

Measuring the Impact of BIM on Complex Buildings

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Measuring the Impact of BIM on Complex Buildings SmartMarket Report

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About Dodge Data & Analytics

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Introduction

A tool is only as good as the results it produces. The compelling business case for BIM hinges on the ability of users to demonstrate tangible and meaningful improvements repeatedly to a variety of project outcomes, positively impacting all key stakeholders.

Because those stakeholders' fates are intertwined, the positive impact of BIM is cumulative through successive stages of a project, with design and preconstruction benefits contributing directly to improving downstream construction outcomes. When well deployed, BIM can benefit the entire project delivery process for everyone. And, ultimately, owners can leverage key data from model-based processes for decades of enhanced operations.

This study focuses specifically on how much BIM is contributing to improved outcomes in successive stages of design and construction on complex buildings (e.g., hospitals, laboratories, manufacturing), where execution is most challenging, risk is typically greatest and the need for improvements is critical. It establishes baselines for:

- The current level of positive impact BIM is generating on 23 distinct project outcomes in 10 categories.
- Metrics for the current degree of positive impact from BIM on six of the most important of these outcomes, and a forecast for future impact.
- The current state of model usage for facility management.
- Factors for success and obstacles influencing BIM's measurable impact.

High/very high impact ratings for BIM point to outcomes where the project team receives key benefits.

- **Improved constructability of the final design earns top ratings from 74% of contractors, along with most owners (68%) and architects (64%).**
- **Owners' top praise goes to increased ability to understand the design (73%), better construction documents (70%), and improved ability to plan construction phasing/logistics (70%).**
- **Engineers lead in citing improved quality/function of the final design (71%), which is also widely appreciated by owners (63%), and architects (62%).**

Examples of specific metrics for outcome improvements include:

- **40% of owners report that BIM accelerated project completion by a minimum of 5%, and 15% credit it with more than 10% schedule compression.**
- **41% of contractors report that BIM reduced final construction cost by at least 5%, with 8% achieving more than a 10% decrease.**
- **67% of contractors report a percentage of improved productivity, with 16% seeing increases of 25% or more.**

We want to acknowledge the support of the U.S. Department of Veterans Affairs as the Premier Partner for this research, and their commitment to improving project delivery with BIM, as well as numerous other organizations who helped to get their members and customers to complete the survey for this research.

We will continue tracking the impact of BIM on these and other outcomes in subsequent studies, and encourage all users to measure the impact BIM is having on your complex projects.



Stephen A. Jones
Senior Director
Industry Insights Research
Dodge Data & Analytics

Stephen A. Jones leads DD&A's Industry Insights Research division. He is active in numerous industry organizations and frequently speaks at industry events around the world. Before DD&A, Jones was a vice president with Primavera Systems (now part of Oracle), a global leader in project management software. Prior to that, he was principal and a Board of Directors member with Burt Hill, a major A/E firm (now merged with Stantec).



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Donna Laquidara-Carr currently provides editorial direction, analysis and content to DD&A's *SmartMarket Reports*. Prior to this position, she worked for nearly 20 years with DD&A's Dodge Dodge editorial team, where she gained detailed insight into the construction industry.

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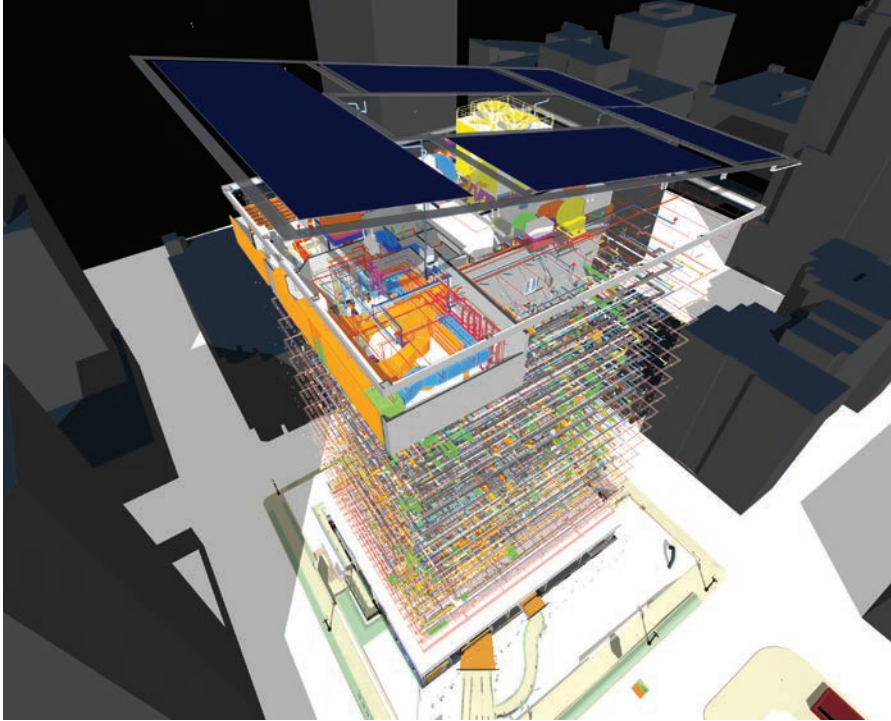
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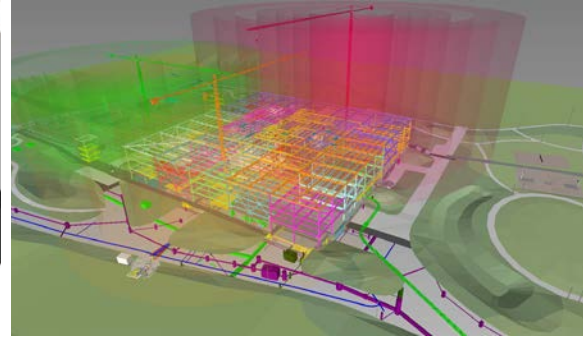
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Front Cover: Blend of the model with a photograph of the new patient tower at Central Washington Hospital in Wenatchee, Washington, demonstrates the accuracy of the model.

This page:

Left: Edith Green Wendell Wyatt Federal Building Modernization model, Portland, Oregon; **Below:** Modeling for crane swing review on the Nintendo of America Headquarters in Redmond, Washington



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Executive Summary

The cornerstone of a solid business case for BIM is the ability to quantitatively measure its positive impact on project outcomes.

Metrics demonstrating tangible and meaningful improvements will drive further implementation and investment by current users, spur those who have not yet adopted and offer everyone targets to meet and exceed on their BIM journey.

BIM Tangibly Improves Outcomes on Complex Building Projects

This research studies the impact of BIM on 23 key project outcomes according to owners, architects, engineers and contractors. **In numerous cases, over half of respondents give high or very high impact ratings to the positive contribution of BIM.** The table shows the five top-rated outcomes, and which type of respondent most highly rates each one.

The other types of respondents generally concur with these top ratings from the leaders, indicating a growing consensus around key BIM benefits. For example:

- **Constructability improvement was also cited by a large portion of owners (68%), engineers (65%) and architects (64%).**
- **Better design understanding by owners also earned top marks from a majority of architects (64%) and engineers (59%).**

BIM Metrics Quantify Significant Benefits

Six of the 23 outcomes were studied to quantify the positive impact generated by BIM. For each of the six, respondents who rated its overall impact as medium, high or very high were further asked to identify the level of improvement within a percentage range. Though some were not sure, most were able to quantify the impact of BIM, and the majority report significant benefits.

- **85% cite a reduction in the final construction cost of their complex projects.**
 - Over half (55%) are seeing at least 5% reduction.
 - One in ten claim more than a 10% decrease.
- **Schedule is even more impacted by BIM, with 88% reporting accelerated completion.**
 - Nearly two thirds (68%) cite 5% or better schedule compression.
 - Almost a quarter (23%) are enjoying above 10%.

Five Top-Rated Positive Impacts of BIM

(According to the Percentage of High or Very High Impact Ratings by Type of Respondent)

Dodge Data & Analytics, 2015

	Respondent Type	% Rating High or Very High
Improved Constructability of Final Design	Contractors	74%
Increased Owners' Understanding of Proposed Design Solutions	Owners	73%
Improved Quality/Function of Final Design	Engineers	71%
Generated Better Construction Documents	Owners	70%
Improved Ability to Plan Construction Phasing and Logistics	Owners	70%

Architects, engineers and contractors were asked about the impact of BIM on reducing the quantity of RFIs (Requests for Information), often an indicator of uncertainty, which can lead to changes, rework and degraded performance. **Three quarters (74%) see at least 5% reduction in RFIs, with almost half (44%) reporting more than 10%.**

Safety is gaining traction as a BIM metric, with over a third (37%) of owners and contractors reporting more than a 5% reduction in reportable incidents, and 12% citing more than 10%.

Two outcomes related to site labor are among the six specially evaluated.

- **87% of owners and contractors from this group reports increased labor productivity on their complex BIM projects.**
 - 20% cite a significant increase of more than 25%.
 - Most (67%) are still seeing less than 25% increase.
- **Nearly the same proportion (88%) of that group also reports reduced site labor as a result of increased offsite prefabrication.**
 - Nearly a quarter (23%) say they see more than a 25% reduction.
 - A few (2%) report more than 50%, demonstrating the powerful degree to which this benefit can accrue to leading practitioners.

Use of BIM for FM Is Still Emerging

While over half of contractors (52%) frequently or always provide models to owners, only 17% of the owners surveyed are frequently or always using models for facility management. This finding is particularly telling because the owners in this survey are already a select group who are knowledgeable about BIM. However, as part of a series of in-depth interviews for this report, expert owners make it clear that this is an important future opportunity for owners to gain value on their complex projects.

Collaboration Is a Key Success Factor for the Use of BIM on Complex Projects

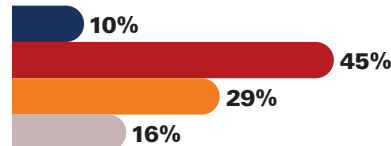
The findings on success factors for the use of BIM on complex projects reveal that all respondents—owners, architects, engineers and contractors—see collaboration and teamwork as key success factors, but that the majority of the AEC respondents still do not prioritize the early contributions of other players. It suggests an opportunity for leadership by owners in promoting increased integration and collaboration on projects to maximize the benefits of BIM.

Metrics for the Impact of BIM on Cost, Schedule, RFIs and Safety (Among Those Rating Medium or Higher BIM Impact on These Outcomes)

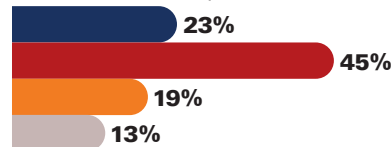
Dodge Data & Analytics, 2015

- More Than 10%
- 5% to 10%
- Less Than 5%
- Not Sure

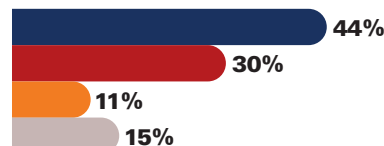
Reduction of Final Construction Cost



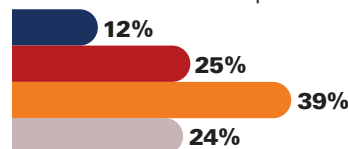
Accelerated Project Completion Due to Schedule Compression



RFI Reduction



Reduction in Number of Reportable Safety Incidents



Data: Introduction

Dodge Data & Analytics (DD&A) has been conducting research on the emergence of building information modeling (BIM) and the value it provides to the construction industry since 2007. From the start, the research has explored how BIM users—who are defined as anyone who creates a model or works with a model created by others—believe that BIM improves their project outcomes and alters their design and construction processes.

Between 2007 and 2012, DD&A found that the percentage of BIM users in North America exploded from 28% to 71%. In 2013, we examined how the value of BIM is perceived by contractors using it in 10 major construction markets across the globe. In 2014, a study of owners in the US and UK demonstrated the power of a single, consistent mandate for BIM use.

While these studies firmly established the positive perception of BIM in the industry, across players and across nations, the questions that specifically measured the value of BIM were based on those from the early studies in order to mark the progress over time of industry perspectives on BIM. Therefore, few hard metrics were sought since many companies would not have had enough BIM experience in the early studies to speak to the specific metrics that support their return on investments in hardware, software and training.

However, by 2015, many companies have gained deep experience with the use of BIM. Therefore, we believe the time has come to take the critical next step in the research and to establish the specific level of impact BIM has on 10 types of design and construction activities. To do so, we asked respondents to quantify the positive impact of BIM for six specific metrics that could be measured in terms of percentage of improvement. The research focused specifically on complex projects because they offer the best opportunity to experience the powerful benefits BIM provides.

The findings clearly demonstrate that the design and construction industry is experiencing real, measurable impact from the adoption of BIM. To a large degree, this impact is not just due to the software but to how it alters industrywide design and construction processes, encouraging collaboration, prefabrication and other ways to make those processes more efficient and productive. The findings demonstrate that the industry recognizes this, with the greatest impacts noted in design, documentation and clearer understanding of the project by all players, which then filter downstream to improve construction.

Note About the Data

The data and analysis in this report are based primarily on an online survey conducted with 391 owners, architects, engineers and contractors who all indicated that their company uses BIM and that they had a moderate or higher level of knowledge about the use of BIM at their company. The specific breakdown of the respondents by firm type is:

- 40 Owners
- 183 Architects
- 68 Engineers
- 100 General Contractors

Each respondent also had to have experience with one of the follow types of complex building projects: data centers, entertainment projects, hospitals, industrial/manufacturing buildings, laboratories and transportation buildings.

In addition to examining differences by firm type, the analysis also focuses on the following variables:

- Level of BIM use, with those using BIM on 50% or more of their projects compared with those using BIM on less than 50% of their projects
- Project type
- Size of firm

DD&A also conducted qualitative in-depth interviews with eight owners who have expertise in using BIM on complex projects. The owners were also asked to evaluate the impact of BIM on various project stages. Their insights add a more nuanced perspective to the findings and are featured in data sidebar articles throughout the report.

