new adopters, most of whom are in the lowest tier. As such, growth in the number of mid-tier users is outweighed as a percentage of the much larger 2012 total.

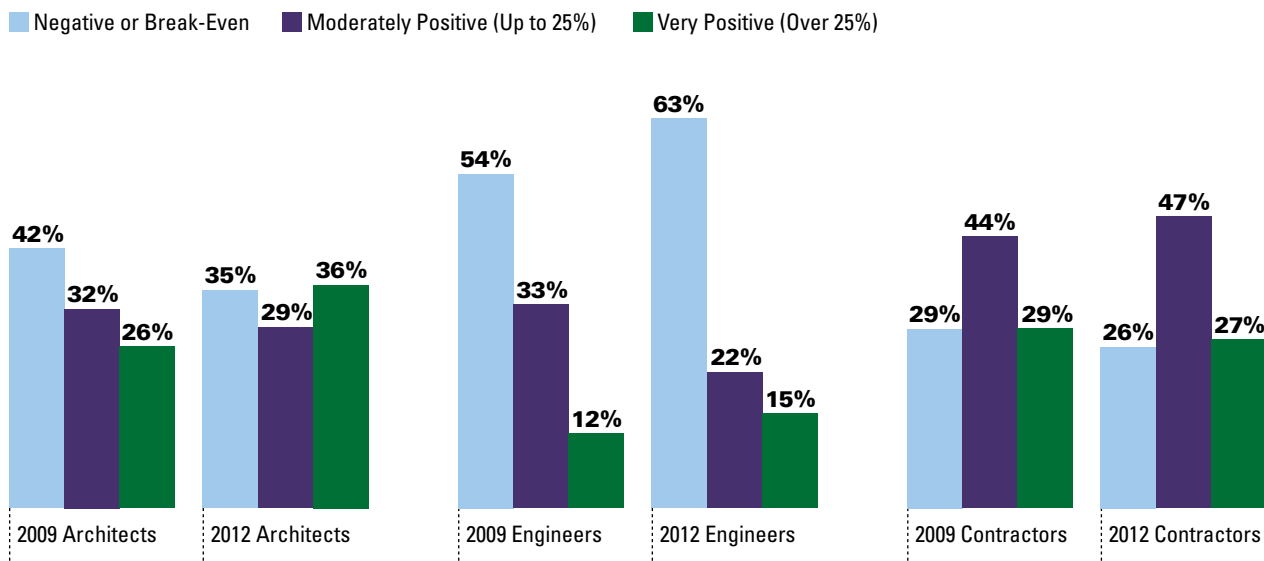
Engineers' struggle to take advantage of BIM to the same degree as the top level architects and contractors.

CONTRACTORS

Contractors display the most classic bell curve distribution, with nearly half in the moderately positive range both years. The similarity between the periods is likely due to the same offsetting effect that is at work in the overall industry, where new users' lower ROI counteracts the increasing ROI of the more experienced users.

BIM ROI by Player (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Elements That Would Improve ROI for BIM Users

The value of BIM is realized in different ways by the variety of firm types in the industry. The specific elements recognized by the largest share of the respondents as improving the potential ROI of BIM users reveals very different perspectives by player type among BIM users.

- **Better project process outcomes is given the greatest weight by contractors and owners, although it scores fairly well with all player types.** Contractors and owners may find this particularly compelling because they are closer to the finished building compared to other players.
- **Increased prefabrication is rated high by 81% of contractors, but only resonates with 19% of architects and 22% of engineers.** As more integrated whole-project-process thinking is facilitated by the growing use of BIM, more design team members will become engaged in designing specifically for activities like prefabrication and modularization, and their understanding of its contribution to the ROI of BIM should increase.

- **Lower project cost is considered important by 83% of owners and 78% of contractors, but only by 41% of engineers.** Engineers may not experience the potential cost impact of BIM yet because of their relatively low level of BIM maturity. In addition, engineers may be driven less by total project cost compared to the cost of their portion of a project, which may keep this factor from having as strong of an impact on their BIM ROI as other players.

Elements That Improve ROI for BIM Users by Player

Source: McGraw-Hill Construction, 2012

	Improved Job-Site Safety	Positive Impact on Sustainability	Positive Impact on Staff Recruitment and Retention	Faster Plan Approval and Permits	Increased Prefabrication	Lower Project Cost	Reduced Cycle Time for Project Activities and Delivery	Better Multi-Party Communication	Improved Project Process Outcomes	Improved Personnel Productivity
Architect	13%	47%	46%	35%	19%	62%	68%	74%	74%	79%
Engineer	13%	20%	28%	28%	22%	41%	50%	65%	59%	59%
Contractor	57%	36%	37%	48%	81%	78%	79%	71%	81%	85%
Owner	33%	67%	17%	50%	50%	83%	50%	100%	100%	50%
TOTAL	33%	37%	37%	40%	48%	65%	68%	71%	74%	77%

More than 75% 51% to 75% 26% to 50% 25% or Less

Formal Measurement of ROI

44% of BIM users do not formally measure their BIM ROI, and another 43% measure it on less than half of their projects. Patterns for formal measurement are similar across player-types.

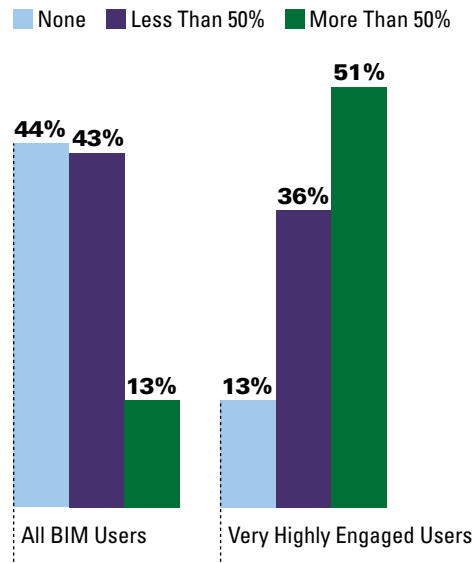
Variation by Engagement Level (E-Level)

A major difference is revealed by comparing all BIM users to those with a Very High BIM Engagement Level. **87% of very high E-Level users are engaged in formal measurement of BIM ROI, compared to an average of only 56% of the total user population. And most of those users are doing so on more than half their projects.** This high level of measurement indicates the advanced BIM maturity of this tier of users.

The 13% of very high E-Level users that never measure ROI may be because they already know the value and no longer feel the need to measure.

Formal Measurement of BIM ROI by Engagement Level

Source: McGraw-Hill Construction, 2012



Averting Problems on a Complex Project

Pantex HEPF
AMARILLO, TEXAS

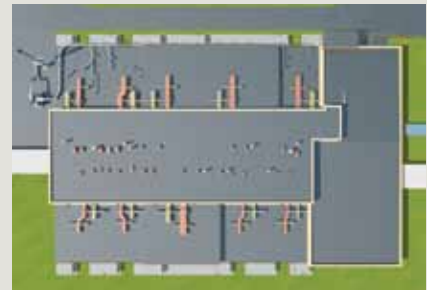
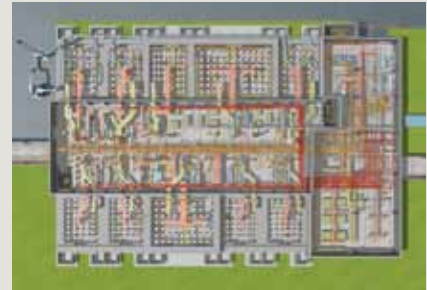
The design and construction team of a processing facility in Texas learned that it is never too late to start modeling a project. The new \$100 million HEPF at B&W Pantex's facility in Amarillo is being developed as a testing facility for the U.S. Department of Energy (DOE). When federal funding issues forced the project to be put on hold in 2006, project managers decided it was a good opportunity to give the facility a second look.

Although it had reached 95% CAD construction documents, B&W Pantex hired CH2M HILL in 2007 to model the project in BIM. B&W project engineer Stephen Forman says that BIM was an emerging technology when design originated, but by the time it neared design completion, he recognized that modeling was already proving its value on other projects. "We were aware of some lessons learned at other DOE sites and saw the potential benefits," he said. "We had been burned in the past by issues in the field and didn't want to relive those. It was worth trying it."

David Fouché, senior technologist at CH2M HILL, notes that it is common in complex and spatially challenging buildings, especially processing type facilities, to encounter problems with installation and operations that could have been caught in a 3D model. "It's simply not possible to piece all the 2D drawings together to create a realistic mental picture of everything that's going on," he says.

Putting ROI to the Test

B&W Pantex invested \$1 million to have CH2M HILL spend four months modeling the design down to the level of 3/4-in conduit. The payback



CH2M HILL was brought in to model the B&W Pantex project in BIM after it had reached 95% CAD construction documents. The \$1 million investment revealed more than 500 significant clashes, including ten "big ticket" items that independent auditors estimated could have cost up to \$10 million to rework in the field.

was realized quickly. Models revealed more than 500 significant clashes, including ten "big ticket" items that independent auditors estimated could have cost up to \$10 million to rework in the field. The team was then able to redesign problem areas to bring the project back on budget.

Since the start of construction, which is scheduled to complete in 2014, the team has continued to leverage the model. When the project was resurrected in 2010, the Tulsa District of the U.S. Army Corps of Engineers (USACE) was brought in as construction manager. In 2011, Kiewit Construction was awarded the contract as general contractor under the Corps.

Meanwhile, CH2M HILL was retained by B&W for BIM services, maintaining a continuously up-to-date record of the state of design and

construction. Although CH2M HILL does not work directly for USACE or Kiewit, it regularly exchanges information with the construction team to keep models accurate. Fouché says that the construction team is not using its own construction model, but is feeding information back into the original design model, ultimately helping to create an accurate ongoing as-built model. "We're helping to ensure transparency and better quality," he says.

Working from the single model, designers and contractors can conduct 3D graphical navigation and database queries, including review and exploration of design options and proposed changes. CH2M HILL also runs quantities, with special designation for items installed to date.

Pantex HEPP AMARILLO, TEXAS

Valuable Validation

In February 2012, CH2M Hill was engaged to assist in multiple validation efforts on the project. The team checked all utility stub-ups that had been installed prior to installation of the facility's thick mat slab. Fouché says B&W wanted to identify missing stub-ups or stub-ups in the wrong locations before the slab was poured and it was too late to fix. The BIM team was able to identify 23 issues that needed to be resolved prior to installation of rebar and pouring concrete. Fouché says that, while some of the issues were minor, some would have been major concerns if not caught at this stage.

The BIM team was also asked to assist in checking the steel rebar submittal. The BIM team modeled all of the rebar in the mat slab and all of the concrete walls. The team found that the rebar design, as documented in the shop drawings, did not work correctly, especially in complex areas such as the joints between two walls and the slab. During its checks, CH2M HILL discovered missing rebar or pieces of rebar that were the wrong size. It also created 3D visuals of the modeled rebar to help with planning and installation in the field. Fouché says that in many cases, the team



By continuing to keep an accurate design model updated with construction information, the model could have future uses, such as helping with facility start-up, training of staff and other post-occupancy tasks.

found that the rebar design was less complicated than previously thought.

The BIM team can also review schedule and sequencing from the model, allowing the team to better monitor construction progress including past progress and look-aheads. In July 2012, the BIM team was directed to produce a schedule simulation showing the baseline schedule against the actual schedule in a side-by-side comparison. Fouché says that the actual schedule showed a slight deviance from the baseline schedule, but that B&W was

Project Facts and Figures

Client

B&W Pantex

Construction Manager

US Army Corps of Engineers

Contractor

Kiewit Construction

BIM Services

CH2M HILL

Type of Project

Testing Facility

Construction Start

2011

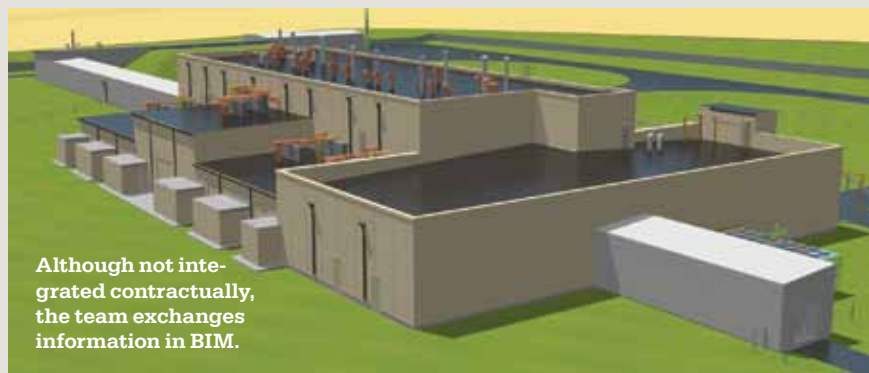
Occupancy

2014

Cost

\$100 million

stats



Although not integrated contractually, the team exchanges information in BIM.

concerned that these numbers were hard to interpret and the significance hard to grasp. The team was tasked to create a movie of the schedule to provide a compelling visual that would help drive the point home. Fouché says B&W also wanted to stress that while there was a current deviation that needed to be reported up the chain of command, that the current schedule showed significant periods of make-up resulting in construction ending on time. The BIM team was able to produce a movie showing the schedule in just a few hours, delivering the desired graphic to B&W on time for their reporting needs.

By continuing to keep an accurate design model updated with construction information, Fouché says the model could have future uses, such as helping with facility start-up, training of staff and other post-occupancy tasks. ■

Interview: Thought Leader

THE BUSINESS VALUE OF BIM IN NORTH AMERICA: MULTI-YEAR TREND ANALYSIS AND USER RATINGS (2007-2012)



Phillip G. Bernstein, FAIA, RIBA, LEED AP

Vice President, Strategic Industry Relations, Autodesk, Inc.

How did Autodesk become involved with BIM?

BERNSTEIN: The idea now called building information modeling has been discussed for three decades. Autodesk decided in 2001 to look at it in greater depth. There was a lot of dialog going on about productivity, refactoring project delivery; sustainability was coming to the fore; and computers were getting powerful enough to actually do it. In 2002 we acquired Revit Technologies, which we thought was the kernel of the right idea. We created the term building information modeling to distinguish it from 3D graphics packages.

How has BIM impacted the industry?

BERNSTEIN: It's dramatic. Pre-BIM design technology was about representation. Thinking and analysis happened elsewhere. Now it is all becoming integrated. You can apply analytical algorithms to models and really begin to reason about the design. Project teams can try to accomplish measurable outcomes as opposed to siloing everyone into their lowest first cost, defensive risk management positions. It's a way of changing your business model, because you are more efficient, effective, and the value you're able to deliver to the process is much greater.

What are the most important current BIM needs to most effectively advance the industry?

"Pre-BIM design technology was about representation. Thinking and analysis happened elsewhere. Now it is all becoming integrated. You can apply analytical algorithms to models and really begin to reason about the design."

BERNSTEIN: The approach to standards has to change. A global intergalactic interoperability super standard that all data somehow adheres to will never work. Google is successful because they index everything. We need to make big piles of discontinuous data infinitely accessible and indexable and searchable.

Education also has to change. Technology is not just another implement, like a belt sander in the woodshop. Our teaching methods have to take a different stance about the relationship between technology and pedagogy because the means of representation is now shifting from drawing to something else. This is not a training issue.

And in technology, giving instantaneous feedback on simulation analysis to a designer or builder by leveraging the cloud so they're unconstrained by computation or storage problems starts to get really, really interesting.

How do you think BIM will change the industry over the next ten years?

BERNSTEIN: Most traditional iconic project delivery models will still exist, but strongly influenced by integrative strategies. In CM-at-risk, for example,

a GMP will be much more robust because of the predictive qualities of BIM. Plus there will be stable, repeatable integrated project delivery models.

You'll also see AEC players in long-term, repeatable relationships, having reduced levels of friction through integrated strategies. And you are going to see some hyper-integrated delivery businesses, where [firms like] AECOM and Balfour Beatty will have built their construction and design muscles such that it will no longer be possible to distinctly identify them as either designers or builders or, in some cases, operators. A lot of projects will be delivered through super one-stop shopping for complete end-to-end delivery, like what already exists in oil, gas and mining.

What are Autodesk's future plans related to BIM?

BERNSTEIN: We like our technologies to be just slightly ahead of our customers. The next five years will be about cloud, social and mobile technologies. AEC professionals will need a wide variety of tools in a flexible and adaptive environment, and that's very much what we are working on. ■

BIM Investments

BIM users' investments in software, hardware, training and other requirements for a successful BIM program will vary depending on their level of BIM sophistication as well as their need to accommodate other competing demands for time and expense.

