McGraw Hill CONSTRUCTION

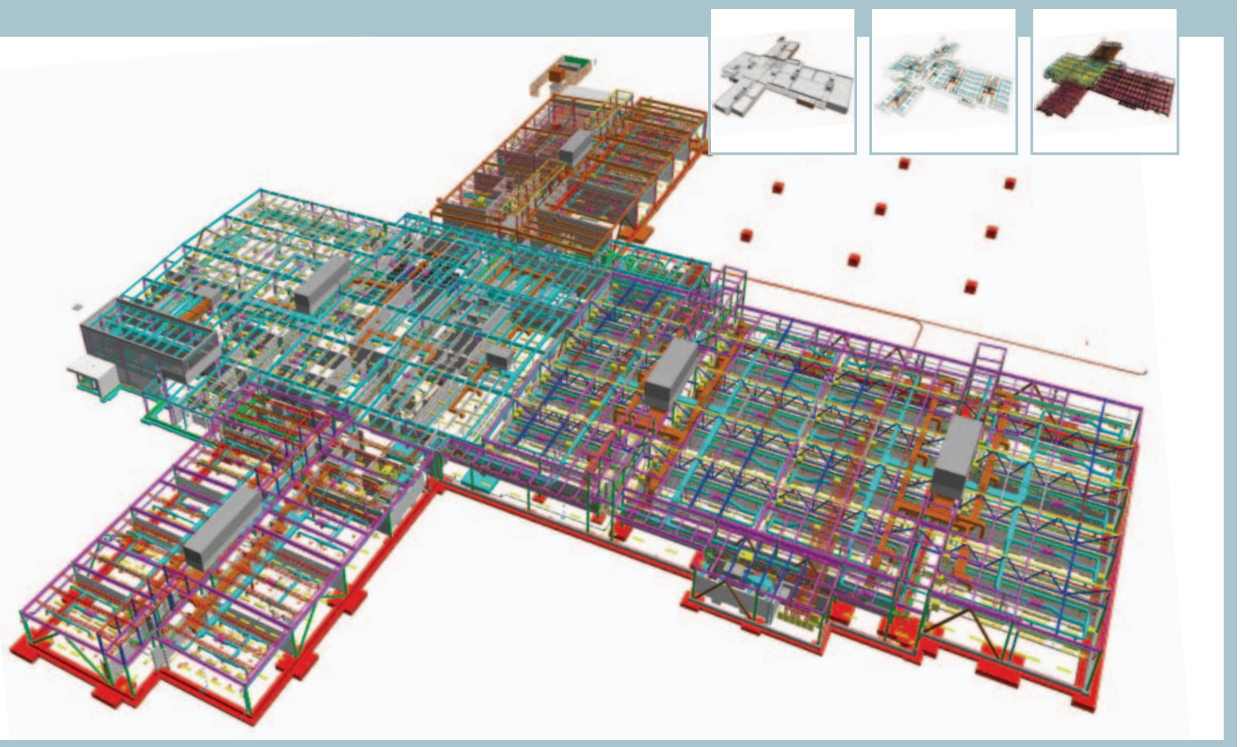
SmartMarket Report

Design & Construction Intelligence

Building Information Modeling (BIM)

Transforming Design and Construction to Achieve Greater Industry Productivity

connecting people_projects_products



Association Collaboration Partners

AIA

AGC of America — The Associated General Contractors of America — Quality People. Quality Projects.

SMPS Society for Marketing Professional Services

ACEC — American Council of Engineering Companies

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DBIA

buildingSMARTalliance

ASCE — American Society of Civil Engineers

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Introduction

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Construction is a team sport, and BIM is dramatically reshaping the way project teams work together to increase productivity and improve outcomes for all. This is driving the most transformative evolution the construction industry has ever experienced. To help everyone in the industry better understand the breadth and depth of this phenomenon McGraw-Hill Construction is very excited to publish the ***SmartMarket Report on Building Information Modeling: Transforming Design and Construction to Achieve Greater Industry Productivity.***

This report, produced in collaboration with 23 construction industry organizations — **including 15 associations and the U.S. Army Corps of Engineers** — is based on extensive interviews with hundreds of owners, architects, civil, structural, and MEP engineers, construction managers, general contractors and trade contractors who are currently using BIM. The goal was to determine knowledgeable users' perceptions of BIM adoption, implementation, value and impact within their firms. We also wanted to measure BIM user perspectives on the developing elements of a BIM infrastructure including standards, content, software, training and certification; and on the use of BIM on green "sustainable" projects.

We found that BIM use on construction projects is growing rapidly — **62% of users surveyed indicated that they will be using BIM on over 30% of their projects in 2009.** The research findings also clearly indicate that BIM expertise leads to greater understanding of BIM benefits and the value of using BIM – **82% of BIM experts believe that BIM is having a very positive impact on their company's productivity and 44% of BIM experts now regularly track BIM ROI.** This powerful trend points to an unstoppable wave of accelerating adoption and creative implementation that will redefine project delivery and affect every company in the construction industry.

In addition to providing highlights of this research, we also present in this SmartMarket Report four case studies that demonstrate how BIM is generating value for owners, design professionals and contractors in a wide variety of project types and activities from site excavation to energy analysis. All of this is further amplified by interviews, special features and a look ahead at what McGraw-Hill Construction believes will be the impact of BIM going forward. Since the need for basic BIM training is one of the findings of the report, we have also included a special **Introduction to BIM** to help educate readers who are new to BIM.

As we face uncertain economic times in 2009, and perhaps beyond, innovative approaches to project delivery such as BIM can be critically important differentiators among service firms and can help owners more effectively control costs, quality and completion schedules. This SmartMarket Report is intended to both enlighten those who have already begun their transition to BIM and encourage companies who haven't started yet. The benefits are tangible and the risks of not participating outweigh those of getting engaged.

Lastly, we want to thank the design professionals, contractors and owners who participated in the research and the sponsors who supported the report, each of whom is committed to advancing BIM for the benefit of the entire industry.

Norbert Young, FAIA, is a registered architect, with professional affiliations including The American Institute of Architects (AIA) and the International Alliance for Interoperability (IAI), where he served as Chairman of the IAI-NA Board of Directors and was instrumental in evolving IAI into the buildingSMART alliance at the National Institute of Building Sciences. A true leader and innovator in his profession, Norbert is a strong advocate for the development and adoption of global standards for data to enable true interoperability in the design and construction industry. He is an active, recognized speaker nationally and internationally, addressing such topics as "interoperability and its impact on our industry," and "current trends in interoperability." Norbert is a Fellow of The American Institute of Architects and in 2008 was inducted into the National Academy of Construction.

Steve Jones leads McGraw-Hill Construction's initiatives in Building Information Modeling, Interoperability and Integrated Project Delivery and develops alliance relationships with major corporations for technology and content. Before joining McGraw-Hill, Steve was a Vice President with Primavera Systems, the world's leading provider of project management software. Prior to that, Steve spent 19 years in a variety of design and management roles with architecture firms. Most recently he was a Principal and member of the Board of Directors with Burt Hill, one of the largest architectural/engineering firms in the world. Steve 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. He serves as Vice President of Industry Analytics, Alliances and Strategic Initiatives for MHC, where he has lead responsibility for MHC's research on thought leadership and green building initiatives. This includes research studies on future industry trends in areas such as interoperability, BIM, the global construction marketplace, sustainability, and innovation. He also is a visiting professor at the University of Reading (U.K.) School of Construction Management and Engineering.. Harvey has an M.B.A in Corporate Marketing 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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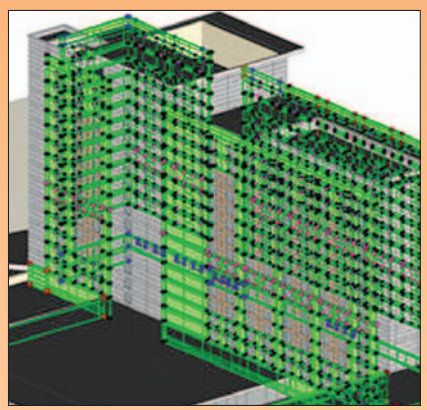

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Building Information Modeling Market Summary

Competitive Advantage of BIM in a Down Economy

McGraw-Hill Construction research shows that, in the face of an economic recession, BIM users expect to significantly ramp up their investment in BIM in 2009. Experienced users are realizing greater productivity, improved communications and a competitive edge when bidding work. As development opportunities tighten, these users continue to differentiate themselves from those who have yet to adopt the technology, bringing value to clients while improving their bottom line.

Key Findings

- **62% of BIM users will use it on more than 30% of their projects in 2009.**
- **82% of BIM experts believe that BIM has a very positive impact on their company's productivity.**
- **72% of BIM users say that BIM has had an impact on their internal project processes.**

Market Adoption and Growth

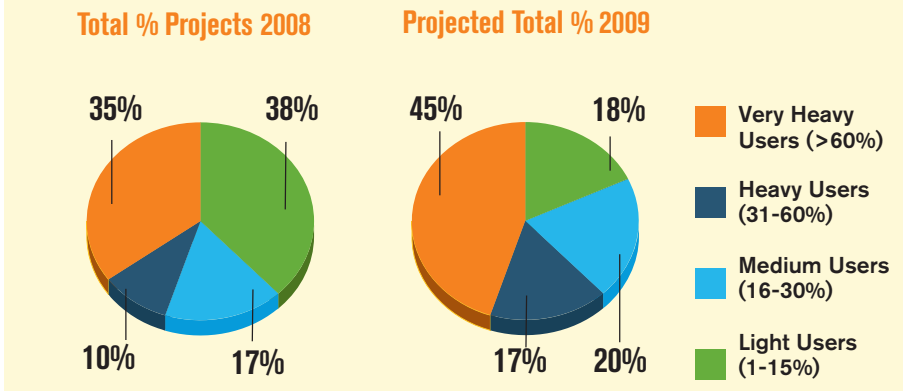
BIM is being broadly adopted across the construction industry with **over 50% of each survey segment - archtect, engineers, contractors, and owners (AEC/O) - utilizing the tools at moderate levels or higher.** In the population as a whole, roughly one-third (35%) of BIM users are very heavy users, one-third (27%) are medium to heavy users, and one-third (38%) are light users. Key segment findings include:

- **Architects are the heaviest users of BIM** with 43% using it on more than 60% of their projects.
- **Contractors are the lightest users of BIM** with nearly half (45%) using it on less than 15% of projects and a quarter (23%) using it on more than 60% of projects.

BIM usage will also grow rapidly in the coming year. **Nearly half of all current adopters (45%) will be heavy users of BIM in 2009**, using it on at least 60% of their projects—a 10 point increase over the previous year.

- **A majority of architects (54%) will be very heavy users of BIM in 2009,** up from 43% in 2008.
- **Contractors expect to see the greatest increase in BIM usage in 2009.** Thirty-eight percent will be heavy users, up from 23% in 2009. Only 12% expect light use of BIM, compared to 45% the previous year.

Growth in BIM Use on Projects



Source: McGraw-Hill Construction, 2008

Market Triggers and Obstacles

BIM users face a very broad range of drivers and hurdles on the path to adoption. In general, BIM users see the need to balance the benefits of improved productivity and coordination with the challenges of BIM-related costs and training issues.

The Top Benefits of BIM

- Easier coordination of different software and project personnel
- Improved productivity
- Improved communication
- Improved quality control

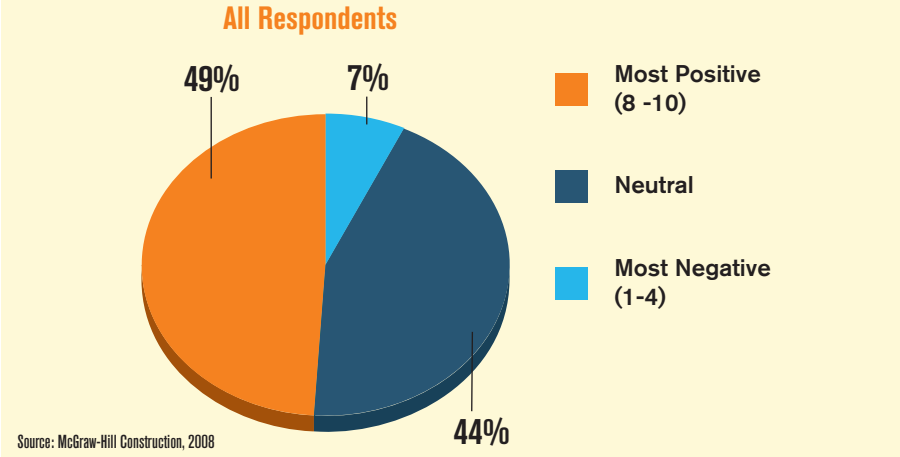
Top Obstacles to BIM Adoption

- Adequate training
- Senior management buy-in
- Cost of software
- Cost of required hardware upgrades

BIM Defined

For purposes of this report, McGraw-Hill Construction defines BIM as: **The process of creating and using digital models for design, construction and/or operations of projects.**

Impact of BIM Adoption on Users



User Experience

The rising use of BIM correlates with a generally upbeat assessment of its impact on users' business practices. **As users begin to see its benefits, they deepen their involvement with BIM.**

- Half of users say BIM has a very positive impact on their respective companies. Only 7% report a negative impact.
- As users gain experience with BIM, their view of its impact improves significantly.
- Contractors (61%) have the most positive view of BIM.
- Most architects see BIM as having a very positive impact on their businesses.
- Owners are beginning to see the value of BIM, with 41% reporting that BIM has a positive impact on their projects. One-third are very willing to purchase BIM software for other team members and half are at least moderately willing to pay extra for time and effort on detailing BIM models.

Measuring the Value of BIM

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

A follow up McGraw-Hill Construction online survey of AGC BIM Forum members (November 2008) found that the average perception of ROI on BIM to be between11% and 30%. However, **those making the effort to measure ROI perceive a higher value.** Among those that do measure it, almost one third report an ROI greater than 100%, with several greater than 1,000%. Thus measuring ROI establishes greater benefit of BIM than mere intuition suggests.

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

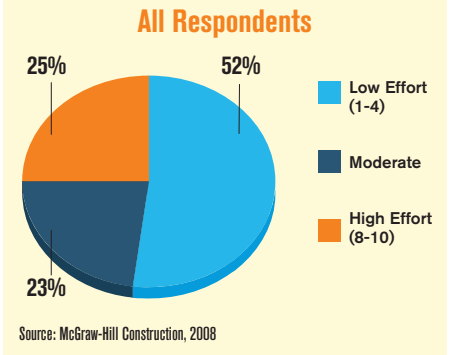
- Improved project outcomes such as fewer RFIs and field coordination problems (79%)
- Better communication because of 3D visualization (79%)
- Positive impact on winning projects (66%)

Expert Outlook

The broad future impact of BIM can be seen in the experience of expert users. **As more users adopt BIM and gain proficiency, they will eventually develop many of the same viewpoints and practices as today's experts.**

- **The positive impact of BIM on a company's practice is seen by the vast majority of experts** (82%), but few beginners (20%)
- **Many experts can quantify their success with BIM .** Nearly half (44%) frequently track ROI compared to 10% of beginners
- **Use of BIM is changing the way expert firms do business.** Experts are three times more likely than beginners to say BIM has had a dramatic impact on their internal processes, and four times more likely to say it has had a dramatic impact on their external processes
- **The ability to leverage data analysis comes with experience** Experts are twice as likely to use BIM data for quantity takeoff, scheduling and estimating compared to beginners
- **BIM plays a more significant role in green projects.** Expert BIM users are twice as likely to see BIM as helpful on green projects compared to beginners

Involvement in Measuring ROI

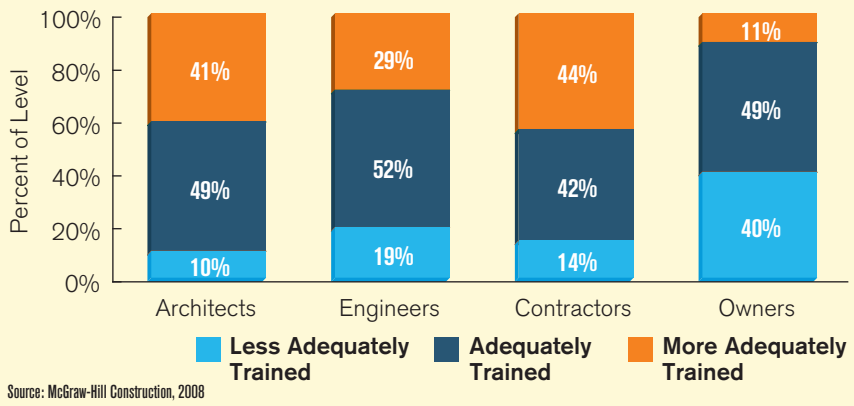


Paths to Expanding BIM Use

Training is critical to increasing BIM implementation. College and on-the-job training can help users unlock the potential of BIM, since research shows that users gain more positive results from BIM as they develop higher levels of expertise.

- 76% of BIM users say the level of training available to them is adequate. One-third believe their training options are highly adequate, suggesting room for improvement.
- Across all experience levels and company sizes, training on BIM basics is seen as the most important training need.
- Users are almost evenly split on the decision to bring in external trainers, train at off-site locations, use internal trainers, or teach themselves.
- The vast majority of respondents (85%) say users in their firms are at least moderately trained in BIM. One-third are very adequately trained, suggesting a demand for more training.

Level of BIM Training



Source: McGraw-Hill Construction, 2008

Rise of the Contractor

While BIM was initially developed with a focus on the design world, it has quickly gained favor among contractors.

Contractors who use BIM:

- Believe they are the most sophisticated users, with 46% considering themselves advanced or expert users.
- Have the most positive view of BIM and are more likely to see themselves as the primary driver of BIM use on projects.
- Create BIM on a majority of their 2D-designed jobs.
- Could see the greatest increase in BIM use in 2009.
- See the greatest need to outsource BIM work in 2009.
- Are most likely to see working collaboratively with other firms in BIM as important.
- Are most likely to see a dramatic impact to external processes with BIM.
- Are the only users likely to modify conventional contracts when using BIM.
- See BIM as having the most benefit to green projects and want greater access to green BIM tools in order to provide more comprehensive construction management capabilities to clients.

Top Decision Makers

In determining whether BIM should be used on a project, **architects are considered the primary drivers of BIM use among all build team members.**

However, many team members, especially contractors and engineers, are as likely or more likely to see themselves in that role. This could reflect the fact that **many contractors see value in using BIM on projects regardless of its use among other team members.**

Software Use

Software provides the tools that make BIM possible. Because BIM can reach across the entire lifecycle of a project, numerous software providers offer a wide array of solutions needed to meet demand. Although these software applications are available on varied platforms, users expect them to exchange project data as seamlessly as possible. **Interoperability is cited as the most important aspect that users want software companies to improve.**

Content in Highest Demand By Users

- Structural elements
- Mechanical equipment
- Building envelope and windows

Most Popular Tools Used in Conjunction with BIM Data

- Quantity takeoff
- Scheduling
- Estimating

Elements Most Likely to Be Modeled in BIM

- Architectural
- Structural
- Mechanical

Internal and External Impact of BIM

BIM is changing the way companies work internally as well as with external team members. In order to reap the greatest benefit from BIM, many users recognize a need to rethink roles and work flow. As a repository of information from multiple team members, BIM also promotes a more collaborative environment that breaks down traditional boundaries between firms and allows the sharing of project data among users.

- Seven in 10 users say that BIM has had at least a moderate impact on their internal project practices.
- Two-thirds of users say that BIM has had at least a moderate impact on their external project processes.

Top Ways BIM Changes How Users Work

- Routinely using BIM's 3D visualization capabilities to communicate with all parties.
- Using BIM on the jobsite to guide construction activities.
- More time designing, less time documenting.

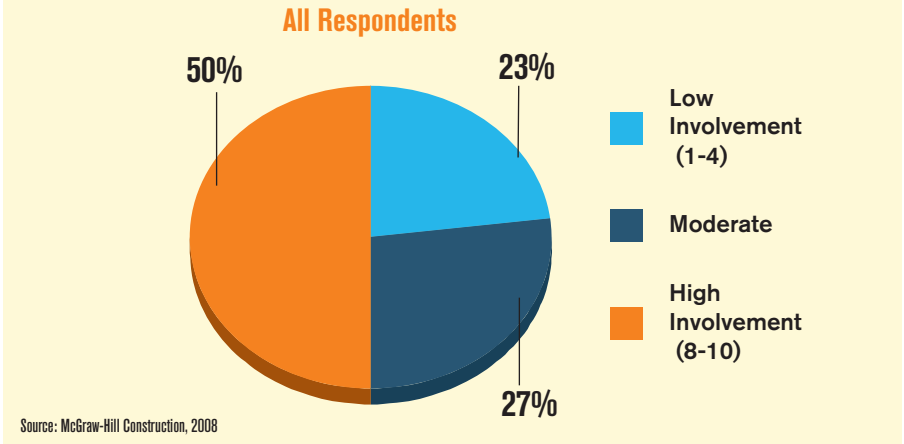
BIM and Green Building

There are significant opportunities for BIM tools to address issues related to green building. Data incorporated into a BIM can be used to analyze the performance of a building, including such green aspects as daylighting, energy efficiency and sustainable materials.

Most BIM users are frequently involved in green projects and find BIM to be helpful with those projects. However, there are significant opportunities to further leverage the benefits of BIM on sustainable projects. For example, BIM could be used to track LEED credits. As BIM continues to develop, technology providers will need to improve its ability to address the sustainable design and construction demands of the industry.

- 77% of BIM users are involved in at least a moderate number of green projects.
- 57% say BIM is at least moderately helpful in producing green projects.
- Half of respondents indicate that a LEED certification tool would be beneficial in motivating them to use BIM on green projects.

Level of Involvement in Green Projects



Source: McGraw-Hill Construction, 2008

Recommendations

- **Beginners: Momentum is critical.** Start small; know what you are trying to achieve; measure the results; and keep your expectations aligned as you move up the learning curve. Research shows that positive experience grows in direct relation to expertise. Don't get discouraged — you will overcome initial challenges. **Designate BIM champions and devote adequate training and time for them.**

- **Intermediate Users: Focus on developing best practices and a training program to expand BIM use internally.** Decide either to build a team of BIM experts to support multiple projects or to make BIM capability a requirement for everyone. Explore the growing universe of analysis tools that work with BIM (e.g. energy analysis). Reach out to companies you work with who are also adopting BIM to develop integrated processes for model sharing and analysis.

- **Advanced and Expert Users:** For design professionals and builders, **leverage the competitive advantage of your BIM expertise by exploring 4D (schedule integration) and 5D (cost modeling),** which provide extremely powerful process efficiencies. Also, consider forming alliances with other BIM-savvy companies that you work well with to approach clients as an integrated delivery team with established processes and a proven track record. You will rise above the competition as demand for BIM inevitably increases.