For more information on the owners who participated in the in-depth interviews, along with the full methodology for the quantitative online research, see page 56.

Data: Impact of BIM

On 10 Aspects of Planning, Design and Construction

Impact of BIM on Key Outcomes for Complex Projects

This part of the study establishes a baseline for the degree to which users are currently achieving 23 distinct outcome improvements from BIM on their complex building projects, organized into 10 overall categories, indicated in bold in the chart at right.

To establish this baseline, owners, architects, engineers and contractors were asked to assign a rating for the impact of BIM on improving outcomes with which they would be familiar, compared with past projects where BIM was not used.

The chart at right shows an index score (1–10 scale) for the relative impact of BIM based on how frequently a high or very impact rating was selected for each of the 23 outcomes studied. It shows at a glance where in the process and to what relative degree users are currently experiencing significant impact from the use of BIM on complex building projects.

Many of the highest-scoring outcomes are related primarily to design activities, such as “increased owners’ understanding of proposed design solutions,” “improved constructability of final design” and “improved quality/function of final design.” This is understandable because architects generally began using BIM before contractors, so these impacts are more widely experienced and, therefore, better established.

Importantly, though, design-related improvements such as “generated better construction documents” drive better contractor engagement, which is suggested by the strong performance of “increased contractors’ understanding of proposed design solutions.” Their enhanced understanding contributes to numerous benefits later in the construction process, such as “improved ability to plan construction phasing and logistics,” “increased predictability/fewer unplanned changes” and “reduced rework.” We expect that future studies will show ever-greater benefits from the cumulative impact of BIM on project outcomes.

The following pages provide detailed data for each of the 23 individual outcomes and show variances among the types of organizations that were asked to provide responses.

Impact of BIM on Complex Project Outcomes (Percentage of High and Very High Ratings, Converted to a 1–10 Scale)

Dodge Data & Analytics, 2015

Owner Engagement and Understanding

Increased Owners’ Ability to Actively Participate in Design Process
Increased Owners’ Understanding of Proposed Design Solutions



Design

Increased Ability to Manage Project Scope
Improved Quality/Function of Final Design



Documentation and Constructability

Generated Better Construction Documents
Improved Constructability of Final Design



Estimating and Bidding

Improved Process and Accuracy of Estimating Construction Costs
Improved Accuracy and Completeness of Bids



Construction Phasing and Logistics

Improved Ability to Plan Construction Phasing and Logistics
Improved Owners’ Understanding of Construction Phasing and Logistics



Contractors’ Understanding of Design

Increased Contractors’ Understanding of Proposed Design Solutions
Reduced Number of RFIs



Cost Control and Reduction

Improved Process of Controlling Construction Costs
Reduced Final Construction Cost of Projects



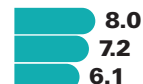
Schedule and Project Duration

Improved Achievement of Planned Schedule Milestone Dates
Compressed Schedule Results in Accelerated Project Completion



Unplanned Changes, Rework and Out-of-Sequence Work

Increased Predictability/Fewer Unplanned Changes
Reduced Rework
Reduced Amount of Out-of-Sequence Work Due to Earlier Problems



Labor, Safety and Material Waste

Improved Labor Productivity
Reduced Site Labor Due to Increased Offsite Fabrication
Reduced Reportable Safety Incidents
Reduced Material Waste



BIM Impact on Owner Engagement and Understanding

It is widely acknowledged that complex projects are usually far more successful when owners are actively engaged and truly understand and participate in the proposed design solution. Not only does this help to optimize the functionality of the final design, it also aligns owner expectations more closely with the completed project, improving the overall experience for everyone.

Owners, architects and engineers were asked to rate the impact of BIM on increasing owners' understanding of the design.

- All parties are nearly unanimous in rating BIM as having medium or higher impact (84% to 91%).
- Among owners themselves, about three quarters (73%) rate it as high or very high, again underscoring its importance to that critical group.

The same group was also asked to rate BIM's impact on driving higher engagement by owners.

- Owners lead architects and engineers in citing the effectiveness of BIM to increase their participation, emphasizing its value to them.
- 91% of the respondents who do more than half their work in BIM rate its effectiveness at medium or higher.
- No respondents rate BIM as having no impact on increasing owner engagement in the design process.

BIM Impact on Owner Engagement and Understanding

(According to Owners, Architects and Engineers)

Dodge Data & Analytics, 2015

Very High High Medium

Increased Owners' Understanding of Proposed Design Solutions

Owners



Architects



Engineers



Increased Owners' Ability to Actively Participate in Design Process

Owners



Architects



Engineers



REFERENCE TO RELATED RESEARCH

For nearly 10 years, research studies on BIM by Dodge Data & Analytics (DD&A) have consistently shown that visualization is a key benefit for all parties.

The findings from the current study reinforce similar results from *The Business Value of BIM for Owners SmartMarket Report* published by DD&A in 2014.

- The most highly rated project-specific benefit of BIM perceived by owners in both the US and UK is that "BIM visualization enables a better understanding of proposed design."
- Among the top three most important ways BIM contributes to US owners' organizations is that it "helps with visualization/understanding of concepts and scope."

The critical contribution of owner engagement and understanding to reducing the negative impact of

uncertainty on projects that leads to problems and dissatisfaction was addressed in the *Managing Uncertainty and Expectations in Building Design and Construction SmartMarket Report*, which was also published by DD&A in 2014.

- 83% of architects and contractors who do mostly complex projects cited "clearer direction from owner" as second among the nine most important factors for reducing uncertainty.
- "More active leadership by owner" was identified by 77% of large architectural firms and 83% of large contractors as third among those nine most effective factors.
- Among all respondents to that survey, "greater leadership or involvement by owner in all stages of design and construction" was named as the second most important mitigating strategy to reduce overall uncertainty on projects.

BIM Impact on Design

Design is a dynamic process, especially on complex projects where user needs are critical and modifications or “scope creep” can have dramatic impact on budget and schedule. Owners and design teams are challenged to manage the scope of a project as it proceeds through design, ensuring it provides the greatest value to end-users, while remaining achievable within time and cost constraints.

Owners, architects and engineers were asked to rate the contribution of BIM to managing scope.

- Owners are most enthusiastic, with over three quarters (78%) rating BIM impact as medium or higher, reflecting an important improvement in a traditionally troublesome process.
- 42% of respondents who do over half their work in BIM rate its impact as high or very high, compared with just 17% of respondents with less experience.

The same respondents rated the contribution of BIM to improving the quality and function of the final design versus traditional methods of design.

- Owners are overwhelming in their support of this assessment, with 93% citing this as having a medium impact or higher.
- The exceptionally strong response from engineers (71% rate its impact as high or very high) may be because they see positive results from energy modeling and performance simulation.

BIM Impact on Design

(According to Owners, Architects and Engineers)

Dodge Data & Analytics, 2015

Very High High Medium

Increased Ability to Manage Project Scope

Owners

18% 25% 35% 78%

Architects

12% 23% 39% 74%

Engineers

15% 22% 35% 72%

Improved Quality/Function of Final Design

Owners

30% 33% 30% 93%

Architects

21% 41% 24% 86%

Engineers

31% 40% 18% 89%

REFERENCE TO RELATED RESEARCH

These findings align with results from the 2014 *Business Value of BIM for Owners SmartMarket Report*, published by DD&A, which shows that over half of US owners and almost all (92%) of UK owners agree at a high or very high level with the statement that “BIM analysis and simulation capabilities produce a more well-reasoned design.”

BIM Impact on Documentation and Constructability

The quality of construction documentation and the constructability of the final design are critical to many downstream project activities on complex projects, from estimating and bidding to the number of RFIs and amount of rework. Previous Dodge Data & Analytics BIM research studies around the world have consistently shown that BIM has a positive effect on reducing rework, and reducing errors and omissions in documentation.

Building on that previous research, respondents in this study were asked to rate BIM's contribution specifically to generating better construction documents and to improving the constructability of the final design versus traditional methods. Over half of all respondents were enthusiastic about the positive impact of BIM on both counts.

- Owners are particularly supportive, with 90% giving medium or higher impact ratings to better construction documents and 88% to improved constructability.
- Reflecting their firsthand knowledge, contractors lead the field for citing improved constructability, with almost all (98%) rating BIM as having at least a medium level of positive impact.
- It is notable that at least four out of five of every type of respondent rate both these factors very positively.

Clearly BIM is making significant contributions to improving both documentation and constructability, and owners are in a position to see and appreciate the change.

BIM Impact on Documentation and Constructability (According to Owners, Architects, Engineers and Contractors)

Dodge Data & Analytics, 2015

Very High High Medium

Generated Better Construction Documents



Improved Constructability of Final Design



REFERENCE TO RELATED RESEARCH

The importance of improving construction documentation was underscored in the *Managing Uncertainty and Expectations in Building Design and Construction SmartMarket Report*, published by Dodge Data & Analytics in 2014. Design errors and design omissions in the documentation were cited numerous times as significant contributors to uncertainty on projects, leading to problems with cost, schedule and quality.

- Owners cited design errors as the most negatively impactful factor on project quality and design omissions as the third most negatively impactful factor.
- Design omissions ranked second in a frequency/cost impact analysis of seven causes of uncertainty because it occurs frequently and introduces additional

project scope that was not included in the budget and not accommodated in the schedule.

- The aggregate of all respondents (owners, architects, contractors) identified design errors and design omissions as the second and third most contributing factors to uncertainty, behind unforeseen construction issues.
- Contractors identified the most frequent types of errors and omissions as follows:
 - Lack of coordination among disciplines in contract documents
 - Gaps or discrepancies in contract documents
 - Constructability issues of proposed design solutions
 - Errors in calculations, details and dimensions in contract documents

BIM Impact on Estimating and Bidding

Improving documentation and constructability of the design for complex projects should create a positive downstream impact on the process and accuracy of estimating, and on the accuracy and completeness of bids.

Owners and contractors were asked to rate the impact of BIM on those aspects of estimating.

- **Around two thirds of owners and contractors cite medium or higher impact, but contractors are especially positive.**
- **42% of contractors report high/very high impact from BIM on estimating, likely reflecting their hands-on role in the process.**
- **Nearly half (45%) of respondents with more BIM experience (at least half of their projects involve BIM) report high/very high impacts, compared with about a third (34%) of less experienced ones.**

There is greater enthusiasm across the board from owners, architects and engineers about the positive impact of BIM on the accuracy and completeness of bidding, with high/very high impact responses ranging from 43% to 47%, while, interestingly, contractors are more subdued.

- **Engineers are particularly positive (25% rate the impact as very high),** perhaps because trade contractors' modeling is producing more refined and knowledgeable bids.
- **Only 10% of contractors report a very high impact for this factor, with 29% reporting low or no impact.** Notably, the majority of those who report low/no impact do less than half of their work with BIM, so more experience may improve their perspective.
- **Among project types, the highest percentage of respondents involved with manufacturing projects (66%) and laboratories (60%) report high/very high impact,** perhaps reflecting the particularly complex nature of estimating and bidding in those environments.

BIM Impact on Estimating and Bidding (According to Owners, Architects, Engineers and Contractors)

Dodge Data & Analytics, 2015

Very High High Medium

Improved Process and Accuracy of Estimating Construction Costs

Owners



Contractors



Improved Accuracy and Completeness of Bids

Owners



Architects



Engineers



Contractors



BIM Impact on Construction Phasing and Logistics

The use of models to plan project phasing and optimize site logistics has consistently been rated as a valuable tool through all of Dodge Data & Analytics' BIM research. Increasingly, sophisticated 4-D simulations and visualizations are also effective for communicating plans to multiple stakeholders.

For this study, owners and contractors were asked to rate the impact of BIM on improving both the ability to develop construction phasing and logistics, and to convey these plans effectively to owners to improve their understanding.

- Both owners and contractors are nearly unanimous in their enthusiasm for the contribution of BIM to improving phasing and logistics planning, with 85% and 90%, respectively, rating its impact at medium or higher.
- Owners and contractors are almost equally enthusiastic about owners' improved ability to understand model-based phasing and logistics, with over three-quarters citing BIM's impact as medium or higher.

These strong results underscore BIM's powerful capability to both plan and communicate work.

BIM Impact on Construction Phasing and Logistics

(According to Owners and Contractors)

Dodge Data & Analytics, 2015

Very High High Medium

Improved Ability to Plan Construction Phasing and Logistics

Owners



Contractors



Improved Owners' Understanding of Construction Phasing and Logistics

Owners



Contractors



REFERENCE TO RELATED RESEARCH

The Business Value of BIM for Construction in Global Markets SmartMarket Report, published by Dodge Data & Analytics in 2014, examined the value reported by contractors of virtual jobsite planning and logistics.

- Nearly a third (30%) of large contractors (annual revenue over \$250 million) included virtual jobsite planning and logistics among the top three ways their organizations are leveraging BIM during design and preconstruction, compared with 23% of all contractors surveyed. This infers the value of this approach for complex projects because these firms are typically working on larger and more complex projects.
- Among regions, German firms were particularly enthusiastic, with 41% including this activity in their top three most frequent BIM-based preconstruction activities.

BIM Impact on Contractors' Understanding Of Design Intent

A direct downstream benefit of better quality construction documentation on complex projects should be an improvement in contractors' ability to more fully understand the design intent. This clearer understanding should be tangibly demonstrated by fewer RFIs (Requests for Information) seeking clarifications or identifying discrepancies, errors or omissions during construction.

To test that hypothesis, architects, engineers and contractors were asked to rate the impact of BIM on increasing contractors' understanding of proposed design solutions and on reducing the number of RFIs during construction.