Technology Investments

Communications infrastructure to improve model sharing—added to the survey in 2012—is the top target for 2014 investments. Reflecting the need for collaborative teams to exchange large files fluidly and manage access rights to them among many firms, this is expected to grow substantially as mainstream technology firms try to adapt their platforms for use in the construction industry and BIM technology firms expand, refine or add this capability to their offerings.

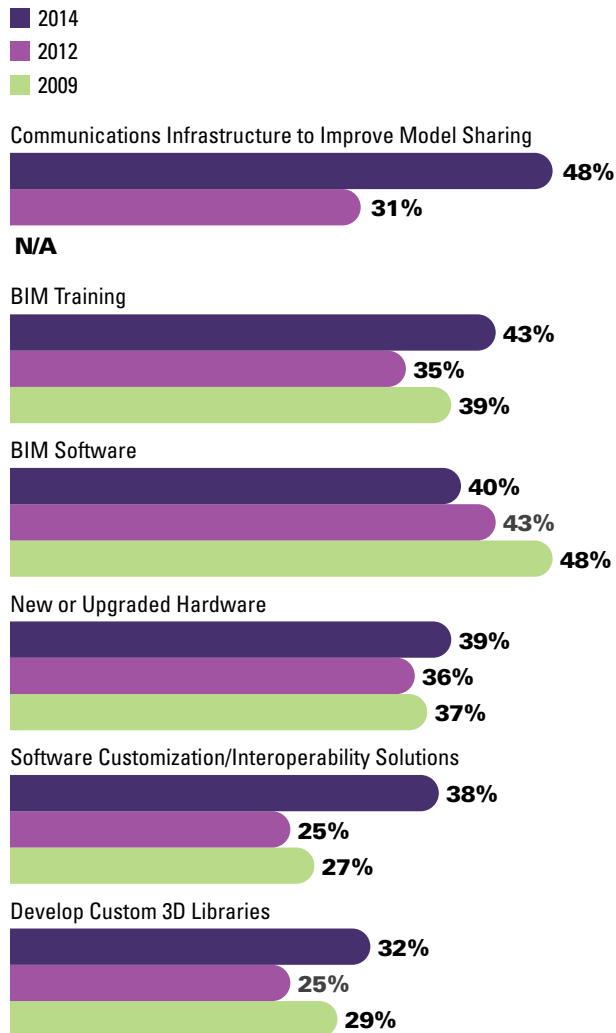
- **BIM training makes a big jump in the forecast** as firms scramble to make their staff BIM-capable. Training is important for several reasons:
 - There is a direct relationship between skill level and ROI (see pages 24–25).
 - Once firms have invested in software licenses and hardware upgrades, training their BIM staff is critical to leverage those investments.
 - Training is also vital for the influx of new users who need to get established with BIM.

As software becomes more complex, BIM training will probably increase as an investment priority with more specialized applications launched to use BIM data.

- **BIM software and new/upgraded hardware are consistent priorities**, although software shows steady decline over the three periods, perhaps because the bulk of initial license costs have been invested and ongoing maintenance requires less annual expenditure. Hardware stays steady, a direct function of new hires and replacement of older equipment, but should decrease over time as new hardware becomes more powerful and less expensive. And, of course, both of these categories are subject to economic conditions and firms' backlog of projects.
- **Software customization/interoperability solutions and developing custom 3D libraries both show large increases for 2014**, after having both pulled back between 2009 and 2012. This makes sense because both improved interoperability between software applications and more 3D building product manufacturer-specific content are top factors that users believe will improve their ability to benefit from BIM (see page 22 for more information).

BIM Technology Investments (2009 – 2014)

Source: McGraw-Hill Construction, 2012



BIM Adoption and Value: Investments

BIM Investments CONTINUED

Process Investments

Developing collaborative BIM procedures with external parties leads all investment categories and also shows the largest percentage increase, growing from 33% in 2012 to 54% in 2014—a jump of 64%. Developing internal collaborative BIM procedures, a related factor, also rates very highly, as it has for all periods. These are very tightly aligned with the top technology investment of communications infrastructure to improve model sharing, all aimed at optimizing collaborative modeling workflows and practices.

The change over the 2009 to 2012 period for these two process investments signals an evolution.

- The strong focus on internal collaborative BIM procedures in 2009 is a hallmark of relatively early stages of adoption and implementation when firms needed to establish and expand their initial technical capability and develop internal methods for BIM deployment.
- 2009 was also a time when on many BIM projects, only one firm was doing any modeling, so internal skills were more important than external collaboration.

The shift in 2012 to looking outwards, towards external parties and technology infrastructure to support model sharing, heralds a critical trend towards driving an integrated approach to design and construction throughout the industry.

Business Investments

Investing in leveraging a firm's BIM capabilities for business development purposes is consistently rated as important by users in all periods. Rising from 40% in 2012 to 63% for the 2014 forecast, marketing your BIM capability ranks second among all investments options, including technology and process investments.

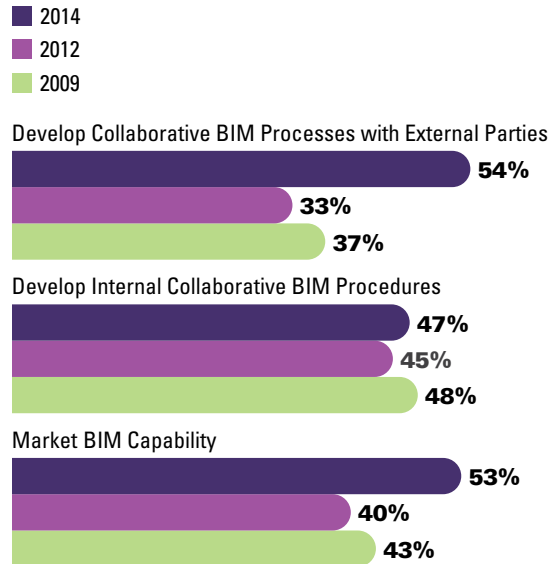
This indicates that firms in a market with few BIM competitors find highlighting their capability a valuable differentiator. Conversely, users in markets with strong competitors have to maintain investments in marketing their BIM experience to continue to compete effectively.

VARIATION BY ENGAGEMENT (E-LEVEL)

Users with higher BIM engagement levels show greater commitment to BIM investments. The analysis shows the difference in levels of commitment by BIM engagement level, as well as the relative size of each engagement tier.

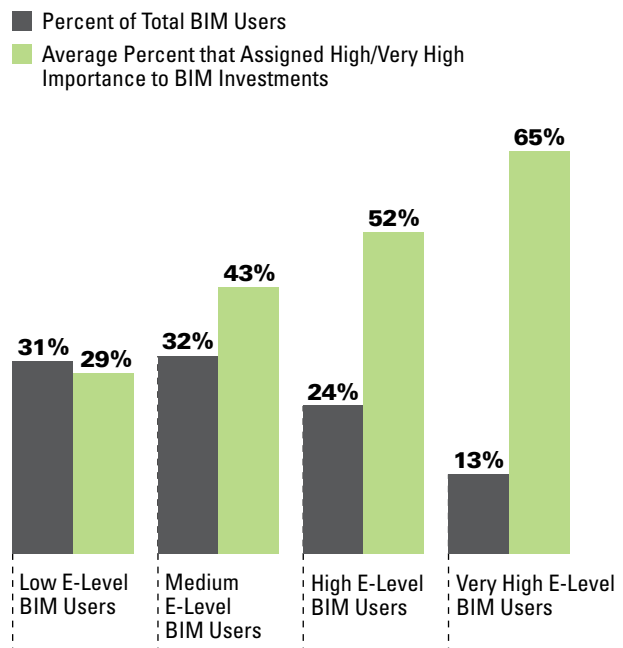
BIM Process and Business Investments (2009–2014)

Source: McGraw-Hill Construction, 2012



Commitment to BIM Investment by Engagement Level

Source: McGraw-Hill Construction, 2012



BIM Adoption and Value: Investments

BIM Investments CONTINUED

THE BUSINESS VALUE OF BIM IN NORTH AMERICA: MULTI-YEAR TREND ANALYSIS AND USER RATINGS (2007–2012) DATA

On average, 65% of respondents in the top engagement tier assigned high/very high importance to the rated BIM investments, more than twice as many as the low engagement group (29%). This high level of BIM investment by the most engaged leaders is a tangible demonstration of the industry's deepening commitment to BIM.

VARIATION BY PLAYER

Analyzing the top investment predictions by firm type highlights both the common and unique perspectives between them.

- **Marketing BIM Capability:** Ranked first or second across all player types, the importance of this investment reflects the growing degree of competitive BIM capability across many markets, which raises the pressure on firms to find ways to make their BIM experience meaningful to prospective clients.
- **Internal and External Collaboration Skills:** Collaboration skills are also considered important by all player types. Architects and contractors are focused more on external processes, while engineers still prioritize internal skills, appropriate for their lower level of BIM maturity and the large number of recent adopters.

- **Communications Infrastructure to Improve Model Sharing:** This investment is considered important by a higher percentage of architects and contractors, reflecting their relatively advanced BIM maturity and growing need for a robust collaborative platform.
- **BIM Training:** Top factor for contractors only, which is consistent with contractors' general commitment to training as a standard part of overhead.
- **BIM Software and BIM Hardware:** Engineers, as newer adopters are still in the cycle of hardware upgrades. Architects rate BIM software as fifth, probably because, having been adopters for the longest time, they are focusing more on process improvements that leverage their technology investment.
- **Software customization/interoperability solutions:** This is a top factor for engineers only, again reflecting their state of BIM maturity where these issues require investment.

Top Forecasted 2014 BIM Investments by Player

Source: McGraw-Hill Construction, 2012

Architects	Engineers	Contractors
1. Marketing Your BIM capability	1. Marketing Your BIM capability	1. Developing Collaborative Processes with External Parties
2. Communications Infrastructure to Improve Model Sharing	2. New or Upgraded Hardware	2. Marketing Your BIM Capability
3. Developing Collaborative Processes with External Parties	3. Developing Internal Collaborative BIM Procedures	3. BIM Training
4. Developing Internal Collaborative BIM Procedures	4. Developing Collaborative Processes with External Parties	4. Communications Infrastructure to Improve Model Sharing
5. BIM Software	5. Software Customization/Interoperability Solutions	5. Developing Internal Collaborative BIM Procedures

Integrated Design Helps Deliver Project with Tight Schedule and Budget

Sutter Medical Center Castro Valley

CASTRO VALLEY, CALIFORNIA



An innovative 11-party integrated project delivery team used BIM to help envision the \$320-million Sutter Health Eden Medical Center in Castro Valley, California.

The best-laid plans often go awry in construction, but Sacramento, CA-based Sutter Health was not willing to accept that risk when building the new Sutter Medical Center Castro Valley. The owner was under a strict state-mandated deadline to build a seismic-code-compliant replacement for its 55-year-old Eden Medical Center in Castro Valley, CA. That forced the team to put the project on an accelerated schedule. To further complicate matters, Sutter Health had to work within a tight \$320 million budget.

Digby Christian, senior project manager with Sutter Health's facility planning and development department, determined that the project would not be possible under traditional delivery methods. Baseline projections showed that traditional delivery would require at least seven years to design, permit and construct the facility. However, the project

had to open within five years. Compared to similar facilities built in the San Francisco Bay area, the privately financed project's budget was near the low end of what would be required to deliver such a project.

At the centerpiece of its development strategy, the owner opted for an innovative 11-party integrated project delivery (IPD) agreement to help ensure that it would get the quality facility it demanded, on time and on budget. To support its integrated approach, the team used building information modeling (BIM) extensively, bringing in designers, engineers, contractors and major subcontractors early to create coordinated models that would help track schedules, keep costs in check and drive precision fabrication.

The strategy paid off. With Sutter Medical Center Castro Valley set to accept its first patients this winter, the team met its aggressive goals, delivering on budget and within its

five-year time frame—30% faster than forecast under traditional methods.

"Integrated project delivery was the foundational concept that allowed us to pull this off," Christian says. "It would be very difficult to take as many big steps forward as we did unless you created an agreement where the team is collectively at risk for failure or reward."

Early Integration

By bringing in team members early, Christian says the team created better models and reduced its risks. "We were able to push the definition of what it means to finalize design. We put massive amounts of decisions into the design phase by using enhanced ways to model."

The architect—Phoenix-based Devenney Group—and the general contractor—DPR Construction of Redwood City, CA—worked alongside key MEP engineers and trade contractors, fire protection services, and a lean/BIM project integrator, Ghafari Associates of Dearborn, MI, that was brought in to finalize a design that was fully coordinated and could be used for fabrication of critical components.

Leveraging its ability to gain early input from team members, a seven-week \$350,000 validation study was conducted to better predict that the project could come in at cost and on budget. Design started in October 2007, and the team had submitted construction documents for permitting by December 2008—a 15-month process. Samir Emdanat, manager of advanced technologies at Ghafari, estimates that, in California, projects of this magnitude take two and a half to three years from beginning of

Sutter Medical Center Castro Valley

CASTRO VALLEY, CALIFORNIA

design to completed design, followed by two years in permitting. Permits for construction were received in six months for this project.

When the project broke ground in June 2009, the team had produced in excess of 25,000 electronic design documents using primarily BIM and BIM-related tools. More than 50 companies were able to access real-time data from any location.

After design was complete, the team continued to heavily leverage the model through construction. Emdanat says early input from contractors and key trades led to high levels of detail in designs that allowed for accurate coordination. He estimates that a project of this scope would typically see in excess of 2,000 requests for information (RFI) under traditional delivery methods. At completion, the project had 555 RFI, roughly 70% below traditional baseline. By using modeling in

an IPD environment, Christian says 55% of RFI were closed the same day that they were opened. Another 20% were closed within a few days. "The designers were fully incentivized to follow this process through construction," he says.

Compared to traditional baseline, Christian says MEP and framing work saw a 60% reduction in rework and an 8% boost in productivity.

Prefabrication and Preassembly

The team also pushed to maximize fabrication driven from the model. Emdanat says structural steel, rebar, sheet metal, piping and major electrical conduit were all fabricated directly from the model. "Shop drawings were created from the models after coordination," he adds.

As a result, many trade contractors and suppliers were able to pre-assemble systems before bringing them to the site. "Construction waste was extremely low," Christian says. "There was virtually no cutting on site and very little welding."

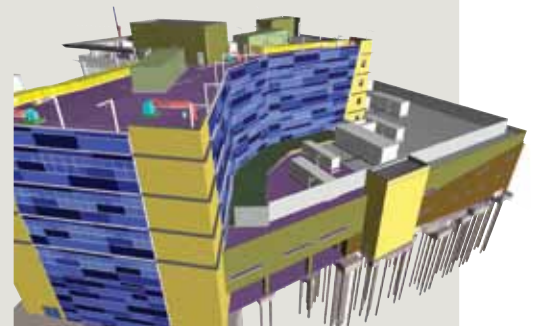
Because the medical center needed to accommodate critical technology with the facility, the team also added fabrication-level installation models for major medical equipment. "That's unusual on a hospital project, but when you talk to the team about the risk of not doing it, it becomes clear that should be the default," Christian says.

While BIM enhanced the team's ability to work together, Christian says the IPD agreement prompted members to communicate better and seek solutions. Throughout construction, the team continued to validate its work against the model, helping it stay on top of any schedule or cost concerns.

Although the project hit its budget and completion goals, Christian says the project did see occasional slips in schedule. Unlike in traditional delivery, Christian says that if a trade contractor's work started to fall behind, the team's reaction was to find a collective solution to help regain schedule.

"That's when an agreement like this [IPD] proves its value," he says. "You can get by with a napkin agreement if things go well, but you need an agreement that really requires the team to stick together if things get challenging."

In the end, the IPD team reaped the rewards, claiming 80% of possible incentives on the project. "This proved to be a much healthier environment for people to work in," Christian says. "Setting up a project this way is incredibly rewarding, and it creates good morale around the project. It was a hard and challenging project, but that's because the work was hard and challenging, not because a [traditional] contract encourages you to fight all the time." ■



At completion, the project had 555 RFI, roughly 70% below traditional baseline. By using modeling in an IPD environment, 55% of RFI were closed the same day that they were opened. Another 20% were closed within a few days.

Project Facts and Figures

General Contractor
DPR Construction

Architect
Devenney Group

Type of Project
Hospital

Procurement Method
Integrated Project Delivery

Construction Start
June 2009

Occupancy
Early 2013

Size
230,000 sq. ft.