For owners, **focus on defining specific BIM requirements for your projects so the most qualified providers will be identified.** Also, work on migrating your completed BIMs into automated operations and maintenance, and have your teams tailor their deliverables to support that.

- **All Users: Leverage resources from professional industry organizations.** Consider joining the buildingSMART Alliance (www.buildingSMARTalliance.org) where you can network with global BIM leaders and help advance the entire industry.

Adoption of BIM

The Rapid Rise of BIM

Building information modeling is quickly gaining traction. After years of development and experimentation in the marketplace, BIM is bringing swift transformative change to how its users approach their work.

Research shows that users see clear benefits of BIM and they are responding by deepening their use of the technology. At a time when the overall development market is tightening, these users are looking for BIM to help them gain a competitive advantage.

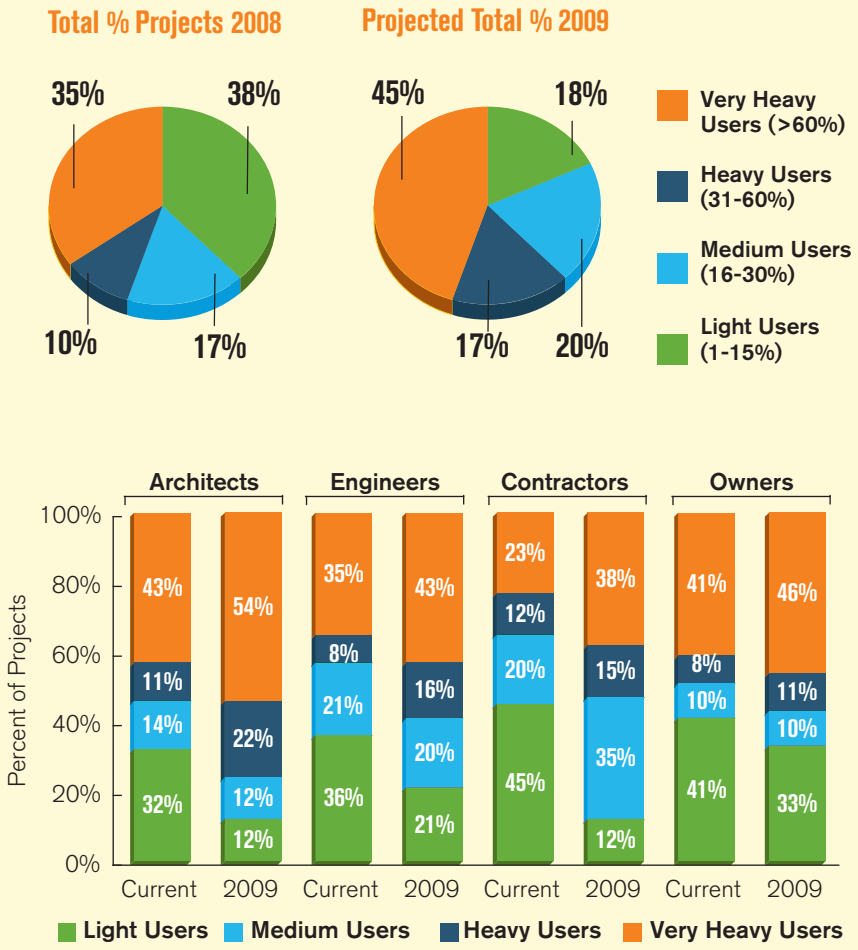
Market Growth

The expanding use of BIM is profound. **All users expect to rapidly increase their use of BIM in 2009.** In 2008, one-third of BIM users said they were very heavy users, involving it in at least three in five of their current projects. Next year, nearly half expect to use BIM at that level—a 10 point increase over the previous year.

User Differences

- **Contractors** could see the greatest rise in use. Although contractors report relatively limited BIM use compared to others, they are quickly catching up. Twenty-three percent currently use BIM on 60% or more of projects. Thirty-eight percent expect to use it at that level in 2009—a 15 point increase.
- **Architects** use BIM on the highest percentage of projects. Because many architects were among the early adopters of BIM, they have a head start on other users. A majority of architects expect to become very heavy users of BIM next year, jumping from 43% in 2008 to 54% in 2009. This substantial commitment to BIM could prompt other team members to increase their use of the technology as well.

Growth in BIM Use on Projects



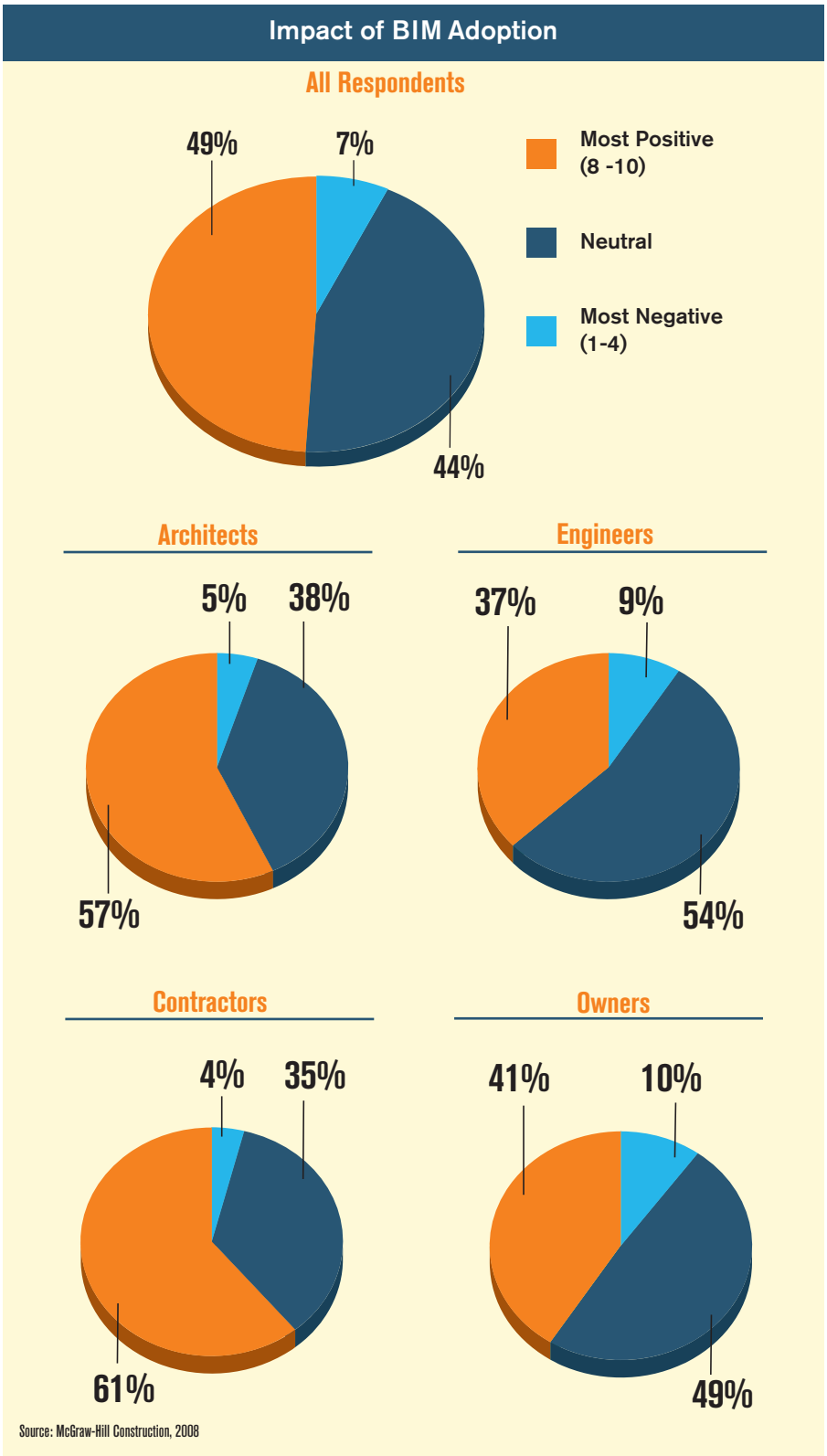
Source: McGraw-Hill Construction, 2008

- **Engineers** see their BIM use increasing, but not as drastically as other build team members. Thirty-five percent use BIM on at least 60% of their current projects. Forty-three percent expect to use it at that level next year.
- **Owners** expect to see moderate increases compared to other build team members. Owners currently have limited opportunities to use BIM for operations and maintenance purposes. As those capabilities develop, BIM use among owners could increase significantly.

Adoption Acceleration

Markku Allison, resource architect at the American Institute of Architects, has witnessed the rapid adoption of BIM in recent years:

"At our 2005 convention, the opening plenary session was about BIM, and of the nearly 4,000 architects in the room we got the impression that 85% had never even heard of BIM. Now when we go on the road, everyone knows what BIM is and the audience can offer up success stories about using BIM."



Perception of BIM

As BIM use becomes more prevalent, much of the industry has a positive view of its effect on their business practices. **Half of users say BIM has a very positive impact on their respective companies.** Only one in ten experience a negative impact.

Users offer an upbeat assessment of BIM despite the fact that a limited number of users measure their ROI (see section "Value of Using BIM"). This suggests that although many users can't quantify its benefits, they still embrace BIM's promise.

User Differences

- **Contractors** have the most positive view of BIM. Sixty-one percent of contractors say it has a very positive effect on their companies. Contractors see benefits such as improved clash detection that can directly reduce costs and delays.
- **Architects** also see BIM as beneficial with three in five reporting it has a very positive effect. Thirty-eight percent say it has a neutral or slightly positive impact. Through use of BIM, many architects find they can spend less time drafting and more time designing.
- **Engineers** are also generally positive about BIM, though slightly less compared to other users. Thirty-seven percent report that BIM has a very positive effect on their businesses. A majority (54%) say BIM has a neutral or slightly positive effect. Engineers can leverage data in BIM to help with simulation and analysis.
- **Owners** are largely positive about BIM, but less than contractors and architects. One in 10 report that it has a negative impact. This could be related to concerns over its cost. Many owners do not see the direct benefits of BIM compared to others. This could change as the capabilities of BIM for owners expand.

Experience Counts

BIM is progressively seen as having a more positive effect on one's practice as the user becomes more experienced. **Sophistication with BIM breeds success.** Eighty-two percent of expert users say BIM has a positive impact compared to 20% of beginner users.

This could be attributed, in part, to the expert user's ability to capitalize on more of the technology's functionality compared to others.

It can't be assumed that all users will eventually become experts. Although beginners may not see the upside of BIM initially, the research suggests that the payoff will happen as they gain experience.

Contractors Creating BIM From 2D Documents

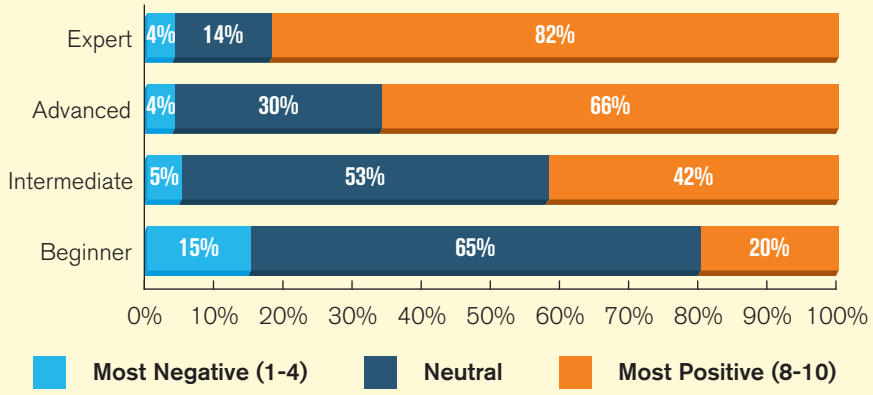
The need for contractors to create their own BIM on projects that were originally designed in 2D is fairly common. Many contractors find they can gain value from BIM even if other team members aren't using it.

Approximately 3 in 5 contractors create BIM on a majority of their 2D-designed jobs with one-third doing so on nearly all 2D projects (80% or more). Forty-four percent rarely create BIM when the project was originally designed in 2D. It can be assumed this group is receiving model files from design professionals and not authoring models themselves.

This practice is significantly more common among experienced users and larger firms. More than 80% of advanced and expert users create BIM on a majority of such projects. Likewise, 17% of beginners say they regularly create BIM on 2D projects.

Sixty-one percent of large firms create BIM on 2D projects compared to 34% of small firms.

Impact of BIM by Experience Level



Source: McGraw-Hill Construction, 2008

Interview with Robert A. Bank, P.E.

U.S. Army Corps of Engineers
Engineering and Construction Department

The U.S. Army Corps of Engineers is requiring BIM-based deliverables as part of its Centers of Standardization program, which focuses on design-build projects for military transformation work. This involves continuous building of 43 standard facility types. The Corps plans to combine, reuse and rebuild BIM models as the basis for these standard facilities and deploy them repeatedly in an adapt-build mode. Robert A. Bank, P.E., with the Corps' Engineering and Construction department, gives his views of this initiative.

How are you evaluating service providers?

We expect our design and construction contractors to develop BIM capabilities. Our RFPs require firms to describe their BIM qualifications. It's a critical evaluation criterion.

What are your metrics for success?

First we focused on getting the eight Centers of Standardization up to speed. Now we're tracking how many districts are doing BIM, which helps to focus our training and development efforts. As of October 2008, we have completed and occupied about 10 BIM projects and have about 40 more underway.

What is working well so far?

We're getting good response to RFPs for design-build projects in BIM. Contractors are willing to meet our BIM objectives. And our customers are pleased with the visualization capability of BIM. They can be much more involved in the projects.

What are the challenges you are coming up against?

There is still some resistance to BIM, especially with smaller contractors who are reluctant to make the investment. Also, there was some misunderstanding about our BIM program being strictly Bentley based. We have been working hard to clarify our position of being vendor neutral. The industry seems to be getting that message.

Where do you intend to take the program from here?

We have a very forward-looking BIM roadmap. We will continue to train our people and to extend BIM into more projects. Our CERL Lab in Champaign, Illinois is developing Construction Operations Business Information Exchange (COBIE) as part of the National BIM Standard so we can move BIM into facilities management. Ultimately we want to bring models and their associated data into a GIS-based decision-making system for our senior management. Another future goal is to incorporate BIM into big horizontal construction projects in our civil works program.

Challenges to Adoption

Although many report a variety of challenges, users tend to view them as moderate or lesser concerns. **As a new technology, costs and training issues have been the greatest hurdles on the path to adoption.**

Training

Receiving adequate training is the greatest challenge to adopting BIM. This could be particularly difficult because only a limited number of users have an expert background that could be used as a training resource. **As more expertise develops in the industry from colleges and universities, within firms and from third parties, training should become less of a challenge.**

- 19% see it as most challenging.
- Engineers are most concerned.
- Owners are least concerned.
- Training is an important concern across all experience levels.

Costs

Cost of software and required hardware upgrades are also considered significant hurdles. These are common concerns with any new technology.

- 15% see software costs as most challenging.
- 13% see hardware upgrade costs as most challenging.
- Architects and engineers are most concerned about hardware upgrade costs.

Staff Buy-In

The higher the level of management in question, the greater the general concern that they may not embrace BIM. Senior management buy-in is considered among the greatest challenges to adoption. This could reflect several factors. Senior managers are more likely to be in a position where they have to justify the costs and efforts associated with bringing BIM into practice. As veterans of the industry, they may also be "used to doing things a certain way" and therefore hesitant to change their processes.

Lower down the ladder, junior staff buy-in is considered the least challenging. In part, this is because junior staffers are in less of a decision-making role. Also, younger staff who are still developing their skills in the industry are likely to be more open to trying new methods of practice and may have been exposed to BIM as part of their college education.

- 17% see senior staff buy-in as most challenging.
- 11% see middle staff buy-in as most challenging.
- 66% see junior staff buy-in as least challenging.
- Owners are the most concerned about buy-in at all staff levels.

Other Factors

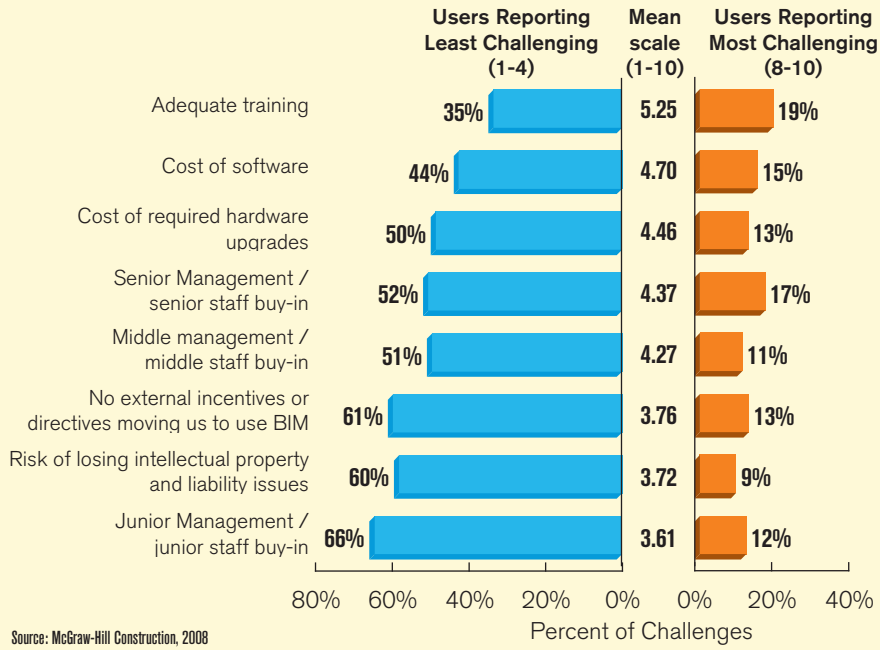
- **Engineers** are most likely to see a lack of external incentives or directives moving them to use BIM.
- **Architects and engineers** are both challenged by the potential risks of losing intellectual property, and liability issues.
- Other than training, **expert users** generally see fewer challenges than beginners.

Upbeat Future Outlook

The largely positive view of BIM among users contributes heavily to its anticipated near-term growth. **The technology's greatest advocates will lead the broader effort to expand its future use.**

- Seven in ten of very heavy users, who expect to use BIM on at least 60% of projects in 2009, also report that BIM has a very positive impact on their businesses.
- No very heavy users say it has a negative impact.
- Among light users, who expect to use BIM on no more than 15% of projects, only 15% hold a very positive view of BIM. A quarter of light users say BIM has a negative effect. Many of these users are also beginners and are likely experiencing the growing pains of BIM adoption. These users may need more experience with BIM to see the advantages of expanding their investment in it.

Challenges to BIM Adoption



Source: McGraw-Hill Construction, 2008

Case Study:

PCL Construction

by Bruce Buckley

Change doesn't often come quickly to companies with over a century of experience in the construction world. But the advent of BIM has executives at PCL Construction based in Denver, Colorado, rethinking their view on internal structure and process. The 102-year-old firm is undergoing a transformation that uses BIM to make virtual design and construction (VDC) an everyday part of its practice.

"In five years, we want VDC to be fully integrated into what we do," says Ed Hoagland, virtual construction manager at PCL.

The company's VDC mission is to build projects twice—once in the virtual world and once in the real world. Before crews take to the field, a project is modeled virtually. PCL teams use BIM to create a prototype where they can identify issues before they have an impact on budget and schedule. When it's time to build the project in the real world, Hoagland says the goal is to have eliminated at least 90 percent of issues before they reach the field.

The process redefines value engineering as the team minimizes redesigns, requests for information, coordination issues and rework on site.

Through VDC, the company aims to improve risk management and communication.

"It's about spending more time planning and less time fighting fires," Hoagland says.

Big Returns

So far, the initiative is paying off in a big way for the company. Hoagland estimates that PCL is realizing roughly a 500 percent return on investment with BIM. The vast majority of that payback is coming from clash-detection efforts that greatly reduce costly change orders. However, the company realizes additional benefits that aren't calculated into ROI.

Image courtesy of PCL Construction

Memorial Hospital, Colorado Springs, Colorado

"It's hard to quantify saving time and effort," he says. "Some of it is just gut-feeling. A lot of what we do results in 'problem avoidance.' That's a benefit that's sellable in the construction industry, whether you can quantify it or not."

As traditional ideas of process change, so does internal hierarchy. Hoagland oversees PCL's BIM initiative from the corporate level—a position that didn't exist five years ago. The company has also hired a least one full-time BIM modeler in each of its 12 U.S. districts.

"We had to create those positions and are working on making a career path for them," he says.

The goal is to have at least one "BIM champion" in each district, who can serve as a BIM expert and oversee VDC efforts regionally, Hoagland says. The company also typically places an on site modeler on its BIM projects, taking the place of a project engineer.

"This isn't something you can do with a modeling department in the corporate office," he says. "If someone in the field needs something, the modeler on site can turn around and handle it right away."

Depending on the number of projects underway, additional modelers are brought on as necessary; however Hoagland says this is only a short-term fix. Eventually, he hopes that BIM will be a skill set that a variety of staff members can employ.

"In the next year, we're looking at sending field engineers through BIM training and making it a stop on their career path," he says. "After six months of working with it, then they are able to go out on a site and use it. It becomes a spoke in the wheel of your career development."

Internal Issues

Although VDC could redefine some of PCL's processes, the company isn't ready to toss out its proven practices. Using BIM data to help generate scheduling analysis—often called 4D—has been an easy call, Hoagland says.

"There are big returns on low effort with 4D," he says.

However, the company is hesitant to fully integrate estimating functions—or 5D—into its BIM work. Hoagland says that PCL is investigating how to retain its existing estimating processes and mak-

ing BIM work within that framework.

"The estimating processes here have been developed over the last 100 years," he says. "In order to get [5D] to work, you've got to tailor it to work within that system. It's about taking the software and making it work for us. It's not about rethinking estimating. It will never work that way."

External Forces

While the company works through its own internal issues as it moves forward with BIM, it isn't waiting for others to get up to speed. Hoagland says the company uses BIM on projects whether other team members use it or not. He says that PCL very rarely receives useable BIM models from designers. Although receiving a model from a designer could cut down on PCL's workload, the company sees significant ROI regardless.

However, Hoagland says, BIM will change the way it interacts with subcontractors. The company often specifies basic file requirements from subs, so that data exchanged between firms can work with its BIM-related software.

The key is to not force subs to learn BIM, he says.

"If they are unable to do the modeling themselves, we've got outsourcing options we can refer them to," he says. "We help make the connection and they pay for it. It shows up as a line item in their bid. We've found that if we don't give them that option, they come back with bids that are completely outrageous. By making those connections, we mitigate that."

Although PCL usually initiates the decision to use BIM on a project, Hoagland says that eventually needs to change.