All respondents acknowledge the powerful impact of BIM on improving contractors' understanding of the design.

- **Contractors themselves are nearly unanimous at 94% in rating the impact as medium or higher, and none of the contractors say that BIM has no impact.** These findings unambiguously confirm this benefit.
- **Interestingly, engineers lead at the top end of ratings with 65% reporting high or very high impact.** Engineers who do more than half of their work with BIM show an even greater proportion (76%) at those levels. This may reflect the advance of model-based design and fabrication processes in structural and MEP (mechanical, electrical, plumbing) work, where multiple stakeholders are benefiting from shared authoring, access and analysis.
- **BIM experience affects perception of this benefit.** Twice as many (27%) of the respondents that do over half of their work with BIM rate the impact as very high, compared with less experienced companies (13%).

The tangible metric of reduced RFIs during construction, which should be a natural extension of better documentation and clearer understanding of the design, again shows strong support, averaging 70% of respondents experiencing medium, high or very high impact levels. It should be noted, however, that contractors outnumber architects and engineers at most of those three levels, perhaps indicating a different perspective on this metric from the design team, which is typically on the receiving end of RFIs.

More detail on the metric of reduced RFIs can be found on page 29 in the "Metrics for the Impact of BIM on Complex Projects" section of this report.

BIM Impact on Contractors' Understanding of Design Intent (According to Architects, Engineers and Contractors)

Dodge Data & Analytics, 2015

Very High High Medium

Increased Contractors' Understanding of Proposed Design Solutions

Architects



Engineers



Contractors



Reduced Number of RFIs

Architects



Engineers



Contractors



BIM Impact on Cost Control and Reduction

The increased certainty provided by modeling during design and preconstruction (due to factors like more highly engaged owners, better documented and more constructable designs, and more accurate estimating and bidding) should enable project teams to exert closer control of costs during the dynamic process of procurement, fabrication and installation of the work on complex projects.

Respondents were asked to rate the impact of BIM on controlling costs during construction.

- **Contractors are tasked with controlling costs, and over three-quarters of them (77%) see at least a medium level of positive impact from BIM on the process.**
- **The fact that the range for all the parties is weighted toward medium versus high or very high indicates that cost control is still an emerging capability and expertise.**
- **Importantly, none of the owners say BIM has no impact on improving cost control.**

It stands to reason that better cost control on top of the other upstream benefits of BIM could result in a reduction of final construction cost.

- **Over half (53%) of all respondents rate the impact of BIM on reducing final construction cost at a medium or higher level, with owners (58%) and contractors (69%) being most enthusiastic.**
- **Similar to cost control, the range of responses is weighted toward medium impact rather than high or very high, again signaling a benefit still in development.**

More detail on the metric of cost reduction can be found on page 27 in the “Metrics for the Impact of BIM” section of this report.

BIM Impact on Cost Control and Reduction (According to Owners, Architects, Engineers and Contractors)

Dodge Data & Analytics, 2015

Very High High Medium

Improved Process of Controlling Construction Costs

Owners

13% 28% 25% 66%

Architects

9% 16% 36% 61%

Engineers

18% 16% 31% 65%

Contractors

11% 27% 39% 77%

Reduced Final Construction Cost of Projects

Owners

13% 15% 30% 58%

Architects

7% 11% 29% 47%

Engineers

10% 13% 21% 44%

Contractors

7% 25% 37% 69%

REFERENCE TO RELATED RESEARCH

Cost modeling (also known as 5D BIM) involves linking objects and assemblies in models to relevant cost data for more dynamic and iterative pricing. *The Business Value of BIM for Construction in Global Markets SmartMarket Report* published by Dodge Data & Analytics in 2014 identifies interesting trends related to both 5D BIM and construction cost reduction.

- **Contractors in Japan (53%), Brazil (52%), France (48%) and Germany (41%) lead in high or very high frequency of practicing 5D BIM, compared with an average or 24% across all regions.**
- **41% of contractors in all global markets surveyed cite BIM's contribution to lower project cost among their top three factors that would improve ROI on BIM.**

BIM Impact on Schedule and Project Duration

Owners, architects, engineers and contractors were asked to rate the contribution of BIM to the achievement of planned schedule milestones and to shortening project duration by compressing the schedule.

- **Encouragingly, about one third of owners, engineers and contractors rate BIM as having a high or very high impact on improving the achievement of milestones.** Owners soar to 78% and contractors to 77% when medium impact responses are included, so clearly these two highly involved parties are seeing a tangible improvement in schedule adherence from BIM.
- **There is little difference in the response rates between companies that do more than half their work in BIM and others that do less,** so the benefit of better schedule adherence accrues about equally to all.

BIM's contribution to shortening overall project duration by compressing the schedule is also cited by all parties.

- **60% of respondents rate BIM's contribution to completion acceleration as medium or higher.**
- **Owners and contractors, the parties most directly involved with and responsible for the schedule, are more enthusiastic, at 65% and 68%, respectively.**

The relatively low awareness by architects and engineers, indicates that this is still perceived as a developing BIM benefit by design teams relative to some others addressed in this research, such as reduced RFIs and better documents.

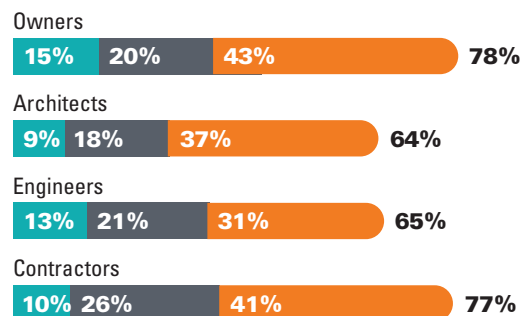
More detail on the metric of schedule reduction can be found on page 28.

BIM Impact on Schedule and Project Duration (According to Owners, Architects, Engineers and Contractors)

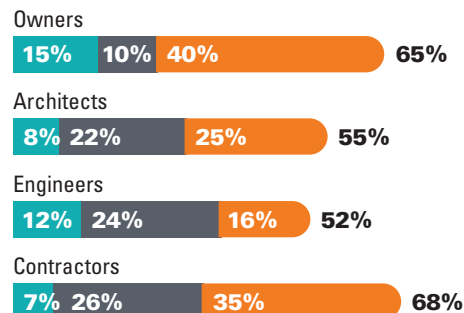
Dodge Data & Analytics, 2015

Very High High Medium

Improved Achievement of Planned Schedule Milestone Dates



Compressed Schedule Results in Accelerated Project Completion



REFERENCE TO RELATED RESEARCH

BIM research by Dodge Data & Analytics over the years has shown an increasing focus on using BIM to improve schedule performance.

Reduced project duration as a direct benefit of BIM was studied in *The Business Value of BIM in North America SmartMarket Report*, published by Dodge Data & Analytics in 2012.

- **37% of all BIM users surveyed (owners, architects, engineers and contractors) experienced the benefit at a high or very high level.** This grew from 27% three years earlier.
- **Over half (53%) of contractors reported the benefit at that level, up from 32% three years previously.**

- **It was cited by almost half (49%) of non-BIM users as a key attraction that would encourage them to adopt BIM.**

In *The Business Value of BIM for Construction in Global Markets SmartMarket Report*, published by Dodge Data & Analytics in 2014, results showed global recognition of BIM's impact on schedule.

- **When measuring the ROI of BIM, schedule-related metrics (such as faster project completion) are rated as the third most important type by contractors across 10 global markets.**
- **Integrating schedule with BIM (also known as 4D BIM) is cited by about a third (29%) of contractors as being among their top three BIM-related preconstruction activities.**

BIM Impact on Unplanned Changes, Rework and Out-of-Sequence Work

Preconstruction benefits of BIM related to better and more constructable documents, improved contractor understanding, more accurate estimating and bidding, and enhanced planning, cost and schedule control should increase certainty and predictability, thereby reducing a number of the problems that traditionally occur during construction on complex projects.

Owners and contractors were asked to rate the degree that BIM increases predictability during construction, resulting in fewer unplanned changes.

- **Response was extremely strong for this BIM benefit from both parties, with an unusually large proportion of each (23%) rating the impact as very high.**
- **Across project types, manufacturing projects earned a very high rating from almost half (48%) of the respondents who work in that market sector.**

The same respondents were asked to rate the contribution of BIM to reducing rework during construction, an all-too-frequent occurrence that almost always negatively impacts both cost and schedule.

- **With 89% finding at least a medium BIM impact, contractors appear to be the most enthusiastic, which makes sense because they are on the frontline of dealing with the multiple negative impacts of rework.**
- **Owners and contractors who do more than half their work with BIM are far more supportive, with 28% rating the impact as very high, versus only 10% of the less experienced respondents.** This reinforces the basic tenet that greater BIM experience drives higher levels of benefits.
- **BIM's impact on reducing rework is most widely noted by respondents doing transportation projects, with well over three quarters (83%) citing the impact as high or very high.** This indicates that BIM is a particularly effective remediating factor for that problem on complex transportation projects.

Out-of-sequence work caused by earlier problems plays havoc with maintaining the schedule, and can be costly as well, frequently requiring premium pay or extra shifts.

Over three quarters of owners (78%) and contractors (83%) concur that BIM meaningfully reduces out-of-sequence work on their complex projects.

BIM Impact on Unplanned Changes, Rework and Out-of-Sequence Work (According to Owners and Contractors)

Dodge Data & Analytics, 2015

Very High High Medium

Increased Predictability/Fewer Unplanned Changes



Reduced Rework



Reduced Amount of Out-of-Sequence Work Due to Earlier Problems



REFERENCE TO RELATED RESEARCH

Reduced rework has been an increasingly meaningful benefit tracked in previous BIM research by Dodge Data & Analytics (DD&A).

In *The Business Value of BIM in North America SmartMarket Report*, published by DD&A in 2012:

- **48% of all respondents (owners, architects, engineers and contractors) cited experiencing reduced rework on their BIM projects at a high or very high frequency.**
- **Contractors named reduced rework as their top benefit of BIM, earning that ranking from nearly two thirds (65%) of contractor respondents.**
- **Owners ranked it second, after reduced errors and omissions in documents, which is often a root cause of rework.**

In *The Business Value of BIM for Construction in Major Global Markets SmartMarket Report*, published by DD&A in 2014:

- **40% of the most highly engaged contractors (most BIM experience, BIM skills and level of BIM implementation) in the 10 global markets studied are experiencing reduced rework at a high or very high level, compared with only 28% of those at the lowest**

level of engagement, underscoring the relationship between BIM experience and reduced rework.

- **Nearly one third (31%) of all contractors surveyed include reduced rework among the top three overall BIM benefits for their organization.** This is especially true for contractors from the US (40%) and UK (35%).
- **Model-driven layout in the field was top ranked as a frequent construction-phase BIM activity among all contractors.** This correlates directly to reduced rework, due to the ability to leverage the precision of laser-guided instrumentation and the granular accuracy of the model to prevent errors in physical location of work-put-in-place, such as sleeves and penetrations in slabs, or embeds for attachment of building envelope elements.
- **Augmented reality, laser scanning for validation of work in place, GPS control of construction equipment and model-driven robotics all scored lower for frequency, but each also has the potential to reduce rework.** Thus, they can be expected to see increased popularity in future studies as they become more widely available, understood and used.

BIM Impact on Labor, Safety and Material Waste

Improved labor productivity, reduced site labor due to increased offsite fabrication, fewer reportable safety incidents and less onsite material waste are increasingly popular metrics tracked by project teams leveraging BIM. This growing popularity is no doubt due to their tangible value, potential for rapid scalability across projects and quantifiable contribution to validating a multifaceted business case for BIM.

Owners and contractors were asked to rate the contribution of BIM to improving labor productivity.

- **Though not garnering a large percentage of very high impact ratings, this benefit performed solidly in high and medium impact designations**, especially with contractors who have the firsthand responsibility for measuring labor statistics.
- **Experience with BIM has a major impact: 14% of the respondents that do over half their work with BIM give this a very high rating, compared with only 2% of those with less experience.**

Owners and contractors also rated the impact of BIM on reducing site labor due to increased offsite prefabrication.

- **This labor-related factor also scored lightly at the very high impact level, but it did similarly well in high and medium impact ratings.**
- **Experience also influences receipt of this benefit, with over three quarters (78%) of respondents who do more than half of their work with BIM experiencing medium or higher impact, versus 56% of less experienced ones.**

Safety is critically important to both contractors and owners. Many parties in the industry are looking for ways for model-based processes to improve safety, and they are leveraging BIM for safety planning and training. For more information, see page 20.

- **The small percentage of owners and contractors noting a very high impact reflects the emerging nature of this BIM metric, rather than a judgement of low effectiveness.**
- **BIM experience impacts safety more than most benefits addressed in this study, with 21% of respondents who do more than half their work with BIM experiencing a high or very high impact, compared with only 5% of less experienced ones.** This commitment by BIM leaders is a positive signal that we can expect to see rapid development, which will add significant, tangible value to the industry.

BIM Impact on Labor, Safety and Material Waste (According to Owners, Architects, Engineers and Contractors)

Dodge Data & Analytics, 2015

Very High High Medium

Improved Labor Productivity

Owners



Contractors



Reduced Site Labor Due to Increased Offsite Fabrication

Owners



Contractors



Reduced Reportable Safety Incidents

Owners



Contractors



Reduced Material Waste

Owners



Architects



Engineers



Contractors



Net reduction in the amount of waste materials generated onsite should be a cumulative downstream effect of BIM benefits like improved site logistics planning, less rework and increased offsite prefabrication. An increasing number of architects and engineers who practice green design are also becoming aware of the importance of reducing site-generated waste as part of a commitment to overall greener design and construction.