Cost
\$320 million

Interview: Thought Leader

John Cross

Vice President, American Institute of Steel Construction (AISC)



How did AISC get involved with BIM?

CROSS: AISC was involved with BIM before BIM was BIM. In the 1990s we took a hard look at the entire structural steel fabrication process. The emerging use of modeling and the exchange of data between dissimilar software packages came out as two factors that could certainly improve overall productivity, particularly if the information contained more than just dimensional data. We researched available standards and adopted CIS/2, a very robust data-rich standard specific to structural steel. We worked with software vendors for structural design and fabrication process control, and with the automated equipment manufacturers on the shop floor, to encourage them all to implement CIS/2. Most of them stepped up and did that. It was a very cooperative effort and certainly we need to give a lot of credit to those original pioneers that took that risk and moved our industry forward.

How has BIM impacted the structural steel industry?

CROSS: [I see] an upward spiral where attention moves from modeling software to data exchanges to legal issues to business model issues and then back to software. And each time we've gone around that cycle, the design and construction industry together moves higher in terms of productivity through the use of BIM.

"[I see] an upward spiral where attention moves from modeling software to data exchanges to legal issues to business model issues and then back to software. And each time we've gone around that cycle, the design and construction industry together moves higher in terms of productivity through the use of BIM."

What are the most important current BIM needs to most effectively advance the industry?

CROSS: The business model portion of the cycle is what we need to focus on right now. We need to define the relationships and the compensation levels of the different disciplines that are involved to make sure that the economic gains from BIM are properly allocated, both on the design and construction side, to those that have had expanded roles and responsibilities and are assuming additional risks because of being involved in BIM.

What do you see as the future for BIM over the next ten years?

CROSS: Certainly a higher level of automation where model information will flow directly to the shop floor, probably involving a greater use of robotic technology. Equipment will start talking to other equipment on the shop floor and tracking things through the process. We'll also see more modularization where larger components are prefabricated. Structural steel fabricators are uniquely positioned to be able to do that, and BIM will be critical in their process.

What are the AISC's future plans related to BIM?

CROSS: We've strengthened our commitment to BIM and model interoperability. We're developing comprehensive data maps defining the exchange of information both within the structural steel supply chain and the external links to other disciplines. We're also developing a methodology that will allow conformance to the IFC standard while still allowing and encouraging individual software developers to push that envelope with new extensions and new applications. We're strongly committed to maintaining our involvement with buildingSMART and the National BIM Standard (NBIMS) to drive the overall process of BIM throughout the construction supply chain. Chris Moor from AISC now chairs the NBIMS development committee. And we will continue to educate our members about the advantages of BIM and the practical aspects of implementing BIM in their individual operations. ■

Level of Interest in BIM by Non-Users

McGraw-Hill Construction's 2007 *SmartMarket Report* about construction industry software predicted that BIM would reach a tipping point in 2008. This did not mean every project in 2008 was expected to be modeled, but that BIM would be an accepted industry practice, here to stay for the long run. Subsequent measures of BIM adoption by McGraw-Hill Construction have supported this conclusion.

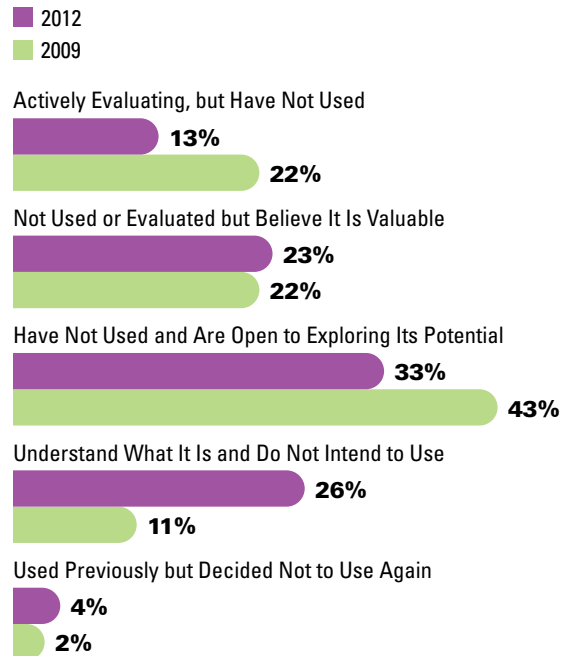
Despite current widespread industry adoption (see page 9), this 2012 research finds that 29% of the survey respondents are not using BIM. While the overall percentage of non-users has dropped significantly, from 51% in 2009, the remaining non-users are hardening their resistance.

- **30% of non-users say they will never use BIM.** This group has more than doubled in size since 2009 and is most extreme with 2012 architects, 38% of whom are devout non-users.
- **The group actively evaluating BIM has shrunk from 22% in 2009 to 13% in 2012** demonstrating the reduced interest among the remaining non-users.
- **Even the neutral category, open to BIM but not believers or actively evaluating, has scaled back from 43% in 2009 to 33% in 2012.**

Non-users in this 2012 research were given an additional option of saying they were not familiar with what BIM is. Despite showing the highest rate (74%) of BIM adoption in 2012, **one out of five non-using contractors still do not understand BIM.**

Non-User Attitudes About BIM (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Reasons for Not Adopting BIM

When asked to rate the importance of reasons for not adopting BIM, respondents in 2012 gave higher ratings to ten out of eleven of the reasons provided as options. This strong response indicates the stiffening resistance among the remaining non-adopters to BIM.

Lack of demand is the top reason in 2012, as it was in 2009. Although demand is certainly not consistent across all markets, this perception may also mean that many BIM owners are only dealing with BIM-knowledgeable designers and contractors. Remaining relevant is an issue for non-users as more owners adopt.

Other trends include:

- **Software and hardware expense both increased significantly as reasons**, probably exacerbated by the economy.
- **Belief that current methods are better and that BIM functionality is not relevant both increased.** Though understandable for certain specialties, it is a weakening argument for mainstream design and construction firms.
- **Reasons related to training, content, interoperability with CAD, ease-of-use and liability all increased slightly but were selected by only one third of respondents.**
- **The only reason that became less of a challenge between 2009 and 2012 is not having sufficient time to evaluate BIM**, perhaps an unintended consequence of the economy. The reduced interest in this reason could also be another measure of the increased entrenchment of those who have still not adopted BIM, with a greater emphasis on active reasons rather than lack of action.

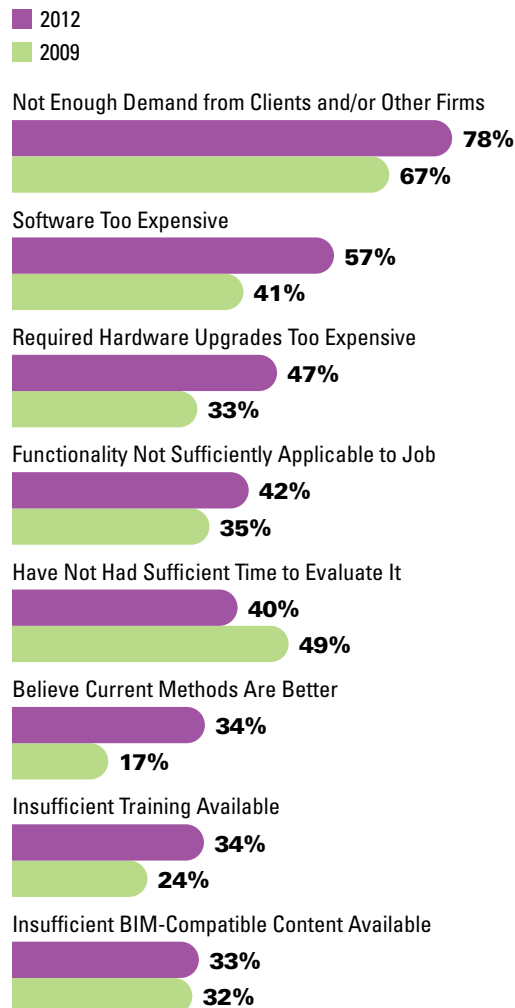
Variation by Player

Architects were early BIM adopters. As such, greater familiarity with BIM in that profession may also lead to greater resistance among those who have still not adopted.

- **Architects express more concern than others about interoperability with CAD, software and hardware expense, difficulty of software use, insufficient training available, inapplicable functionality and believing current methods are better.**
- **Engineers are most outspoken about lack of demand, and not having sufficient time to evaluate BIM.**
- **Owners object most to insufficient BIM-compatible content.**
- **Contractors report less challenges compared to other players, though they report lack of BIM content at the second highest level.**

Reasons for Not Adopting BIM According to Non-Users (2009 and 2012)

Source: McGraw-Hill Construction, 2012



AEC Perception: Competitor and Client Use of BIM

Competitor Use of BIM

Non-users' perception of the extent of BIM use by their competitors has increased. **Over three quarters (76%) expressed awareness of competitors using BIM, up from 70% 2009.**

Perception of how much BIM their competitors are doing also increased, with 25% now seeing moderate to very high competitive usage, up significantly from 15% in 2009. This increased sense of competitive pressure may ultimately counteract the hardening resistance found among 2012 non-users (see page 37).

VARIATION BY PLAYER

Looking at the non-user responses by firm-type reveals interesting differences in their perceptions.

- **Engineers have the strongest perception of competitors' BIM activity, with almost two-thirds (63%) reporting at least light usage in their market.**
- **Engineers are also the only group among non-users perceiving any competitive activity at very high levels of implementation (more than 60% of projects).**
- **By contrast, non-using contractors are almost three times as likely to be totally unaware of competitive BIM activity compared to engineers—35% for contractors compared to 13% for engineers.**

The engineers' heightened awareness of BIM use in the industry may be the result of their work as consultants to other prime design firms on teams. Through their contact with other firms, they may be directly exposed to the BIM activity, though not participating themselves.

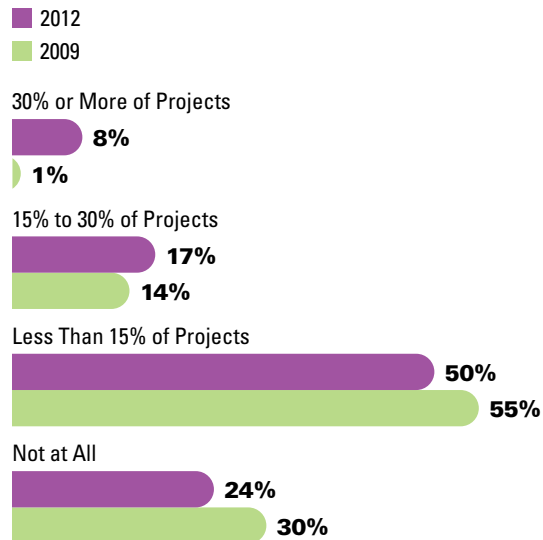
Client Use of BIM

Architects, engineers and contractors also perceive higher levels of BIM use by current and prospective clients:

- **73% of 2012 non-users are aware of clients using BIM, up from 66% in 2009.**
- **The group perceiving high or very high levels of implementation by clients (i.e., more than 30% of the client's projects) almost doubled from 2009 to 2012, from 13% to 22%.**

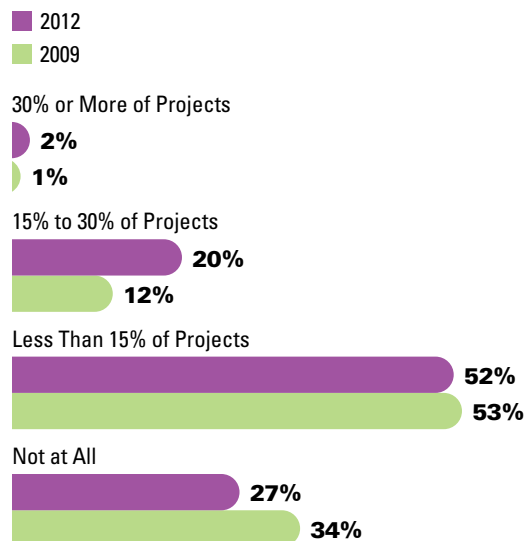
Perception of Competitors' Use of BIM According to Non-Users (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Perceptions of Client Use of BIM According to Non-Users (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Top BIM Benefits That Would Convince Non-Users to Consider Adopting BIM

Non-BIM users rated 21 BIM benefits for their relative influence on potentially convincing them to adopt. Divided into two categories (reducing problems and increasing beneficial outcomes), the top findings from each indicate what non-users are looking for as compelling reasons to adopt BIM.

Reducing Problems

Reduced number of field coordination problems ranks first among all influential benefits, and aligns closely in practice with two other top ten drivers—reduced number and need for information requests and improved accuracy of construction documents. There are enough credible metrics available from a variety of BIM projects to demonstrate that these BIM benefits can reliably be achieved by a new adopter.

Reduced construction costs and reduced construction schedule were both reported by BIM users in this research study to have increased benefit levels between 2009 and 2012.

Increasing Beneficial Outcomes

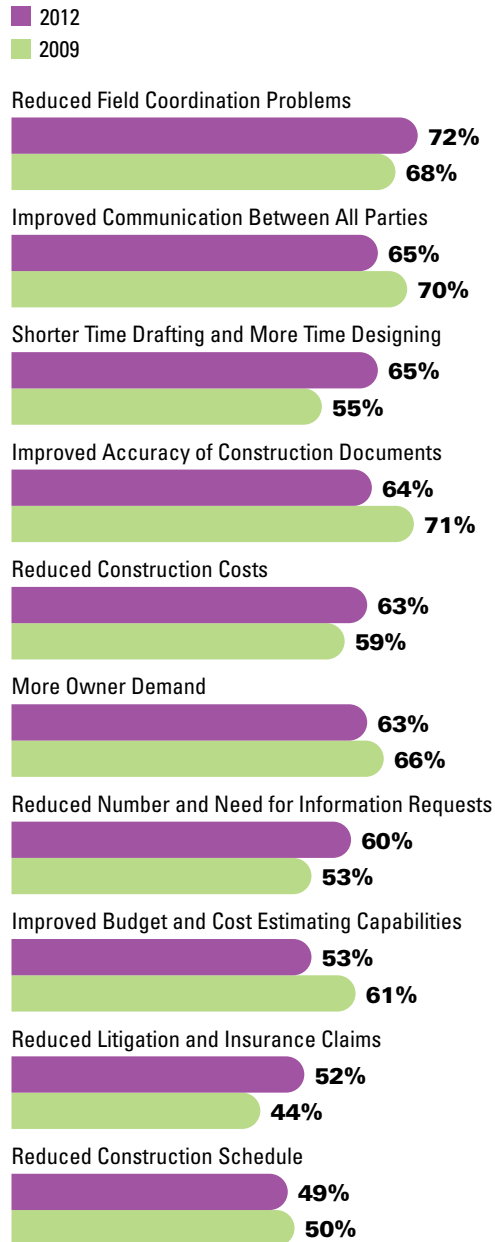
More owners demanding BIM on their projects and the ability to win new business or maintain repeat business are two sides of the business development benefit of BIM. Non-users first want to be invited to adopt BIM, but then they want other clients to hire them because of their new BIM capabilities.

Other beneficial outcomes include:

- **Improved communications between parties is a consistent theme throughout all aspects of the 2012 research.** Though difficult to measure quantitatively, its beneficial impacts are increasingly appreciated, and case studies could be leveraged to demonstrate BIM's value in this area.
- **Improved budgeting and cost estimating capabilities are being aggressively addressed by technology firms** and will benefit from modeling standards that define data in deliverables. Because these activities are so critical to contractors' businesses, however, definitive proof of reliability is necessary before a non-user would adopt BIM for this reason.
- **Reducing litigation and insurance claims is a highly tangible benefit, but will be difficult to demonstrate convincingly until many BIM projects are completed without problems.**

Top Benefits That Would Influence Non-Users to Consider Adopting BIM (2009 and 2012)

Source: McGraw-Hill Construction, 2012



Data: User Ratings for Design and Construction

Introduction to User Ratings Data Section

McGraw-Hill Construction's 2012 BIM research features an important new set of BIM user ratings of the frequency, value, difficulty and/or impact of several dozen specific BIM activities and processes. The resulting user ratings are:

- **User Ratings of BIM Activities**
- **User Ratings of BIM Processes**

Indexes Used to Analyze the User Ratings Research

McGraw-Hill Construction developed weighted indexes on a 1–10 scale for each BIM activity and process reflecting users' relative attitudes.