"In the long run, we need to find some way to get from design-intent models to construction models," he says. "That's a burning question throughout the industry right now. We don't want to be building every model. In the end, we don't want to be a modeling company. This is a construction company and BIM is a tool we use to get there."

Recent successes

Through recent BIM projects, PCL has found value at different phases in the construction process.

BIM was beneficial in pursuit of its Metropolitan Gardens project in Denver. Hoagland says the models were integral in helping PCL win the project, showing the owner a 4D schedule of construction phasing along with a quantity survey. With 100 man-hours spent on BIM work, Hoagland says the company gained a competitive advantage during project pursuit; increased the comfort level with ownership; and generated a valuable communication tool within the team.

On PCL's Silverline project in Telluride, Colorado, BIM helped PCL avoid very costly errors during preconstruction. Hoagland says the project site, which is set along a steep hillside, is sensitive because it neighbors a gondola that operates most of the year. Truck traffic and risks to homes located uphill from the site were also of concern to the town council. The team used a 4D schedule of excavation and shoring in BIM to show how it would mitigate issues which helped it gain approvals from the town council, Hoagland says.

PCL also used its Silverline model to pull quantities as a back-check to its original takeoff. The original estimate for excavated material was around 100,000 cubic yards. Hoagland says checking the model revealed that the quantity was closer to 170,000 cubic yards As a result, PCL avoided a nearly $3 million error before guaranteed maximum price was finalized. The combined effort required 560 man-hours, generating expenses well short of its total cost savings.

PCL has consistently seen payoffs during the construction phase. On its Memorial Hospital project in Colorado Springs, Colorado, PCL used BIM to overcome numerous challenges, but perhaps none greater than clash detection. In addition to housing the complex array of MEP systems commonly seen in hospitals, Hoagland says the architectural design was complicated and nonlinear. By layering the architectural, structural and MEP systems in BIM, he says the team discovered nearly 3,500 total clashes. Although the vast majority were errors that could have been caught and fixed easily in the field, Hoagland says that at least 500 of them would have had a significant impact on cost and schedule. From pursuit through construction, PCL logged nearly 1,200 man-hours in BIM.

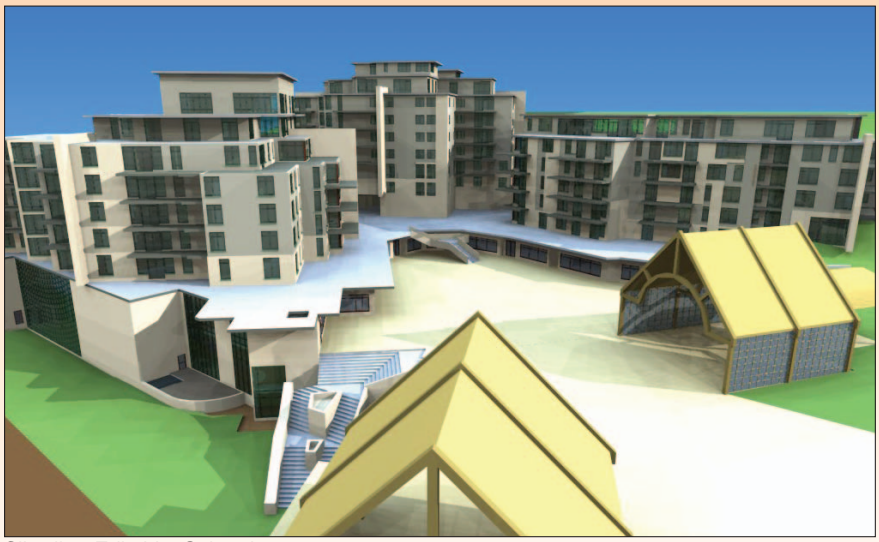


Image courtesy of PCL Construction

Silverline, Telluride, Colorado

Usage of BIM

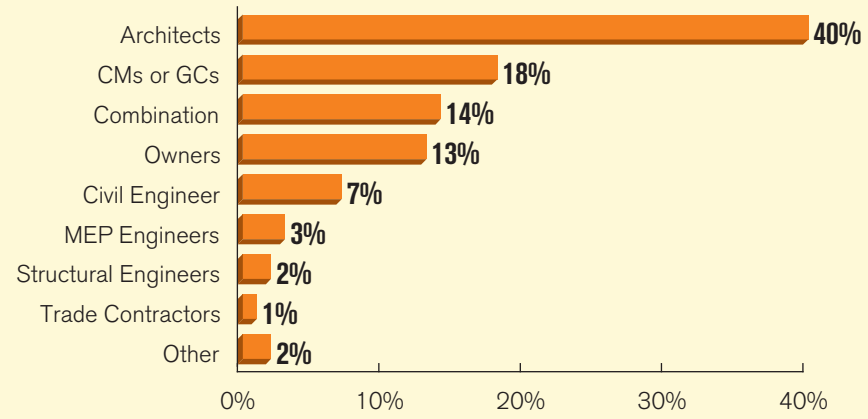
Range of Use

The great promise of BIM is its expansive range of applications for users. At its basic level, BIM represents an evolution from traditional 2D design to a dynamic 3D model built around a database of a project's physical and functional characteristics. **The more data users add to the model, the more benefits can be leveraged from it.** Beyond 3D visualization of a project, information about specific objects within the model can be used for a wide range of analyses such as building performance, schedule and costs.

Today, 3D modeling is by far the most popular use of BIM, with architects leading the way. Other users, such as engineers, are finding selective ways to model elements in BIM. Contractors are building momentum for the use of BIM in 4D (scheduling) and 5D (cost estimating).

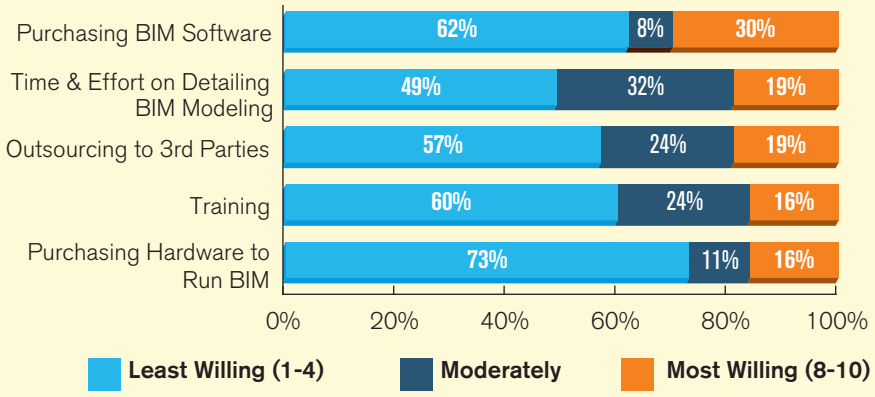
As users continue to gain expertise with BIM, they will further capitalize on the technology's potential and push for new ways to garner benefits in areas such as sustainability and building operations. Architects and engineers will likely use BIM to do energy analyses, and owners will use the BIM model to manage and maintain their facilities.

Primary Drivers of BIM Use on Projects



Source: McGraw-Hill Construction, 2008

Owner Willingness to Pay Extra For BIM



Source: McGraw-Hill Construction, 2008

Drivers of BIM Use

While BIM can be used by all build team members on a project, some are more likely to drive its use than others. **Architects are considered the primary driver of BIM use.** Beyond its obvious design applications, architects are early decision makers and their technology choices can set the tone for how a project will progress. By using BIM, architects also create information that can be shared with other team members, developing the framework for an integrated environment.

User Differences

- **Architects** are seen as the primary driver by 40% of all team members. Four in five architects see themselves in that role, but few contractors see architects as the primary driver.
- **General Contractors and CMs** are considered the primary drivers among 18% of team members. Half of contractors see themselves in that role, while few other team members credit them with driving its use. This could reflect the fact that many contractors use BIM on projects regardless of its use among other team members.
- **Engineers** are as likely to see themselves as the primary driver as they are to see architects in that role (one-third each).
- **Owners** are more likely than others to credit a combination of individuals as the driver (26%). This suggests that owners see BIM as more of a collaborative process than others.

Owner Investment

Many owners are willing to pay some extra costs to designers and contractors for use of BIM on projects.

- 30% are very willing to purchase BIM software for other team members.
- Half of owners are at least moderately willing to pay extra toward the time and effort needed to model in BIM, with half being at least moderately willing. This is logical because owners are more accustomed to paying team members for their time.

Modeled Elements on BIM Projects

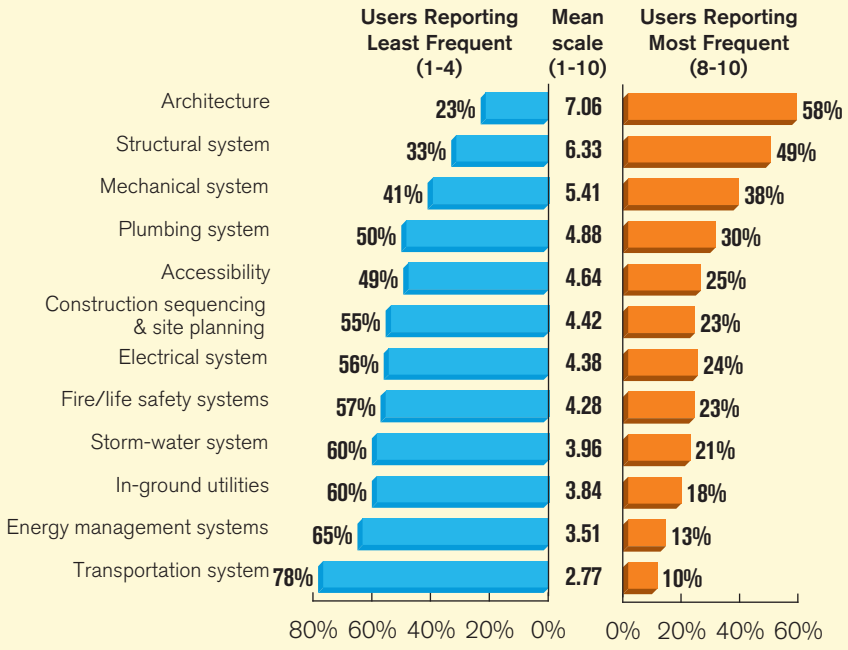
Build team members say that **architectural, structural, mechanical and plumbing elements—in that order—are the most likely to be modeled when using BIM.** This view holds generally true among all team members, although the larger and more experienced the firm is, the more likely it is to see these elements modeled on BIM projects.

This view makes sense in light of the BIM adoption and usage patterns of various disciplines. **Architects lead the way** with 54% reporting to be either heavy or very heavy users in 2008. Engineers lag slightly as 43% of all engineering disciplines combined are at that usage level. In 2009, fully two-thirds of architects predict being either heavy or very heavy users—a 41% increase. By comparison, engineers predict a 37% increase at this usage level in 2009.

Electrical engineers lag behind mechanical and structural. This is likely due in part to the relative lack of content for electrical elements. These elements also have smaller physical size requirements in buildings compared to bulky structural systems, large mechanical elements like duct work, and the diameter and pitch/location requirements of plumbing waste lines. As such, electrical coordination issues are less challenging and modeling is less critical.

Users suggest a relative prominence of accessibility planning as a special function (30%). **This points the way toward more innovative uses of BIM modeling beyond visualization and clash detection.** During construction sequencing and site planning, some contractors are gaining powerful efficiencies by using simulation to optimize logistics, phasing, equipment locations and materials handling. As more enabling applications come online that extract relevant data from design models to automate valuable tasks, it is likely that their use will dramatically increase.

Frequency of Modeling Elements with BIM



Source: McGraw-Hill Construction, 2008

Emerging Maturity Models for BIM

In the National BIM Standard (NBIMS) Version 1, Part 1, the National Institute of Building Sciences (NIBS) has published a preliminary guideline to establish the minimum level of information that constitutes a BIM, setting a threshold for what legitimately can be called a BIM versus a set of weighted criteria.

NIBS further outlined a Capability Maturity Model (CMM) for users to evaluate their BIM processes and set goals for improvement. It is based on 10 levels of maturity in 11 areas of interest, including: data richness; lifecycle views; change management; roles or disciplines; business processes; timeliness/response; delivery method; graphical information; spatial capability; information accuracy; and interoperability/IFC support.

NIBS provides an interactive workbook so that users can easily see where their operations are the most mature. The electronic version of the CMM workbook can be downloaded at: **www.facilityinformationcouncil.org/bim/I-CMM.**

The Alliance for Construction Excellence (ACE) at Arizona State University also tackled this challenge in its publication entitled "Building Information Modeling: An Introduction and Best Methods Approach." ACE outlines a three-level rating system where Level 1 is considered the basic and fundamental use of BIM, Level 2 represents a more significant investment in BIM at a project level, and Level 3 is a more advanced, complex, and integrated approach to BIM. This document is available at: **www.garyaller.com/publications.asp.**

Modeling Details

BIM users gravitate toward using the technology to model specific elements within their respective practices. Although some use BIM for a **broad range of applications, there is significant room for expanded use of the technology to model certain design elements.** Architects tend to use BIM to model a full range of elements at a high level. However, electrical engineers and contractors do very little electrical design modeling. Among some disciplines, such as mechanical engineering design, there is a mix of preferred uses of BIM, suggesting that users have yet to realize the benefits of some design elements.

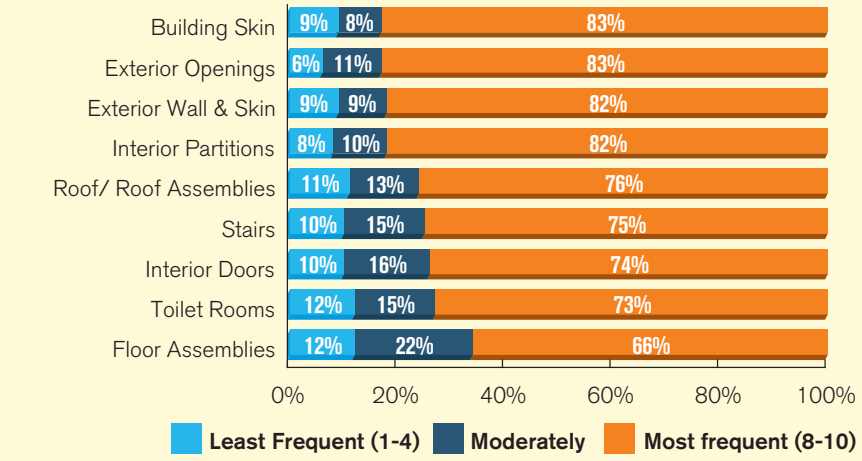
Architectural Elements

- The frequency of modeling all architectural elements is high among architects.
- Exterior openings, building skin, and exterior wall and skin are the most frequently modeled elements by architects.
- Floor assemblies are the least frequently modeled element by architects. However, these elements are still modeled at a high level.

Mechanical Elements

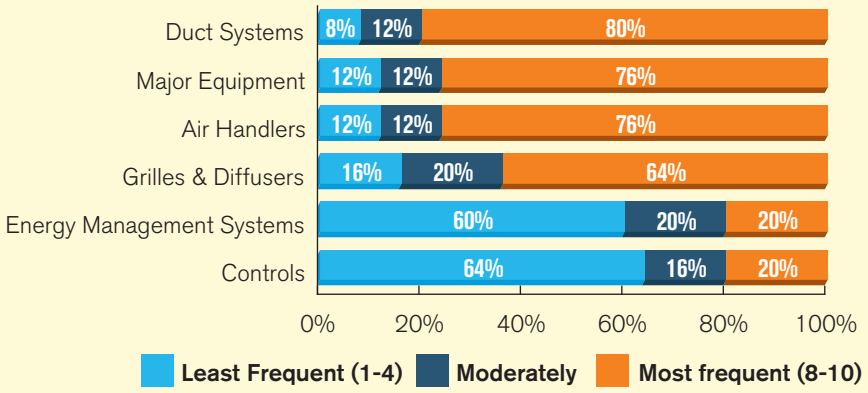
- Mechanical engineers and contractors use BIM to model duct systems, air handlers and major equipment very frequently.
- Grilles and diffusers are also modeled fairly often by mechanical engineers and contractors.
- Notably, energy management systems and controls are rarely modeled by mechanical engineers and contractors, with three in five saying they don't model those elements frequently. With the rapid rise of the green movement, demand to model these elements more frequently could quickly gain momentum in the near future.

Modeling Architectural Elements in BIM



Source: McGraw-Hill Construction, 2008

Modeling Mechanical Engineering Elements in BIM



Source: McGraw-Hill Construction, 2008

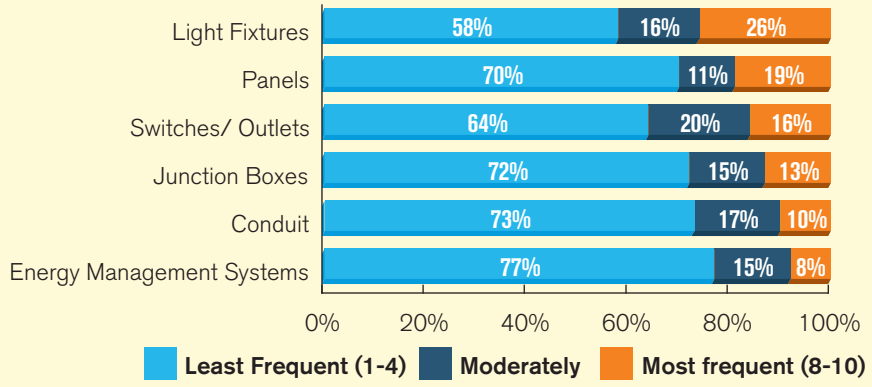
Differentiating Between Design and Construction Models

Derek Cunz, director of project development at Mortenson Construction, says his company likes to work with integrated design teams early in projects, but often builds its own construction models.

"There are design-intent models, and there are construction models, and they are different in what they are intended to do," he states. "With design-intent models we see an opportunity to collaborate, do analysis, do validation and look at schedules early. In the construction phase, traditionally we're building from scratch because of the amount of detail required in a construction model [that isn't in a design model]."

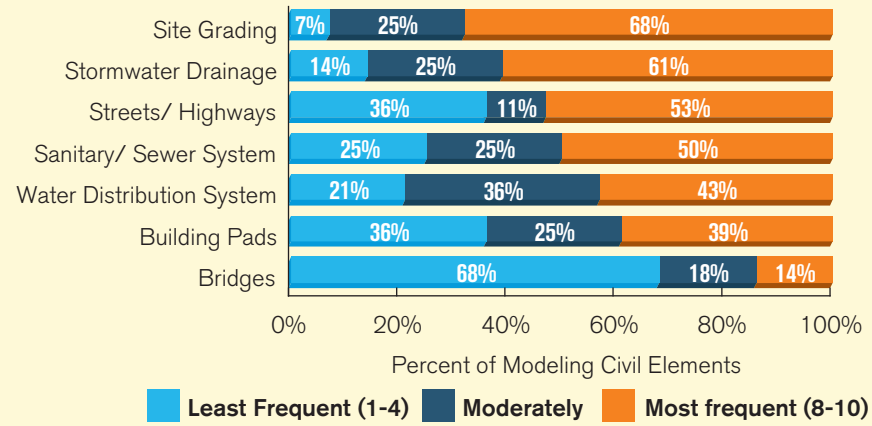
During schematics, Mortenson uses the design team's model for analysis but won't create its own model at that point because the design is still evolving. Even with the added work to build the construction model, Cunz says the process ultimately saves money.

Modeling Electrical Design Elements in BIM



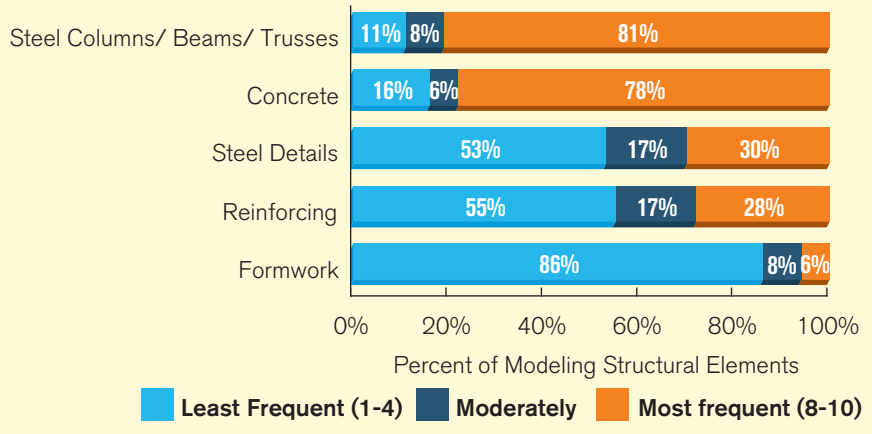
Source: McGraw-Hill Construction, 2008

Modeling Civil Engineering Design Elements in BIM



Source: McGraw-Hill Construction, 2008

Modeling Structural Engineering Design Elements in BIM



Source: McGraw-Hill Construction, 2008

Electrical Elements

- The frequency of modeling all electrical design elements is low among electrical engineers and contractors.
- A quarter of electrical engineers and contractors model light fixtures frequently—more than any other element.
- Energy management systems and junction boxes are rarely modeled by electrical engineers and contractors. Again, demands related to increased green design and construction could prompt engineers to model these elements more frequently in the coming years.

Civil Elements

- Civil, environmental and transportation engineers model site grading and stormwater drainage very frequently.
- Sanitary, sewer and water distribution systems are frequently modeled by civil, environmental and transportation engineers.
- Bridges are rarely modeled in BIM by civil, environmental and transportation engineers. This represents an opportunity for future expansion that needs to be further explored.

Structural Elements

- Steel columns, beams, trusses and concrete are very frequently modeled by structural engineers and contractors.
- Nearly half of structural engineers and contractors model reinforcing and steel details in BIM.
- Formwork is almost never modeled in BIM by structural engineers and contractors. This represents an opportunity for future expansion that needs to be further explored.

Scheduling in BIM

The potential of BIM to offer scheduling functions—also referred to as 4D—is an emerging benefit. Although the design capabilities of BIM are widely employed by users, **the industry is still in the early phases of adopting BIM for scheduling.** This is likely due to the large investments that firms have already made in project management software. As BIM use among contractors expands faster than among other users, greater use of 4D can be expected in the near future.

User Differences

- **Contractors** are most likely to use scheduling in BIM, as that is a significant portion of their practice.
- As could be expected, **architects** (78%), **engineers** (85%) and **owners** (87%) use scheduling in BIM much less frequently than contractors.