Impact of BIM on 10 Aspects of Planning, Design and Construction

BIM Impact on Labor, Safety and Material Waste

CONTINUED

- The finding that over half of owners and contractors give a medium or higher BIM impact rating indicates awareness of this benefit and is encouraging.
- The number of engineers giving a very high impact rating (12%) relative to architects (5%) may indicate the greater visibility at the site of the reduction in large

systems-related items, such as unused duct runs that are often major elements of site waste.

More detail on the metrics of improved labor productivity, reduced site labor due to increased offsite fabrication, and reduced reportable safety incidents can be found on pages 31, 32 and 30, respectively.

REFERENCE TO RELATED RESEARCH

Productivity

The relationship between BIM and increased productivity has been a consistent theme in previous Dodge Data & Analytics (DD&A) BIM research. Findings in *The Business Value of BIM for Construction in Major Global Markets SmartMarket Report* published by DD&A in 2014 demonstrate that relationship globally.

- Improved productivity of personnel was cited as third among the top five benefits that would have a high or very high impact on improving contractors' ROI for BIM. Almost half (45%) of U.S. contractors named it as a very high impact factor.
- 43% of contractors who are highly engaged with BIM (most BIM experience, BIM skills and level of BIM implementation) experience this benefit at a high or very high level, versus 34% of low-engagement firms. While this demonstrates the value of greater BIM engagement, it also indicates that, with over a third of the least-engaged firms seeing a significant improvement in productivity, this benefit is available almost immediately to contractors upon starting to work with BIM.

In the 2012 *Business Value of BIM in North America SmartMarket Report*, improved productivity ranked as the top metric overall that BIM users believe would have a high or very high impact on improving their ROI for BIM (architects 79%, engineers 59%, contractors 85%).

Prefabrication

The growing use of leveraging models for prefabrication has also been addressed in Dodge BIM research.

- *Business Value of BIM for Construction in Major Global Markets SmartMarket Report (2014)*
 - Model-driven prefabrication is cited by 43% of contractors across 10 global markets as being among the top three ways their organization leverages BIM

during construction, placing it second on the overall list (after model-driven layout in the field).

- BIM engagement increases the perceived value of model-driven prefabrication, where 61% of the most engaged contractors (most BIM experience, BIM skills and level of BIM implementation) cite it among their top three activities during the construction phase.

In the 2012 *Business Value of BIM in North America SmartMarket Report*, increased prefabrication is cited as having a high or very high impact on improving BIM ROI by 81% of contractors.

Safety

The 2014 *Business Value of BIM for Construction in Major Global Markets SmartMarket Report* shows an emerging relationship between BIM and safety.

- Just 7% of contractors cited improved safety as one of top three BIM benefits for their organization, ranking 14th out of 15 options. Among regions, Germany is most active with 22% of contractors naming improved safety among their top three BIM benefits.
- However, widespread interest in BIM's potential impact can be seen in the finding that safety metrics applied to BIM ROI calculations scores as high or very high with 50% of all contractors, with small companies (56%) leading large (46%). Japanese firms (86%) lead other regions in citing safety metrics.
- Because it affects them more directly, a higher percentage of trade contractors (21%) included improved jobsite safety among their top three factors that would improve their BIM ROI than did general contractors (14%).
- 6% of contractors identified safety planning/training as among the top three activities for which their organization leverages BIM during design/preconstruction, ranking it last among 10 choices.

Safety Planning With BIM

is Gaining Critical Traction Among Industry Leaders

Safety is a multifaceted issue, and contractors are actively leveraging BIM both to mitigate specific hazardous situations and to plan safer logistics for the entire project.

BIM enables project teams to incorporate safety more effectively into planning. As Steve Smithgall, senior vice president of safety at Balfour Beatty Construction, puts it, “BIM generates discussion about risk elimination or mitigation before the challenge is staring you in the face. You can model for something as simple as where to locate tie-off points for work at height, or something more complex like modeling an excavation to determine where the top of a slope is located, when shoring is necessary, or when you may have an engineered slope in play.”

Conducting Safety Planning With BIM

To illustrate project-wide minimum safety requirements, Lend Lease uses safety models during trade buyouts. “It can be tough for subs, so we model and sequence safety elements to show how to integrate them into the workflow,” says Alexis McGuffin, Lend Lease BIM integration manager.

Jennifer Downey, AIA, national BIM manager at Turner Construction, New York, N.Y., finds BIM an excellent tool for automated safety logistics checking. “We can use BIM to set up rules to evaluate geometric relationships in models to be sure that [safety] requirements—including OSHA and local requirements—are covered,” Downey says. She makes the further point that “Any pre-planning processes are important for

“BIM generates discussion about risk elimination or mitigation before the challenge is staring you in the face.”

safety; this is the best way to prevent incidents. You get an idea in 2D, but in 3D you have to think through all the details and you can’t forget the Z [vertical] dimension.”

Realizing the power of BIM, Turner recently used BIM to preplan the pour process and equipment sequencing for the Wilshire Grand Hotel in Los Angeles, which was “pursuing a Guinness World Record for the largest continuous mat slab pour,” Downey says. “We modeled down to the level of rebar, then adjusted the model from where it deviated from the design to account for the quantity difference,” she recalls. She notes that the potentially dangerous 18-hour pour was completed with no safety incidents.

At Skanska, project teams find BIM is an effective way to eliminate risks to welders. Specifically, they use it to detail concrete and steel so accurately that the team can cast the imbeds and the attached beams four levels up without the need for a worker to go up an elevator shaft to weld it, according to Greg Smith, director of virtual design and construction at Skanska in Seattle.

Challenges

Despite these benefits, Smith points out that “in logistics planning, there is still a perception that the cost of using 3D BIM is more expensive than

2D.” Also, modelers have to be “very knowledgeable, understand the modeling process, and construction phases and process[es],” Downey says. Lack of engagement in BIM by environmental health and safety managers on the jobsite is another challenge. Smith says, “Getting them in the room while planning would help.”

Using Visualization and Gaming Technologies to Improve Safety Planning With BIM

To drive deeper engagement Skanska is incorporating augmented reality, “which lets you see behind walls and identify potential hazards before taking action,” says Smith. Skanska has also used virtual reality in hospitals to “understand patient flow, by having nurses look at a VR model and help identify possible patient flow safety issues,” he continues.

Smith further notes that Skanska has developed “virtual reality games that set up scenarios for superintendents and test them to see if they can identify, for example, 10 different hazards.” ■

BIM and Collaboration Deliver Powerful Impacts for Major Hospital Project

The UCSF Medical Center at Mission Bay

SAN FRANCISCO, CALIFORNIA



New 878,000-square foot UCSF medical complex at Mission Bay in San Francisco

MEASURING THE IMPACT OF BIM ON COMPLEX BUILDINGS

The University of California San Francisco (UCSF) Medical Center recently completed a major new hospital complex in the city's Mission Bay district. Under the direction of J. Stuart Eckblad, FAIA, Director of Design & Construction for the Mission Bay Hospitals Project, the team, which included Anshen + Allen (part of Stantec Architecture), DPR Construction and almost 20 subcontractors, collaborated intensively in a specially created Integrated Center for Design and Construction (ICDC) over the course of the three-and-a-half-year project.

The team leveraged BIM extensively in this collaborative environment, and credits numerous positive impacts on project outcomes to its use. Examples include:

Concrete

- 99.7% of the 2,500 anchor bolts in the 300 pile caps were installed in exactly the right location.
- Material waste was less than 6% versus typical rate of 15%.

Drywall

- Saw an 8% increase in production of full-height framing.

- Accurate MEP (mechanical, electrical, plumbing) openings in the model minimized RFIs and come-backs due to held-up changes or other trades not completing correctly.
- Saw a 4% increase in production for sheetrock installation, and 11% increase of production for taping and finishes.
 - They were able to frame per modeled layout of drywall in standup (vertical) versus railroading (horizontal), which minimized butt joints and increased finished quality.
- Saw a 6% decrease in waste in drywall and framing material, compared with 15% typical industry performance.
 - These results were achieved by extracting material quantities directly from model.

MEP Penetrations in Priority Walls

- Used fabrication-level output (spool sheets) from the model to build MEP penetrations before the MEP trades arrived, thus eliminating work (and frequent rework) associated with typical hand layout and/or cutting the framing later.

MEP Deck Inserts

- Completed 300 inserts per day with 99.7% accuracy rate versus typical rate of 125 per day with conventional methods.
 - They used model-guided field equipment to lay out inserts on permitted model.

Precast Panels

- Achieved installation rate of 14 to 15 precast panels per day, compared with typical rate of 10 to 12.
 - Precast panel supports could be detailed during preconstruction and prefabricated onto the structural steel.

Structural and Miscellaneous Steel

- Saved \$2 million by prefabricating overhead boom supports for operating rooms versus normal field fabrication costs.
 - These are typically field fabricated due to complicated detailing.
 - They did early coordination in the model with MEP systems and detailed the supports during preconstruction, so they could be prefabricated with the structural steel. ■

Data: Owner Insights

On BIM Impacts on Complex Projects

Owner Insights

On BIM Impacts on Complex Projects

Eight expert owners agree that, currently, they see the greatest impact from BIM on their complex projects from trade coordination and design.

Eight owners with proven expertise in the use of BIM on their projects were asked in a series of in-depth interviews (IDIs) to evaluate several ways in which BIM improves outcomes on their complex projects. The greatest consensus on value is for trade coordination and design, which supports the findings in this SmartMarket Report. However, a few owners also reported other aspects of their work that BIM impacted positively, from planning to regulatory compliance.

Trade Coordination

The top-cited BIM benefit among the owners participating in the IDIs is improved trade coordination. A couple of owners provide specific metrics.

Andy Reinach, Alexandria Real Estate Equities, Inc., reports that he sees direct profit from BIM in this area: “giving the trades the ability to find issues in real time and work them out so that you finish the design virtually before you hit the field gives you the best bang for your buck.”

In particular, he notes that on one recent laboratory project, he expected, based on general industry expectations, to have around 900 RFIs. The use of BIM for trade coordination reduced the number of RFIs actually produced on that project to 200.

Joe Porostosky, Ohio State University, also reported a reduction in RFIs and change orders on a

complex laboratory project that he attributes to using BIM for trade coordination. He notes that this project in particular had “a very mature BIM process ... and a lot of coordination upfront.”

Stuart Eckblad, UCSF, notes that they were “generally always right on schedule or early with the subs’ work” due to the value BIM added to the coordination process. He is an advocate for having this take place as early as possible to support the opportunity for prefabrication: “The model allows [mechanical, electrical and plumbing trade contractors to] really think through the sequence much better and coordinate that with all the other trades,” which facilitates prefabrication.

■ **Meghan Ruffo, Carolinas HealthCare System**, sees trade coordination as connected to the other benefits she experiences from BIM:

“To me, the trade coordination touches on a lot [of benefits], the schedule improvement, the quality improvement, construction activities and the design quality too.” In fact, she credits BIM-supported trade coordination with helping them achieve a 25% reduction in errors and omissions.

■ **Digby Christian, Sutter FPS**, states the importance of BIM for trade coordination quite directly: “Without the ability to push BIM heavily into design and trade coordination, it would be essentially impossible to build projects that are this complex.”

However, full team engagement is critical to optimizing this benefit. **Ryan Marzullo, Delta Airlines**, reports that the efforts they put into trade coordination during the design phase on their recent project at JFK airport were discarded by the construction management team because they did not communicate effectively with them about it. “We lost the value because of failure in communication bridging design and construction.” In the upcoming Phase III of that project, he will bring in the trades early “and get them involved in the modeling effort, especially where we have more complex problems to solve.”

Design

There was also broad consensus across all the IDI participants that BIM’s impact on design contributes value to their complex projects in several important ways.

■ **Visualization: Several of the owners point to the benefits of BIM visualization for communicating with stakeholders and other team members.**

• **Ruffo** states, “Having end users—nurses, doctors, other clinical staff—be able to see the virtual mockups helped them better understand the design process [and provide more information earlier].”

• **Porostosky** finds he is able to improve stakeholder satisfaction with the final building. “Most normal people do not understand 2D drawing. They think they know what it is, and then invariably, they

get into the space and say, 'This is not what I envisioned.'"

- **Reinach** explains that visualization is key to his sales process for his spec laboratories: "We have an opportunity to sit our client down with the design team and the model and show them in three dimensions in vivid detail the space they agreed to lease, a huge part of their new excitement of being our tenant."

- An IDI participant from a **large technology company** who has requested to remain anonymous echoes findings in this report that BIM helps teams improve the constructability of a design. "Often our engineer and our designer don't take into account constructability... [Trades] don't understand there's a lot of assumptions that the engineer and the AE [make]."

- **Accountability: Christian sees the advantages of visualization go beyond just communication and help to drive accountability.** "If it's in a 2D drawing, humans are very good at talking around issues. Whereas, if you show that a piece of steel is actually poking through the ceiling in a 3D model, you can say, 'What are you going to do about that?'"

- **Reduce Value Engineering:** **Ruffo** states, "[Looking at] the constructability and design at the same time, we're looking at that kind of comprehensiveness earlier in design rather than doing a VE process at the end of the construction documents."

- **Opportunities for Innovation: Eckblad** says, "Getting people trained to think based on the model was really helpful ... to test different ideas."

"Without the ability to push BIM heavily into design and trade coordination, it would be essentially impossible to build projects that are this complex."

Cost Control and Schedule

Most of the IDI participants did not tie cost or schedule improvements directly to BIM, as reported by many in the survey result. **However, several owners found that BIM's ability to improve predictability and increase their understanding of value was important for cost, and that its ability to support effective work sequencing had a positive impact on schedule.**

Porostosky affirms, "We've seen benefits with time and cost ... because there was a solid model upfront and we know they used that for the estimating and costing ... Predictability is the best way to say it. We had a lot less issues with changes later in the project."