- **Frequency Index** represents how often BIM users engage in the activity or BIM is used for a process.
- **Value Index** represents the relative level of value that BIM users receive from the activity or the use of BIM for the process.
- **Difficulty Index** represents the relative degree of difficulty that BIM users face in achieving value from that activity or to use BIM for that process.
- **Impact Index** represents the beneficial impact that using BIM has on a process.

Value/Difficulty Ratio

This ratio divides the value index by the difficulty index for certain BIM activities in order to show how valuable they are relative to how hard they are to do. The ratio is based on a scale where zero means the value and difficulty are equal. The ratio score for each activity is the percentage above or below that zero equilibrium point.

- **A positive value/difficulty ratio means an activity creates a lot of value and is relatively easy to do.**
- **A negative ratio means an activity is harder to do than the value it generates.**

Implications of the Indexes and Ratio

A BIM activity with a low value/difficulty ratio ought to have a low frequency index because users would avoid activities harder to do compared to the value they generate. But interestingly, exceptions occur, and these indicate a strong enough commitment to the value of the BIM activity to engage in it frequently in spite of its difficulty. These are activities requiring industry attention to improve ease-of-use.

Conversely, some activities with a very positive value/difficulty ratio are still not widely done, indicating a potential for rapid growth once awareness increases.

Key Findings in the User Ratings Data Section

BIM ACTIVITIES FOR DESIGN

- Modeling the building envelope by architects is the most frequent BIM design activity and has the highest frequency index of any activity rated in this research.
- Interior space calculations and analysis has the most positive ratio between high value and low difficulty among design activities—and of all activities rated in this research.
- Analyzing mechanical system performance by mechanical engineers is rated as the most difficult design activity.
- Structural analysis rates is among the most difficult activities, but very high frequency and value ratings indicate a critical need to make it easier to perform.

BIM ACTIVITIES FOR CONSTRUCTION

- Spatial coordination dominates both the value and frequency ratings among team-oriented preconstruction activities.
- Quantity take-off is a fast-growing activity that will be accelerated by better modeling standards.
- Constructability analysis and job site logistics are contractors' top-rated uses of BIM for their scope of work.
- Mechanical and structural are the leading uses of BIM for model-driven fabrication.

BIM PROCESSES

- On three quarters of the projects where architects produce models, they are the only team member doing so.
- The highest level of model-sharing activity is taking place between contractors and fabricators.
- Most owners, architects and engineers give strong ratings to accuracy, completeness and quality of models they receive from others.
- Although the use of BIM for operations and maintenance/facility management processes is still emerging, its use to involve those staff in design review is an important trend.

Base Building Design Activities

Design-related activities with BIM are the most widespread and mature, with many practitioners at high experience and skill levels. These user ratings demonstrate the advanced state of certain activities and point towards more development to come in some emerging uses.

Modeling the Building Envelope

Because it is such a mature activity, it is not surprising that using BIM to model the building envelope receives an 8.2 frequency index, highest among all BIM activities rated in this research. It is especially popular with very high E-Level users (9.6). It also features one of the most positive value/difficulty ratios (21%).

Asked to identify the factors that impact the difficulty, the following percentages of architects rated the importance of these specific challenges as high or very high:

- **Software too hard to use: 67%**
- **Hardware insufficient: 21%**
- **Available content insufficient: 65%**
- **Internal skills insufficient: 52%**

Position a Project on Its Site

This use of BIM for this is also popular, with a frequency index of 5.9. Its lower value/difficulty ratio (13%) may reflect the findings about the difficulty of getting modeled site information to use as a starting point.

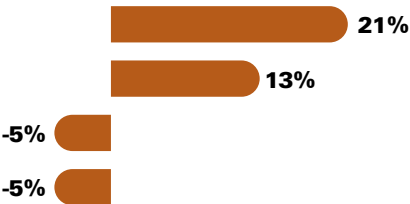
Sustainability Rating and Life Safety/Code Analysis

Although many respondents see value in using BIM for these activities, few are doing them, even among the top E-Level group. The high ratings by all users on the difficulty index explain the challenge. This clearly represents an opportunity for the industry to improve the usability of these tools and encourage more users to perform these valuable activities.

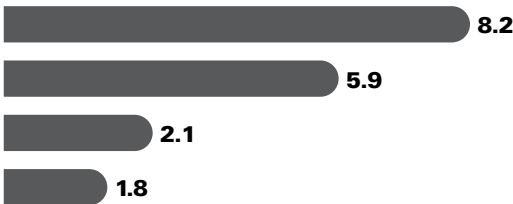
BIM User Ratings for Base Building Design Activities

Source: McGraw-Hill Construction, 2012

Value/Difficulty Ratio



Frequency Index



Interior Planning and Construction Activities

As BIM use for base building design continues to advance, applying it to design and construction of interior spaces is a natural extension. **The interiors category is unusual because all the activities show very positive value/difficulty ratios, far exceeding the average 6% for all 25 rated activities.** This suggests users are getting great value with relatively low effort for these activities.

Modeling Interior Construction

The frequency indexes for interior work also score well above the total research average of 3.6. Use of BIM to model interior construction is particularly widely adopted with a frequency index of 7.2, not far behind modeling the building envelope (see page 42). This is logical because the activities are often conducted by the same staff, leveraging architectural training and detailing skills. The greatest challenge reported by architects is a lack of BIM content to support this type of work.

Difficulty Index for Architects Using BIM to Model Interior Construction

- Software too hard to use: 46%
- Hardware insufficient: 14%
- Available content insufficient: 75%
- Internal skills insufficient: 14%

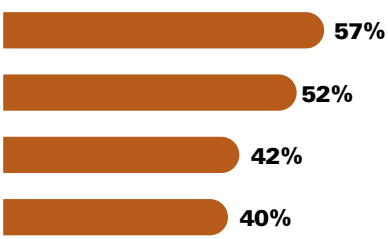
Interior Space Calculations and Analysis and Layouts and Space Plans

Though performed slightly less frequently, these are still quite common activities and have strong value/difficulty ratios. Layout and space planning rates especially well with top E-Level users, reaching an 8.4 frequency index with that group. This suggests a learning curve for less experienced users that is holding back the overall scores, but as experience increases, use of these features should increase.

BIM User Rating for Interior Planning and Construction Activities

Source: McGraw-Hill Construction, 2012

Value/Difficulty Ratio



Frequency Index



Technical Analysis Activities

Technical analysis remains a challenging aspect of BIM use, but will certainly gain importance as the data in models become more reliably consistent and the tools to conduct analysis become easier to use and more comprehensive.

Structural Analysis

The use of modeled data for structural analysis has a healthy frequency index of 5.0, well over the 3.6 average, but it is one of the worst performers in the value/difficulty ratio (-19%). Looking more closely at the data by respondents' E-Level shows that their assessment of difficulty increases with skill and experience, an opposite finding from almost every other BIM activity. The highest E-Level users are very active (8.0 frequency index) and ascribe a very high value (9.0), but give structural analysis with BIM the most extreme difficulty index (9.5) of any rated activity.

Mechanical Systems Performance

Although mechanical engineers are active modelers for spatial coordination and fabrication, their use of BIM for analysis of mechanical systems performance shows the most negative value/difficulty ratio (-29%) of all 25 rated activities.

Other Technical Analysis

- **Energy use/performance** by architects and engineers, **lighting/daylighting analysis** by electrical engineers and **thermal comfort analysis** by mechanical engineers all show slightly positive value/difficulty ratios, but are still well below average (3.6) in usage.
- **Airflow analysis (computational fluid dynamics) is least used by architects and engineers** and is very difficult for the value received. This is definitely an emerging BIM activity, where further awareness and development of technology, processes and best practices is needed.

Structural Analysis Indexes According to Structural Engineers

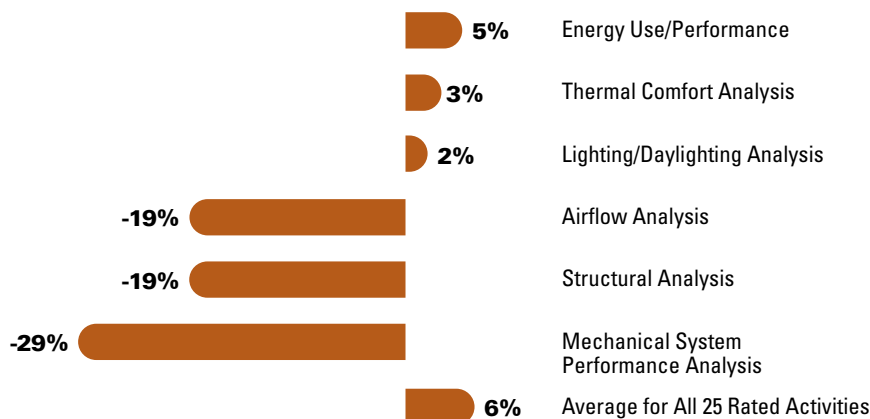
Source: McGraw-Hill Construction, 2012

	Low E-Level	All	Very High E-Level
Frequency Index (1–10)	5	5.2	8
Value Index (1–10)	4.2	6.4	9
Difficulty Index (1–10)	6.7	7.9	9.5

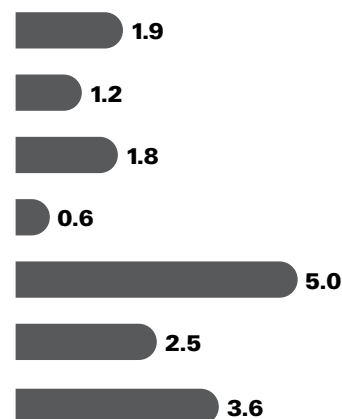
BIM User Ratings for Technical Analysis Activities

Source: McGraw-Hill Construction, 2012

Value/Difficulty Ratio



Frequency Index



Interview: Thought Leader



Charles Eastman

**Professor in the Colleges of Architecture and Computer Science
Director, Digital Building Laboratory (DBL),
Georgia Institute of Technology**

How did you get involved with BIM?

EASTMAN: In 1970, I got a [National Science Foundation] contract at Carnegie Mellon University to develop building model representation. Before BIM was invented as a term, we just called it 3D parametric modeling of buildings. The construction industry didn't pick it up back then so I consulted to General Motors and Boeing on 3D solid modeling, but I was at the very beginning.

How has BIM impacted the construction industry?

EASTMAN: Technology now is an important player in success or failure in architecture firms, in construction firms, in fabrication companies. It is very synergistic with Lean Construction methods for reducing costs and reducing errors.

I think it's also attractive to young, smart people who see this is really exciting, not the old-fashioned industry it was a few years ago. When we were using construction documents, how many people on a whole construction team could really read those documents and interpret them at a level needed to build the building? Not very many. Now everything is visual—the 3D clash detection meetings in the iRooms, the owner walkthrough of the details of a project. Communication has been fundamentally changed. I think architectural drawings are like medieval, archival documents that

"I think architectural drawings are like medieval, archival documents that nobody can understand. They won't need to understand them ten years from now."

nobody can understand. They won't need to understand them ten years from now.

What are the most important current BIM needs to most effectively advance the industry?

EASTMAN: There are two big needs. One is model checking to validate the information in a model that we're relying on for estimation, scheduling and other critical functions. The second is better interoperability.

How do you think BIM will change the industry over the next ten years?

EASTMAN: We're going to see a big growth of offsite fabrication, even of custom, highly varied systems. That will impact scheduling, where it's not three days or here's the schedule for the week; we'll have day-by-day scheduling or even less than that. Deliveries will be just-in-time.

Another thing will be heavy use of laser scanning for quality control and placement, not only in retrofit operations but in new ones. Tolerancing in reinforced concrete structures is an example. If you want a waterproof building, today's one inch tolerances are not acceptable. With lasers we should be able to pin that down to 1/16 of an inch

or less. Also, we'll see a lot more design optimization with parametric modeling. Now it's viewed as a kind of research, but I think that'll be really common.

What are the Digital Building Lab's future plans related to BIM?

EASTMAN: DBL is focused on developing new applications and uses of BIM, such as augmented reality to view a model through an iPad to see maintenance information about the mechanical equipment. Or simulating the 4D construction process for better schedules and safer working conditions among multiple crews. We're also improving [U.S. Department of Energy] energy analysis software to include an uncertainty factor when you do an energy simulation. And one of our core areas will continue to be interoperability using the IFC ISO standards, particularly for structural steel, reinforced concrete and precast concrete. I think we're in line for some revolutionary changes. ■

BIM Standards Evolve with Greater BIM Use

Even when BIM was just emerging in the construction industry five years ago, practitioners already realized its potential for transformation and recognized the need for new contracts and standards. As BIM adoption becomes prevalent, greater efforts are being made on this front.

With the emergence of BIM as a tool for sharing intelligent models among team members, several industry initiatives were launched in 2007 and 2008 to help better define the collaborative process.

Given that many firms were just beginning to add BIM and BIM-related tools to their workflow, those initiatives generally established high-level standards and guidelines, allowing flexibility as technology and techniques evolved.

As BIM has become standard practice among a growing segment of the industry, teams have developed best practices and ventured into new applications of the technology, prompting several industry groups to update their BIM business standards and make them more comprehensive.

Contracts

In August 2012, the AIA produced a draft to update its digital practice documents. Markku Allison, resource architect at AIA, says that AIA recognized by 2010 that it would need to look into updating its BIM-related documents.

“Our typical drafting schedule is on a 10-year cycle, but that doesn’t work with something as new and transformative as BIM,” he says.

As part of its scope, Allison says he expects the documents will better address various delivery methods. He notes that in a linear process, like design-bid-build, not all parties are typically working on a project when

agreements are first drafted.

“You aren’t at a stage in the project where it’s easy to delve into the detailed protocols,” he says. “The [proposed e203 draft] allows you to set the framework with regard to expectations with digital data and BIM, so that you can negotiate the scope of services based on assumptions of how you will use digital data and BIM on the project. When it makes the most sense, you sit down and set up the detailed protocols.”

Allison says he expects the documents will better address emerging uses as well, such as post-construction purposes.

AGC started a working group in 2012 focused on updating its ConsensusDOCS 301 BIM Addendum, which was originally released in June 2008.

“The challenge at this point is to define what is the state of the art and how are people using it,” says Brian Perlberg, senior counsel at AGC.

One critical area that is being considered for update is “level of reliance.” The current BIM Addendum allows a party to choose between three levels of reliance:

- **Each contributor represents that the dimensions in its contribution to a model are accurate and take precedence over the dimensions called out in the drawings or inferred from the drawing. Details and components that are not represented in a contribution to a model must be retrieved from the drawings.**

- **Each contributor represents that the dimensions in its contribution to a model are accurate to the extent that the BIM execution plan specifies dimensions to be accurate, and all other dimensions must be retrieved from the drawings.**
- **Contributors make no representations with respect to the dimensional accuracy of their contribution to a model. A model can be used for reference only, and all dimensions must therefore be retrieved from the drawings.**

Levels of Development

The AGC BIMForum also has a working group looking into expanding and refining the definitions of Levels of Development (LOD) to help teams working in a BIM environment better understand expectations. The basic LOD framework was established per the AIA E202 document in 2008. Since then, the five levels of LOD have served as high-level guidelines for how to model.

Generally, users understand the different levels of development as:

- **LOD 100 = Conceptual Design**
- **LOD 200 = Schematic Design/Design Development**
- **LOD 300 = Construction Documents**
- **LOD 400 = Fabrication**
- **LOD 500 = As-Built**

But James Vandezande, principal at HOK and a member of the LOD work-group, says those kinds of broad definition often cause confusion.

"If anyone is using LOD today in the context of sharing and collaborating on models, it's problematic," he says. "You can't have any kind of contractual or legal reliance on the data without more definition."

The workgroup aims to further define what different levels of development mean for different disciplines. Vandezande expects the group to deliver a detailed LOD specification that can be used by any team member to define individual expectations.

Currently, Vandezande notes that some stakeholders are creating their own refined definitions. For example, the U.S. Army Corps of Engineers (USACE) released its Minimum Modeling Matrix (M3) in September 2012.

Under USACE's M3, for example, LOD 300 is defined as: "Model elements are modeled as specific assemblies accurate in terms of quantity, size, shape, location and orientation. Non-geometric information may also be attached to model elements, accurate to the degree dimensioned or indicated on contract documents (i.e., a pump would be a generic pump of accurate size complete with connections and clearances for a complete system)."

Within each LOD, M3 then uses a grading system where "A" means 3D and facility data; "B" means 2D and facility data; and "C" means 2D only.