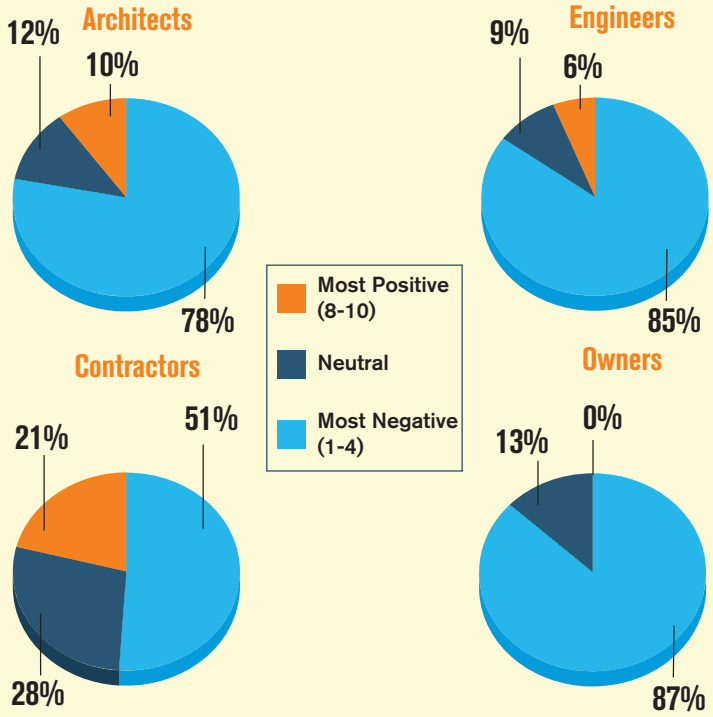
Cost Data in BIM

As with scheduling, users are still exploring how to incorporate cost data—also known as 5D—into BIM. In some cases, companies may struggle with how to integrate BIM with existing estimating systems. Although there are considerable opportunities to improve the use of scheduling in BIM, **the lack of cost analysis being executed in BIM represents even more potential for future growth.**

User Differences

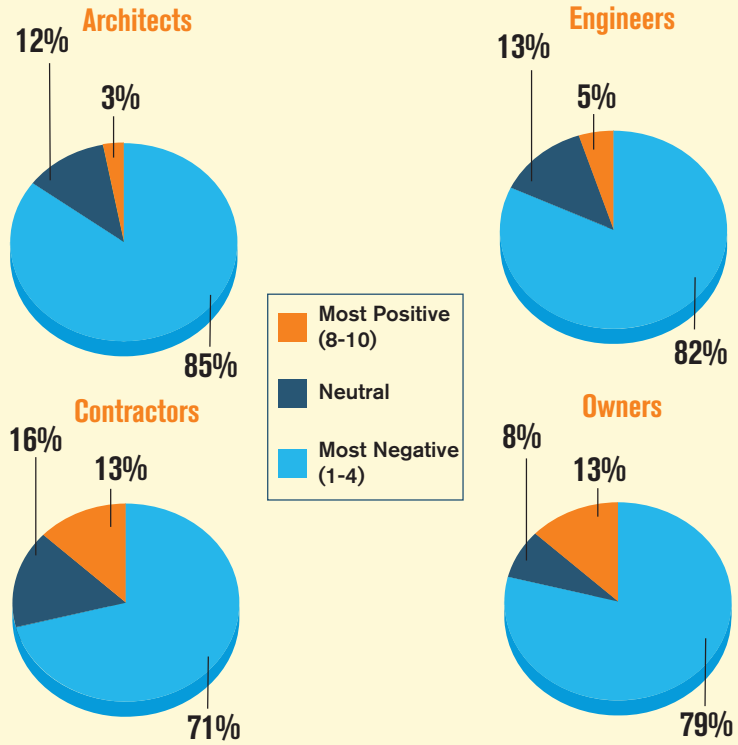
- **Contractors** are most likely to use cost data in BIM, as estimating is a key part of their practice. Three in 10 use it at least moderately frequently.
- After contractors, **owners** are next most likely to use cost data in BIM. Owners also focus heavily on costs.
- **Engineers** (82 %) and architects (85%) are least likely to use estimating in BIM.
- **More experienced** users are far more likely to use cost data in BIM than others.

Integration of Scheduling Data with BIM



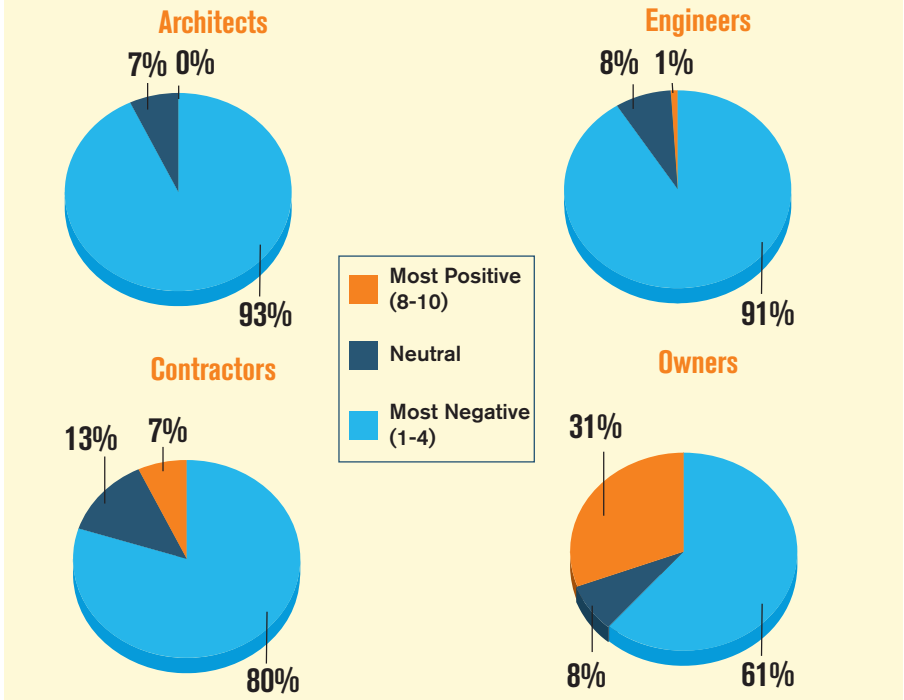
Source: McGraw-Hill Construction, 2008

Integration of Cost Data with BIM



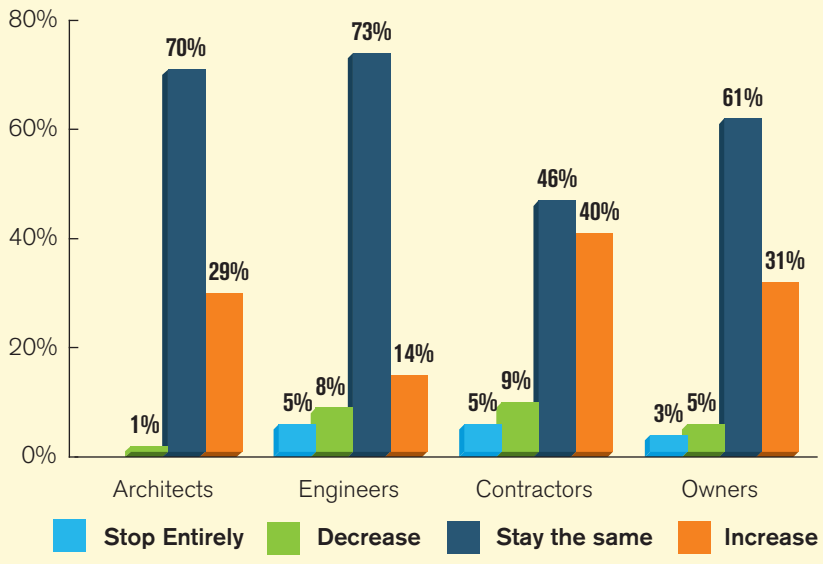
Source: McGraw-Hill Construction, 2008

Outsourcing of BIM Work



Source: McGraw-Hill Construction, 2008

Projected Outsourcing of BIM



Source: McGraw-Hill Construction, 2008

Outsourcing BIM

With the exception of owners, build team members largely handle their BIM work in-house. However, **as the use of BIM expands rapidly among current adopters there will be a greater need for outsourcing in 2009 to meet demand.** Eventually, the in-house capabilities of firms could catch up with demand, but not until growth eases.

Future Use

- **Owners** are most likely to outsource BIM work with one-third reporting they do so very frequently. That could expand significantly as one-third also expect to increase outsourcing in 2009.
- Few **contractors** (7%) outsource BIM work very frequently. However, **contractors** see the greatest need to outsource BIM work in 2009, with 40% expecting it to increase. This is not surprising considering that contractors also predict that they will see the largest increase in use of BIM on projects next year (see the section "Adoption of BIM").
- Few **architects** currently outsource BIM work, but three in 10 expect to do so in 2009.
- The majority of users (60%) who expect to increase outsourcing of BIM in 2009 are **beginner or intermediate users**.
- The majority of users (53%) who expect to increase outsourcing of BIM in 2009 are **medium-large to large firms**.
- One-third of users who expect to increase outsourcing of BIM in 2009 **currently use it on 60% or more of their projects**.
- Two in five users who expect to increase outsourcing of BIM in 2009 also **expect to use it on 60% or more of their projects in 2009**.

Growing the Connection Between BIM and Green

Just as BIM use is rapidly expanding within the design and construction industry, so is the green building movement. Although these two trends are evolving along their own paths, **there are significant opportunities for BIM tools to address issues related to sustainability.**

Data incorporated into a BIM can be used to analyze the performance of a building, including such green aspects as daylighting, energy efficiency and sustainable materials. As the green movement gains momentum, **BIM users are beginning to tap into the technology's potential.** As BIM continues to develop, technology providers will need to improve its ability to address the sustainable design and construction demands of the industry.

BIM Users and Green

As sustainability continues to gain momentum, BIM users are among its adopters.

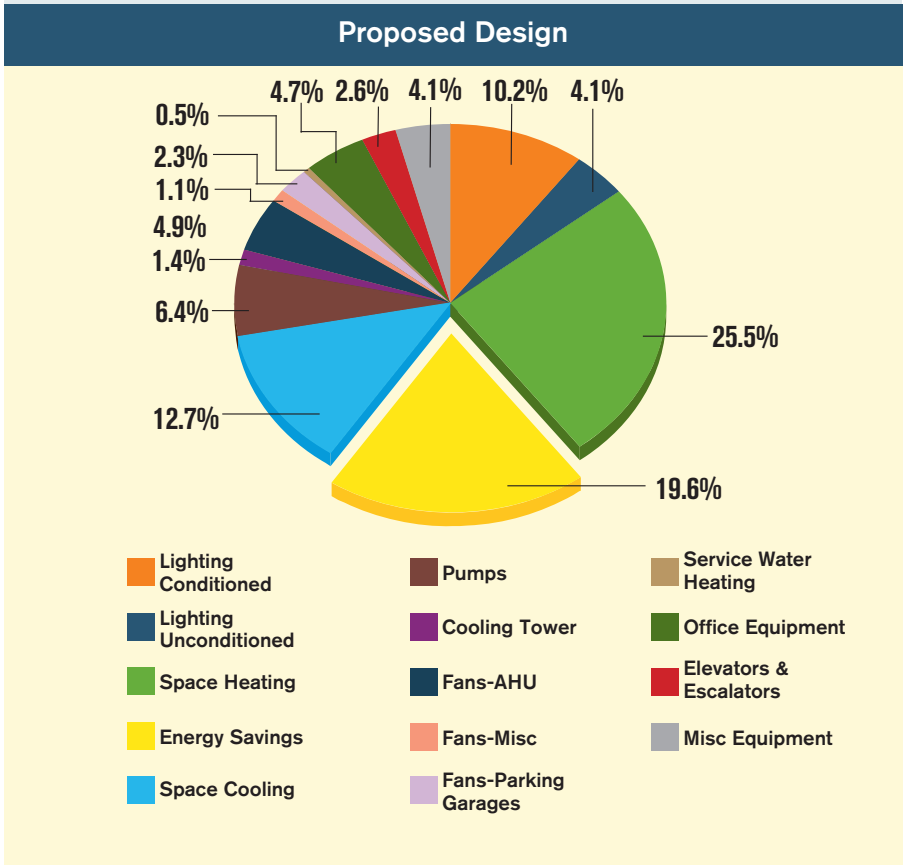
Three-quarters of BIM users are involved in at least a moderate level of green projects with half reporting that their involvement in green building is at a high level.

User Differences

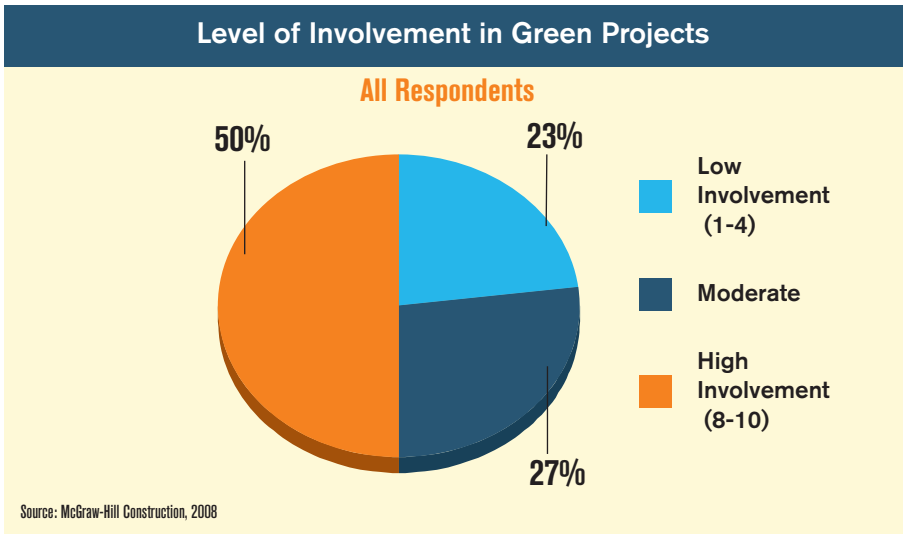
- **Architects** and **contractors** are most heavily involved in green projects with three in five reporting a high level of activity.
- Nearly half of **owners** are involved in green projects at a high level.
- **Engineers** are the least involved in green projects.
- **Large firms** are significantly more likely to be involved in green projects.
- **More experienced BIM users** also tend to be more heavily involved in green projects than others.

BIM Energy Modeling Tools

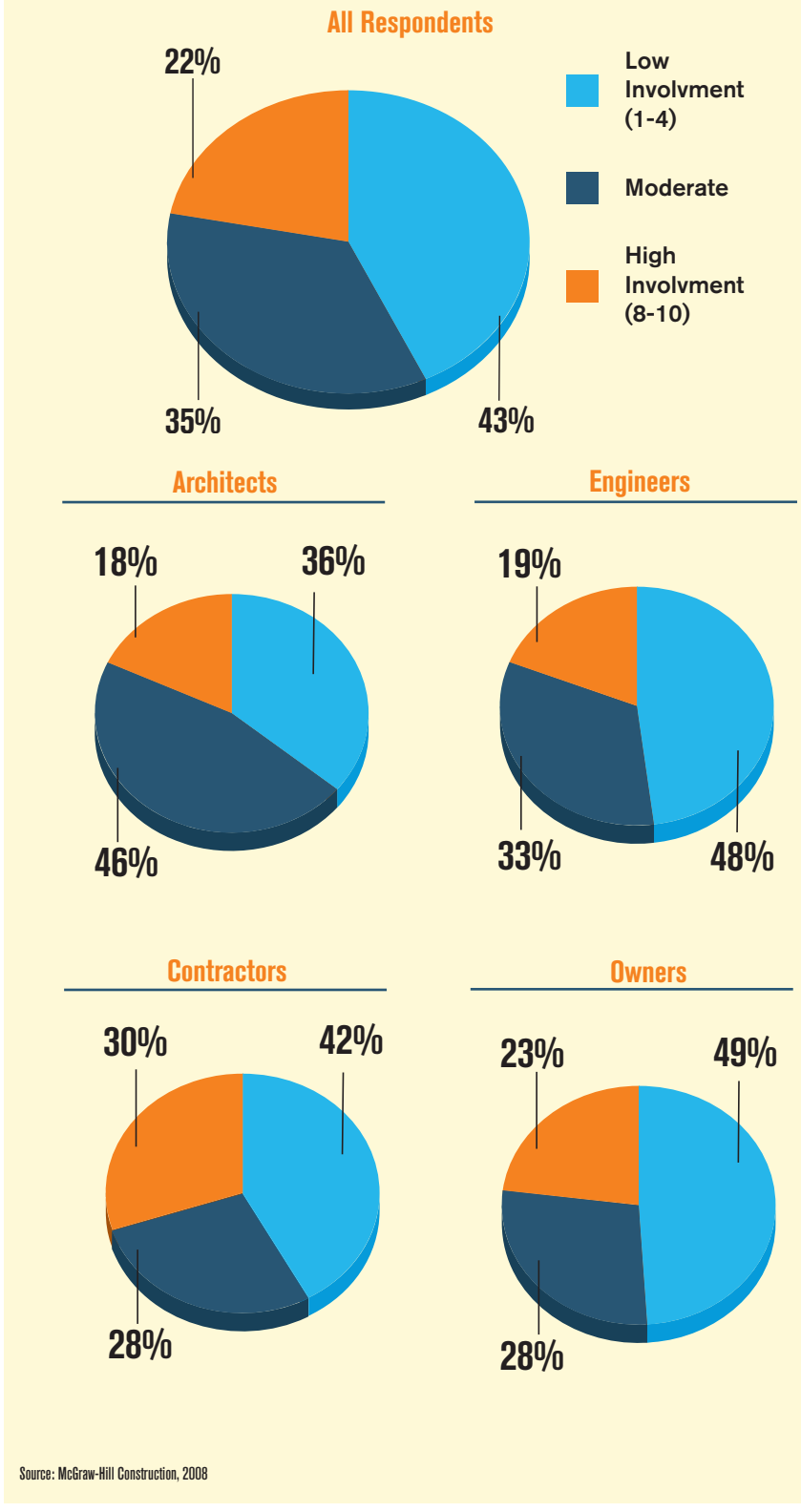
Firms like SmithGroup are using BIM tools to redesign buildings to be more energy efficient. As shown in the graph below, using the modeling tool, SmithGroup was able to identify energy savings of 19.6% resulting in cost savings of 22.4%. This was primarily achieved through lowering space cooling and lighting, and through exchange of pumping and heating energy usage.



Energy efficiency analysis of Constitution Center Renovation, Washington DC (Source: SmithGroup)



BIM Use in Green Projects



Source: McGraw-Hill Construction, 2008

BIM and Green Projects

As BIM users tend to be involved in many sustainable projects, **some see BIM as providing a high level of assistance with their green work.**

A majority of users (57%) say BIM is at least moderately helpful in producing green projects. Forty-three percent currently see little involvement of BIM in green projects, indicating that a stronger connection to BIM's analysis capabilities needs to be made. The development of new green tools could also bolster its use in the coming years.

User Differences

- **Contractors** see BIM as having the most benefit to green projects with three in 10 reporting a high level of assistance.
- Two-thirds of **architects** see BIM as at least moderately helpful.
- A majority of **engineers and owners** see BIM as helpful.
- **Expert BIM users** are twice as likely to see BIM as helpful compared to beginner and intermediate users.
- Perceived helpfulness of BIM in producing more sustainable projects is relatively similar **regardless of company size**.

Green Tools

The development of additional analysis tools could further spur use of BIM on green projects. Several BIM analysis tools were identified by users as being needed for green projects:

- **50%** indicated that LEED calculation software integrated with BIM would be very helpful.
- **47%** thought that more building product content with data about the products sustainability characteristics should be integrated into BIM tools.
- **44%** believe energy analysis software should be integrated with BIM.

Case Study:

Springfield Literacy Center

by Bruce Buckley

In designing the new Springfield Literacy Center, the choice by design and engineering firm Burt Hill to use BIM was a natural one. While planning the Springfield (Pennsylvania) School District's first new building in nearly 50 years, school officials aimed to create an inspirational learning environment that connects students to nature. Everywhere within the 50,000 square foot building students can view nature, including a grove of mature trees and a neighboring creek.

The building itself also needed to be environmentally sensitive, offering green elements that would not only improve the performance of the building but serve as a tool for students to better understand sustainable practices.

The project proved to be a learning experience for Burt Hill as well. When the firm came on board in 2006, their K-12 studio was presented with the perfect opportunity to implement a fully-integrated BIM strategy for the first time. With the goal of achieving LEED certification, Burt Hill's performance analysis team was brought in early to help affect key design decisions during the schematic phase. By getting involved early, the analysis team could expeditiously offer feedback about design choices and provide alternatives as necessary.

"Normally we don't come in until the design document phase or even the construction document phase," explains Matthew Rooke, architectural engineer on Burt Hill's performance analysis team. "We're traditionally an afterthought, and projects miss a lot of benefits as a result. With some of these analysis questions, the ideal time to address them is during the schematic phase. It takes much more effort and redesign once you're in design documents."

Effective daylighting was a critical component in achieving the client's goals. Initial designs included floor-to-ceiling windows in all classrooms, but analysis showed that the windows would produce high levels of glare. The team was able to redesign smaller windows that maximized natural daylight while minimizing glare. Energy analysis was also used to determine optimal levels of window transparency to balance lighting demands with thermal performance concerns. Light shelves and external shading were also added to portions of the building as a result of early analysis.

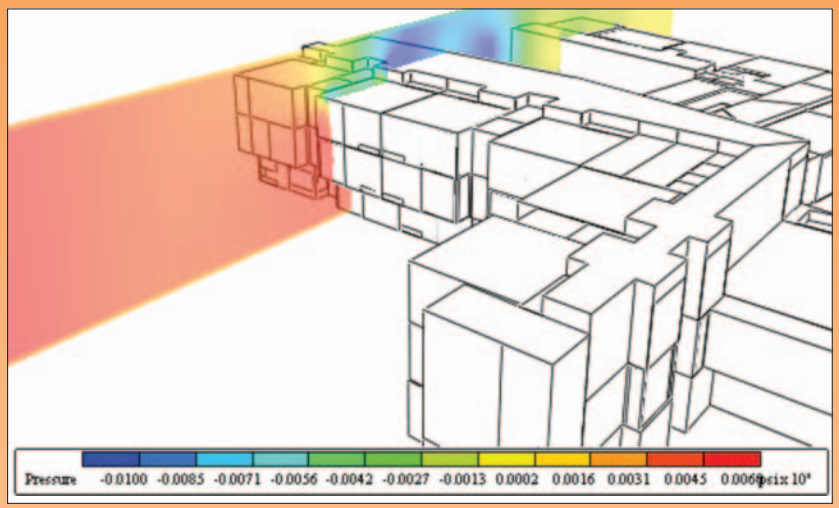


Image courtesy of Burt Hill

Performance analysis of Springfield Literacy Center

Other sustainable design elements include geothermal heating, recycled materials and a green roof.