Denton Wilson, Methodist Health System, also highlights predictability rather than direct cost reduction. "Because of the realignment of knowledge and the impact of making decisions earlier in the process [due to BIM], you actually understand value ... When we are pricing out things, we have the knowledge at the table at that time. That's the predictability."

Wilson also confirms that BIM's impact on schedule should be judged by other standards than shorter schedules. "I am so tired of getting the shortest schedules rather than the right schedules ... [Based on forecast exposure from BIM] we are totally changing how we phase programs and projects based on

constructability. Instead of saying, 'Contractor, give me the shortest schedule,' we say, 'Show me what is the least impact to the schedule that creates the best value to the patient journey.'"

Other Benefits

Porostosky ranked planning as the top area of value provided by BIM at **Ohio State** because they are actively modeling their existing buildings—about 43% of the campus has been modeled so far—in order to be able use a 3D campus model for more holistic planning. The use of BIM also allows them to better prioritize their planning efforts, upcoming renovations and energy audits.

Two owners also report notable improvements in reducing the impact of regulatory compliance and inspections on their projects due to BIM. **Ruffo** reports the value of having "virtual documentation:" "In one project, we had zero infractions from the regulatory review agency, which is rare ... It's helped being able to provide documentation quickly and effectively to review groups."

Eckblad sees the inspection process improved. "This is the only time when the superintendents came into my office and said, 'I have to praise your inspectors, because they can see what's going on right now, they're on time, we don't argue about what was on the drawing.'"

Modeling, Coordination and Prefabrication Lead to Higher Productivity, Reduced Schedule and Improved Safety

Alfred I. duPont Hospital for Children Delaware Expansion
WILMINGTON, DELAWARE

A broad BIM strategy was required to deliver a 414,000-sq-ft expansion at the Alfred I. duPont Hospital for Children Delaware Expansion in Wilmington, Del.



MEASURING THE IMPACT OF BIM ON COMPLEX BUILDINGS

Delivering a five-story, 414,000-square foot expansion with emergency department, ICU, inpatient bed and surgical bed capabilities to an existing hospital comes with inherent complexities and challenges. Add in the fact that the entire building was designed on a six-degree radius, and the team needed to explore ways to ensure accuracy and preserve schedule.

"Everything was on a radius," says Bill Hawthorne, project executive at Skanska USA. "There wasn't a straight wall in the place, even the mechanical rooms in the basement were on a radius. We needed a high level of precision."

The team's plan included uses of BIM for 4D scheduling, 3D coordination, logistics, prefabrication, virtual and physical mockups, digital layout and barcode tagging for supply chain management.

Prefabrication Strategy

Skanska was awarded the job after design documents from FKP Architects were complete. In order to preserve the design and maintain schedule, Skanska proposed extensive use of prefabrication. Although meeting the November 2014 completion date was a concern, Hawthorne says Skanska trusted that if more time was committed toward early prefabrication design and coordination, construction time would be reduced.

"We gave them more time upfront to do the design," he says. "Take a few months upfront to do the mock-ups and get the decisions made right. If we prefab it, we can make up that time difference in the construction. The end-date won't move."

A BIM manager, IBSECAD, was hired to maintain a single-source model for all trades involved in prefabrication. The prefabrication strategy included building 144

bathroom pods, 152 overhead MEP racks and 144 patient headwalls. Crews worked at an offsite warehouse, approximately 10 miles from the jobsite. By building offsite in a controlled environment, the team could better control schedule, eliminate waste, enhance quality and improve safety.

"Everyone works at waist height like an assembly line," says Matt Pentz, senior MEP project engineer. "We had zero accidents, and there are never bad weather days when you're in the warehouse."

The MEP racks and bathroom pods needed to be engineered to a curved corridor, so materials like copper pipe were ordered "pre-bent" from suppliers to avoid the need to bend and stress them during assembly.

Prefabricated pieces were delivered to the site as needed, reducing the need for onsite storage. On average, teams delivered 12

Alfred I. duPont Hospital for Children Delaware Expansion

WILMINGTON, DELAWARE

bathroom pods per day. Crews were able to hang about six MEP racks per day. Around 40% of the square footage of work was completed at the prefabrication warehouse, making the hospital jobsite significantly less congested.

Barcode tagging was used to coordinate prefabricated modules from warehouse fabrication to onsite installation. The team printed barcode stickers for each prefabricated component, and then the barcodes were scanned with an iPad camera and tracked in the system with associated equipment, documents and locations. The team created a status system to track completion of components through schedule of delivery to the site.

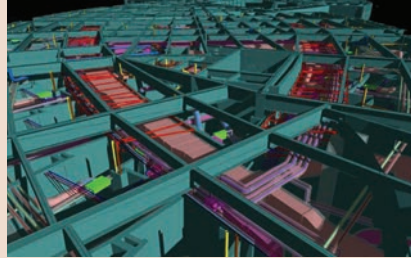
Skanska recorded no rework associated with prefabrication.

For inspections, the jurisdiction was brought into the prefabrication warehouse once to sign off on all operations, rather than the typical process of conducting inspections on an ongoing basis.

Based on the time savings accrued through construction time, inspection time and reduced rework, Skanska estimates that the prefabrication strategy saved about two months on the overall project schedule. That translates into a more than 10% savings on the construction schedule.

Other Modeling Advantages

Skanska credits modeling and coordination for speeding installation of other building components as well. Hawthorne says installation time for the building's panelized curtainwall system was reduced by more than 50%.



The entire building was designed on a six-degree radius.

"[Crews] could install 14 to 18 panels per day because of how good the coordination was," he says. "Typically, they might install six to eight per day."

Digital layout was another critical component of the team's strategy. Pentz says the team pushed for digital layout in part because the complex design had zero dimensions. "We saw it as really the only way to do layout," he says. "Without dimensions, layout would have been nearly impossible."

For the bathroom pods, layout points were identified by the plumbing subcontractor, the concrete subcontractor and Skanska.

In the field, the digital layout process was guided by a virtual model and allowed the team to layout approximately 500 points a day with one person.

The plumbing subcontractor was responsible for the sleeve positions of the drain, sanitary and vent lines. The drain was the most critical to align with the prefab bathroom being set in the depression. The concrete subcontractor had to maintain 1-inch oversize and make sure crews were spot on as the curtainwall was ½ inch from the prefab wall. When setting the prefab pods, crews had to maintain the layout inside the depression.

Project Facts and Figures

Construction Manager
Skanska USA

Type of Project
Hospital expansion with ground-level parking garage

Size
414,000 sq. ft. over 5 stories

Demolition
March 2011

Completed
November 2014

BIM-Related Results

A strategy that relied heavily on prefabrication reaped a variety of benefits:

- Two months schedule savings
- 50% less time needed for layout by using digital process
- Zero injuries in warehouse
- No rework needed on prefabricated pieces
- Streamlined delivery and installation with barcoding

Skanska estimates that digital layout offered 50% time savings compared with a manual process. Without digital layout, Pentz says the team would have achieved 250 points a day with two people. "We never would have achieved that without digital layout" he says. "Quality was improved and the production achieved was unreal." ■

Data: Metrics for the Impact of BIM on Complex Projects

Metrics for the Impact of BIM on Complex Projects

This section of the study focuses on quantified impact metrics for six specific outcomes on complex projects:

- **Percentage Reduction of Final Construction Cost**
- **Percentage of Accelerated Project Completion Due to Schedule Compression**
- **Percentage of RFI Reduction**
- **Percentage Reduction in Number of Reportable Safety Incidents**
- **Percentage of Improved Labor Productivity**
- **Percentage Reduction of Site Labor Due to Increased Offsite Fabrication**

To capture these metrics, any respondent giving a medium, high or very high impact rating to one of these six outcomes from the first part of the study was then asked to select a percentage range for the actual degree of impact experienced. The ranges of impact were developed with input from experienced industry sources and vary based on the expected degree of current and potential impact on each outcome.

- **The ranges of the percentage impact choices for cost, schedule, RFI's and safety metrics are relatively low (in increments of 5%, from less than 5% to more than 10%).**
- **The ranges for labor productivity and reduction of site labor due to prefabrication are deliberately higher (in increments of 25%, from less than 25% to more than 50%) because of the anticipated impact BIM will have on these metrics as its use matures.**

- **For simplicity of reporting, the responses of architects and engineers are shown combined to reflect a unified, design team perspective.**





















The chart at bottom shows the percentage of each type of respondent who identifies the middle or higher range for degree of impact for these six outcomes. We expect that the proportion of users experiencing these top level outcome improvements will grow significantly in future studies.

It is worth noting that each of these six outcomes scores relatively low in the BIM impact ratings set forth earlier in this report, suggesting that they are still emerging. (See page 7 for a clear representation of how each of the 23 measures performs on a one to 10 scale.) Their quantified scores in this part of the study will offer the opportunity to track the degree of progress over the coming years as users advance in their effectiveness in using BIM, compared with the already highly ranked outcomes where the impact of BIM is more established, and future increases are likely to be incremental. We anticipate adding more outcomes to this quantified metrics evaluation process in future studies.

Respondents Reporting Top BIM Metrics on Key Project Outcomes

(Percentage in Top Two Tiers of Both Impact and Quantified Metrics)

Dodge Data & Analytics, 2015

	Owners	Architects and Engineers	Contractors	All
Lower-Scaled Metrics	More Than 5%	More Than 5%	More Than 5%	More Than 5%
Percentage Reduction of Final Construction Cost	 30%	 25%	 41%	 32%
Percentage of Accelerated Project Completion Due to Schedule Compression	 40%	 38%	 45%	 41%
Percentage of RFI Reduction		 47%	 63%	 37%
Percentage Reduction in Number of Reportable Safety Incidents	 13%		 14%	 13%
Higher-Scaled Metrics	More Than 25%		More Than 25%	More Than 25%
Percentage of Improved Labor Productivity	 10%		 16%	 13%
Percentage Reduction of Site Labor Due to Increased Offsite Fabrication	 8%		 21%	 14%

Percentage Reduction of Final Construction Cost

While over half (53%) of all respondents give a medium, high or very high rating to the impact of BIM on reducing the final construction cost of complex projects, there is significant variety among the individual responses of contractors (64%), owners (45%) and design teams (37%) who can provide a percentage of reduction experienced.

The fact that contractors most commonly report a medium or higher impact on cost is important because they are most closely involved with managing the costs. Therefore, they are in the most qualified position to make this judgement. In fact, the disparity in perceptions across the groups may reflect their relative distance from exposure to the direct cause-and-effect relationship between BIM and cost on a day-to-day basis throughout the course of a long and complex project. So the lower ratings from owners and design teams may just reflect lack of familiarity rather than informed dissent.

Percentage of Impact

Among those who do agree on the positive impact of BIM on final cost reduction, there is remarkable alignment around their assessment of the percentage impact, with almost identical profiles weighted strongly toward the middle range of 5% to 10%.

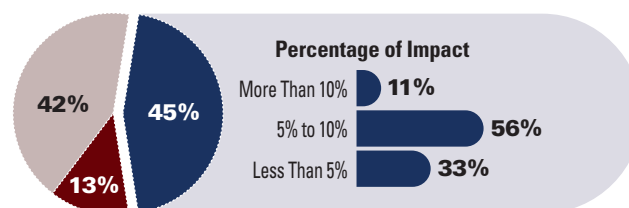
- On the design team, more engineers (26%) than architects (8%) perceive cost reduction to be greater than 10%. This may relate to their growing model-based integration with trade contractors and fabricators, helping to eliminate over-engineering, documentation-related issues and other unnecessary cost drivers.
- BIM experience does not appear to influence this metric, with nearly equal proportions of higher and lesser experienced respondents weighing in at each metric level. This would suggest that BIM's impact on cost reduction can accrue to project teams of all skill levels.

Percentage Reduction of Final Construction Cost (According to Owners, Design Teams and Contractors)

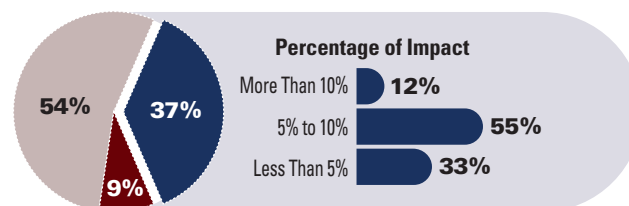
Dodge Data & Analytics, 2015

- BIM Has Medium or Higher Impact on Final Cost and Know the Percentage of Impact
- BIM Has Medium or Higher Impact on Final Cost But Not Sure of Percentage of Impact
- Low/No/Don't Know Impact of BIM on Final Cost

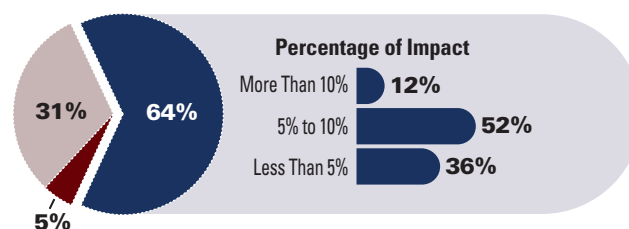
Owners



Architects and Engineers



Contractors



Percentage of Accelerated Project Completion Due to Schedule Compression

Roughly 10% more respondents overall report that they see at least a medium impact from BIM on accelerating project completion than they do on reducing final construction cost.

- Among all respondents, almost six in ten (59%) give it a medium, high or very high impact rating for accelerated completion, compared with 53% who give that rating for cost reduction.
- Experienced users report more impact on accelerated completion, with 11% of those who do more than half their work with BIM rating its impact as very high, versus just 4% of the less experienced respondents.

Owners and contractors are more closely aligned on the meaningful impact of BIM on schedule than on cost.