While those definitions are helpful when working with a specific client, Vandezande says a universal specification is needed to have a broad impact. He expects that users will be able to include recognized industry-wide LOD specifications within contracts to better define risk and improve model sharing.

The workgroup, which started in 2011, hopes to wrap up the LOD project in 2013.

Implementation Plans

The Computer Integrated Construction (CIC) Research Program at Penn State helped establish the need for teams to focus early on the end-product when it released its BIM Project Execution Planning Guide in 2007. The guide focuses on creating a BIM project execution plan to provide a structured procedure for planning and communication among the project team members.

In 2012, CIC expanded its efforts to focus on the emerging needs of owners with its BIM Planning Guide for Facility Owners. "The goal of the guide is to help an owner organization with planning an overall implementation strategy for BIM on an organizational level," says John Messner, associate professor of architectural engineering at Penn State.

The new guide helps owners create a high-level strategy planning road map that would include BIM and a detailed implementation plan that can be developed by BIM implementers within the organization. Another section of the guide focused on contracting strategies to enable owners to hire additional support for their BIM efforts.

Messner says the guide takes on what is arguably the most challenging aspect of BIM planning. "It's difficult to change the way people execute facilities management. For BIM to be successful within an owner organization, that organization needs to look at the fundamental processes

they are performing and consider new ways to gain efficiencies. But it takes a culture shift and a process shift for organizations, which is not easy. There are legacy systems within owner organizations that have been in operations for decades. With an owner, you're moving into a functioning organization and you need to convince them to alter that." ■

Team Preconstruction Activities

The user ratings for applying BIM to preconstruction activities that focus on team integration demonstrate the clear, practical relationship between value, difficulty and frequency for each activity.

Spatial Coordination

This ranked as a top activity in McGraw-Hill Construction's 2009 BIM research, and the strong 2012 user ratings in both frequency and value-for-effort demonstrate its value to BIM users. **Only 5% of respondents classify spatial coordination as very difficult and all users (100%) believe it has value, which gives it the second most positive value/difficulty ratio (53%) among all activities rated.**

Already being used to some degree by 91% of respondents, spatial coordination is expected to see nearly universal use over the next few years as it is adopted as standard practice.

Quantity Take-Off

A fast growing use of BIM, quantity take-off leverages the underlying database of information in a model, eliminating hours of manual counting work from printed plans. The quality of the model presents the largest challenge because the data need to be complete and accurate. As standards for Level of Development gain traction in the industry, this practice should become routine. (See page 46 for more information on Level of Development standards.)

Preliminary Design Phase Budgeting

The ability to bring more cost certainty in the early design stage may prove to be one of the most important ways that BIM will impact the design and construction industry. The current challenge is that BIM users find this budgeting hard to do, driving a negative value/difficulty ratio. These challenges may reflect issues with the quality and quantity of information in early stage models.

4D Models for Relocations/Moves

4D models, which are 3D models linked to schedule, are seeing relatively low frequency of use to plan phased sequences and occupancy in renovation, retrofit, additions or multi-project programs. Yet again, this is an example of strong perceived value outweighed by difficulty, thereby discouraging frequency. Improving BIM skills and interoperability with scheduling tools will help this activity become standard, especially if demanded by owners.

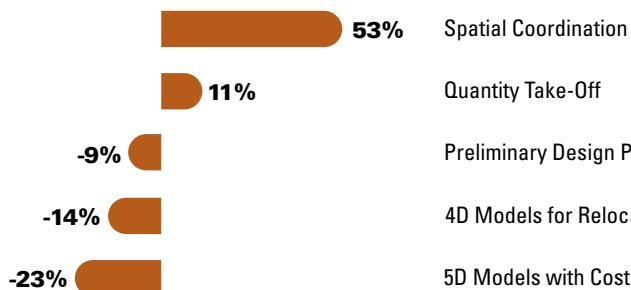
5D Models with Cost

Universally viewed as difficult, the integration of BIM models with schedule and cost data is one of the great promises of BIM. But at this point, even the very high E-Level users are cautious, with only 8% believing it is easy or very easy. However, the seamless integration of geometry with schedule and cost data has the potential to be a fundamental value proposition of BIM in the future if its difficulty can be surmounted.

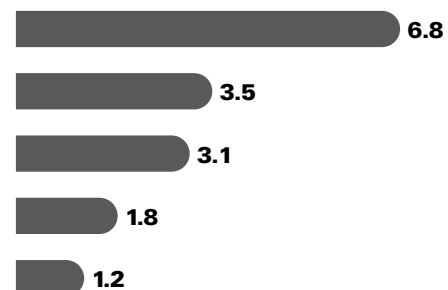
BIM User Ratings for Team Preconstruction Activities

Source: McGraw-Hill Construction, 2012

Value/Difficulty Ratio



Frequency Index



Contractor Activities

The research data demonstrate that BIM is seeing increasing growth among contractors (see page 9). That growth is due to the ways in which BIM supports many activities during the construction phase of the project.

Constructability Analysis

Using BIM to validate constructability is becoming a standard practice among contractors with modeling skills. Generally involving the further development of a design team's work to a deeper level of fabrication-ready detail, constructability analysis can reduce risk by proving greater certainty of in-place performance as well as constructability, especially on high risk elements like the building envelope.

The moderate frequency index (4.4) likely reflects the percentage of contractors with the internal skills to conduct this activity. This is supported by examining the results by E-Level, where high users who report frequency rates three times higher than low users.

Jobsite Planning and Logistics

The value/difficulty ratio and frequency index are nearly as strong for job site planning and logistics as they are for constructability analysis, which suggests that once contractors develop internal modeling skills, they apply them to a wide variety of practical uses. Indeed, the very high E-Level users show twice the frequency of the low E-Level for these tasks.

Labor and Cost Estimating for Bidding

This is a low frequency activity across all levels of BIM use. Three quarters of low E-Level contractors never do it, and very high E-Level BIM users only have a 2.2 frequency index, not much higher than the 1.8 rating overall. The problem is the difficulty—even the high E-Level contractors report a high difficulty index of 6.7. Until model data can be trusted as accurate and comprehensive, users will rely on existing methods.

4D Models for Construction Phasing and Scheduling

With a very negative value/difficulty ratio (-26%) and a below average frequency index (2.3), the use of 4D BIM models by contractors is clearly still in its developing stages. Even very high E-Level contractors report low use, and all firms report high difficulty. Despite the high profile 4D work being done by some of the larger contractors, most firms cannot take advantage of this activity.

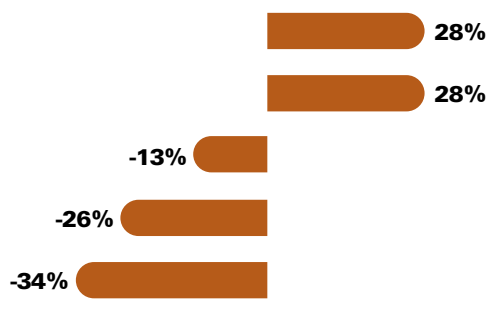
Cost, Project Management and Accounting Software Integration

This complex integration confounds and frustrates many practitioners, due to the compound challenges of inconsistent data quality from models and the lack of interoperability between key tools. This is an activity where the very high E-Level users ascribes a higher difficulty index (7.5) compared to low users (5.8), likely because these more experienced companies have actually tried it and understand what is really involved.

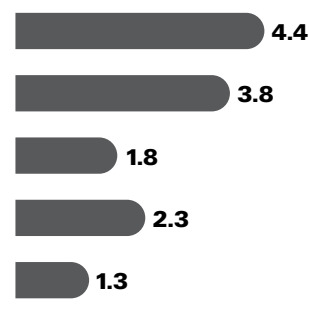
BIM User Ratings for Construction and Fabrication Activities

Source: McGraw-Hill Construction, 2012

Value/Difficulty Ratio



Frequency Index



Model-Driven Fabrication

One of the most exciting areas of BIM is the use of models for fabrication at a high degree of accuracy, often in off-site facilities where labor is less expensive and quality control can be enhanced. Research published in the 2011 *Prefabrication and Modular Construction SmartMarket Report* demonstrates that prefabrication can lead to significant reductions in the project budget and schedule.

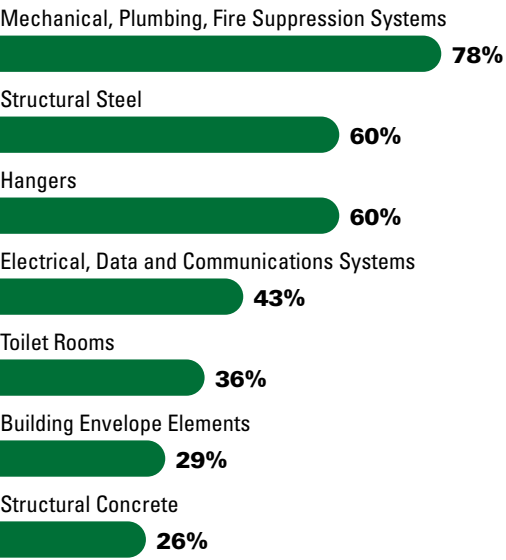
Model-Driven Fabrication by Trade

- Mechanical contractors lead with mechanical systems and hangers in the top three most popular building elements for BIM-driven fabrication.
- Structural steel fabricators have a long and successful history with model-driven fabrication. (See page 36 to for more information on using BIM to support steel fabrication.)

Using prefabricated toilet rooms has become more common recently, and it may be a precursor to use of BIM for prefabrication of larger and more sophisticated room-types, with buildings ultimately being assembled on site rather than constructed there. This emerging trend will have profound business impact for everyone. (See page 52 for more information on the potential benefits of wider use of modularization through BIM.)

Contractors' Use of Models for Digital Fabrication

Source: McGraw-Hill Construction, 2012



Digital Construction at the Job Site

Getting BIM to the Job Site

Contractors are developing numerous ways to bring the power of BIM to the workers on the site, enabling access to models as easily as possible.

Contractors Reporting High or Very High Activity:

- **Computer Terminals in Trailer Providing Access to Models: 52%**
- **Computer Terminals on Site to Provide Access to the Models by the Trades: 25%**
- **Mobile Devices: 20%**
- **Specialized Environments for Viewing Models (e.g., BIM caves): 14%**

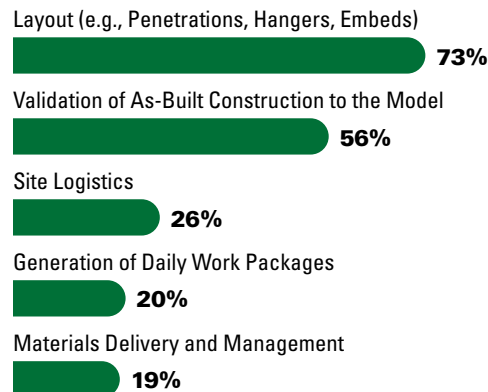
Use of BIM on the Job Site

Contractors are finding ways to leverage the modeled data to improve on-site construction work. As reflected in the frequency and value findings for job site planning and logistics, the use of BIM for a variety of site logistics will certainly continue to grow as contractors' modeling skill levels increase.

- **Contractors use model-guided tools to precisely locate penetrations, hangers, embeds and other site elements.** This trend is in keeping with the growing offsite fabrication of mechanical and building envelope assemblies.
- **Validation of as-built conditions against the model is another emerging use.** Laser scanning and digital photogrammetry are increasingly involved to capture the as-built so it can be digitally compared to the model.
- **Some leading firms use BIM to create highly detailed daily work packages for the key trades,** often involving 3D images to help convey the precise design intent and construction process.
- **Integration of BIM with radio frequency identification technologies (RFID) is enabling sophisticated materials delivery and management,** generating substantial savings of time in finding material and cost of lost or damaged material.
- **Integration of multiple parties with model data facilitates lean supply chain strategies** involving just-in-time deliveries on site, minimizing the need for storage space on tight sites and exposure of materials to the elements.

Contractors' High Frequency Use of BIM for Construction Activities on the Job Site

Source: McGraw-Hill Construction, 2012



Modularization on the Rise

Modularization is still emerging as a practice, but firms with experience report better results when projects are planned from the beginning with modularization in mind.

Greater team integration, more emphasis on lean techniques and increased use of 3D modeling have helped support a surge in prefabrication and modularization. The 2011 McGraw-Hill Construction *Prefabrication and Modularization: Increasing Productivity in the Construction Industry SmartMarket Report* found that nearly all survey respondents (98%) expected to be doing prefabrication/modularization on projects by 2013. Although the report showed that only a third of respondents were using it on a majority of projects, 45% expected to be using it at that level in 2013.

While many firms are perfecting preassembly, expanding into modularization can prove challenging. Many trade contractors have been able to work from coordinated models to prefabricate portions of their own work, such as racks of pipes. However, modules typically incorporate elements from several trades and sometimes can be difficult to coordinate, depending on which trades take the lead.

Learning Curve

Barry Brunet, virtual construction manager at Metairie, LA-based MCC Group, says the company soon saw challenges after it put its first modular plan into action on a project in December 2011. Brunet says the lead designer and general contractor on the project did not incorporate modules into the initial design. Instead, MCC suggested



Aditazz developed floor decks as components for use in its modular strategy.

the use of modules after it was brought onboard. "We probably over designed it," he says. "At the time we didn't have a lot of structural advice to go by, so we ended up wasting time and money on the front end that had to be redone."

On its next four projects, the modular concept was part of the original design. "Those have gone much better," he says. "Everything is headed in the right direction because of the commitment we have from the entire team."

Brunet says that when his team takes the lead, modular construction

can work regardless of how involved the design team is in the process, but the earlier it is incorporated into the design, the more cost-effective it will be for the client. "If the owner knows he wants modules before he even picks an architect, that would be ideal," he says. "It gets less ideal as each day passes. After a job is coordinated, it's way too late."

Owning the Process

Scott Pittman, CAD Manager at RK Mechanical in Denver, CO, says his company prefabricates nearly everything that comes out of its shop, and the firm is pushing toward greater use of modularization. Currently, the company is able to fabricate modules ranging from bathrooms to full "e-buildings."

Pittman says the company sees high potential in modular solutions because it has significant in-house services, so it coordinates with fewer parties on modules. For example, the company has a subsidiary dedicated to fabricating and installing structural steel and miscellaneous metals. As a result, the company has been able to fabricate entire small modular buildings, including water injection skids of up to 32ft. long by 16ft. wide that are used for oil extraction.

"We're doing these skids for work that's happening in the Dakotas," he says. "We can build them here in our shop [in Colorado] with our own steel and have the electricians come here and install their equipment. It's a controlled environment where we don't have to work out in the snow and

the wind. Plus the labor rate in the oil fields is outrageous, so it's more affordable."

In general, Pittman says RK Mechanical likes to take the lead on modules, but it pushes to integrate and coordinate with the entire team. "We've gotten to the point where we are trying to get our people in with the mechanical engineers while they are drawing," he says. "If we sit with them and they tell us what they want, we draw it once and we draw it right. If they do it, we end up redrawing, which is a waste of time with the time crunches we are under these days."

One Model, Many Components

Aditazz of San Bruno, CA, sees modularization as a critical component to its unique design and construction

strategy. The company is developing a system based on computer chip design that would allow building owners to simulate and virtually operate facilities during early design. This would help guide the design to ensure that a building meets owner demands, says Zig Rubel, founder of Aditazz. "Architects are good at building the building right, but not always good at building the right building," he adds.

To help keep costs down and improve reliability, Aditazz is designing modular components as part of its system. Just as computer chip designers can add and subtract "logic gates" to virtually assemble their products before fabrication, Aditazz aims to incorporate modular components early in its designs, knowing how those pieces will

function in the completed building. The company has focused on major repeatable pieces first, patenting a modular floor deck. Rubel says the trick to making reliable decks is ensuring that they will be flat by pouring concrete in a controlled environment. The company also has a patent pending on a fire-rated wall assembly. "We realized that once you know you can make floors flat, you can treat walls like furniture," he says.

The key difference with the Aditazz approach is that it isn't looking to sell its components to others. Just as with chip companies, Aditazz aims to design buildings and drive fabrication of its own proprietary components. That way, Rubel says a project team can work efficiently from one model. "At our company, we believe there should only be one model, and we want to own the data for our model. If we don't, then we'll constantly say it's not our problem."

That said, Rubel recognizes that Aditazz is not providing a fully integrated in-house solution and will partner with others who can help deliver its designs. Rubel also says he is open to incorporating modular components created by other companies, as long as they are standardized and reliable. "The typical problem is [firms] come up with the design and then try to wrap the modular concept around it."