Interoperability proved a key to productivity. The performance analysis team used software that exchanged nearly all data seamlessly with the BIM, eliminating redundancies such as reentering data.

"It was a good tool for real time and efficient dialogue," adds Michael Corb, senior associate at Burt Hill. "With the energy analysis, we didn't create new models for each specific purpose and then just throw them away. We always had the one BIM model and we kept detailing it until we got our final product."

BIM also greatly improved communication with the client. The team held regular charettes with school officials to go over designs and make changes on the spot.

"In a lot of our meetings, we brought the model in, talked about programming certain spaces and got buy-off from the owner on design concepts right way," Corb says. "They gave us feedback that we put back in the model in real time. At the end of the discussion, we'd throw the rendering back up so they could respond and approve it. We didn't have to go back to the office, rework it, take it back to them and hope it's what they want."

Between improved communications, a reduced need for reentering data between software applications, and the ability to avoid many costly redesigns late in the schedule, Corb says the process of using BIM along with analysis software in an integrated environment significantly improved productivity.

In the end, it will also ensure quality. By running analysis early and incorporating the results into BIM, Rooke says the team came up with optimal ways of achieving project goals. When the school is completed in late 2009, the team is confident that it will achieve sufficient LEED points toward certification and that the building will use 26% less energy than a similar traditional facility.

"By being involved early, the team could set its target [toward LEED] earlier on instead of just hoping to get it," Rooke says. "This way, we can tell the client with greater confidence that we'll be able to achieve certification."

Introduction to BIM:

SmartMarket Report Special Section

by Stephen A. Jones

Building Information Modeling (BIM) is driving an unprecedented revolution in the construction industry. It involves using digital modeling software to more effectively design, build and manage projects, and is providing powerful new value to the construction industry firms that adopt it.

Simultaneously, it is breaking down age-old barriers between these players by encouraging the sharing of knowledge throughout the project lifecycle and closer collaboration to integrate valuable fabrication, construction and operations expertise into the overall design. This improves constructibility, adherence to schedule and budget, lifecycle management and productivity for everyone involved.

Other major industries have already improved productivity by adopting modeling technologies and integrating their design, production and operations activities. For decades, aerospace, automotive and shipbuilding companies have designed their complex products virtually, working closely with their suppliers, and used the models to drive their fabrication equipment. In effect they build the product twice, once virtually to ensure optimization, then physically in exact compliance with the model, at a high level of quality and production efficiency, in safe clean conditions with a skilled and well-trained workforce. This has contributed enormously to improved productivity, safety and product quality in those industries.

This proven approach is now being introduced to the construction industry as BIM. The potential for benefits is clear and most current BIM users are experiencing positive results very quickly after adopting. Without a doubt, BIM has arrived, and everyone's business will be affected. We are entering the most transformative time our industry has ever experienced.

The Key Concepts of BIM

Most of the important benefits of BIM can be tied to three fundamental concepts:

1. Database Instead of Drawings

2. Distributed Model

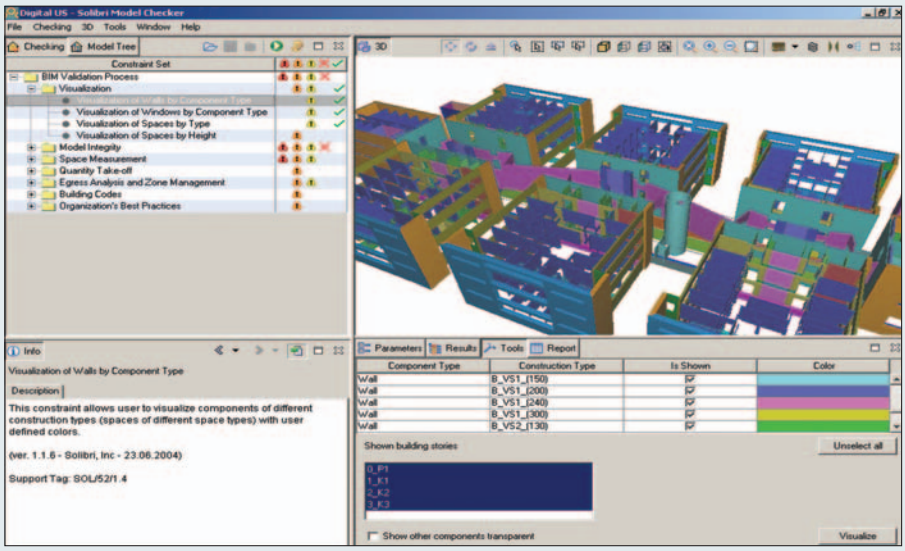
3. Tools + Process = Value of BIM

Database Instead of Drawings

For centuries, designers have used drawings and physical models to convey their mental vision of a project to those who need to approve and ultimately build it. Drawings have become standardized documents (plans, elevations, sections and details). When supplemented by additional documents that specify construction quality requirements, identify specific products to be used, or demonstrate a fabricator's detailed approach to achieving the design intent, they generally achieve their purpose.

But the method of authoring these documents is a major obstacle to improving integration and coordination. Typically there are hundreds or thousands of documents for each project and each is an individual, stand-alone segment of the total design. There is no central repository that effectively integrates all that information to represent the totality. The pieces require human interpretation to tie them together into a comprehensible whole. As a result, effective coordination between the design disciplines and communication of design intent to the field are constant challenges.

The breakthroughs from aerospace, automotive and shipbuilding demonstrate the power of developing designs as a **digital database** rather than a series of separate documents. That database serves as the central repository of all the physical and functional characteristics of a product, or in the case of BIM, a construction project. Documents are still useful, but with BIM they are generated on demand from the database which represents the most current, shared understanding of the project. Documents are no longer the primary, core representation of the project. Instead, the database is "the truth" at any moment in time; a shared resource for reliable, collaborative decision making. Consequently, documents become special-purpose work products generated from that database.



Model-checking software applies user-selected business rules to automatically analyze, find, count or calculate from a BIM. Source: Solibri

A BIM project is not "drawn" in the traditional sense, as lines, arcs and text in multiple documents representing the information about all the elements of the project. Instead it is "built" digitally as a database in BIM software, using **"intelligent objects"** that represent all the elements of the project. So instead of having to look in separate drawings, schedules, specs and cut sheets for all the information on a particular element, let's say an entrance door, all the pertinent information is built into the intelligent object of that door in the BIM. The object knows everything about itself. So, once placed in a BIM it will automatically represent itself in any plan, elevation, section, detail, schedule, 3D rendering, quantity takeoff, budget, maintenance plan, etc. Furthermore, as the design changes, the object can adapt itself parametrically to adjust to the new design.

As a result, all the physical and functional characteristics of a project are in a database format, which opens up enormous potential for fluid exchange of information between project team members and their technology tools, generating exciting process efficiencies and more collaborative design and construction. Additionally, the owner gets a "digital double" of the completed project that can be used for decades of operations and maintenance.

Distributed Model

No one BIM tool can do everything. There are two basic types of BIM tools available today: authoring and analysis. BIM users are taking a "distributed" approach that combines the value of authoring tools with the power of analysis tools.

In a distributed BIM environment separate models are usually authored by the appropriate design and construction entities. These can include:

- **Design models** – architectural, structural, MEP and site/civil
- **Construction model** – breaking the design models down into construction sequences
- **Schedule (4D) model** – linking the work breakdown structure to project elements in the model
- **Cost (5D) model** – linking costs to project elements in the model
- **Fabrication model** – replacing traditional shop drawings and driving fabrication equipment
- **Operations model** – for turnover to the owner

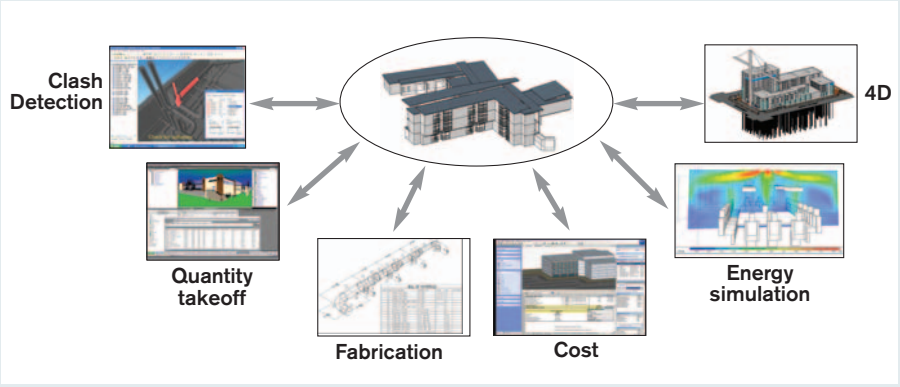
This differs importantly from the current fragmented practice of numerous individual sets of drawings because these models are BIM databases. So, for example, they can be viewed together to identify "clashes" (geometric conflicts between architectural, structural and MEP systems) that can be fixed virtually to avoid field problems. Authoring tools allow 2D or 3D viewing from any angle or section, and can also generate standard documents (plans, elevations, specifications, etc.)

Since the BIM database holds the information from each of the intelligent objects in a BIM, it can "publish" specific subsets of that data to analysis tools on demand. For example, an energy analysis tool can extract just the information about a project's site orientation, glazing, doors, mechanical system performance, equipment electrical loads and heat generation, surface reflectivity of the exterior materials, and envelope insulation properties. The energy analysis tool already has the annual solar path, temperature and wind conditions for the site, so it can analyze a proposed design solution for energy performance and potential LEED credits. The team can then modify the BIM and retest multiple times until satisfactory. All of this happens digitally, with no manual reentry of information from multiple sources into separate tools. It is seamless, fast and highly effective.

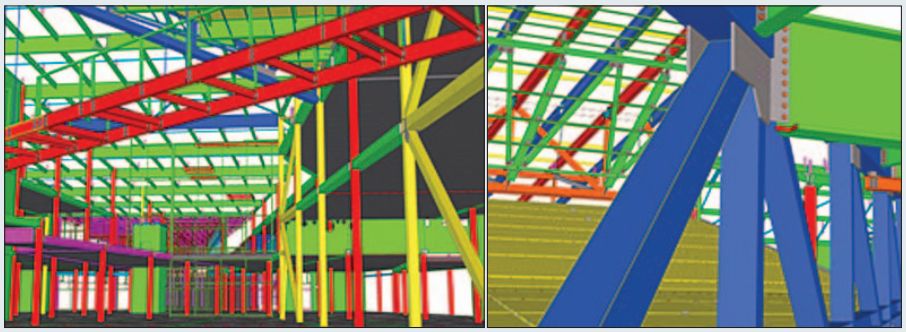
Additional **analysis tools** are rapidly being developed and refined, including:

- **Model-checking** - Applying user-selected business rules to automatically check design models for clashes, or for compliance with accessibility regulations, building codes, etc.
- **Scheduling** – Linking work breakdown structure to relevant project elements to plan construction sequencing. Can produce animated visualization of process.
- **Estimating** – Matching BIM elements to cost codes to produce construction estimates. Can produce "visual estimates".
- **Ingress and Egress** – Populating a BIM with people to simulate scenarios such as emergency evacuation or peak-time elevator queuing.

As more analysis tools are developed to work with authoring tools, the power of BIM will increase exponentially.



Analysis applications extract data from design models and perform valuable functions quickly and reliably. Source: Burt Hill, University Mechanical of Arizona, Ryan Homes, View By View, The Beck Group, Turner Construction Company



Structural models are widely used for design, coordination, analysis and fabrication.
Source: Tekla

Tools + Process = Value of BIM

While modeling tools provide significant benefits for individual users, leveraging BIM just to produce "silos of excellence" minimizes the greater potential for large-scale improvement of the entire industry. The AGC BIM Forum (www.bimforum.org) calls this dichotomy "lonely BIM" vs. "social BIM". Encouragingly, a trend called **Integrated Project Delivery (IPD)** is rapidly emerging and leverages the power of modeling to facilitate collaborative decision making.

IPD brings key construction management, trades, fabrication, supplier and product manufacturer expertise together with design professionals and the owner earlier in the process to produce a design that is optimized for quality, aesthetics, constructibility, affordability, timeliness and seamless flow into lifecycle management.

Using model-checking applications to detect system clashes (e.g. Autodesk NavisWorks, Solibri, Bentley ProjectWise Navigator) is an effective IPD activity, particularly as a starting place for less-experienced BIM teams. Firstly because of their ease of use and powerful visualization capability; but also because they offer the opportunity to collectively resolve what are often contentious, expensive and time-consuming conflicts in the field in a non-confrontational, collaborative process during design, while they are still relatively inexpensive to correct.

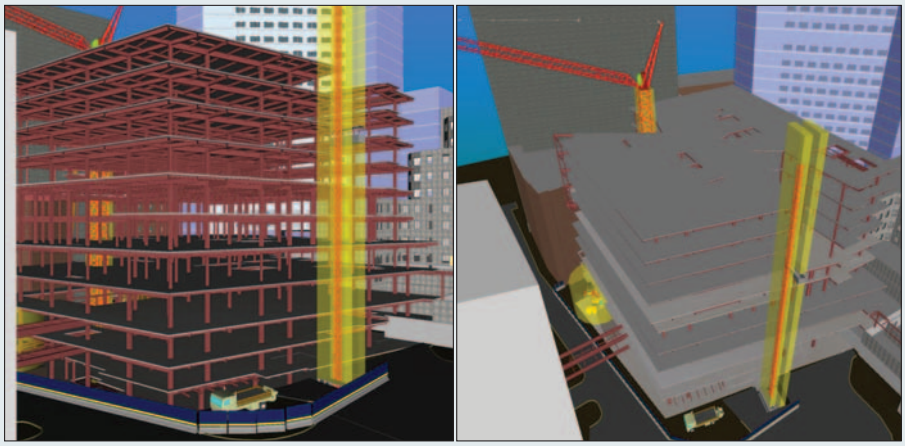
This productive engagement around clash detection sets the stage for improved collaboration among team members. For example, the structural design team can provide its structural model to the steel fabricator, who details directly in the same model. The fabricator then utilizes the detailed model both for approval by the design team, thereby reducing the slow and wasteful process of shop drawings, and to drive its fabrication equipment on the shop floor.

Overall, it is the powerful combination of modeling and analysis tools with integrated, collaborative processes that is creating the sea change related to BIM. And as adoption of these tools and processes spreads, teams will continue to find new productivity-enhancing ways to leverage the power of BIM for better projects.

THE IMPACT OF BIM

BIM will forever change the way projects are designed, built and operated for everyone. As traditional inefficiencies become things of the past, many current roles, tasks and responsibilities will become obsolete. Reward will always follow value, and current models for scope, compensation, risk and project delivery will change to adapt. Among the changes we predict are the following:

- Ecosystems will form of companies that have learned to effectively provide integrated solutions, and they will compete together for new work based on demonstrated past successes. This will include design professionals, construction companies, manufacturers, suppliers, fabricators and specialty consultants.
- Certification initiatives underway from AGC and elsewhere will help to separate qualified practitioners from those merely promoting "BIMwash". Academic institutions will incorporate collaborative modeling into their core curriculum to meet the demand for BIM-savvy graduates. And training programs, internal and external, will proliferate.



Modeling of construction logistics is growing in popularity because of its contribution to cost avoidance and site optimization.
Source: Turner Construction

- Although current BIM usage is focused on buildings, innovative firms are already applying it to civil and engineering projects, and its use will continue to expand rapidly as the benefits for all project types become more widely recognized.
- As with aerospace and automotive, modeling will enable prefabrication of larger and more complex portions of construction projects. Lower labor costs, safer conditions, reduced raw materials and more consistent quality will provide compelling economic, workforce and sustainability incentives to drive this trend. Project sites will shift from labor intensive construction to highly skilled assembly, and manufacturers will adopt flexible production processes to facilitate more product customization.
- Owners will expect much more clarity about cost, schedule and quality far earlier in the process. This will facilitate increasingly earlier engagement by manufacturers, suppliers, fabricators and trade contractors and expand the use of 4D and 5D analysis tools.
- Contracting methods will emerge to support integrated project delivery based on principles of mutual respect and trust, mutual benefit and reward, collaborative decision making and limited dispute resolution. The AIA and AGC are currently launching initial versions of these documents.
- As more completed models are integrated into ongoing operations, a whole new source of in-place performance data for building systems and products will become available. This "living laboratory" of operations models will create a feedback loop that will directly influence future design solutions and product selections. This will help green design to become mainstream, by carefully monitoring building performance against sustainable goals.

WHAT TO DO ABOUT BIM

If your firm has not yet become engaged with BIM, there are steps you can take to start the process.

Owners, Design Professionals and Construction Companies

- Establish and maintain senior management support. BIM transition requires both funding (software, more powerful hardware and training) and time. Designate a BIM Champion and support that person to lead the change process.
- Build momentum by starting small. It may take two or three projects before you see net positives, so set appropriate expectations and stay committed. Small successes will be the best driver for wider adoption.

Building Product Manufacturers

- Begin creating intelligent BIM objects of your most popular products. Your organization already has the required product data and there are a growing number of qualified content producers. McGraw-Hill research shows many BIM users are more likely to specify products on BIM projects if the BIM objects are available, and they don't have to build the objects themselves.

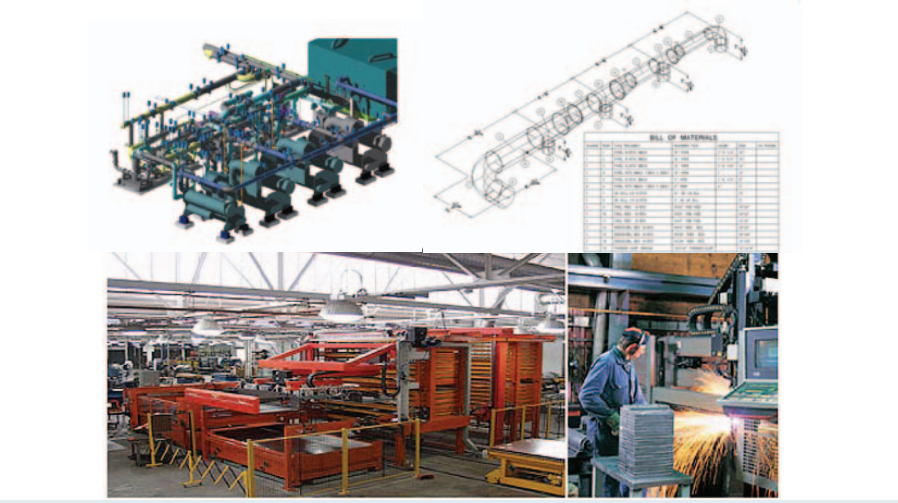
Everyone

- Talk with peers and companies you regularly work with to determine where they are in the process. Collaborate on BIM to accelerate everyone's progress.
- Get smarter about BIM. There are a growing number of print and online research resources, and industry organizations are all gearing up to help members make this transition. Leverage those resources.

CONCLUSION

Although it can be said that we are still in the "wonder years" of this industry transformation, one thing is clear, we are not going back. Your career and the prosperity of your company depend on becoming familiar with the tools, processes and value propositions of BIM.

The BIM revolution is happening from the bottom up, driven by individuals and companies who see the potential and devote their energies towards building the bright new future of the construction industry. If you have already begun the journey, congratulations, you have more fellow travelers every day. And if you are still waiting to take the first step, don't wait too much longer. Your competition isn't.



Model of mechanical system produces bill-of-materials and directly drives fabrication equipment for exceptional accuracy and productivity in pre-fabrication. Source: ViewByView

Interview:

with Phil Bernstein, Vice President, Autodesk, Inc.

Autodesk has been at the forefront of 2D and 3D design software development for decades—from its introduction of AutoCAD in 1982 to the first version of Revit in 2000, which today is its BIM platform. Phil Bernstein, vice president at Autodesk, offers his view on how BIM has evolved and how its influence will continue to grow in the future.

BIM has reached a tipping point as implementation is gaining significant momentum. How would you characterize the evolution of BIM?

I started working on this more than six years ago and the theory has always been that transformational process change in the A/E/C industry takes about 10 years before you get to acceleration. The fact that we're seeing serious acceleration in Year 7 is a good thing. It's happening very fast and in a slightly different way than I would have anticipated. Rather than it just being an improvement in the means of production, we're in a very profound discussion about the A/E/C process—what we do and why we do it. It's a much more interesting problem set than we originally anticipated. I spend more time talking about things like the future of the process, the role of the architect, integrated project delivery and the impact of digital fabrication—implications of the tools rather than the little technological improvements we need to make.

How do process challenges affect analytical tool capabilities, such as scheduling and cost?

Cost and timing are analytical capabilities that are relatively straightforward in how they are derived from a BIM. The problems have more do with a lack of clear process definitions around how things work and how you would be able to do the analysis. The issues have more to do with worldviews of how estimating works across the bridge between design and construction. The rules of engagement about who is responsible for the cost estimate and what level of detail is needed.

By definition, design professional information falls under the rubric of design intent. The contractor needs construction execution insight. An architect wants to see a continuous piece of concrete that's represented as a single floor in a model. The contractor wants to see where to put the pump or the dimension of the concrete forms. In a world of deep process integration with designers and contractors working together, the contractor could tell the architect how he would like to see something represented. Right now we haven't worked out that process. We're capable of making those types of representations, but there are process questions in the way.

There are limited ROI metrics about BIM to prove its value. On what basis are firms adopting it?

The discussion about implementation is caught in this twilight zone right now, where part of the firms are doing this because they want to be ahead of the curve and part are doing it because everyone else seems to be doing it. I went through the hand-drafting-to-CAD transition [as an architect]. We didn't do a lot of math about ROI—you could just feel it coming. The thing you hear is that productivity significantly increases. One ROI question is, if you're working more efficiently, what do you do with that time? Do you fold it back in and do more design or do you keep it as profit? The other metric I hear is the dramatic decrease in the percentage spent on change orders relative to coordination errors. We hear from firms that consistently say it's below 1% [with BIM], when normally it's 3% to 5% [without BIM]. There are a lot of ways to capture value.

What are the big developmental steps that BIM needs to take now?

The main problem has to do with cross-disciplinary integration—moving information that's created in a series of adjacent models smoothly. A second big issue for us right now is analysis, meaning taking information from the model and being able to reason about the design. At Autodesk, right now our two main emphases are around sustainability and structural engineering.

Who will lead the charge toward wide-spread BIM implementation?

We're seeing this very interesting dynamic where you have young architects who are extremely digitally skillful, but they don't know anything about putting a building together, along with baby boomer architects who know a lot about putting buildings together and have no digital skills whatsoever. It's changed the mentoring structure. The generation of architects who are going to shepherd this through are not the baby boomers. It's the next generation of more digitally facile and more intellectually flexible architects who define the problem set differently than my generation did. They are the ones that will figure out how this whole thing will happen.