- The percentages of contractors (61%) and owners (55%) seeing at least medium impact are much more similar than the percentage of those reporting medium or higher cost impacts (64% and 45%, respectively), suggesting greater consensus on this outcome.
- The impact of BIM on schedule acceleration is also supported by the related findings on BIM's ability to improve the achievement of planned milestones (see page 15), for which 77% of contractors and 78% of owners report medium or higher impact.

Percentage of Impact

Among those who do agree on the positive impact of BIM on accelerated completion,

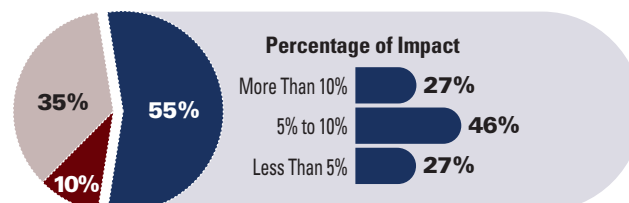
- About half of each respondent type report schedule acceleration from BIM to be in the middle range of 5% to 10%.
- More owners (27%) and design team members (29%) report completion acceleration impact of more than 10% than contractors (21%), and far higher proportions of each respondent type report this level of impact than they do for cost reduction (11%, 12% and 12%, respectively).
- On the design team, far more engineers (15%) than architects (4%) respond that, although they believe BIM has a medium or higher impact on accelerating the completion, they cannot identify a percentage range for that impact. This may reflect their relative distance from the day-to-day management of the schedule and direct visibility to BIM's impact on it.
- BIM experience has a moderate effect on this metric, with 28% of respondents who do more than half their work with BIM reporting more than 10% impact, versus 21% of less experienced respondents.

Percentage of Accelerated Project Completion Due to Schedule Compression (According to Owners, Design Teams and Contractors)

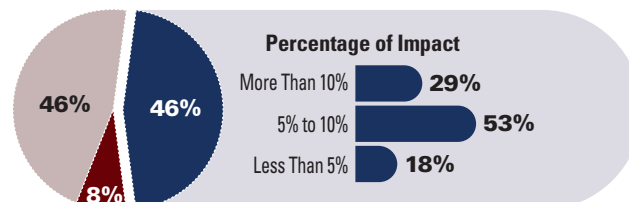
Dodge Data & Analytics, 2015

- BIM Has Medium or Higher Impact on Completion and Know the Percentage of Impact
- BIM Has Medium or Higher Impact on Completion But Not Sure of Percentage of Impact
- Low/No/Don't Know Impact of BIM on Completion

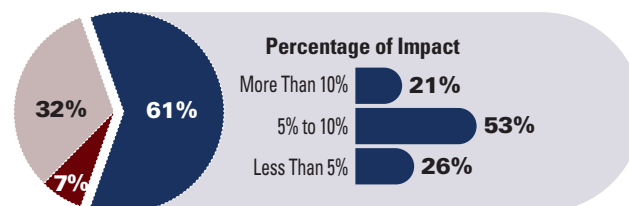
Owners



Architects and Engineers



Contractors



Percentage of RFI Reduction

Since owners are typically not directly involved with the RFI workflow, only contractors and design team members were asked to identify the percentage that RFIs are reduced on their BIM projects.

The impact of BIM on RFI reduction is the highest among all six major metrics studied in this report.

- **Almost three quarters (70%) of all respondents give BIM a medium, high or very high rating for its impact on reducing RFIs, compared with 53% and 59% at that level for cost and schedule improvement.**
- **Although the overall response is highly positive, significantly more contractors (81%) report a medium or higher impact on RFI reduction than do engineers (71%) or architects (64%), indicating an interesting divergence of perspectives between the parties that generate RFIs and those that receive them in this biaxial workflow.**
- **Experienced users report more impact on RFI reduction, with 15% of those who do more than half their work with BIM reporting the top (very high) level of impact, versus just 8% of the less experienced respondents.**

Percentage of Impact

Among the contractors and design team members who report a specific reduction, the top level of impact (more than 10%) is more commonly reported.

- **On design teams, a higher percentage of engineers (57%) report more than 10% RFI reduction than architects (45%), perhaps showing the downstream benefit of more collaborative and integrated design activities with trade contractors and fabricators.**
- **65% of structural engineers report more than 10% RFI reduction compared with 50% of MEP firms.** This likely reflects a more mature BIM workflow process in the structural segment of the industry, which has longer experience working in model-based environments according to several previous BIM research studies by Dodge Data & Analytics.
- **Across all respondents, however, BIM experience (doing over half your work with BIM) exerts a relatively small degree of influence (five percentage points of difference between more and less experienced respondents) compared with some of the other metrics studied.** This indicates that this benefit can accrue at a significant level to even less experienced BIM teams.

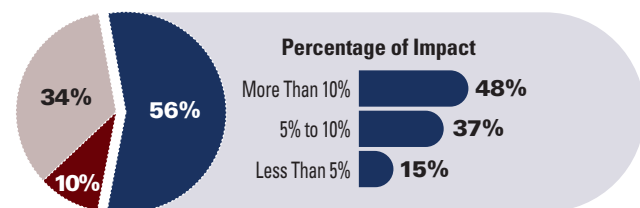
Percentage of RFI Reduction

(According to Design Teams and Contractors)

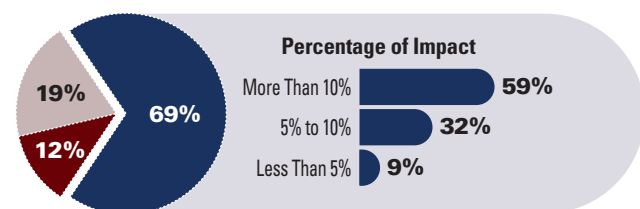
Dodge Data & Analytics, 2015

- BIM Has Medium or Higher Impact on RFI Reduction and Know the Percentage of Impact
- BIM Has Medium or Higher Impact on RFI Reduction But Not Sure of Percentage of Impact
- Low/No/Don't Know Impact of BIM on RFI Reduction

Architects and Engineers



Contractors



Percentage Reduction in Number of Reportable Safety Incidents

Because of its critical importance, the construction industry has established standard methods for tracking contractors' safety performance that are now widely accepted. The number of reportable incidents is one of those standard methods and provides a useful metric to determine the impact of BIM on safety.

Owners and contractors were asked for the percentage reduction in reportable incidents on their BIM projects.

- **Although the use of a reportable safety incidents metric for BIM is still emerging compared with more mature processes such as cost, schedule and RFIs, it is encouraging that 38% of owners and 36% of contractors currently perceive a medium or higher BIM impact on reducing these incidents.**
- **15% of owners believe there is a meaningful impact, but they can't assign a percentage to it.** Only 6% of contractors fall into this category, probably because of their direct responsibility for tracking safety.
- **A higher percentage of respondents who work on manufacturing and transportation projects report a medium or higher impact, compared with those doing hospitals, laboratories and entertainment projects.** This may reflect greater inherent risk of injury on those project types.
- **BIM experience influences receipt of this benefit, with 21% of respondents who do more than half of their work with BIM rating its impact as high or very high, compared with 5% of less experienced ones.**

Percentage of Impact

Among respondents who can assign a percentage to the reduction of reportable safety incidents on their complex BIM projects:

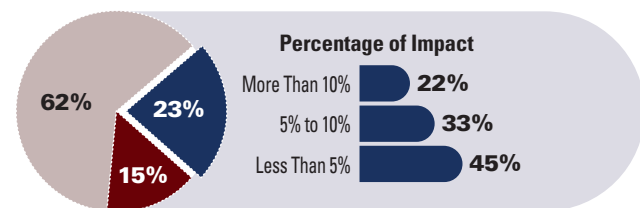
- **Owners weigh in a little more strongly than contractors, with over half (55%) reporting 5% or better reduction versus 46% of contractors.** Hopefully, this will translate to a broader demand on behalf of owners for their construction teams to refine and implement the BIM practices that have the most impact on safety, incorporate them into their BIM guidelines and raise general industry awareness of BIM as an effective tool for maintaining safety.
- **Similar to several other metrics, BIM experience influences the degree of reduction experienced, with twice as many (17%) respondents who do more than half their work in BIM reporting a percentage reduction of more than 10%, compared with those with less experience (8%).**

Percentage Reduction in Number of Reportable Safety Incidents (According to Owners and Contractors)

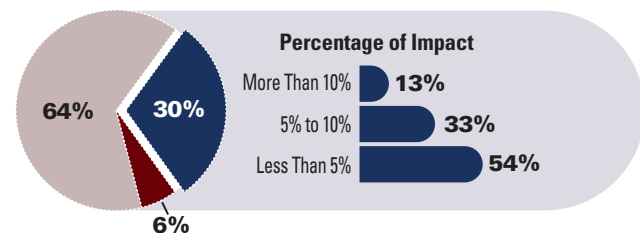
Dodge Data & Analytics, 2015

- BIM Has Medium or Higher Impact on Safety Incidents and Know the Percentage of Impact
- BIM Has Medium or Higher Impact on Safety Incidents But Not Sure of Percentage of Impact
- Low/No/Don't Know Impact of BIM on Safety Incidents

Owners



Contractors



Percentage of Improved Labor Productivity

Forecasts for the construction industry agree that labor supplies will tighten over the coming years. Therefore, the promise of improved labor productivity from model-based processes will become more critical as a metric for BIM, and its demonstrated effectiveness will greatly raise its value.

Importantly, two thirds (66%) of owners and three quarters (73%) of contractors state that BIM has a medium, high or very high impact on improving labor productivity. This is a highly validating finding for this important metric.

- **Owing to their focus on and responsibility for labor productivity, only a small percentage (6%) of contractors were not able to assign a percentage to the improvement achieved on their BIM projects.**
- **Among project types, 90% of owners and contractors who work on laboratories rate the impact of BIM on productivity as medium or higher.** This may relate to the systems-intensity of these types of projects, which benefit from the improved coordination and increased prefabrication available to BIM-based projects.

Percentage of Impact

To assess the current state of this metric, owners and contractors were asked to identify the percentage range of improved labor productivity they experience on complex projects where BIM is deployed. Note that the tier scaling for improved labor productivity (in increments of 25%, from less than 25% to more than 50%) is higher than for the cost, schedule, RFIs and safety metrics also studied in this research (see pages 27–30). This is based on input from industry leaders and meant to set an aggressive baseline for comparison in future studies.

Among the respondents who can assign a percentage to their labor productivity improvement:

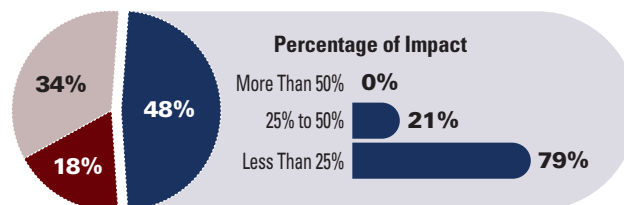
- **About a quarter reports labor productivity increases in the middle-tier (25% to 50%), although the vast majority are currently experiencing less than 25% improvement.** None report more than 50%, although that is expected to change in the future as BIM processes continue to mature.
- **BIM experience has a moderate influence, with 28% of all the respondents who do more than half their work in BIM reporting middle-tier results, compared with 18% of those with less experience.**

Percentage of Improved Labor Productivity (According to Owners and Contractors)

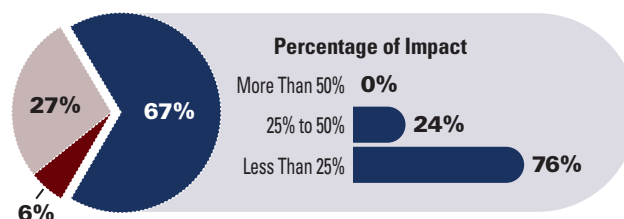
Dodge Data & Analytics, 2015

- BIM Has Medium or Higher Impact on Labor Productivity and Know the Percentage of Impact
- BIM Has Medium or Higher Impact on Labor Productivity But Not Sure of Percentage of Impact
- Low/No/Don't Know Impact of BIM on Labor Productivity

Owners



Contractors



Percentage Reduction of Site Labor Due to Increased Offsite Fabrication

The expanded opportunity for offsite and near-site prefabrication based on accurate and coordinated models is a rapidly advancing benefit of BIM, according to multiple studies conducted by Dodge Data & Analytics around the world. This is fueling an accelerating industry shift toward prefabricated and modular assemblies, instead of onsite construction from raw materials and components. The resulting reduction in the requirement for relatively expensive and increasingly scarce site labor is a measurable benefit of this trend and a tangible metric to validate the use of BIM.

Similar to the labor productivity metric, a very large portion of respondents (70% of owners and 68% of contractors) believe that BIM-related prefabrication is having a medium or higher impact on reducing site labor.

- Even more (78%) respondents who do at least half their work in BIM believe it has a medium or higher impact, so the benefit increases with greater BIM implementation.
- Similar to the findings for productivity, a very small percentage (4%) of contractors in this group were not able to assign a percentage to the reduction in site labor, underscoring their attention to labor utilization on complex projects.

Percentage of Impact

Owners and contractors were asked to identify the percentage range of reduced site labor due to increased prefabrication on their complex BIM projects. Similar to the scaling for improved labor productivity, these ranges (in increments of 25%, from less than 25% to more than 50%) are intentionally higher than the cost, schedule, RFI and safety metrics in this study (see pages 27–30), in order to establish an aggressive baseline against which to track what is anticipated to be strong future growth.