"We're saying come up with the design with the modular solution in mind. It's a kit of parts that need to be thought about at the beginning." ■



Aditazz claims that by developing flat decks, walls can be treated "like furniture."

Interview: Thought Leader



Dana Kennish "Deke" Smith, FAIA

Executive Director, Building Seismic Safety Council and buildingSMART alliance, National Institute of Building Sciences (NIBS)

How did NIBS get involved with BIM?

SMITH: The Institute started with the Construction Criteria Base, which then expanded into the Whole Building Design Guide. These contained CAD details, so the next obvious step was to develop the National CAD Standard. The International Alliance for Interoperability, North American Chapter became part of the Institute, which was then combined with the Facility Information Council and eventually became the buildingSMART alliance. It has been a natural succession from CAD to BIM.

How has BIM impacted the industry?

SMITH: The biggest thing about BIM is that it changes relationships. People look at this as a much more collaborative process. As a result, they need a greater level of trust in the information they get from other people. It's a different relationship, truly a partnership type of environment.

What are the most important current BIM needs to most effectively advance the industry?

SMITH: Most people are still practicing "lonely BIM," and they're not necessarily communicating or interacting through models with other companies yet. Some of that resistance has to do with liability and intellectual property concerns. Consistent application of metadata to models will allow the intellectual

"There's about 57% waste or non-value-added effort in the industry. I think [by using BIM] we should be able to capture at least 30% of that—and potentially more."

property that somebody provides to the model to be continually attributed to them. That's really key to get to a higher level of trust between companies around models.

I think project delivery contracts have to change, whether we do more design-build, or even private-public partnerships where the builders actually run the building for some number of years.

The changes that have started in place with integrated project delivery are very positive, but I think that we need to make sure that expands past the hand over stage to the facility manager. So we're doing a lot of work with [the International Facility Management Association] and [International Institute for Sustainable Laboratories] to get facility managers ready to accept BIM information.

How do you think BIM will change the industry over the next ten years?

SMITH: The Construction Industry Institute and Lean Construction Institute back in 2004 calculated there's about 57% waste or non-value-added effort in the industry. I think we should be able to capture at least 30% of that, and potentially more.

What are NIBS' future plans related to BIM?

SMITH: Our biggest initiative over the next five or ten years is the National BIM Standard, which is only about 2% to 5% complete as of version 2. We're also putting in place agreements with other countries for content and expertise we can draw on. Therefore, it won't be just a U.S.-only solution. Since many companies are multinational, we need international standards. A good example of that, of course, is IFC (Industry Foundation Class—ISO 16739).

There are 150 professional associations that play different roles in the development of a facility or infrastructure and we're trying to build the alliances between the different organizations that will be the subject matter experts for the change. We see BIM expanding into infrastructure quite rapidly right now, so we will be looking at tying into GIS, too. Another big area is manufactured products and how we're going to work with the 250 or so manufacturer's associations.

I know we haven't really seen the full impact of what BIM is going to do to the industry yet. Once we can get all the currently disconnected successes linked together we will see profound change. ■

BIM Team Use of Integrated Project Delivery

BIM users report very low frequency of use of formal integrated project delivery (IPD), which involves using an IPD agreement such as AIA E202, Consensus Docs BIM Amendment, or some other other sanctioned agreement.

However, many more BIM users are engaging in less formally structured integrated design processes, defined in the research as “Establishing an openly discussed and mutually acknowledged understanding from the start of the project among key players that all parties will collaborate as much as possible to the benefit of the project.”

In practice, project teams are currently incorporating aspects of structured collaborative processes and shared goal-setting, but without the use of one of the standard agreements. Some key differences among respondents:

- **Variation by Player:** Engineers are among the players most frequently using a formal IPD. This may reflect the fact that there are several types of engineers engaged on a typical IPD project, resulting in a large number of respondents citing involvement.
- **Variation by Engagement (E-Level):** Very high E-Level users demonstrate significant leadership in the use of an integrated design process, highlighting their willingness to innovate with contracting arrangements.

Authoring Models

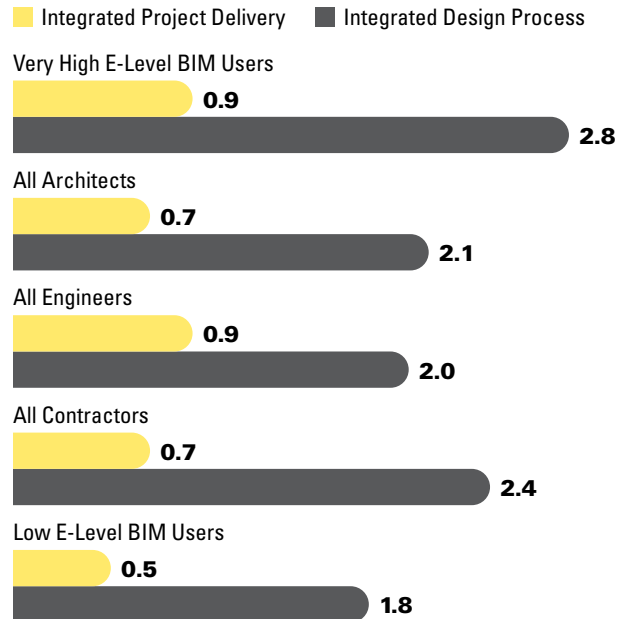
Although an increasing number of BIM projects feature multiple firms generating models, there are still many BIM projects where only one firm is creating them. This practice is especially frequent with low E-Level users, who show almost equal proportions of BIM authoring and solo BIM authoring. They may be venturing into BIM as a pioneer on a project where the rest of the team is still doing traditional CAD. This type of team arrangement is sometimes referred to as “Lonely BIM.”

Very high E-Level companies, who author models on almost all of their projects, show a 4.7 Frequency Index for being the only ones modeling.

Architects most frequently model compared to other players, but when they produce models on a project, they are the only one doing it three quarters of the time.

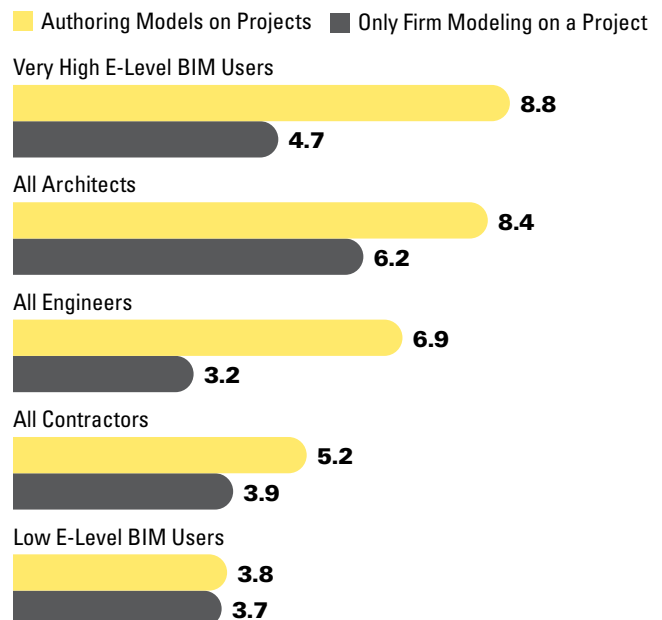
BIM Team Use of Integrated Project Delivery Frequency Index (1–10)

Source: McGraw-Hill Construction, 2012



Frequency of Authoring Models and Being the Only Team Member Modeling: Frequency Index (1–10)

Source: McGraw-Hill Construction, 2012



Model Sharing Processes

between Architects, Engineers, Contractors and Owners

Contractors share models more frequently than architects and engineers, especially between other contractors and fabricators. The lower value index (5.5) for sharing with other contractors and fabricators may be due to the need for even more of their peers to adopt BIM so that model-sharing can be universal. 26% of contractors do not currently use BIM, and of those, one in five still do not even know what BIM is. (See page 37 for more information.)

Architects and engineers are the least likely to share their models, a common complaint by contractors because it causes them additional work to recreate models from 2D deliverables that were originally authored in BIM. Design firms have strong intellectual property concerns when it comes to project documents, including those created using BIM.

The least frequent process, architects/engineers sharing with trade contractors is the only category where the perceived value exceeds the frequency, indicating a possible trend towards increased collaborative activity directly between design firms and trades.

Variation by Engagement (E-Level)

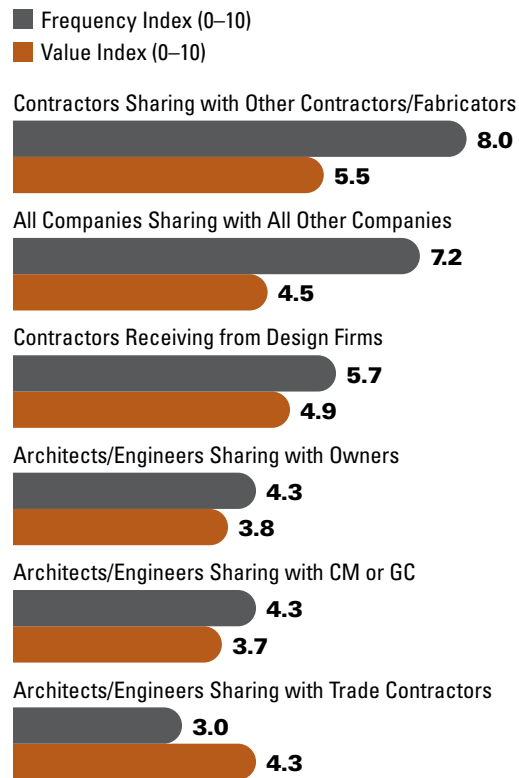
Frequency index levels for model sharing with general contractors or construction managers vary strongly by engagement level:

- **High E-Level architects/engineers: 5.8 compared to 4.3 on average**
- **All architects/engineers: 4.3 (average)**
- **Low E-Level architects/engineers: 3.8**

Design firms with higher E-Level ratings would be expected to collaborate more actively, thus accounting for their strong engagement level in this category. In addition, the very high E-Level design firms, whose behavior often predicts trends, are exchanging models with trade contractors at twice the frequency of their low E-Level peers, while also reporting significantly more value.

Frequency and Value of Model Sharing Processes Between Architects, Engineers, Contractors and Owners

Source: McGraw-Hill Construction, 2012



How Model Files Are Shared

The model-sharing infrastructure in the construction industry is still developing.

- **Most firms are using ftp sites to exchange models, especially contractors.**
- **Commercial project and document management tools with web capability is next most frequently used method of sharing, especially by owners,** a major target of the technology companies that produce project collaboration tools.
- **Email attachments are used only by a small portion of respondents—the largest share is by contractors at only 25%.** They are the least popular with owners, whose corporate IT departments usually limit large attachments.
- **Though tiny by comparison today, the emerging field of mobile devices will gain share as devices become more robust, connectivity is more reliable and functionality matures.** As an indicator of this trend, very high E-Level BIM users lead in their use.

Methods Frequently Used to Share Model Files Between Architects, Engineers, Contractors and Owners

Source: McGraw-Hill Construction, 2012

	Low E-Level BIM Users	All Architects	All Engineers	All Contractors	All Owners	Very High E-Level BIM Users
ftp Sites	48%	52%	55%	66%	33%	57%
Project/Document Management Software	22%	32%	27%	35%	52%	38%
Email Attachments	19%	19%	13%	25%	8%	15%
Mobile Devices	5%	3%	5%	9%	6%	11%

Guaranteed Energy Performance Through Modeling and Coordination

Energy Systems Integration Facility, National Renewable Energy Laboratory
GOLDEN, COLORADO

When an owner runs the premiere research laboratory for renewable energy in the U.S., it seems only fitting that energy efficiency would be the top priority when delivering a new facility. With development of the \$135-million Energy Systems Integration Facility (ESIF) on the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) campus in Golden, CO, the design-build team faced a daunting energy-performance-based guarantee that compelled the team to prove its work against energy models on an ongoing basis.

Throughout design and construction, the team, led by contractor JE Dunn Construction with SmithGroupJRR as lead designer, leveraged its extensive BIM modeling data to prove the 182,500-sq.-ft. facility could meet NREL's strict standards.

Under terms of its firm fixed-price contract, the team faces seven performance validation milestones throughout the project lifecycle, beginning at the end of preliminary design and ending at 12 months post-occupancy. The project is scheduled for occupancy in early 2013.

"This is one of the most complex and detailed energy models that one would ever build to validate a design," says Rodd Merchant, senior vice president at JE Dunn. "We had to prove everything at every step along the way. It required volumes of information, and the energy model had to be directly extracted from the BIM model."

One-of-a-Kind Facilities

Adding to the challenge, the team had to build one-of-a-kind facilities and accommodate



The \$135-million Energy Systems Integration Facility project required high standards for sustainability. The design-build team, led by contractor JE Dunn construction with SmithGroupJRR as lead designer, leveraged its extensive BIM modeling data to build a highly-complex energy model, proving its work on an ongoing basis.

high-performance equipment with large-scale energy demands. The facility includes a high-bay electrical research lab, which will be used to conduct megawatt-scale testing of electrical grids. When completed, it will be the first facility of its kind in the U.S.

The ESIF will also house a high-performance data center. At initial build out, it will demand 1.5MW of power, but it is capable of up to 10MW. The data center is designed to be among the most energy efficient in the world.

Energy-efficient office spaces are also being built.

■ Energy conservation strategies include:

- Reuse of data center and high-bay laboratory waste energy to maximize building/campus heating.
- Transfer of electrical energy from experiments between laboratories for simultaneous use/reuse.

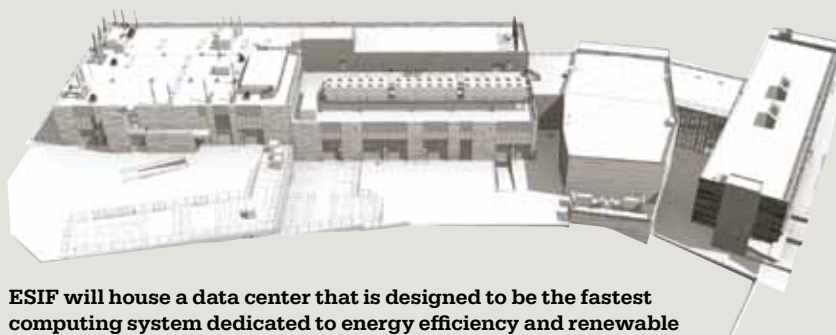
- Underfloor air distribution for interior cooling and ventilation; outside air economizer
- Active radiant beams providing perimeter cooling and heating
- Evaporative-based central cooling that meets ASHRAE 55 thermal comfort range
- Natural ventilation mode with operable windows and ventilation shafts
- Daylighting with high efficiency lighting (daylighting only from 10 AM to 2 PM)
- Energy Star-rated equipment

Tight Coordination and a Clear Plan

Merchant says the team's goals could only be achieved through tight integration and a clear BIM execution plan. NREL chose to select its design-build team through a competition, so the design sub-consultants along with electrical and mechanical sub-contractors were brought in "from

Energy Systems Integration Facility, National Renewable Energy Laboratory

GOLDEN, COLORADO



ESIF will house a data center that is designed to be the fastest computing system dedicated to energy efficiency and renewable energy technologies in the world. It will also be one of the most energy-efficient data centers in the world.

day one,” working collaboratively through the competition phase. The team used AGC ConsensusDOCS with the 301 BIM Addendum along with a “lengthy” BIM execution plan, referenced through the addendum. “We felt it was important to get standards into our subcontracts, so we did the same addendum for design consultants as well as subcontractors,” Merchants adds.

The BIM plan detailed levels of development for each discipline and their required model objects. The team kept downstream prefabrication capabilities in mind from the outset of design to cut down on future rework. Software was also defined. A mix of platforms was used—from CAD to BIM—but the team was able to use the data to create a 3D federated model.

For energy modeling, the team worked from the design model, adding input from various team members to use for analysis of energy use as well as daylighting.

Merchant says that although NREL set aggressive performance targets throughout the project, it wasn’t prescriptive about how the team should model it. “They only asked that we use commercially known energy analysis tools,” he said. “Some of those tools were developed with the help of NREL researchers.”

Due to the specialized aspects of the facility, the team worked with consultants located around the country. To help keep everyone working from the same models, the team used an early deployment of “BIM-in-the-cloud” technology. The system also helped maximize communication and transparency with the owner. While in design, the owner had access to the design model. The team could email hyperlinks to stakeholders that would direct them to specific labs.