Value of Using BIM

Perceived Value of BIM

BIM offers valuable benefits to users, helping drive expanding investment in the technology. Half of users say BIM has a very positive impact on their business practices (see the section "Adoption of BIM"), which helps drive its rapid near-term expansion.

Benefits cited by users include:

- Easier coordination of different software and project personnel
- Improved productivity
- Improved communication
- Improved quality control

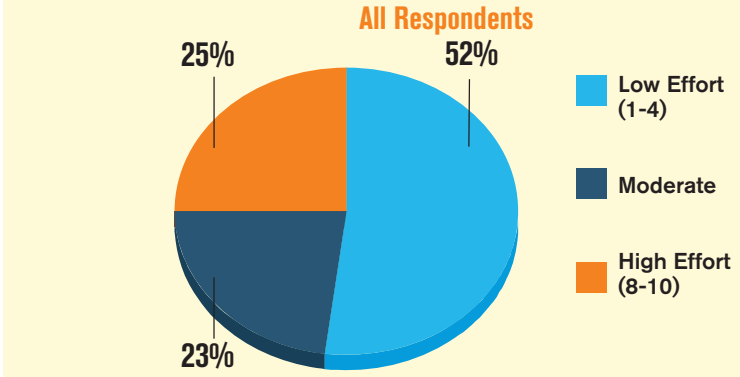
However, **quantifying some of these benefits can be challenging.** Some BIM users are tracking their ROI, but many aren't. Establishing better metrics for measuring ROI could help users prove its value to doubters and increase future use.

Measuring Value

Some users are making in-roads toward measuring ROI. **Half of current users (48%) measure ROI on at least a moderate level.** Results from companies who are actively tracking BIM ROI (see PCL Construction Case Study and Holder Construction interview) are showing **initial BIM ROIs of 300 to 500% on projects where BIM was used**.

A follow-up McGraw-Hill Construction online survey of AGC BIM Forum members found their average perception of ROI on BIM to be between 11% and 30%. But **those making the effort to measure ROI perceive a higher value**. Among those not measuring ROI, almost 10% perceive a negative ROI, only 7% perceive an ROI greater than 100%, and none perceive ROI greater than 300%. Whereas among those that do measure it, less than 2% perceive a negative ROI, almost one third report an ROI greater than 100%, with several greater than 1,000%. So, it appears that measuring ROI establishes greater benefits from BIM than mere intuition suggests.

Involvement in Measuring ROI of BIM by Respondent Type



Source: McGraw-Hill Construction, 2008

Interview with Michael LeFevre, AIA, NCARB, LEED© AP

Vice President, Planning & Design Support

Holder Construction Company

Holder Construction Company today is actively measuring return on investment on many of their BIM projects. Michael LeFevre, Vice President of Planning & Design discussed how his company is gathering and using BIM metrics:

How long has Holder been using BIM on projects and how long have they been tracking BIM ROI? We have been using BIM since 2005. During the first year we were still developing the modeling skills and deciding on what metrics to track, so most of our tracking data is from 2006 forward.

On how many projects have you been able to track BIM ROI so far? Some of our BIM projects span multiple years. We are actively tracking 20+ projects and have probably tracked a total of 30 or more projects since we began to collect and analyze metrics.

What aspects of BIM ROI do you track today? We are primarily tracking direct collision-detection cost-avoidance savings. We have also tracked some planning-stage savings and some value-analysis options savings where the model helps bring us back into budget.

How do you calculate the value of a collision detection? There is a certain science to the way we approach this. Our approach is to have our project team look at the collision, analyze what is colliding, assess the level of severity, and then multiply it by the unit-cost crew-hour rates that are effected. Most of the collision costs we have used fall between $1000 to $3,000 per collision — a very conservative number.

What are your overall ROI results? Most of what we have done is model geometry creation and collision detection. The cost of collision detection is only a fraction of a percentage of the overall construction costs. When you just focus on this one direct cost we are easily seeing a three to five times return vs. the model costs and we think that this is a very conservative number.

What BIM ROI metrics will you be measuring in the future? There are so many different categories of indirect costs that we would like to analyze. This includes construction team time savings, general conditions cost avoidance due to schedule compression, the value of better decision making and savings related to better building performance.

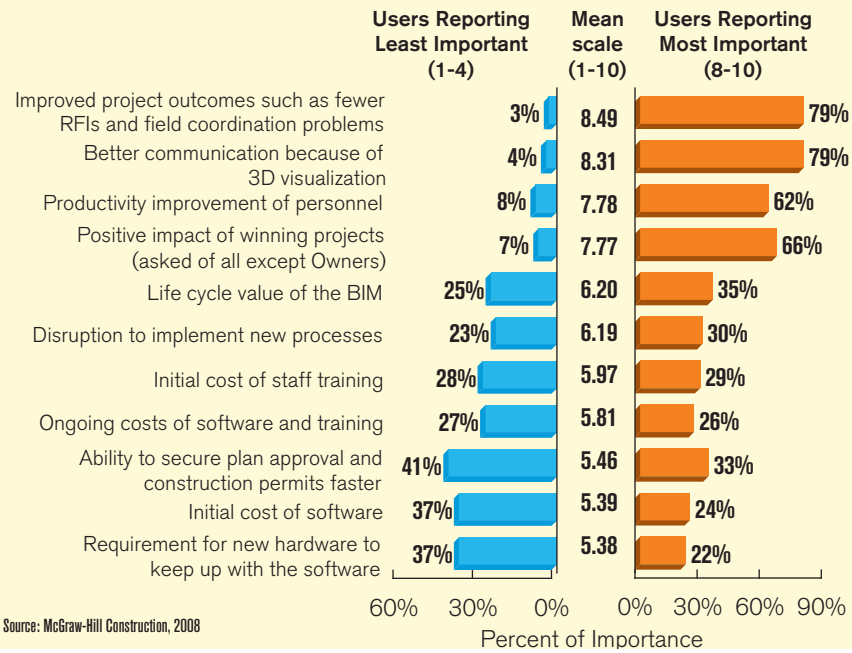
Importance of Tracking ROI

BIM can provide wide-ranging benefits: however **users who measure ROI focus primarily on areas that involve communication and personnel coordination.**

Key Aspects

- **Improved project outcomes such as fewer RFIs and field coordination problems.** Contractors and architects place the highest emphasis on this benefit as these are the areas that impact them more directly compared to others. An example is the cost savings associated with clash avoidance.
- **Better communication because of 3D visualization.** Contractors and owners place the highest emphasis on this benefit. Visualization is key to keeping owners informed and bringing workers in the field up to speed on construction tasks. Savings can also be identified during the planning stage.
- **Productivity improvement of personnel.** Architects and engineers place the highest emphasis on this benefit. Once input, BIM data is available to be used for multiple purposes, offering more opportunities to design rather than draft. Contractors can also utilize BIM onsite to adjust personnel to changing schedules due to site conditions.
- **Positive impact on winning projects.** Contractors and engineers place the highest emphasis on this benefit. Firms that regularly bid work need to know that BIM can give them a competitive advantage.
- **Lifecycle value of BIM.** Architects and engineers place the highest emphasis on this benefit. The data created during their early involvement in BIM projects can live on long after their work is complete. Energy modeling can be used during design with results analyzed after completion.
- **Initial cost of staff training.** Architects and engineers place the highest emphasis on this challenge. The initial costs of BIM can be onerous for some of these users, particularly for smaller firms.

Importance of Aspects for Measuring ROI



Source: McGraw-Hill Construction, 2008

Most Valuable Aspects

- **Easier coordination of different software products and project personnel** (28% of all users). Architects are most likely to see this benefit (35%).
- **Improved efficiency, production and time savings** (11% of all users). Owners are most likely to see this benefit (18%).
- **Communication** (8% of all users). Architects and contractors are both most likely to see this benefit (11%).
- **Improved quality control/improved accuracy** (8% of all users). Engineers are most likely to see this benefit (10%).
- **Aids with visualization of the project** (7% of all users). Architects and contractors are both most likely to see this benefit (9%).
- **Advantage of 3D modeling and coordination** (5% of all users). Architects are most likely to see this benefit (11%).
- **Keeping pace with advances by competition and others in marketplace** (5% of all users). Engineers are most likely to see this benefit (10%).
- **Advantage of 3D modeling and coordination** (5% of all users). Architects are most likely to see this benefit (11%).
- **Clash detection and avoidance** (4%). Contractors are most likely to see this benefit (11%).

Experience Pays Off

As with many BIM-related issues, the level of involvement in measuring return on investment increases as the user gains experience.

At face value, this is a logical progression. BIM experts are more likely to have a grasp of the BIM-specific factors at play in tracking ROI. However, this also means **beginner and intermediate users must trust that BIM is beneficial since they are not likely to be able to measure their ROI yet.**

- Forty-four percent of experts frequently track ROI compared to only 10% of beginners.

Case Study:

Crate & Barrel

by Bruce Buckley

When billion-dollar companies like Northbrook, Illinois-based Crate & Barrel speak up about building information modeling, the design and construction industry can't help but notice. Crate & Barrel is among a growing number of owners who preach the benefits of BIM and require it on projects. Through use of BIM, the company is seeing reduced costs, improved communications and shorter schedules that contribute to greater productivity.

With more than 160 stores, Crate & Barrel has established a reputation for avoiding prototypes and giving each location a distinct neo-modernist design. In order to ease the challenges of rolling out so many unique buildings, Crate & Barrel focuses on maximizing efficiencies.

Through the use of BIM, Crate & Barrel has been able to take advantage of integrated project delivery (IPD). The method allows greater exchange of information and ideas among team members by bringing them together earlier in the process when they can offer more benefit. By orchestrating collaboration and rethinking traditional roles, John Moebes, director of construction at Crate & Barrel, says IPD allows the company to optimize schedules and eliminate redundant or low-value steps.

The cornerstone of that effort is BIM. In recent years, the company has required use of BIM to facilitate information exchange and, in turn, improve project results.

Part of the company's drive to mandate BIM stems from its own place in the process. The company has an in-house design group and a construction department that acts as a construction-manager-at-agency.

"It creates a unique position for us as an owner," says John Moebes, director of construction at Crate & Barrel. "We're not just sitting on a tall seat like a tennis referee watching the back and forth on the court. We're on the court with a racquet."

Image courtesy of Crate & Barrel

On its IPD projects, the company has started to find its rhythm. Most projects have a 6-week conceptual design phase, a 24-week document schedule, a 32- to 42-week construction schedule and a 4-week commissioning period.

"In the past, some projects would go over a year in construction while others took 36 weeks," he adds. "It was completely unpredictable."

Among its greatest recent successes is the early integration of prime subcontractors into the team. Steel subcontractors are brought in to help influence design elements in the model such as column lines and beam penetrations with an eye on economizing the design. Once the structural engineer is finished, information from the model can be used to generate a mill order.

"The process is remarkably smooth," says Rob Rutherford, project manager with Charlotte, North Carolina-based SteelFAB, who has worked on eight projects with Crate & Barrel. "It makes all the difference in the world when the owner is driving this. All of the trades give it attention."

The payoff has been considerable. The average project weight has dropped from 190 tons to 140 tons. Steel schedules have been cut roughly in half with fabrication reduced from six weeks to two weeks; shop drawings down from six weeks to three weeks; and erection times of three weeks instead of six.

"By getting in early, we can throw out frame options and save weight," Rutherford adds.

Team integration and BIM use are also beginning to pay off with MEP subcontractors. On a recent job in Skokie, Illinois, the team was able to share data with Hill Mechanical of Chicago,

helping Hill speed up its schedule for fabrication and installation.

"We already use 3D, so even if it wasn't in BIM we would have had to do that ourselves," says Andrew Yonkus, a senior project engineer at Hill Mechanical. "Having that information come from Crate saved us a lot on the coordination process."

By using BIM and prefabricating materials, Yonkus says the company was able to install all of the rough-in work in two and a half weeks—nearly half the time it would normally require.

General contractors are seeing the benefits as well. Tocci Building of Woburn, Massachusetts, is used to building its own models on jobs, so staff was pleasantly surprised to learn it would receive models from the architect and engineer on a Crate & Barrel project in Natick, Massachusetts.

"We worked at the beginning of the project with the design team about the ways that we model and the ways that they model so that we could figure out the best ways collectively to build the project models," says Laura Handler, virtual construction manager at Tocci. "They were very receptive and agreed to adopt some of our strategies. They were willing to meet us halfway on some things. That's less effort we put in, which creates more value."

In addition to coordination, Tocci is using the models for scheduling and logistics planning.

"One thing we're doing is using [software] to do construction layout from the model," she adds. "We think that's important on a project like this because clean lines are very important to Crate & Barrel. We'll be able to deliver that much better when we can lay everything out and we know precisely where things should go. The model gives us much more accuracy."

Across all contractors, Moebes says one the biggest savings of time and money has been a drastic reduction in requests for information. Unlike past projects, Moebes says that now he sees only a small number of RFIs, and in some cases there are no RFIs dealing with rework.

"We don't see RFI published regarding things like pipes [routed] through beams anymore," he says. "Those are gone, which is good since those are the hardest RFI to deal with because you have to go back to rework something that was poorly understood to begin with. You end up spending time fixing content versus adding content."

BIM will continue to serve as a critical tool for Crate & Barrel as it looks to pursue additional strategies such as prefabrication and modularization. In the coming years, Moebes can't predict exactly where the technology may lead the company. Based on history, it's difficult to know where innovation will take you.

"It's like the early days of airplanes," he says. "The first aircraft didn't look the same or act the same as the ones being used 10 years later. We're on that same path now. Where we're headed in the future is very different from where we are now."

Image courtesy of Crate & Barrel

Impact of BIM on Internal and External Processes

Process Paradigm Shift

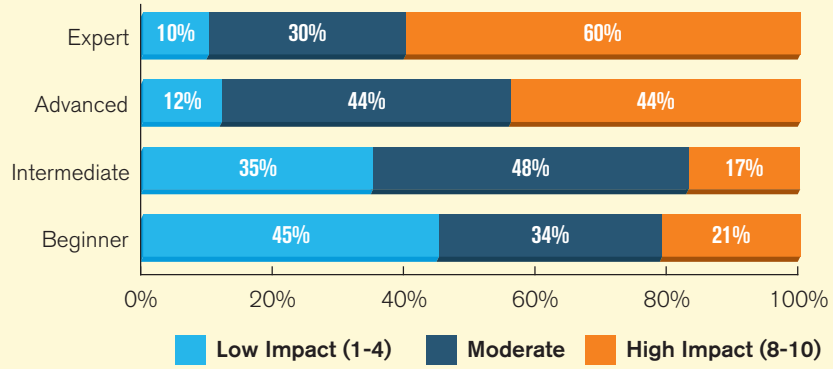
Among BIM's strongest advocates, it represents a paradigm shift in processes for design and construction.

The ability to create a model that combines data which was traditionally spread across multiple documents along with the ability to share information between different models presents **an opportunity for greater collaboration. This in turn produces better design solutions.**

Internally, this can result in a rethinking of roles, workflow and, in some cases, creating new positions tailored to virtual design and construction. **A majority of current BIM users recognize this need and have made the necessary changes in-house to reap the rewards.**

Externally, this paradigm shift can break down traditional barriers between team members and promote a more integrated delivery team. **BIM facilitates greater exchange of project data between team members, which can impact how teams work together.** In many cases, having this data early in the process can help improve quality and cost effectiveness. Rather than the traditional handoff of one team member's work to the next in line, an integrated environment allows more decisions to be made collaboratively early in the process. **Two-thirds of current BIM users have changed how they work externally as a result of BIM.** As more firms adopt BIM in the coming years, its impact on external processes will be even more profound.

Impact of BIM on Internal Project Processes by Experience Level



Source: McGraw-Hill Construction, 2008

Impact of Experience

While average users view BIM as having a moderate impact on their internal processes, **users tend to make increasingly dramatic changes in practice as they gain experience with BIM.**

Only one in five beginner and intermediate users says BIM has had a significant impact, while nearly half of advanced users and three in five expert users say it has had a dramatic impact.

This shows BIM's potential to promote the paradigm shift in process. It also suggests that, as more users gain experience over the years, the technology could have a far-reaching effect on the industry and help redefine the way it works.

Internal Process Change

Regardless of whether a company shares its BIM-related data with other team members, **BIM is significantly changing the way companies work internally.** Seven in 10 users say that BIM has had at least a moderate impact on their internal project practices.

Given the decades-long traditions of many firms, this is a profound finding. Companies develop their own best practices over years of project experience, yet a large percentage of users are willing to rethink those processes when using this still nacent technology.

- **Architects** are more inclined to see an impact than others. This could reflect the advanced rate of adoption by architects relative to other users.
- One-third of **contractors** who use BIM say it has had a dramatic impact on their internal practices. However, one-third report little impact. As contractors realize a projected dramatic increase of BIM adoption in 2009 and beyond, internal impact on them will likely follow the pattern set by architects.
- **Owners** see the least impact on average with one-quarter reporting high impact and one-third reporting low impact. Currently, most process changes related to implementing BIM during design and construction are experienced by contractors and designers. As BIM-enabled facility management advances, owners can expect to experience more impact internally.

External Process Shift

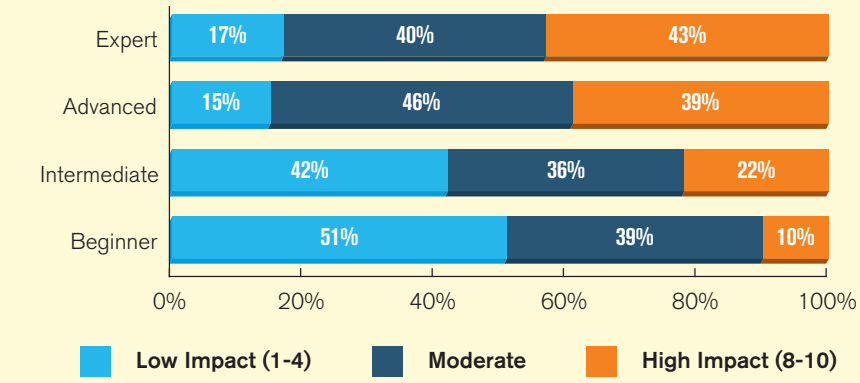
Along with changing how users execute their own work, **BIM is changing how build team members interact with each other.** New ways of using project data coupled with the opportunities to share that data with other team members can create more integrated teams than traditionally seen.

Two-thirds of users say that BIM has had at least a moderate impact on their external project processes. This is only slightly less, on average, than the impact reported on internal processes. Some of this difference could be related to companies who "silo" their use of BIM, employing it only for their own purposes. However, the fact that the difference is relatively small (around 5%), suggests that siloing is not as pervasive as might be expected.

User Differences

- **Architects** are most likely to say BIM has had little impact on external processes compared to other build team members. Two in five report it at that level. In fact, architects report the greatest impact of BIM being more time designing and less time documenting, which is primarily an internal benefit.
- Nearly half of **engineers** report that BIM has had a moderate impact on their external process. Civil, transportation and environmental engineers report utilizing BIM to facilitate regulatory approvals significantly more than architects, owners and other engineering disciplines, possibly foreshadowing the emergence of another high-value application of BIM. Conversely, civil engineers only utilize the 3D visualization capability of BIM to communicate at half the frequency of architects and contractors. This is likely to increase as integrated teams compile more aspects of a project into collaborative models. Civil engineers again take the lead among all design disciplines in leveraging BIM for cost estimates, and fall only slightly behind general contractors in that practice.
- **Contractors** are most likely to see a dramatic impact to external practices compared to other build team members. One-third report it at that level. Contractors lead all other project team members by 50% in their utilization of BIM's clash detection capabilities, and by nearly that margin in conducting BIM reviews in collaborative environments with multiple project participants. **This data suggests that contractors are the driving force in moving BIM from an internal tool to a team-wide process.**
- **Owners** are evenly split between saying BIM has little, moderate or dramatic impact on external processes.

Impact of BIM on External Project Processes by Experience Level



Source: McGraw-Hill Construction, 2008

Impact of Experience

Just as with internal processes, average users report that BIM has **a moderate impact on their external processes. Likewise, the tendency to make those changes increases significantly as users gain experience with BIM.**

Only one in 10 beginners says BIM has had a dramatic impact, while more than two in five experts say it has had a dramatic impact.

Again we see that as more users gain experience with BIM, the technology is changing how teams interact.

Notably, experts do not say BIM has had nearly as much of a dramatic impact on external processes (43%) as they do on internal processes (60%). This could reflect siloing, whether it is intentional or not.

Many users have made the decision to embrace BIM and make it a significant part of their practice regardless of its use by others. This outlook could change over time as more team members get up to speed on BIM and can offer data that can be shared with others.

How BIM Is Used

BIM is being developed with a broad range of users in mind. As such, its uses are extremely varied and in many cases can differ significantly among build team members.

Still, there are some areas where team members agree on its appropriate level of use.

- **Routinely using BIM's 3D visualization capabilities to communicate with all parties** is the highest-ranked use reported by each team member.
- **BIM reviews in collaborative environments with multiple parties** is used moderately by each team member.
- **Eliminating shop or field drawings by having parties work within a shared model** is still emerging among all team members.