Among respondents who can assign a percentage to their labor productivity improvement:

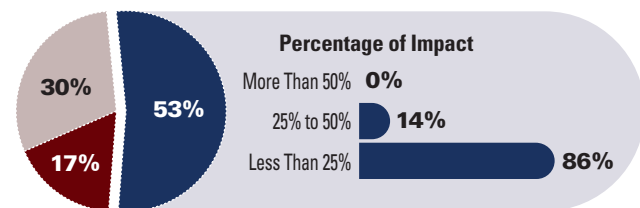
- More than twice as many contractors (30%) report the reduction to be in the middle tier (25% to 50%) than owners (14%), which likely relates to the level of detail at which contractors track site labor compared with owners, rather than an evidence-based difference of opinion. The relatively large percentage of owners (17%) who, though they believe model-driven prefabrication is reducing site labor, cannot assign an actual percentage to it supports that inference.

Percentage Reduction of Site Labor Due to Increased Offsite Fabrication (According to Owners and Contractors)

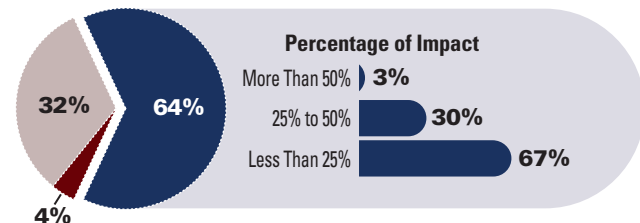
Dodge Data & Analytics, 2015

- BIM Has Medium or Higher Impact on Site Labor and Know the Percentage of Impact
- BIM Has Medium or Higher Impact on Site Labor But Not Sure of Percentage of Impact
- Low/No/Don't Know Impact of BIM on Site Labor

Owners



Contractors



- Similar to productivity, BIM experience has a moderate influence, with 30% of all the respondents who do more than half their work in BIM reporting middle-tier results, compared with 21% of those with less experience.
- A small (3%) but important portion of contractors are currently reporting greater than 50% reduction in site labor due to increased prefabrication. We anticipate that studies will reveal a much higher percentage in this tier as this trend continues to grow.

Forecasting the Future Impact of BIM on Key Project Outcomes

Among the six outcomes where metrics for the impact of BIM are included in this study, all respondents who were asked about those metrics were also asked to designate the one they believe will have the greatest impact over the next five years.

“Accelerated project completion due to schedule compression” is the outcome that scored highest.

- **This is also currently one of the leading impacts overall;** so many users clearly believe that this will continue to be highly impactful.
- **Interestingly, contractors are the least likely to select this outcome,** indicating either that they believe future improvements will be limited or, more likely, that they simply expect more growth elsewhere (e.g., cost, RFIs).
- **The No. 2 ranking among owners clearly indicates that owners will be expecting improved schedule performance from their BIM project teams.**

“Reduction of final construction cost” and “RFI reduction” tie for second in terms of the average across all types of respondents. Importantly, though, the cost reduction metric scores more strongly with owners, indicating that they increasingly expect to see cost improvement from teams deploying BIM.

“Improved labor productivity” ranks fourth out of six. Interestingly, engineers lead in the percentage selecting this impact. Engineers may see more potential gains in mechanical, electrical, plumbing and structural productivity, achievable through increasing model-based integration of design with fabrication/installation.

Although ranking fifth overall, the fact that owners cite “Reduction of site labor due to increased offsite fabrication” top among these six outcomes should be noted by project teams as indicating that owners will expect to see this impact on future projects.

“Reduction in number of reportable safety incidents” ranks last. This certainly does not mean it is considered unimportant as a desired outcome, but more likely provides further evidence that the direct connection between BIM and improved safety is still emerging compared with the other five outcomes studied.

Project Outcome Expected to Have the Greatest Positive Impact From BIM in the Next Five Years (Respondents Could Only Select One Outcome)

Dodge Data & Analytics, 2015

■ Selected by Over 25% ■ Selected by 15% to 25% ■ Selected by Less Than 15%

	Owners	Architects	Engineers	Contractors	Average
Reduction of Final Construction Cost	20%	21%	17%	26%	21%
Accelerated Project Completion Due to Schedule Compression	31%	42%	31%	12%	29%
RFI Reduction	6%	21%	23%	27%	19%
Reduction in Number of Reportable Safety Incidents	0%	0%	0%	1%	0%
Improved Labor Productivity	9%	16%	29%	13%	17%
Reduction of Site Labor Due to Increased Offsite Fabrication	34%	0%	0%	21%	14%

Seeing Benefits From Predesign to Post Occupancy From BIM

Central Washington Hospital, New Patient Tower

WENATCHEE, WASHINGTON

Faced with the complexities of building a new patient tower that is bounded on three sides by an operating hospital, the team on this Central Washington Hospital project used a comprehensive BIM strategy that ultimately led to 10 weeks of schedule savings and created \$7 million in budget savings that was passed on to the owner.

The team of Mortenson Construction and architecture firm HDR worked closely with the owner to execute a BIM plan that carried through the project from early design visioning to post-occupancy facilities management.

Although HDR and Mortenson held separate contracts with the owner, Mortenson was selected three weeks after HDR, allowing the contractor to assist with the design. "It was very collaborative from the get-go," says Gene Hodge, director of project development at Mortenson Construction.

Early Engagement

Early on, the team evaluated massing and site design options to determine the best location for the tower. The selected configuration for the 6 story 288,415-square foot tower maximized adjacencies to existing hospital departments, took advantage of views of the nearby Cascade Mountains and fit within the hospital's 15-year campus master plan.

The plan called for demolition of 30,000 square feet of existing hospital space. The existing building had been constructed over many phases and several years, resulting in inconsistent foundation elevations and roof heights. Mortenson modeled existing conditions and provided those to the architect to inform ongoing design.

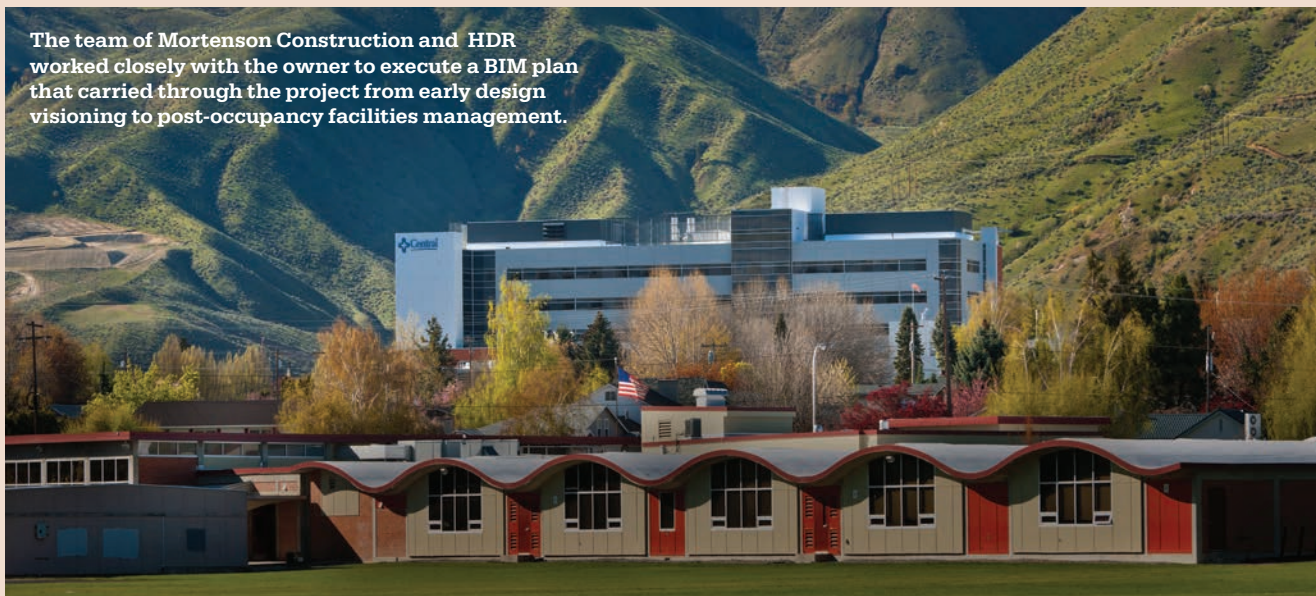
Systems Coordination

The team also had to consider the impact on hospital operations. Eleven different utilities passed

through the demolition area. Mortenson was able to identify and reroute utilities, scheduling shutdowns and reconnects in conjunction with hospital staff. Key trades, including mechanical and electrical, were brought in at the end of the schematic design to help with the effort.

"A huge part of that effort was refeeding the chilled water for the building," Hodge says. "The chilled water for the whole campus came through the demolition site. The old feeds were built in the 1970s, and they were degrading to near failure. We also needed to replace an existing chiller plant. We had a six-month window during the winter, when we had to refeed the whole hospital. We originally had the chilled water going up to the first floor then coming back down. When we looked at the schedule of the structure, we weren't able to support it. So we were put in a position to bring in chillers temporarily. We used BIM

The team of Mortenson Construction and HDR worked closely with the owner to execute a BIM plan that carried through the project from early design visioning to post-occupancy facilities management.



Central Washington Hospital, New Patient Tower

WENATCHEE, WASHINGTON

to find a path to route those chilled water mains at the ground level.”

Early modeling helped the team develop an approach that allowed many utilities to be permanently—rather than temporarily—rerouted, saving more than \$200,000 in costs. Modeling also enabled designers to reduce the floor-to-floor heights from 16 feet to 15 feet 6 inches on the upper floors, saving an additional \$120,000 in enclosure and structure costs.

Through use of coordinated models, trade contractors were able to prefabricate a total of 144 headwalls in the hospital. A mockup was provided to the owner to approve final locations for all utilities. Prefabrication was executed to an accuracy within 1/8 inch. Coordination and prefabrication of the headwalls saved an estimated 18% in manhours, including four weeks on interior rough-in and three weeks on casework.

The exterior framing subcontractor was able to collaborate with the team to prefabricate the enclosure system. Mortenson estimates that by using this coordinated system to eliminate potential conflicts and speed installation onsite, the prefabricated exterior framing saved six weeks on the exterior framing schedule.

During interior rough-in, the team relied on scheduling—planned one year earlier—to start drywall on time. Crews eventually met the final acoustic ceiling tile date eight weeks ahead of schedule.

Ultimately, the team’s coordination efforts with BIM resulted in a 50% reduction in RFIs, compared with a similar project that did not utilize BIM.

Although the team worked together to anticipate all needs as early as possible, they did have

to accommodate some changes. During construction, the owner decided to change the patient lifts used in the hospital. “We did have to go back and re-coordinate some above ceiling space, but we were able to work from the model, so it was very straightforward—not a big challenge,” Hodge says.

Critical Communication

Interaction with the model was not limited to the project offices—crews were also able to access BIM in the field via wireless access points. Field personnel could reference the model at mobile computer stations. Tablets were also used to help with tasks such as inspections (including in-wall and overhead) and punch lists. This saved hours of time that would otherwise be spent traveling between the jobsite and the project trailer.

Throughout the entire project, BIM was used extensively to communicate with key stakeholders. The architect and contractor worked with the owner, hospital maintenance staff and physicians to inform the design and construction plan.

Virtual mockups allowed users to visualize and provide feedback on potential designs for patient rooms, nurse stations, lobbies and the business center. Prior to construction, key hospital staff reviewed the operational access required for future maintenance and repair. Mortenson estimates that this approach reduced the potential for costly design changes during later phases of the project, contributing to the project’s early completion.

Upon completion, the team provided a model that the hospital’s facilities management group could

Project Facts and Figures

Construction Manager
Mortenson Construction

Type of Project
Hospital Patient Tower/
Expansion

Size
288,415 sq. ft. over 6 stories

Completed
February 2011

BIM-Related Results

The BIM strategy led to 10 weeks of schedule savings and \$7 million in budget savings:

- 50% reduction in RFIs
- \$200,000 in savings during utility relocation
- Prefabricated headwalls saved an estimated 18% in manhours: four weeks on interior rough-in and three weeks on casework
- Prefabricated exterior framing saved six weeks on the exterior framing schedule

use for building operations in the future. At occupancy, maintenance staff was able to use touchscreen computers to access the model, linked electronic documents, in-wall photos, electronic O&M manuals and shop drawings.

“The facilities director was heavily involved,” Hodge says. “He told us that when we came in and talked about BIM, he didn’t believe in it. But when we were done, he said, ‘I don’t know how you’d build a building without it.’” ■

Data: BIM for Facility Management

Delivery of Models

and/or Data Derived From Models to Owners

As the responses of the owners who participated in the in-depth interviews for this report reveal, many owners familiar with BIM in the US regard the ability to use it for the management and operation of their buildings after construction to be a significant part of the value of BIM for their organization (see page 41 for more information).

However, few owners in the US are currently capitalizing on this opportunity. According to the 2014 *Business Value of BIM for Owners SmartMarket Report*, over two thirds of owners in the US report that they had little or no capability to leverage BIM for building operations after construction.

Delivery of Models to Owners

Interestingly, despite this low level of use, this study finds that **over half of contractors (52%) frequently/always provide models to owners at the close of construction**. Not surprisingly, a higher percentage of general contractors (58%) report doing so than do trade contractors (33%).

The contractor findings are also roughly proportional to the owner findings, where 62% report frequently or always receiving models on their projects.

Both contractors who use BIM on 50% or more of their projects and large contractors also report delivering models more frequently to owners:

- **68% of contractors using BIM on 50% or more of their projects also frequently/always deliver models to owners at the end of construction.**
- **61% of medium-size contractors (those with annual revenues of \$250 million to less than \$1 billion) and 79% of large contractors (annual revenues of \$1 billion or more) frequently/always deliver models to owners.**

These findings indicate that owners of complex buildings where BIM is deployed frequently have access to models after construction is complete. However, the relatively low percentage of owners who report actively using BIM for facility management (see page 38) suggests that most owners do not yet know how to capitalize on those models in the operational phase of the building.