“The hydrogen center director told us that we cut down the comments they would typically have made about drawings by 70% because it was much easier than reading [traditional] drawings,” Merchant adds. “Seeing the model helped their reading process and we got

tremendous feedback. Within a cloud-based environment available through an Internet browser, we literally taught them nothing more than to click one button. It was a big home run.”

Although NREL set a high bar for energy-performance standards, the team was incentivized to go above and beyond those targets. The entire facility, including the data center, must meet a minimum of LEED Gold certification. However, Merchant says the project is tracking toward LEED Platinum. He credits team integration and constant attention on energy modeling for helping the team exceed its goals.

Still, the team faces one last test. Final design validation will happen after 12 months of occupancy. “They will meter the heck out of this building because the energy-efficiency mission is critical to what they do,” Merchant adds.

Merchant forecasts that, with the evolution of energy modeling, similar procurement strategies could be required in the future. “Rather than just setting LEED certification targets, I’m confident that more owners will start putting these types of [ongoing] energy-performance guarantees in contracts,” he says. “The only way you can prove [a design] effectively is through detailed modeling.” ■

Project Facts and Figures

Client

U.S. Department of Energy

Contractor

JE Dunn Construction

Architect

SmithGroupJJR

Type of Project

Research Laboratory

Size

182,500 sq ft

Green Goal

LEED Gold certification
(minimum)

Construction Start

2010

Occupancy

Early 2013

Cost

\$135 million

Productivity and Green Improvements Through BIM

Terminal Renewal and Improvement Program, DFW International Airport
FORT WORTH, TEXAS

A mission to go paperless has evolved into a means for getting digital documents out into the field and improving data exchange within the build team at DFW International Airport's seven-year Terminal Renewal and Improvement Program. This finding is evidence of a fundamental shift in the understanding of the composition of green buildings. No longer is the industry equating a green building with just being an energy-efficient building. There is an increased understanding that other factors, including travel around the site, resources and productivity, are also critical for green projects.

Digital Documents in the Field

Since 2011, a joint venture of Balfour Beatty Construction, Azteca Enterprises, H.J. Russell & Company and

CARCON Industries has run the job completely paperless. Jeff Pistor, project manager at Balfour Beatty Construction, says that as part of its scope—which includes renovating two of the airport's four terminals—the team initially estimated that more than 60,000 drawing sheets would be produced and printing sets could reach nearly \$200,000.

Beyond its concerns about printing costs, the team also forecast that paper documents would hamper productivity substantially. The site is nearly 1.5-miles across with numerous secure areas that require screening by TSA. The team estimated that it could easily take employees up to 30 minutes for a one-way trip. Since the drawing sets would be based in the team trailers, some staff might have to devote hours every day to traveling back and forth between the trailers and the field just to review drawings.

To extend its capabilities beyond the trailers, more than 200 staffers are now equipped with iPads to keep digital documents at their fingertips at all times. The system syncs to a cloud server where team members can download the most up-to-date versions of drawings to their iPads. Using iPad apps, the team is able to view and markup documents. Apps are configured to automatically search for the most up-to-date versions of those documents.

Going Wireless

Due to the volume of the documents, users are encouraged to sync their iPads at night, ensuring that they start each day with updated files. However, portable WiFi hubs have been added throughout the site so that documents can be synched in real time throughout much of the site.

WiFi also enables a faster and more streamlined flow of information. Ben Bringardner, assistant project manager of integrated projects at Balfour Beatty, says the system can be used to make it easier to generate an RFI from the field. "If there is an issue, someone can take a photo of it, drop that photo on the floorplan with a note, and then send it back to the project engineer," he says. "A lot of the legwork would be done for that RFI without having to travel back to the trailer."

Due to contract requirements, Bringardner says the system is set up in a traditional manner, with each sheet from the drawing set represented by an individual digital file. To help improve flow between sheets, the team has inserted hyperlinks that direct users to additional information. "You get references to other drawings, so all you have to do is tap



James Nelson, BARC general superintendent, reviews drawings in the digital plan room, where monitors and his iPad access drawings from the same source.

Terminal Renewal and Improvement Program, DFW International Airport FORT WORTH, TEXAS

the link and it will take you there," he says. "If you need a section cut, just tap the link. It's a spider web of information."

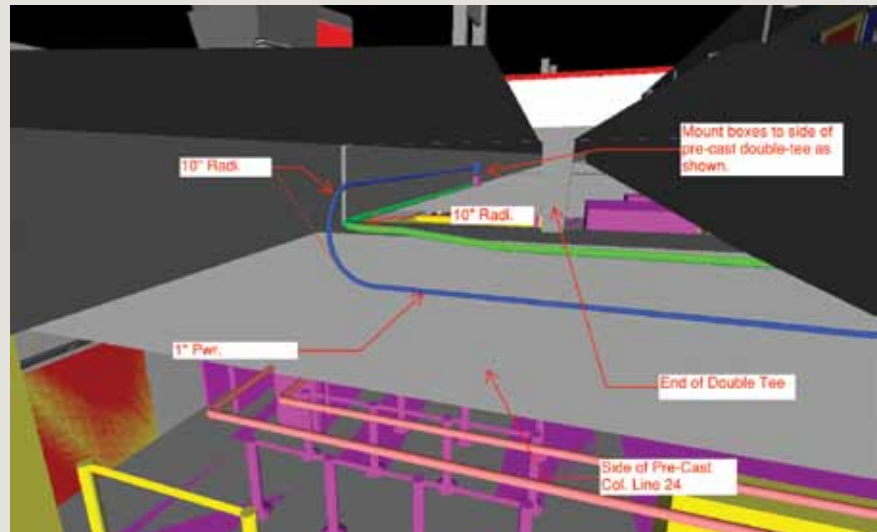
User Friendly

In developing the mobile system, the primary consideration was speed and user experience. Bringardner says it uses a time-based standard to determine maximum file sizes. "If a superintendent has to wait more than ten seconds for a file to open, they will lose patience with it," he says.

As a result, the team uses primarily PDF files among the team, which can be kept relatively compact and are easy to use. Still, the team is experimenting with emerging mobile apps for sharing BIM models, but Bringardner says the team faces a perception barrier. "Models can be complex, so it's assumed that it's difficult to navigate through one," he says. "But that's not true. Almost everyone could learn to do basic navigation, but they are resistant."

Given that PDFs seem more approachable to users, Bringardner says that 3D PDF would be ideal. However he notes that apps haven't been developed to read the files yet.

The strategy quickly reaped significant savings in both time and money. To date, more than 200 iPads have been purchased for the team. Bringardner estimates that by not keeping two full sets of printed drawings—representing around 780,000 pages—during the life of the project, Balfour Beatty saved around \$180,000. That estimate does not take into account potential savings for subcontractors, owner representatives, designers and other parties that use iPads.



Making images like these available on the iPad facilitates communication with the field. In this shot from above the airline ticket office, the team was working out a particular power path and needed to communicate its intent clearly to the installer.

The time-savings is even more significant. Given the amount of time it can take to drive around the site, Bringardner says workers can save hours by not having to return to the trailers to review plans. For example, quality control staff save up to two hours per day in travel time that they can instead use to address issues in the field, he says.

As part of an ROI study of the system, Balfour Beatty estimated the maximum time required to payback the cost of an iPad. If a user saved two hours in travel time per week, used the most expensive server and took advantage of full IT support, the most expensive iPad available would be paid off in six months.

"That doesn't even account for reduction of errors in the field and improved communications," Bringardner adds. "We know these pay off much faster on average if you consider all the factors." ■

Project Facts and Figures

Project

DFW International Airport Terminal Renewal and Improvement Program, Terminal A and C Renovations, New Rail Station

Joint Venture

BARC- Balfour Beatty Construction, Azteca Enterprises, H.J. Russell & Company and CARCON

Program Manager

Freese and Nichols

Type of Project

Airport

Construction Start

2011

Contract Value

\$900 million

Architects, engineers and especially owners give good marks to the accuracy, completeness and quality of models they receive from others. This is consistent across all E-Levels. Some notable differences in ratings:

- **Engineers and contractors are less enthusiastic on rating the overall usefulness of others' models to their business processes.** This may reflect poor coordination around expectations and requirements for levels of development (LOD) of the incoming models.
- **Receiving a model with a designated LOD is not rated very highly, with 20% or fewer AEC firms rating it high or very high.** Engineers report the lowest at 13%. The exception to this is owners, where 30% rate it highly.
- **Contractors frequently are required to sign restrictions or limitations of liability as a condition of receiving models from others, whereas it is rare for designers.** This explains why 43% of contractors rated this aspect highly.

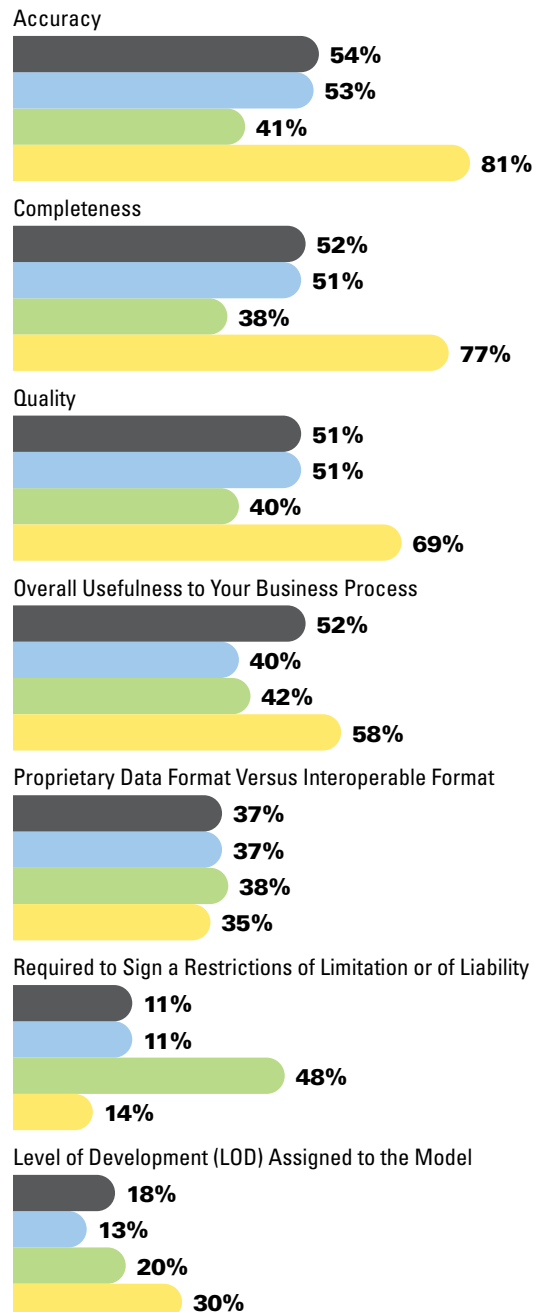
As more firms exchange model files and rely on them for incremental work, the quality of the files and the way they are constructed becomes increasingly critical. For more information on industry initiatives to address model quality, see page 16 and the Resources section on page 69.

Rating Specific Aspects of Models Created by Others

Highly Rated Aspects of Models Created by Others (High or Very High Rating)

Source: McGraw-Hill Construction, 2012

■ Architect ■ Engineer ■ Contractor ■ Owner



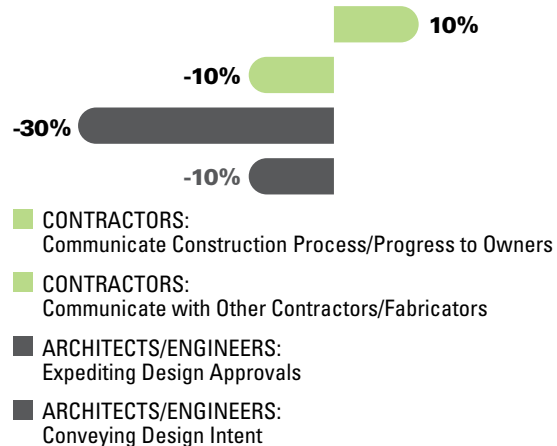
Use of BIM-Generated Visualization for Specific Processes

Contractors and design firms frequently leverage the powerful visualization capabilities of BIM for business purposes, but they mostly report receiving below-average levels of value. Analyzing the ratio between their frequency and value ratings for specific activities reveals some interesting trends.

- **Though the frequencies are similar, architect and engineer respondents find far greater value using BIM-generated visuals for conveying design intent than they do for expediting the design approval process, which would be a more tangible business-related impact.**
- **The lowest frequency for contractors is using BIM visuals to communicate construction process/progress to owners, yet it has the only positive frequency/value ratio.** This suggests that use of this activity can be expected to grow because of its effectiveness in keeping project teams coordinated and helping owners make better, more-informed decisions.

Frequency/Value Ratios for Specific Uses of BIM-Generated Visualization

Source: McGraw-Hill Construction, 2012



Using BIM for Project Close-Out Processes

Contractors, with the assistance of architects and engineers, are responsible for several close-out processes and many are finding ways to leverage models to increase efficiency.

- **BIM is least actively used for punch list creation and management.** However, as tablet compatibility with BIM increases, this process will certainly show growth.
- **Using BIM for close-out submittals is three to four times more popular than punch lists.** Linking product

and material information to the objects in a model is a fundamental value proposition of BIM for Operations & Maintenance (O&M)/Facility Management (FM).

- **As-built record models are increasingly required by owners. In fact, only 7% of BIM contractors report never being asked for one.** This is the most-used BIM close-out process, and it is likely to become a fixture of BIM projects, especially as model standards for O&M/FM, such as COBiE, are more fully deployed.

High Frequency Use of BIM or Project Close-Out (by Firm Type)

Source: McGraw-Hill Construction, 2012

	Punch-List	Close-Out Submittals	As-Built Record Model
Architect	7%	22%	45%
Engineer	4%	16%	34%
Contractor	11%	34%	60%
Owner	9%	17%	46%

Operations and Maintenance/Facilities

Management Staff Involvement with Design

In general, far more money is spent operating, maintaining and managing a constructed asset over its lifecycle than is invested in its design and construction, which has made BIM for operations and maintenance (O&M) and facilities management (FM) a critical goal of virtual design and construction. Increasingly, owners and project teams are embracing the view that design and construction is just the first part of the overall asset lifecycle, and that the people who will ultimately be responsible for the later phases should have input earlier.

However, at this point the activity level is still very low. The user ratings in this section and those that follow may be significant as a baseline against which to measure future progress in this needed area.

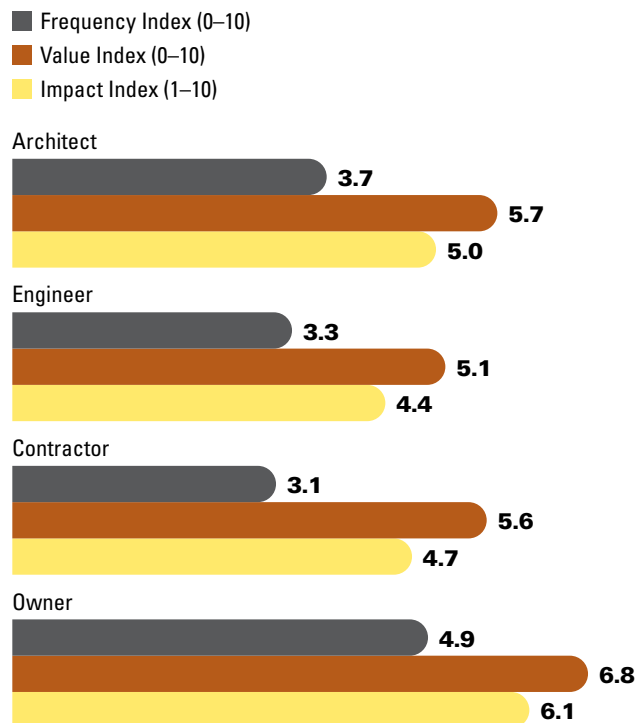
Perspectives from each firm type reveal that this factor matters most to owners:

- **Owners perceive that O&M/FM staff are more involved in BIM compared to perceptions from the design and construction teams.** This may result from internal briefings that the rest of the team does not attend.
- **Although everyone sees great value from O&M/FM staff involvement and believes it creates positive impact, owners are significantly more emphatic.**

Given the strong support by owners for their involvement, it is likely that O&M/FM participation will eventually become a standard feature of project process.