User Differences

The top uses of BIM among **architects** include:

- Routinely using BIM's 3D visualization capabilities to communicate with all parties
- Increased time spent on design
- Reduced time spent on contract documentation

The top uses of BIM among **engineers** include:

- Routinely using BIM's 3D visualization capabilities to communicate with all parties
- Increased time spent on design
- BIM reviews in collaborative environments with multiple parties

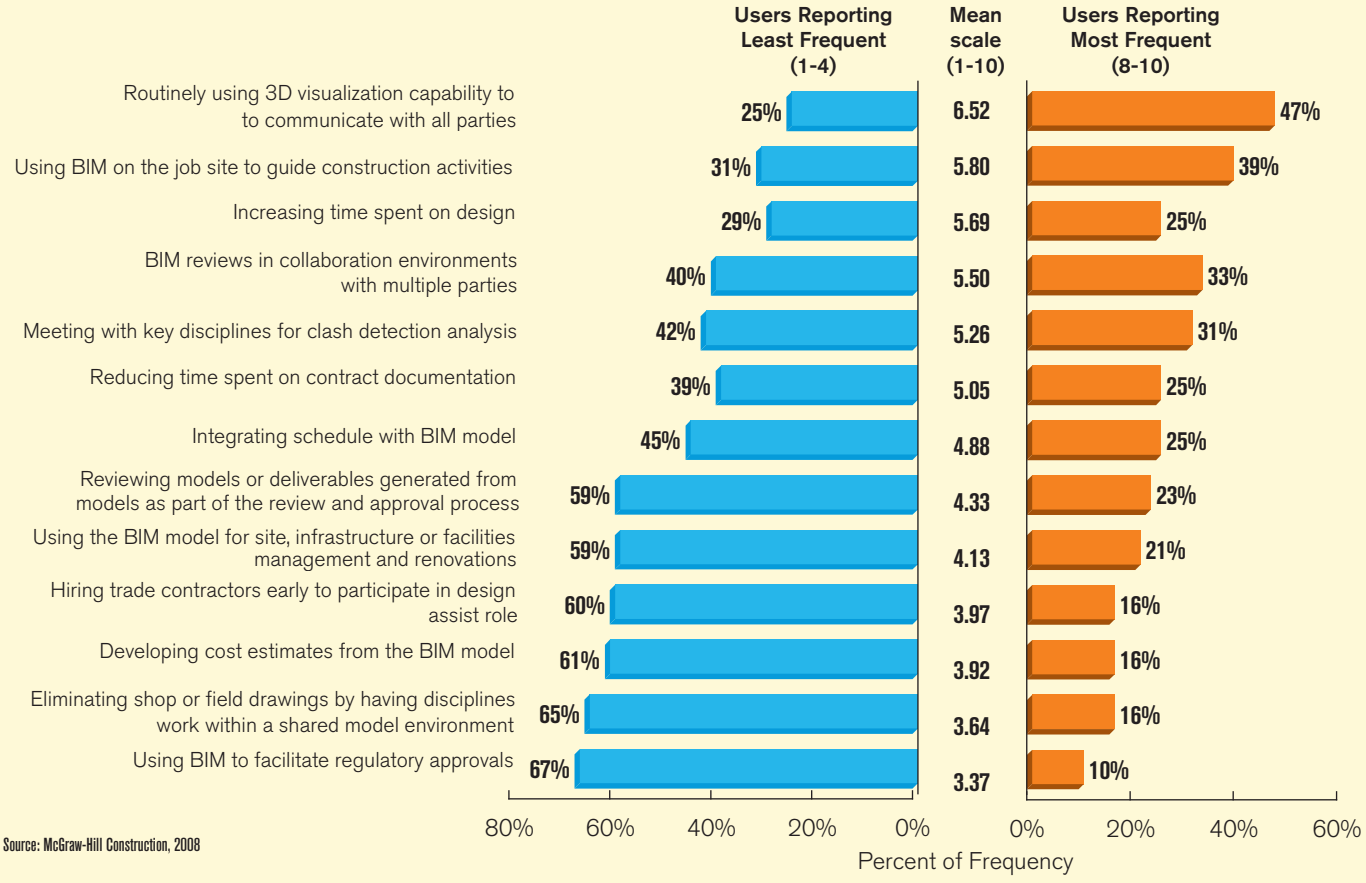
The top uses of BIM among **contractors** include:

- Routinely using BIM's 3D visualization capabilities to communicate with all parties
- Meeting with key disciplines for clash detection analysis
- BIM reviews in collaborative environments with multiple parties

The top uses of BIM among **owners** include:

- Routinely using BIM's 3D visualization capabilities to communicate with all parties
- BIM reviews in collaborative environments with multiple parties
- Meeting with key disciplines for clash detection analysis

Frequent BIM-Related Activities



Source: McGraw-Hill Construction, 2008

Risks When Using BIM

As BIM changes the way that firms work internally and externally, many questions loom about its potential risks and liabilities.

- **Errors and accuracy issues** concern owners far more than other users. Errors can result in significant future costs and possible safety issues for owners.
- **Liability and legal issues** are of equal concern to architects, engineers and contractors. As BIM allows the exchange of data between team members for their common use on projects, there is often a concern among these users about the reliability of this data. An integrated environment offers considerable advantages to productivity, but team members must hold a greater level of trust in each other. Resolving liability issues early is a key to a successfully integrated project team.
- **Inexperience of end users and learning curve** concern to architects and owners more than other users. Because BIM is an emerging technology, levels of expertise can vary greatly within a project team as well as within one's own company. Architects are early adopters of BIM compared to other users and often have more experience than their counterparts. Because data can be frequently exchanged among team members using BIM, there is a perceived risk that the "weakest link" in the chain could jeopardize the project as a whole.
- **Ownership of the model after distribution and taking responsibility for changes made by others** is of much greater concern to architects and engineers. The debate over who "owns" a project model has been particularly heated among these users in recent years. Firms that "silo" their BIM work in-house— not sharing data with others—largely avoid these issues. However, as teams become more integrated there is the potential to open up more liability questions.

Integrated Project Delivery

Integrated Project Delivery (IPD), according to the AIA, "leverages early contributions of knowledge and expertise through the utilization of new technologies, allowing all team members to better realize their highest potentials while expanding the value they provide throughout the project lifecycle." The AIA California Council and the AIA's Contract Documents Committee developed an Integrated Project Delivery Guide to "assist owners, designers and builders to … utilize IPD methods to achieve enhanced design, construction and operations processes." Markku Allison, AIA, resource architect for AIA Strategy and Business Development, articulated the critical need when launching the IPD Guide. "Project delivery models must change to increase the quality, cost effectiveness and sustainability of the built environment. We understand that this model is still in its infancy and have worked to provide a resource that aids the industry in the paradigm shift from current fragmented processes that focus on the short-term to value-based services with high outcome long-term results for all parties involved in the construction project." The IPD Guide is a valuable resource for architects, engineers, consultants, contractors and owners to envision the potential of collaborative processes and implement them on their projects. See www.aia.org/ipdg.

Contract Language

Although there are some perceived risks unique to BIM projects, **little is being done to mitigate those liabilities in contracts.**

- All users are most likely to use conventional contracts without any modifications to accommodate use of BIM.
- Very few users are adopting new kinds of contracts on BIM projects.
- Contractors are the only users likely to modify conventional contracts when using BIM.

Many users (42%) are aware of efforts to develop BIM contract forms. A portion of those respondents were able to identify AIA and AGC as working on BIM contract initiatives.

AGC launched its ConsensusDOCS initiative in September 2007 (www.agc.org/cs/contracts).

The October 2008 release of AIA Contract Documents includes agreements for BIM and integrated project delivery (www.aiacontractdocuments.org).

Use by Experience

Many of BIM's uses only gain favor among team members as users gain experience. The greatest divide between more-experienced and less-experienced users can be seen when:

- Reviewing models or deliverables generated from models as part of the review and approval process.
- Using the BIM model for site, infrastructure or facilities management and renovations.
- Meeting with key disciplines for clash detection analysis.

Case Study:

UCSF Cardiovascular Research Institute

by Bruce Buckley

On the campus of the University of California San Francisco, build team members are using BIM to find harmony. In constructing the university's new $254 million 236,000-square foot Cardiovascular Research Institute laboratory, team members are adopting BIM as part of a strategy to break down traditional barriers between firms and deliver the project on time and on budget.

"This is a job where rules had to be changed and people had to be willing to look at things in a new way," says Luminita Ruva-Ciupitu, principal at SmithGroup.

The project, which SmithGroup was awarded in 2005, represents the San Francisco office's first large-scale foray into building information modeling.

"This is one of the most efficient labs we've ever designed," Ruva-Cuipitu explains. "We were interested in doing a major BIM project and this was the right opportunity."

Thanks to the owner, that decision came easy. Michael Bade, director of capital programs in UCSF's Capital Projects and Facilities Management department, was also eager to put BIM to the test. After spending 12 years working on construction projects in Japan, Bade wanted to foster a more cooperative way of working on public projects.

"When I came to work for the university, I saw projects run into difficulties because of the lack of cooperation and problems happening because of a lack of complete information," Bade recalls. "Since I became responsible for UCSF's project delivery processes in 2004, I've been looking for ways to use cutting edge tools and processes to improve that situation and allow projects to benefit from improved information flow and management processes."

Image courtesy of SmithGroup

Early on, SmithGroup's use of BIM helped set the stage. Starting in November 2006, the firm got up to speed with BIM during the schematic design phase. Once design development began in April 2007, the larger process change that BIM promotes became more obvious. Architects, structural engineers and MEP designers all fed information into the model. Many of the details that traditionally weren't expressed until later had to be addressed.

"In BIM you input elements and you have to know a lot more details so that the software can draw it for you," Ruva-Cuipitu says. "You have to spend the time at that point to investigate what you need, which takes more time to input."

As a result, instead of spending the anticipated four months in the DD phase and eight months in the construction documents phase, SmithGroup devoted six months to each phase.

But those early design details paid off in other ways. Thanks to the additional project data, UCSF could bring other team members on earlier and accelerate portions of the work. Steel orders were running at a 10-month lead time, so the team was able to sequence the creation of bid packages from the model to get a steel order placed in the mill queue while design was at 30%.

Contractors were also brought on during design development, a move that required avoiding the traditional design-bid-build delivery method used on projects. With approval from the state legislature, UCSF experimented with a best value system. When contractors submitted bids, they also answered questions in five detailed areas laid out by law, including questions about each firm's expertise in BIM.

UCSF scored the answers and divided the score into the dollar amount of bids to get a cost per point. With the lowest cost per point bid, Rudolf and Sletten of Redwood City, California, was awarded the job.

The same process was also used with awarding major subcontracts for the MEP and building envelope work.

Although the bidding process took place during a time of major price escalations in the Bay Area, bids came in as projected, keeping the project on budget.

"BIM helps take out a lot of the guesswork," Bade says. "Doing designs in BIM and showing ahead of time that you have a coordinated job makes it desirable for contractors. Suddenly you have more bidders, prices come down and risk premiums evaporate. It's a virtuous circle."

Leading up to the start of foundation work in January 2008, use of BIM was well underway among contractors. In addition to using BIM for clash detection, Rudolf and Sletten did advanced 4D (schedule) simulations of the structural steel system, site logistics and the building's highly complex skin system.

"We took the model, revised the organization and added model elements in order to have all of the components in place to do week-by-week simulations, including showing the equipment that would be used for lifts," says Michael Piotrkowski, director of technical development at Rudolf and Sletten. "By doing that, you can see instantly any object or component that hasn't been included in the schedule. You quickly learn what's missing."

While BIM facilitates the frequent exchange of data between team members, UCSF is pushing for even greater teamwork. Bade instituted a project management method among key team members and prime subcontractors that rewards cooperation through incentives. Each team member has a weekly work plan, but instead of paying out incentives for individual performances, the results are judged collectively. If the team doesn't reach its goal together, no one receives a bonus.

Image courtesy of SmithGroup

"The key is anticipating issues," Bade says. "The team works to anticipate issues, clear constraints and develop the information needed to build and meet goals. It uses peer pressure and rewards people for cooperating."

To help lower communication barriers, representatives of every key firm are housed in the same site trailer.

"The benefit is that people develop relationships by working in the same space," Bade adds. "You can go and ask questions on an informal basis and solve problems before they become RFI."

With completion scheduled for December 2010, Bade is confident that the strategies which have kept the project on budget and on schedule so far will keep the project on course to the finish.

"The information we have is really good so we have confidence that the building can stay on target," he says. "We'll avoid a lot of rework, avoid a lot of downtime and improve our overall productivity. It's all about information flow."

Image courtesy of SmithGroup

BIM Infrastructure

Understanding BIM Infrastructure

Getting up to speed with BIM requires a varied set of tools and skills. Although it stems from traditional processes and principles, BIM represents a new way of achieving project goals.

The transition to BIM is analogous to the transition from riding a bike as transportation to learning how to drive a car:

- **BIM technology**—such as software, hardware and connectivity—represents the vehicles you use and the roads, bridges or tunnels you travel.
- **BIM content** is like the fuel for your vehicle, which needs to be plentiful and easily accessible.
- **BIM standards** represent the rules and regulations for all aspects of the infrastructure that allows you to travel efficiently and consistently.
- **BIM education, training and certification** are like the learning and licensing processes for operating your vehicle.

These are all key components to BIM, and without them you won't get far.

Opportunities for Improvement

BIM users want to improve their experience with BIM technology as it relates to their own data and the data generated by other team members.

- One-third of users cite the need for software to be more interoperable.
- Only a small portion of users (1 in 5) want the software to be more user friendly.
- Although many users could not name ways to improve BIM software, few (13%) do not believe it needs to be improved or have no opinion.

User Differences

- **Architects** do not see a great need to improve training.
- **Contractors** are far more likely to see the need to improve interoperability.
- **Owners** are much more concerned about improvements to training and standardization of the BIM process than others.

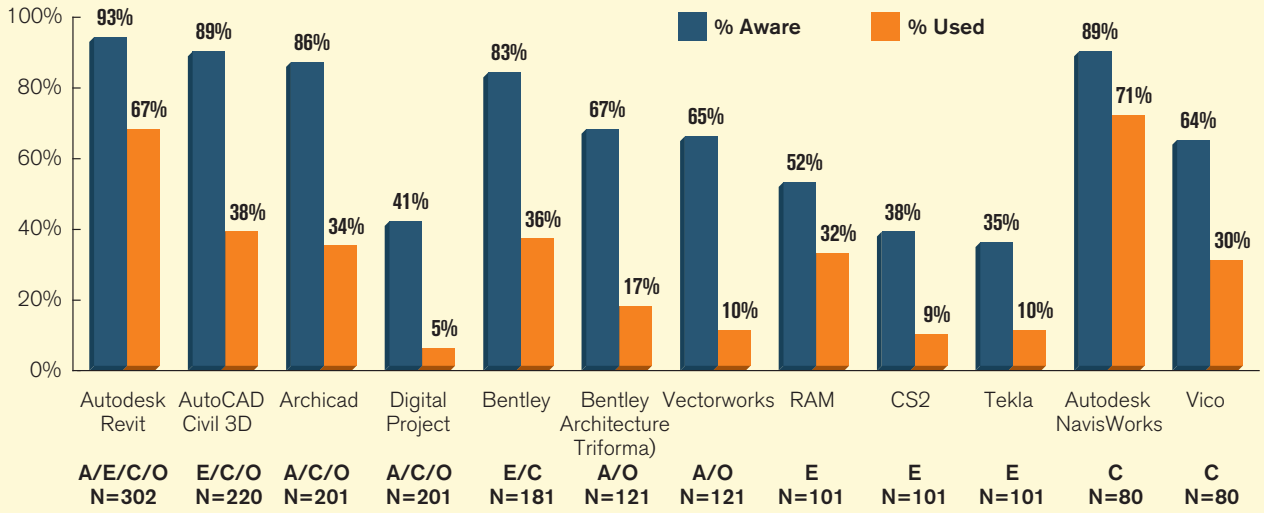
Technology Choices

BIM users are generally savvy about the software choices on the market. **Most are highly aware of the primary BIM software platforms available and have a moderate awareness of other software tools that are used in conjunction with BIM.**

This understanding of software choices can prove critical on jobs that use integrated project delivery. Although every user does not need a working knowledge of every tool outside the user's specific area of practice, it is helpful to know what software is available to other team members and how those tools can affect one's own work. For example, while a team member may not use fabrication software, it can be useful to know how one's data can work with that software.

In an integrated team environment, the limitations of a piece of software can have implications far beyond its primary user. As such, the decision by one team member to use a particular piece of software can be influenced by others. As users gain experience with BIM and tackle the barriers of non-interoperability, this level of joint understanding will grow.

Awareness of BIM-Related Tools



A = Architect; E = Engineer; C = Contractor; O = Owner

Source: McGraw-Hill Construction, 2008

Project Analysis Tools

One of the drivers of BIM expansion as a project process is the increasing ability of specialized analysis tools to extract data from design models and perform valuable analysis. Data standards initiatives are helping facilitate the exchanges required for these activities. This holds considerable potential to significantly increase the value of BIM for all users.

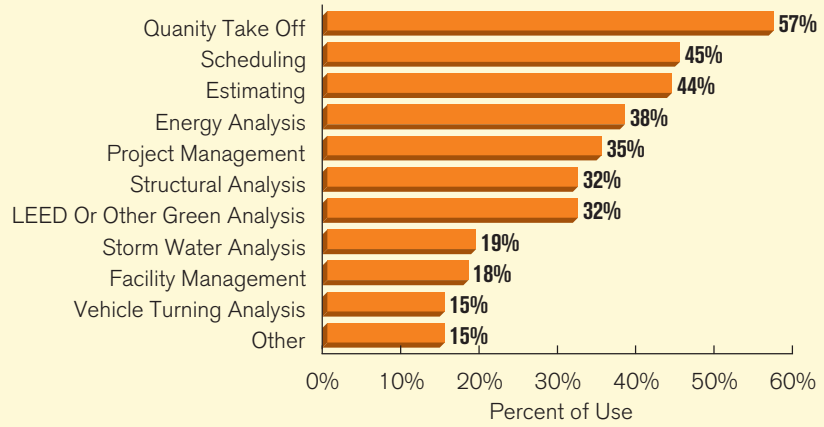
Quantity takeoff is the leading example of this functionality. Overall, 57% of users say they extract quantity information from BIM, with contractors leading at 71%.

Data related to cost and schedule is critical to all parties on a project. The potential benefits of 4D (schedule) and 5D (cost) capabilities rank high among BIM users, although use of these is still emerging.

User Differences

- Nearly half of **architects** commonly use energy analysis or other tools related to sustainability rating.
- One-third of **contractors** say they use BIM data for quantity takeoff, scheduling and estimating. General contractors and construction managers report performing these tasks with BIM 20 to 30% more frequently than trade contractors. Conversely, trade contractors are using sustainability rating system analysis tools with BIM one-third more frequently than general contractors and construction managers.
- Half of **engineers** use BIM data for quantity takeoff. In general engineers gravitate strongly toward BIM analysis tools that support their specific practice area, with 82% of civil, transportation and environmental engineers reporting use of tools for storm water analysis and 61% for vehicle turning analysis. Similarly, two-thirds of MEP engineers report using energy analysis tools with BIM.
- Half of **owners** use BIM data with project management software. Owners focus far more on BIM analysis during design and construction then in facilities management, where only 19% report activity. This is likely to increase as models become more integrated with operations-oriented software.
- Use of BIM data with analysis tools rises with experience. In some cases, it's a dramatic increase. **Experts** are twice as likely to use BIM data for quantity takeoff, scheduling and estimating compared to beginners.

Use of BIM Analysis Tools



Source: McGraw-Hill Construction, 2008

Object Data

Although BIM promotes a new way of working, many of the traditional demands remain. As with working in CAD, **architects still prefer to begin a BIM design with generic objects**, substituting them with manufacturer-specific objects later. Nearly half of architects agree strongly with this view.

Contractors, however, need details. Logically, nearly half of contractors feel strongly that they need as many manufacturer-specific objects as possible. when starting a model. While contractors may get some object data from other team members, **many contractors build their own models and create objects themselves** in the process. As more contractors emerge as significant users, the pressure to provide manufacturers' information for BIM could rise.

Object Sources

- **Creating objects in-house** is the most popular option for users as a whole with one-third reporting they do so most or all of the time. Only owners say they rarely do this. More experienced users are far more likely to create their own objects than others.
- **Manufacturer websites** are the second most popular choice for object data with more than a quarter saying they use such tools most of the time. Architects are slightly more likely to pursue this option compared to others.
- **Free object libraries or online user group sites** are the third most-popular option with one-quarter using these sources most of the time. Architects and contractors are slightly more likely to use these sources than engineers or owners.
- **Paid subscriber services** are rarely used by any build team member.

Content Demand

As capabilities and content continue to be developed for BIM, users see gaps they need filled. Although many have demands that are specific to their practices, areas that all users agree need to be further developed include:

- Structural elements
- Mechanical equipment
- Building envelope and windows

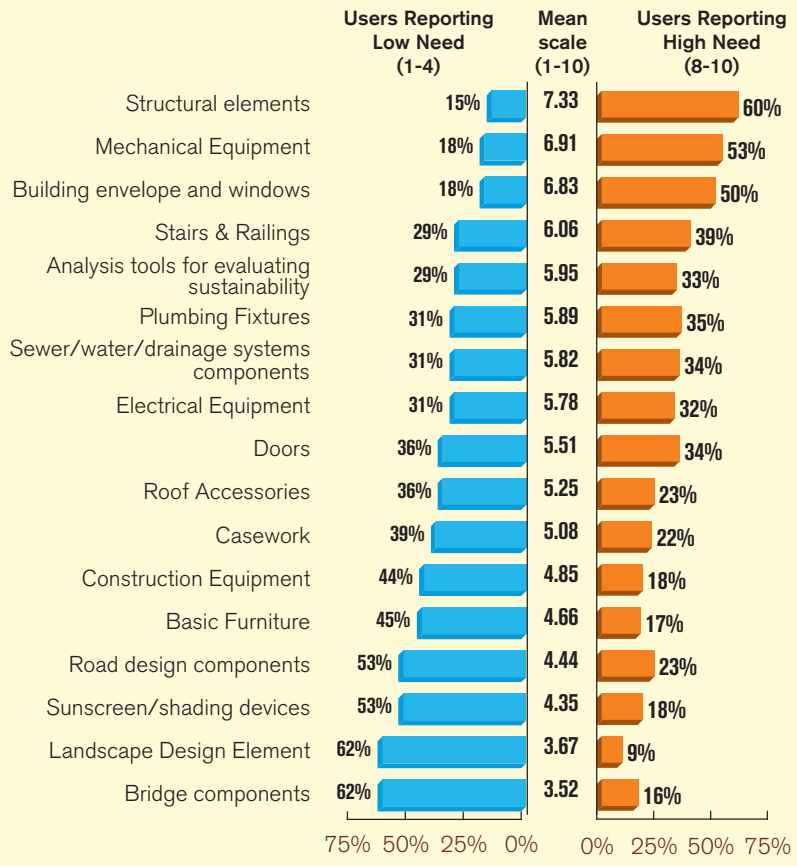
User Differences

Architects see the greatest need for additional content. The top BIM content demanded by architects includes building envelope and windows; structural elements; stairs and railings; and objects that work with analysis tools for evaluating sustainability.

Engineers report the lowest need for additional content. The top BIM content demanded by engineers includes structural elements; mechanical equipment; and sewer, water and drainage system components.

Contractors and owners both demand the same top-three areas of BIM content: structural elements; mechanical equipment; and building envelope and windows.

Use of BIM Analysis Tools



Source: McGraw-Hill Construction, 2008

Establishing BIM Standards

The development of building information modeling is bigger than any one company, industry group, software platform or practice area. Because of its broad impact, players throughout the industry are contributing to its evolution.

This broad-based approach has created a very dynamic environment in which new pieces are regularly added to the puzzle. The greatest pitfall is that any added piece might not exactly fit into the big picture with the others. As a result, build team members might not be able to share data across the various technologies used on a BIM-related project.

With so many players working to develop BIM, many are calling for standards that will make these divergent platforms and applications interoperable.

Under this mission, the building-SMART Alliance was founded in 2006 as an expansion of the International Alliance for Interoperability to define standards of data interoperability within the building environment.

Among its efforts, the group helped establish Industry Foundation Classes (IFCs), which electronically define elements of a building design in a format that can be shared between applications. Players throughout the industry are experimenting with implementing IFCs.

Other standards are also at play, including XML, which stands for Extensible Markup Language. This format is used for exchanging data via the Internet.

Impact of Interoperability

Interoperability is a cost issue for technology users. In 2007, McGraw-Hill Construction released the *Interoperability in the Construction Industry SmartMarket Report* which showed that users attributed 3% of project costs to software non-interoperability.

Major contributors to cost included:

- Manually reentering data from application to application
- Time spent on duplicate software
- Time lost to document version checking

The report also showed that concerns over interoperability increased among BIM users as they gained expertise with the technology. **With more users rapidly gaining BIM experience, the need for interoperability solutions is more pronounced.**

These issues can significantly affect user decisions. For example, research for this report shows that **58% of users say interoperability would factor into a decision to purchase project management software.**

Solving the Problem

Although standards are being developed as a means of improving interoperability, **only half of users are aware of these efforts.** Data standards are a technical aspect of the issue that many build team members don't understand or deal with directly, and may be a reason why they don't recognize these initiatives.

- Two-thirds of users say that their respective professional industry organizations should develop standards. Owners are the least likely group to agree with this.
- One in 10 say software companies should lead standards development. Contractors are the most likely group to agree with this.
- One in 10 say government agencies should lead the effort.

Interview with Dana "Deke" Smith, FAIA

Executive Director buildingSMART Alliance

Data standards represent a possible solution to problematic interoperability issues among collaborating firms in the design and construction industry. Despite altruistic goals, getting players from the various disciplines to find common ground is no easy task. Dana "Deke" Smith, executive director of building SMART Alliance, brings us up to speed on his organization's efforts to bring everyone to the table.

Where do we stand in terms of getting industry-accepted standards for BIM? When you talk about industry acceptance of BIM standards, it's important to acknowledge that BIM is not just about technology, it's a significant culture change issue. In order to have successful standards we need to engage a wide variety of industry players who have worked somewhat independently for many decades. I'm told we have over 10 million people in our industry, and the way I see it only a couple of hundred thousand of them currently recognize that there is an opportunity for major transformation on the horizon. The primary function of the alliance is coordinating international industry efforts to most efficiently develop workable standards, both for defining the types of information that need to be exchanged among stakeholders and the data structure and format of those exchanges. The pioneers at work now will be tapped as the subject matter experts as they gain knowledge. That way we don't need to have everyone reinvent the wheel. Instead we can identify best practices and make those available to others quickly and broadly.

What's working? Standards efforts are enabling better connections all the time, certainly between designers and with contractors, but newer initiatives like Construction Operations Information Business Exchange (COBIE) are now defining standards so that models and their information can flow from construction to owners and sustainers of facilities. The vision of information flowing through the entire facility lifecycle is beginning to be realized, albeit not on a single project quite yet.

What are the challenges? The culture of fragmentation must be overcome. We need to get people comfortable with sharing. We must overcome the fear factor. As more people succeed, more will put their feet in the water. Technology and standards are not the problem. They will develop as we identify the business requirements of the practitioners and all stakeholders for increasingly effortless data exchange.

What's the prognosis? We have a long way to go to truly realize the vision of everyone working together seamlessly. But I think we will see a dramatic change in the way the industry does business within five years, and that progress will beget further progress. It's an amazing time to be in this industry.

Demand for Training

As more BIM adopters significantly expand their use of the technology to gain a competitive advantage, **many companies can expect their training needs to increase** as well.

Since BIM is still an emerging technology in the industry, users express the strongest immediate need for basic skills. However, as they gain experience, it can be expected that higher levels of training will be needed in the coming years.

Training Methods

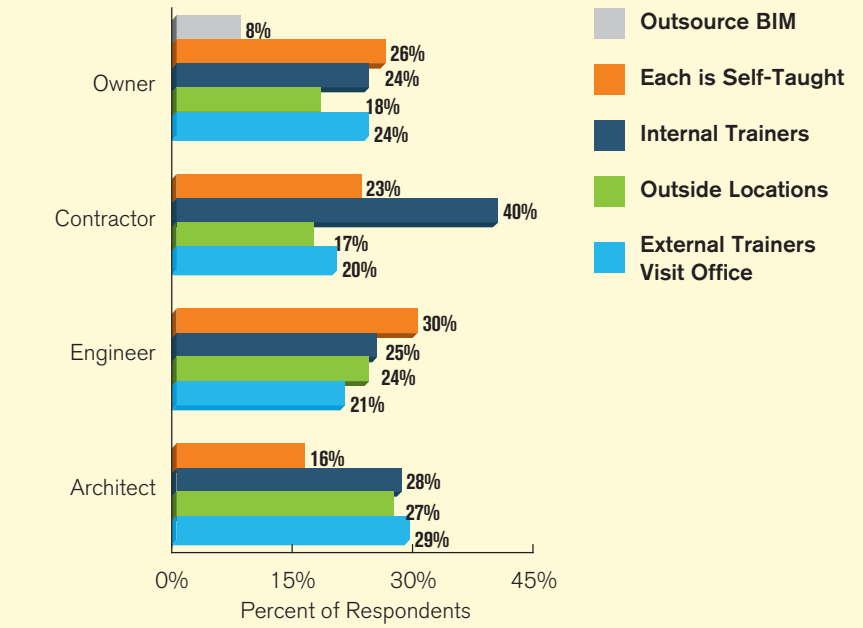
BIM users as a whole draw from a diverse cadre of training resources. **Users are almost evenly split on the decision to bring in external trainers, train at off-site locations, use internal trainers, or teach themselves.**

User Differences

- **Architects** are least likely to be self-taught and most likely to use external trainers at their offices or at outside locations. **Engineers** are most likely to be self-taught.
- **Contractors** are most likely to use internal trainers and least likely to train outside the office.
- One in ten **owners** outsource BIM and therefore don't need training.
- A majority of **expert users** rely on internal trainers. The use of internal trainers rises steadily as the company gains experience. This suggests that as users become more invested in BIM, they see the benefits of staffing trainers.
- **Beginners and small firms** are far more likely to be self-taught than all other users.

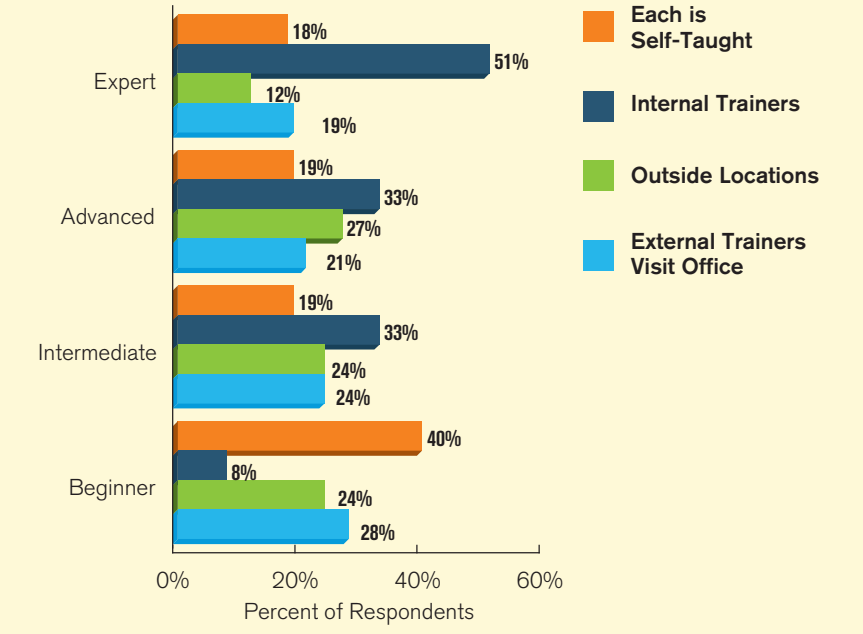
Another solution to quicken the BIM learning curve is for firms to encourage colleges and universities to train students in BIM tools and to recruit ready-made BIM experts when the students graduate.

BIM Training Methods



Source: McGraw-Hill Construction, 2008

BIM Training Methods by Experience Level



Source: McGraw-Hill Construction, 2008

Proficiency and Adequacy

Most BIM users still have a lot to learn, and they are looking for better ways to get educated.

Levels of Training

Half of companies see their users as having received moderately adequate levels of training. This holds true among all build team members.

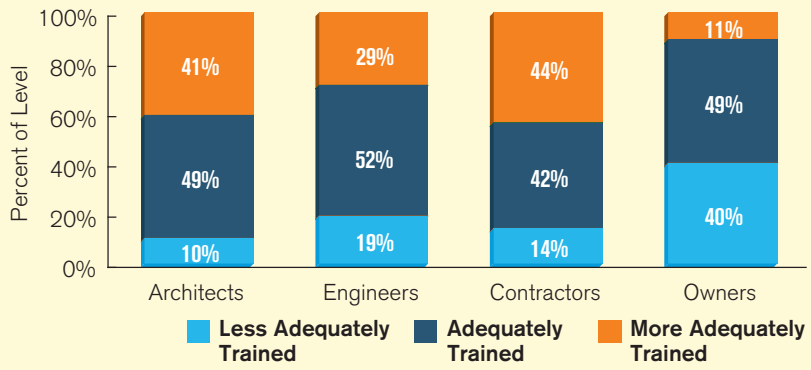
- One-third believe they are very adequately trained.
- **Contractors** and **architects** are most likely to see their BIM users as very adequately trained.
- One in ten **owners** report that their users are very adequately trained, while 40% are inadequately trained.

Insufficient Training Methods

On average, users do not rate the level of training available to them as highly sufficient.

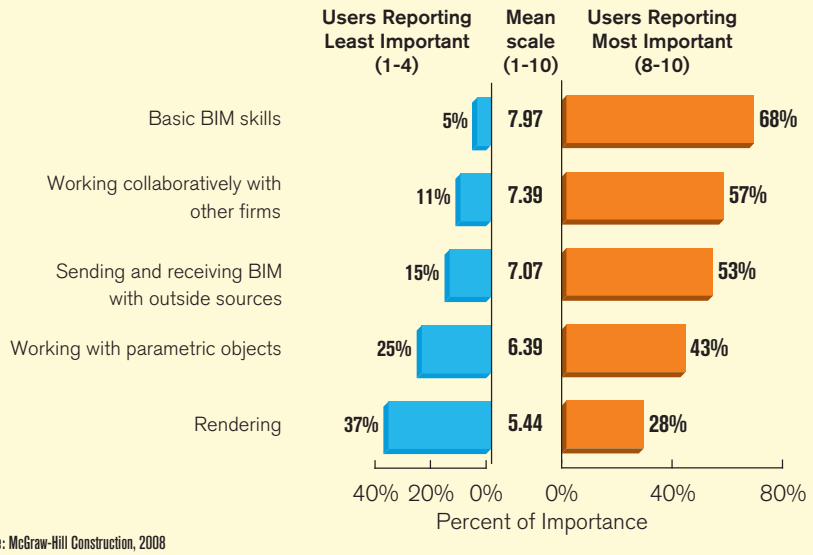
- Nearly half of **architects** believe they have highly-sufficient resources training. Two in five **contractors** believe this too.
- Most **owners** do not believe the level of available training is adequate.

Level of BIM Training



Source: McGraw-Hill Construction, 2008

Importance of BIM Training Needs



Source: McGraw-Hill Construction, 2008

Training Needs

More than anything, BIM users are looking for basic skills. Seven in 10 users rate basic skills as very important. This is true regardless of company size or experience level. This demand reflects, in part, the ongoing adoption of the technology by additional users.

Specific Needs

- **Engineers** express the highest demand for **basic BIM skills**.
- Training related to **working collaboratively with other firms** is most important to **contractors**.
- **Sending and receiving BIM files with outside clients, working with parametric objects, and rendering** are the training topics ranked highest by **architects**.

AGC BIM Training and Validation Program

Validating a company's ability to work in the BIM environment is important. The Associated General Contractors of America (AGC) is preparing a six-unit training and validation program for contractors to become fully competent in BIM and help owners, architects, and others in the construction community distinguish the truly competent BIM contractors.

The program will cover: Introduction to BIM; BIM Legal Issues and Risk Management; BIM Technology; BIM Process and Integration; BIM Case Studies and Lessons Learned; and Advanced BIM.

"At the conclusion of this process, a contractor can validate to a prospective client that they are BIM ready," says Leonard Toenjes, president of AGC of St. Louis.

Conclusions

Strategic Advantage in a Challenging Economy

As recognition of the benefits of BIM grows, the ability of design professionals, contractors, fabricators and suppliers to work effectively in this new environment will increasingly become a competitive differentiator in winning work. In challenging economic times this kind of edge can be critically important to survival. Also, owners competing for scarce capital resources will find an advantage in being able to demonstrate the ability to more accurately control costs, quality and schedule through implementation of BIM.

Owners' Lifecycle Focus Enhanced by BIM

Ultimately, as thousands of completed models are turned over to owner/sustainers along with their physical counterparts, applications will emerge to integrate their rich data with robust management systems for all aspects of networked lifecycle operations.

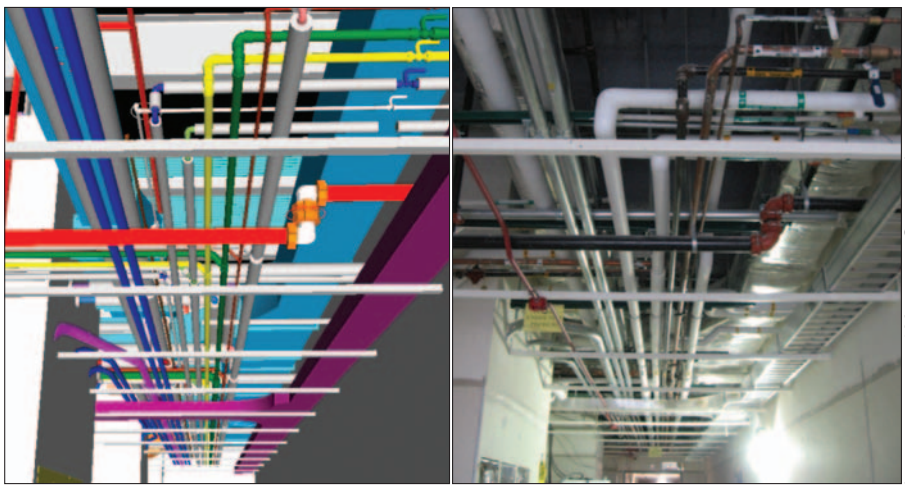
The current work being done to standardize property sets and data exchanges will bear fruit for decades of productive utilization of these "digital doubles." And the in-place performance data will cycle back to inform better design for the entire industry.

Expertise Breeds Positive Experience

The research clearly shows that as users become more expert with BIM they enjoy proportionately greater benefits and have an increasingly positive experience with BIM. This powerful alignment between skills and rewards augers well for expanded implementation within firms and broader adoption across the industry.

BIM-Driven Prefabrication on the Horizon

Following the project process, it is natural to predict that fabricators will be the next group to embrace the power of BIM. As in other manufacturing industries that have integrated virtual design with automated production to reduce cost and increase quality, innovative firms in the construction industry are already finding these efficiencies. Larger and ever more complex portions of projects will be created in ideal factory conditions for assembly at sites, rather than being more wastefully and dangerously constructed from parts and materials in the outdoors. This will have a direct impact on the workforce challenges faced by the construction industry by making working conditions safer and more appealing for a new generation of industry workers.



Images courtesy of Mortenson Construction

2009 Will Be the "Year of the Contractor" in BIM

Contractors are predicting an acceleration of BIM usage that significantly outstrips the other groups surveyed, and paves the way for 2009 to be "the year of the contractor" in BIM.

Most contractors using BIM are not waiting to receive BIM files from designers but are doing 2D-to-BIM conversion from whatever CAD files or paper documents they can get their hands on. The tangibility of the benefits that contractors can extract from BIM makes a compelling business case for investing.

This trend mirrors the traditional lifecycle progression of a project, where the architect is initially responsible for the format of information and shares it judiciously with a small group of consultants. Then contractors assume responsibility, using their own tools and processes to interpret, divide and distribute that information broadly for multiple purposes through to completion.

BIM has now evolved from a focused tool set for design to a more comprehensive platform for design and construction integration, driving major changes in the ways all the players interact.

"There's this surge wave of interest in BIM right now. If you're not on the front end of it, you're falling far behind."

—Linda Morrissey
Senior
Preconstruction Manager
Mortenson Construction

> **"Leveraging BIM expertise to differentiate your firm in the crowded construction marketplace is critical."**
>
> ***–Leonard Toenjes, CAE, President AGC of St. Louis***

Collaborative Silos

Increasingly, users are adopting discipline-specific BIM applications, especially to perform analyses on data extracted from design models that supports their workflow and unique project responsibilities. But this apparent fragmentation is less of a problem with BIM applications than it has been with previous discipline-specific IT tools. That is because applications that can work with multiple BIM formats to perform tasks such as clash detection are providing the benefits of interoperability even if the data structures of the core tools aren't truly interoperable. So each discipline is applying modeling to its own part of the project, and the benefits can still be leveraged across the entire team.

Steve Cook of Kristine Fallon Associates described this well in the February 2008 issue of *Midwest Construction*, saying "[BIM] seems the most efficient and effective way to get all parties around the table and make decisions about any issues that come up. We're not really creating a master model. Everyone owns their own information and does their own [model]. It's just a way to briefly bring these together, identify needed changes, and then let each party go back and make its changes until the next time we meet."

Faith-Based BIM Adoption

Most users report that although they are not yet quantitatively measuring ROI, they can definitely tell that they are working more productively and effectively with BIM and have complete faith that it is a better way of working.

This is logical because many of the benefits of BIM center on cost avoidance rather than cost reduction, and thus are more challenging to measure but are clear to experience.

This will certainly change as teams collect and share more consistently measured results.

Research efforts, such as the ongoing study of completed BIM projects by the Center for Integrated Facility Engineering (CIFE) at Stanford University, sponsored by the GSA, will continue to examine and compare results to find the meaningful trends and give shape to the appropriate expectations for value by BIM teams.

Discipline-Specific Evolution Path

The path to adoption and implementation is developing unique patterns by discipline.

As 3D visualization was the initial attraction of BIM for architects, clash detection is emerging as the gateway for contractors.

Once on board, design professionals advance into aspects of BIM that support their practice needs, such as energy modeling, and contractors move into quantity takeoff, estimating, schedule integration and construction logistics and sequencing. Each player finds their "BIM sweet spot" where the value is most tangible and relevant.

BIM Drives Integrated Project Delivery

As contractors and design professionals continue to accelerate BIM adoption, the benefits of collaboration and integration of information will become increasingly compelling.

Efficiencies achieved by firms deploying BIM solely within their own sphere will be multiplied when they begin integrating with other modelers.

This will shift the focus of the entire industry from technology adoption to process reinvention, and the tools will adapt to support this perspective.

Workforce Demographics

Senior management buy-in is reported as the second greatest challenge to adoption, while resistance from junior staff is last on the list of issues.

This follows a familiar pattern for technology adoption across U.S. industries. People in their twenties are ready willing and able to adopt digital technologies in the workplace.

According to a McGraw-Hill Construction white paper on workforce, the construction industry will need to fill12 million new jobs by 2012. And an estimated 95,000 new craft workers will be needed each year for the next decade to replace those leaving the industry.

For construction, the widespread adoption and implementation of BIM has the potential to help reverse the decline of the industry's image and attract more talented young people to replace the rapidly retiring ranks of experienced workers.

Resources and Methodology

Resources that can help you get smarter about BIM

McGraw-Hill Construction

- Main Website: **www.construction.com**
- Research and Analytics: **www.analytics.construction.com**
- *Architectural Record*: **www.archrecord.construction.com**
- *Engineering News-Record*: **www.enr.com**

Premier Corporate Partner

- Autodesk **www.autodesk.com/bim**

Corporate Partner

- CMiC **www.cmic.ca**

Corporate Collaboration Partners

- Barton Malow **www.bartonmalow.com**
- HOK **www.hok.com**
- Mortenson Construction **www.mortenson.com**
- Skanska **www.skanska.com**
- Walbridge **www.walbridge.com**

Association Collaboration Partners

- American Council of Engineering Companies **www.acec.org**
- American Institute of Architects **www.aia.org/ip**
- American Institute of Steel Construction **www.aisc.org**
- American Society of Civil Engineers **www.asce.org**
- American Society of Professional Estimators **www.aspenational.org**
- Associated General Contractors of America **www.agc.org**
- buildingSMART Alliance **www.buildingsmartalliance.org**
- Charles Pankow Foundation **www.pankowfoundation.org**
- Construction Owners Association of America **www.coaa.org**
- Construction Specifications Institute **www.csinet.org**
- Construction Users Roundtable **www.curt.org**
- Design-Build Institute of America **www.dbia.org/pubs/**
- International Code Council **www.iccsafe.org**
- Mechanical Contractors Association of America **www.mcaa.org**
- Society for Marketing Professional Services **www.smps.org**

Government Partner

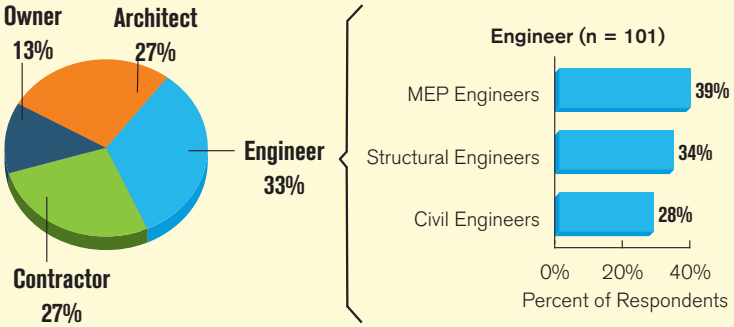
- U.S. Army Corps of Engineers **www.usace.army.mil**

BIM Survey Methodology

McGraw-Hill Construction conducted the 2008 Building Information Modeling Study to assess the understanding, perceptions and usage patterns of BIM software among knowledgeable users in key player segments. The research in this report was conducted through a survey of 82 architects, 101 engineers, 80 contractors, and 39 owners (total sample size of 302) between June 18th and August 8th, 2008. The "total" category displayed throughout the report represents the four respondent groups combined as the total build team. In addition, MHC further segmented the Engineer's category, gathering additional information on civil, structural and MEP engineers.

The use of a sample to represent a true population is based on the firm foundation of statistics. The sampling size and techniques used in this study conform to accepted industry research standards expected to produce results with high degree of confidence and low margin of error. The total sample size (302) used in this study benchmarks at a 95% confidence interval with a margin of error of less than 6%. For each of the architect and contractor respondent groups, the confidence interval is 90% with a margin of error of 9%. The owners had a confidence interval of 85% with a margin of error of 11%. Further, within the engineers category, the confidence interval is 90% with a margin of error of 8%.

Respondent Profile



Source: McGraw-Hill Construction, 2008

SmartMarket Report

Design & Construction Intelligence

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