Frequency, Value and Impact of Maintenance and Operations Staff Involved in Design Review on BIM Projects

Source: McGraw-Hill Construction, 2012



Use of Models for Operations and Maintenance and Facilities Management Processes

The use of BIM for operations and maintenance (O&M) and facility management (FM) is an emerging practice, with relatively few BIM owners engaged at high levels. As O&M/FM technology tools become better able

to integrate with BIM data, and standards for turnover models become established, these are likely to become regular practices because the long term benefit to owners is so great.

Percentage of Owners Frequently Using BIM for Operations and Maintenance (O&M) and Facilities Management (FM) Processes

Source: McGraw-Hill Construction, 2012

	Building Performance Against Specified Design	Maintenance Scheduling	Asset Management	Space Management and Tracking	Building System Operating Analysis
Owner	18%	24%	24%	24%	32%

Voice of the Industry:

BIM Users Forecast Its Impact Over the Next Ten Years

BIM users forecasted the most influential impacts of BIM over the next ten years. Responses ranged across a variety of value propositions.

There was broad consensus around the positive impact of greater collaboration and integration on the entire project delivery process, making it “more transparent and better, faster, safer, cheaper” for everyone, in the words of George Pontikes, president of Satterfield & Pontikes Construction. Joseph Binning from MEPCor foresees that “IPD will become the norm in our industry.”

Analogies to other industries were also plentiful. According to Ben May, of May Construction Services, “We will take advantage of what the manufacturing sector has been enjoying for decades. That is...virtual design and troubleshooting, prefabrication and excellent onsite delivery, fit and finish for a better way to build!”

A number of users anticipate important changes in current project responsibilities. For example, Christopher Wilkins, director of engineering for Hallam-ICS and chairman of the ASHRAE BIM Steering Committee predicts that BIM will “enable A/E firms or teams to take back responsibility for developing detailed coordinated designs instead of ceding coordination to contractors.”

Leveraging BIM

Leveraging BIM for green design was on many users’ minds. “Quantification of carbon footprint will begin to drive design decision making,” according to Tom Nelson AIA, principal with Mithun. He hopes BIM will produce “immediate quantification of the energy performance characteristics and material lifecycle impacts

of a building project as you design it”.

Cool technologies adapted for construction were cited by several users, including Krupesh Kakkente, BIM Phoenix Engineer at DPR Construction who identified “cheap interactive hologram technology” for the job-site, allowing trades to get “dimensions, connection details, etc. by interacting with the design model hologram in the field.”

Business Impact

Business impact on efficiency is widely anticipated. Darren Lewis, AIA, director of design technology for Lionakis is excited about “new heights of efficiency and agility from tying BIM data into business information systems. [It is] like having modeling activities automatically fill out time cards or the model knowing its own project schedule to provide progress reports that inform billing and staffing decisions.” Viktor Bullain, regional manager, Virtual Design and Construction for Turner Construction Company sees the entire industry becoming more productive through “the convergence of BIM and lean construction methodologies.”

Owners Critical Role

Patrick MacLeamy, CEO of HOK and chairman of buildingSMART International predicted, “Over the next ten years, building owners will demand ever-increasing usage of BIM as a precondition, ushering in a new era of accuracy, quality and sophistication for the building industry.”

The importance of building

operations will also become paramount. Thomas Strong, director of virtual construction for EllisDon believes “BIM will increase the owner’s return on investment by simulating the construction and subsequent operation of facilities virtually during design, to optimize and deliver predictable operations, reduce risk, provide cost certainty and reduce financial lending costs.” Charles Matta, FAIA, deputy CIO of GSA Public Buildings Service goes even further, stating that “effectively employing BIM in the lifecycle management of a facility and Real Property Portfolio will transform the industry in ways not seen since the introduction of elevators multiplied the number of floors in buildings.” ■

Using BIM In Post-Construction Facility Management

Albert Sherman Center, University of Massachusetts Medical School
WORCESTER, MASSACHUSETTS

In 2009, much of the design and construction community was still exploring the possible benefits of building information modeling (BIM), but few had tackled its potential post-occupancy uses for operations and maintenance. That didn't deter the University of Massachusetts (UMass) Medical School when it set out to develop the Albert Sherman Center, a new 516,000 sq.ft. research and education facility at its Worcester campus.

Through its ongoing construction program, the school had begun to reap the benefits of BIM on recent projects through improved visualization, coordination and productivity, but officials saw greater potential. John Baker, associate vice chancellor of facilities management at UMass Medical School, says the school had been operating on a computerized maintenance management system for nearly a decade when plans for the Albert Sherman Center began

to take shape. He was interested in working with the build team to figure out how it could leverage data from digital as-built models to augment its facilities management (FM) capabilities. "I didn't have the solutions, but I had the vision of the end product," he adds.

The project team, which included architect ARC/Architectural Resources Cambridge and general contractor Suffolk Construction, had extensive knowledge of BIM, but neither had experience with providing data-rich models for facilities management.

Mark Dolny, senior associate at ARC, says that starting with the RFP process, Baker made it clear that he wanted to see digital integration of BIM data and facilities management data, rather than having rolls of drawings and binders of documents.

"Early on, John was saying, 'We want to be able to visualize the project by doing fly-throughs [during

design and construction], and we're hoping this will be something we can use ourselves someday,'" he recalls. "We didn't know what that meant at that time. It took a while after we were [awarded the contract] to understand that and figure out what they wanted from BIM."

Owner-Driven Initiative

Erik Servies, assistant project manager with PMA Consultants, the owner's representative, says that while there was a top-down directive to use BIM, it was not prescriptive. The team developed a BIM execution plan using ConsensusDOCS 301 to make sure key players were working in BIM and BIM-related tools, but it kept the road map flexible. "We had a general vision of what we wanted and all agreed to work together as a team to define that as we went," he says.

Even though the FM model mission wasn't well defined at first, Tom Watson, BIM/VDC director at Suffolk Construction, says the team aimed to "begin with the end in mind." Watson says it was understood that any deliverable would need to be heavily coordinated and highly detailed.

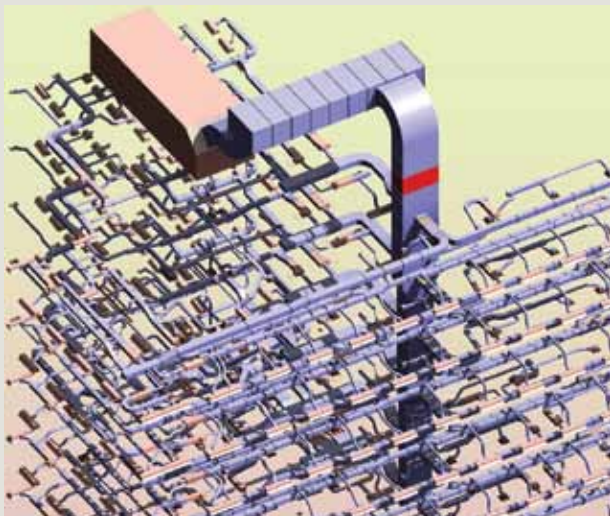
Working closely with its major consultants, ARC brought together 11 different models. In order to reduce rework, Watson says that Suffolk took design models at roughly 80% completion to start producing its construction model. From there, the team began to populate the model with fabrication-level data. "As the approved shop drawings were validated, we enhanced the model to LOD 400 or 500," he adds.

Watson says finalizing the deliverable for facilities management was a nearly two-year process. Ultimately, Suffolk's construction



While building the Albert Sherman Center, a new 516,000 sq.ft. research and education facility at The University of Massachusetts Medical School's Worcester campus, the team developed a plan to leverage BIM data for facilities operation and maintenance.

Albert Sherman Center, University of Massachusetts Medical School WORCESTER, MASSACHUSETTS



Facilities management will be able to reference models (left) as well as the properties of its elements (above).

model serves as the basis for the digital as-built models handed over to the client. The build team decided that a full-BIM model was too complex of a database for facility use, so a simpler model will be provided with appropriate FM-data, he says. "It's a much more lightweight environment," he adds.

Facilities Management Capabilities

Operations and maintenance staff will be able to use 3D models to visualize all major aspects of the facility for planning, asset management, scheduling and analysis. Users can type in a room number, then isolate everything attached to that room. Users can then select objects and bring up a control panel with information about that object. "We came up with about ten essential pieces of information that objects should have and wrote a script to pull that from the model," Watson says.

Because the model has intelligent volumes, users will be able to schedule and track everything.

The model is also able to aid in system analysis. The model contains balanced airflow and water-flow data, and users can run capacity testing. "If they need to do a renovation in the future, they could look at this model and see that they need an additional 10,000 [cubic feet/minute] in a particular spot," he says.

In the electrical systems, users could conduct circuit scheduling, lighting schedules by circuit and access facilities information by lighting type.

Although the build team has worked closely with the facilities management staff to make the model as intuitive as possible, UMass staff will need to be trained to use it. Baker is confident it will become a commonly used tool over time. "When we first installed our computerized maintenance management system over ten years ago, people said they wouldn't use it," he recalls. "We changed that mentality within a few years and now that's how we do all work orders. I see this the same way. When our guys see the benefits, they will use it."

Project Facts and Figures

Construction Manager
Suffolk Construction

Architect
ARC/Architectural Resources
Cambridge

Owner's Representative
PMA Consultants

Construction Start
September 2009

Occupancy
Spring 2013

Type of Project
Research and Education Facility

Size
516,000 sq.ft.

Green Goal
LEED Silver certification

Cost
\$400 million

While the basic deliverables have been determined, forward-looking questions remain. The model shows as-built conditions, so the FM staff will need to decide how to keep the model up to date as the building undergoes any system modifications or renovations. The model is also not currently linked to the existing building automation system, but the department may look into that in the future.

"This is the first step in an evolution," Baker says. "We'll get there." ■

Methodology:

BIM in North America Study Research

This study builds and expands upon the Building Information Modeling Study conducted in 2009 by McGraw-Hill Construction to assess adoption of BIM across the construction industry and to gauge the perception of value that firms are receiving by implementing BIM. The research in this report was conducted through an Internet survey of industry professionals between August 2 and September 18, 2012. The survey was open to construction industry professionals who classified as either BIM users or BIM non-users based on how they responded to a question about BIM engagement. The total sample size (582) used in this sample benchmarks at a 95% confidence interval with a margin of error of less than 5% for categorizing respondents as BIM users or BIM non-users.

BIM Definition

For the purpose of the survey BIM was defined as the creation and use of digital models and related collaborative processes between companies to leverage the value of the models.

Practitioners or users are individuals who are authoring and/or using models or deriving direct benefit from the use of models by others (e.g., owners).

Survey Sample

The survey sample was drawn from the following:

- **Player data from the Dodge database of construction projects**
- **Participation by ten associations who sent the survey link to their members, including AGC, AIA, ASA, ASCE, CMAA, COAA, DBIA, NIBS, SMACNA and SMPS.**

Respondents by Player

The survey had 582 complete responses. For comparison to 2009 data, the player categories are defined as follows:

- **179 architects (30.8%)**
- **111 engineers (19.1%)**
- **208 contractors (35.7%)**
- **36 owners (6.2%)**
- **48 other (8.2%) industry respondents**

Respondents by Size of Firm

The distribution by size of firms was 33% small firms, 31% small to medium firms, 15% medium to large firms and 21% large firms, with the following definitions of firm size:

- **Architect and Engineer: 2011 Billings**
 - Small firms: Less than \$500,000
 - Small to medium firms: \$500,000 to less than \$5 million
 - Medium to large firms: \$5 million to less than \$10 million
 - Large firms: \$10 million or more
- **Contractors and Owners: 2011 Revenue**
 - Small firms: Less than \$25 million
 - Small to medium firms: \$25 million to less than \$100 million
 - Medium to large firms: \$100 million to less than \$500 million
 - Large firms: \$500 million or more

Respondents by Region

The respondents' offices were distributed across the four U.S. Census regions as follows:

- **Northeast: 16%**
- **Midwest: 25%**
- **South: 30%**
- **West: 24%**

5% of the respondents were from outside the U.S.

Indexes Used for Analysis

ENGAGEMENT INDEX

For the purpose of analysis a new engagement index was created for this report. Please see page 8 for information on how the new index was calculated.

INDEXES USED TO ANALYZE THE USER RATINGS RESEARCH

McGraw-Hill Construction developed weighted indexes on a 1-10 scale for each BIM activity and process.

- **Frequency Index: How often BIM users use BIM for an activity or a process**
- **Value Index: The level of value that the user received from use of BIM for an activity or process**
- **Difficulty Index: The degree of difficulty in achieving value from the use of BIM for an activity or process**
- **Impact Index: The beneficial impact that using BIM has on a process**

VALUE/DIFFICULTY RATIO

The ratio is created by dividing the Value Index by the Difficulty Index, and demonstrates how valuable certain BIM activities are relative to how hard they are to do. The ratio is based on a scale where zero means the value and difficulty are equal. The ratio score for each activity is the percentage above or below that zero equilibrium point.

A positive Value/Difficulty Ratio means an activity is relatively easy to do and creates a lot of value. Some activities such as Spatial Coordination have positive ratios as high as 60%.

A negative ratio means an activity is harder to do than the value it generates. Some of the most challenging activities have negative ratios as low as -30%. ■

Resources

Organizations, websites and publications that can help you get smarter about building information modeling.

McGraw Hill CONSTRUCTION

McGraw Hill Construction

Main Website: construction.com

Dodge: construction.com/dodge

Research & Analytics:

construction.com/dodge/

dodge-market-research

Architectural Record: archrecord.com

Engineering News-Record: enr.com

GreenSource: greensourcemag.com

Sweets: sweets.com

SmartMarket/Industry Insights Reports:

construction.com/market_research

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BIMForum: bimforum.org

buildingSMART alliance: buildingsmartalliance.org

CADsoft Consulting: cadsoft-consult.com

Charles Pankow Foundation: pankowfoundation.org

Clark Construction: clarkconstruction.com

Hensel Phelps: henselhelps.com

HOK: hok.com

Mortenson Construction: mortenson.com

Pinnacle Infotech: pinnaclecad.com

Satterfield & Pontikes Construction, Inc.: satpon.com

techsuite: willscot.com/techsuite

Research Partners

The American Institute of Architects: aia.org

American Institute of Steel Construction: aisc.org

American Subcontractors Association: asaonline.com

American Society of Civil Engineers: asce.org

American Society of Professional

Estimators: www.aspenational.org

Construction Management Association
of America: cmaanet.org

Construction Owners Association of America: coaa.org

Construction Specifiers Institute: csinet.org

Construction Users Round Table: curt.org

Design-Build Institute of America: dbia.org

Sheet Metal and Air Conditioning Contractors'

National Association: smacna.org

Society for Marketing Professional Services: smmps.org

■ Design and Construction Intelligence

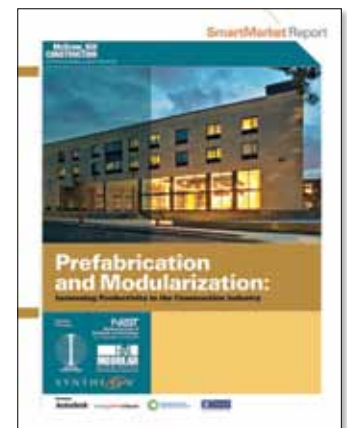
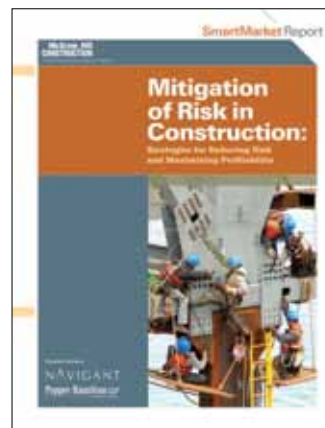
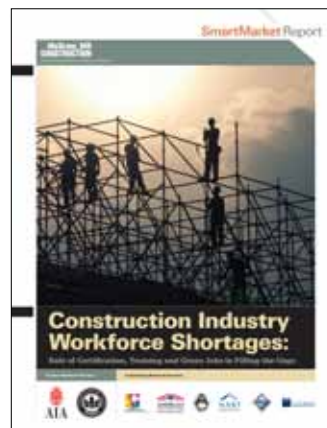
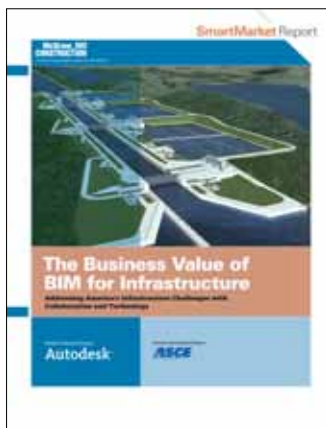
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