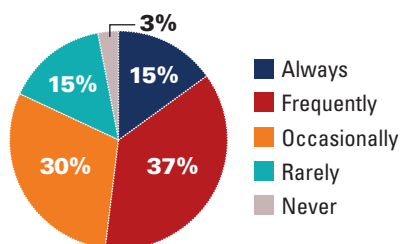
The findings of the 2014 *Business Value of BIM for Owners SmartMarket Report* demonstrate that this concern can be addressed through a top-down mandate, such as the one currently in effect in the UK, that includes standardization of BIM data to allow it to be used throughout the building lifecycle. That study contrasted the responses of US owners to respondents from the UK,

Frequency With Which Owners Receive Models on Their Projects

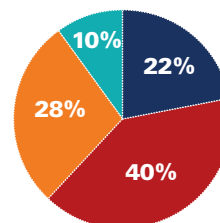
(According to Contractors and Owners)

Dodge Data & Analytics, 2015

Contractors Providing Models to Owners



Owners Receiving Models on Their Projects



BIM for Facility Management

Delivery of Models and/or Data Derived From Models to Owners

CONTINUED

where nearly all respondents (87%) report that they have at least moderate ability to leverage BIM for facility management.

While a similar mandate in the US is not likely because of the number of different, independent government agencies handling public construction, efforts to use COBie (Construction-Operations Building Information Exchange) standards to help make data more accessible to owners may eventually add to the value owners find in BIM.

Delivery of Data Derived From Models to Owners

Less than one third (30%) of contractors are currently providing data derived from the models for owners to use in facility management. Even though a smaller percentage are delivering data versus models, the same patterns evident in the delivery of models also hold for the delivery of data, just on a smaller scale:

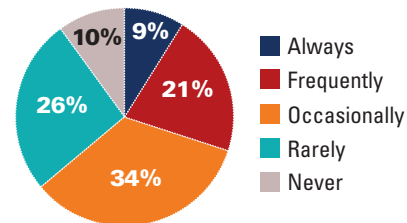
- General contractors (35%) are more likely to deliver data to owners than trade contractors (8%).
- The larger a contracting firm is, the more likely it is to deliver data to owners, with 38% of firms with annual revenues of \$1 billion or more providing data, compared with 18% of those with revenues under \$250 million.
- More firms using BIM on 50% or more of their projects (37%) provide data to owners than those using BIM less frequently (16%).

The relatively low numbers, even among larger companies and those doing BIM more frequently, suggest that contractors largely consider the extraction of data for use in facility management to be the owner's concern. However, they may be missing a crucial opportunity to make their services more valuable to owners and differentiate themselves from competitors as BIM use becomes increasingly prevalent. Owners who can see value beyond the construction phase from the contractor deliverables may be more likely to seek out that contractor again for future projects.

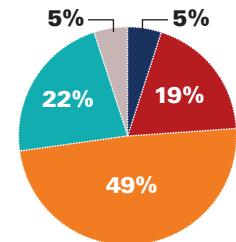
Frequency With Which Owners Receive Data Derived From Models on Their Projects (According to Contractors and Owners)

Dodge Data & Analytics, 2015

Contractors Providing Data Derived From Models to Owners



Owners Receiving Data Derived From Models



BIM for Facility Management:

Owner Engagement With Models and Data Derived From Models

Use of models for facility management presents one of the greatest opportunities for owners to gain value from the use of BIM, not just during design and construction, but across the lifecycle of their projects. While many owners are now receiving models on their projects (see page 36), the study findings show that use of the models, or the data within the models, during the building's operational phase is still quite limited.

The first chart at the right represents the owners' responses about their requirements for, standards for and use of models. The second chart represents contractor responses about owner requirements, standards and use of models.

Models

USE OF MODELS FOR FM

While 86% of owners who receive models at least occasionally state that they frequently or always require the use of models on their projects, only 17% report always or frequently using BIM models for facility management (FM). Certainly, there are factors that could influence this finding, such as the possibility that some owners may have implemented this policy relatively recently and therefore may not have sufficient buildings modeled to impact their overall approach to FM. Nonetheless, these results are striking.

There are two conclusions suggested by this finding:

- Most owners see strong enough benefits from the use of BIM in the design and construction phases to encourage them to require it.
- Many owners may be struggling to figure out exactly how to marry BIM and the data it contains to their existing FM systems.

The findings of the in-depth interviews with owners support the second conclusion that far more owners recognize the potential of employing BIM for FM than are currently able to do so (see page 41).

It is notable that there is a 21-point differential between the contractors who report that owners at least occasionally require the use of BIM (76%) and owners who report doing the same (97%). This is likely due to the fact that the owners who participated in the survey had to have at least a moderate knowledge of BIM. Since owners often do not directly use the software as contractors do, that makes the pool of owners responding to this survey a select group, rather than representative of the broader industry, as the contractors are. Therefore, it is clear that

Owner Engagement With Models for FM (According to Owners Who Receive Models at Least Occasionally)

Dodge Data & Analytics, 2015

■ Always/Frequently ■ Occasionally

Require Models

86% 11% 97%

Have Specific Standards for Models

66% 17% 83%

Actively Use Models for FM

17% 43% 60%

Owner Engagement With Models for FM (According to Contractors Who Provide Models to Owners)

Dodge Data & Analytics, 2015

■ Always/Frequently ■ Occasionally

Owners Require Models

17% 59% 76%

Owners Have Specific Standards for Models

11% 46% 57%

Owners Actively Use Models for FM

11% 45% 56%

BIM for Facility Management

Owner Engagement With Models and Data Derived From Models CONTINUED

even well-informed owners are still struggling to use BIM for FM effectively.

HAVE STANDARDS FOR MODELS

Owners who qualified for participation in the survey also frequently have standards that their project teams must follow for models, with **two thirds (66%) reporting that they have specific standards for models frequently or always on their projects**. This is much higher than the percentage of contractors who say that owners frequently/always have standards for their models.

This differential suggests that owners who are familiar with BIM understand that having a standard for BIM on their projects is more likely to result in a model containing useful data for them.

Data Derived From Models

In some cases, owners want to extract the data contained in the model that would be useful for facility management rather than have their building operators use the model directly. One of the challenges currently facing the industry is the lack of interoperability that prevents that data from being easily extracted and used.

To better understand the prevalence of these activities, owners and contractors were asked about the standards owners have for data derived from models and whether the owners use model-derived data for facility management. As on the previous page, the top chart represents the owner responses and the lower chart represents the contractor responses.

USE OF DATA FOR FM

31% of owners who receive data derived from models at least occasionally from contractors report always/frequently using that data for FM. While this is still a relatively low percentage, it is notably higher than the 17% of owners using models.

HAVE STANDARDS FOR DATA

Despite the higher percentage using the data, a **slightly smaller percentage frequently/always have standards for that data (59%) than the owners who report frequently/always having standards for BIM (66%)**.

However, it is worth noting that the inclusion of owners who are just occasionally setting standards reverses that trend, and a higher percentage set standards for data (93%) than models (83%). This may indicate that this is an emerging trend, with more owners just beginning to set standards for model-derived data and points to possible future growth for owner-mandated data.

Owner Requirements for/Use of Data Derived From Models (According to Owners Who Receive Data at Least Occasionally)

Dodge Data & Analytics, 2015

■ Always/Frequently ■ Occasionally

Have Specific Standards for Data Delivery



Actively Use Data for FM



Owner Requirements for/Use of Data Derived From Models (According to Contractors That Provide Data to Owners)

Dodge Data & Analytics, 2015

■ Always/Frequently ■ Occasionally

Owners Have Specific Standards for Data



Owners Actively Use Data for FM



Value for Owners

in Using BIM for Facility Management

MEASURING THE IMPACT OF BIM ON COMPLEX BUILDINGS DATA

Nearly three quarters (74%) of owners who use models or the data derived from models for facility management (FM) believe that this offers them tangible value. While the number of owners in the survey who are using models or data for FM is relatively small, their evaluation of specific benefits reveals clear trends about where they find the greatest value and provides objectives for owners who want to join them.

- **The benefit experienced most widely is the ease of accessing data when needed, reported by over 80% of owners using models/data for FM.** Models can contain not only as-built information that accurately indicates the location of all building elements in a graphical image, but they also can include critical information like when to perform scheduled maintenance. Access to this information saves valuable time for building managers and helps them operate the building more efficiently.
- **Over half of the owners also find that using models/data for FM helps with space management.** Having an accurate, as-built version allows facility managers to more easily engage in space management, including the ability to plan alteration projects with greater certainty.
- **Approximately one third of owners agree that they are better able to answer unanticipated problems, have an improved preventative maintenance program and have better information in their CMMS programs from the day the building opens.** Not only is the data itself contained within the model useful for maintenance programs and onboarding the building into their CMMS programs, but the presence of a digital double for the facility helps to deal with unexpected questions.

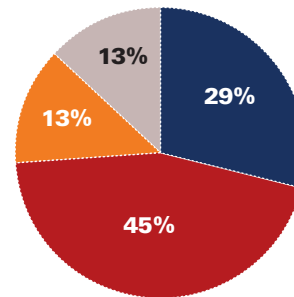
Studies reveal that the cost of operating and maintaining a building across its lifecycle is higher than its initial construction cost.¹ While the findings of this study show that many owners already see enough value in BIM during design and construction to require its use (see page 38), the potential for owners to mandate BIM is increased notably if they can leverage the model effectively in the operations phase of the building. For more information on the benefits and challenges owners experience with using BIM for FM, see the discussion from owner in-depth interviews on page 41.

Owner Organization Is Receiving Tangible Value From Models or Data Derived From Models for Facility Management

(According to Owners Using Models and/or Data for Facility Management)

Dodge Data & Analytics, 2015

- Strongly Agree
- Agree
- Neither Agree nor Disagree
- Disagree



One oft-cited study is Graham Ivey's 2006 report "Reexamining the Costs and Value Ratios of Owning and Occupying Buildings." One such citation is found in a U.S. Forest Service Document on calculating building lifecycle costs at <http://www.fs.fed.us/t-d/pubs/htmlpubs/html08732839/page01.htm>.

Data: Owner Insights on BIM for FM

Owner Insights on BIM for FM

Even among the expert owners included in the owner IDIs, only a few are using BIM for facility management. The majority, though, consider it an important future opportunity to gain more value from BIM on their complex projects.

Use of BIM for Facility Management (FM)

Out of the eight expert owners interviewed, only two actually report using models or data derived from them in their facility management program. However, all but one of those who are not using it right now consider it a strong opportunity for the future.

CURRENT VALUE REPORTED FOR MODELS/DATA FOR FM

Meghan Ruffo from Carolinas Healthcare System reports that they are able to use models in their space management system and to populate the data from the model in their enterprise asset management system. She reports that **the time required to input data for space management has been cut from 40 hours to one hour because now a data transfer can automatically populate the data into their system.**

Creating requirements for the model is an important part of this program. Ruffo states, "We have pretty detailed requirements: We have a template that everybody has to use, we have tools or add-ins that we've developed that check the models at each milestone phase and also help with the input of some of the data that we require from our consultants."

Andy Reinach from Alexandria Real Estate Equities Inc. reports that his company manages the laboratory spec buildings they build, so being able to use BIM for FM is important to him. His engineers use the model as follows:

- They have all the as-builts.
- They have preventative maintenance information on iPads that are embedded in the model. "If there's an issue anywhere, they can zoom in on the model."
- They can track how specific equipment is running in their building management system.
- They can remotely troubleshoot issues like temperature and contact someone onsite to make adjustments at a specific VAV box.

However, he believes that this is just the start and that within two years, they may be doing things differently "because it [BIM] is going to evolve that rapidly."

Expected Future Value of BIM for FM

Among the remaining six owners who are not currently using BIM for FM, only **Digby Christian from Sutter FPS** does not necessarily believe that he will see great value from its use in the future, because he believes that most FM needs can be addressed in a "two-column spreadsheet with the equipment number and the room it is in." However, the other five owners express a strong desire to find ways to utilize BIM in their building operations.

Denton Wilson from Methodist Health System explains the opportunities and the challenges he sees: "At this moment, the models are so big and cumbersome, we haven't found a tool that sucks out

the level on the model that can actually be of purpose to a director of engineering ... So what we would love to see is to be able to have all those barcodes on there for all your PMs. That would be fantastic."

Joe Porostosky from Ohio State University is aggressively pursuing the use of BIM for FM by modelling 35 million square feet of his current building portfolio.

Porostosky is attempting to address the challenge of accessing needed data at the appropriate level from BIM for his FM team with clear direction about what the model needs to contain in order to achieve their goal of using it more effectively during facility management: "We're telling [the project team] 'Here's what we want to see at the end of the project very specifically' ... It's COBie-light, we want specific fields per different type of asset or piece of equipment." (For more information on COBie, see page 37.)

Stuart Eckblad from UCSF raises the question of what the scale of the project needs to be for there to be sufficient value in creating the model for use in FM, but he is unambiguous about its value for complex buildings: "For complex buildings like hospitals and labs, I think there is no question that [FM] is really the future of the whole BIM ... if I get to FM, I'll be pretty happy." ■

Data: Success Factors and Obstacles for Complex Projects

Project Processes

That Contribute Most to the Success of Complex Projects

The construction industry has been grappling with how to improve the processes involved in the design and construction of a project. The need to make these improvements is magnified on complex projects, where the results of inefficient processes can be detrimental to cost, schedule, safety and quality. The key value of BIM and other advanced technologies lie not in the tools themselves but in the manner in which they support these process improvements.

Survey respondents were asked to select the BIM-oriented processes that they believed contribute most to the success of complex projects. The chart at right represents the top seven of 13 processes that they were asked to consider. Respondents were allowed to select up to eight of the 13 processes.

Processes Identified as Important by All Players

IMPROVED TEAMWORK AND COLLABORATION

Selected by the highest percentage of owner (73%) and design team (68%) respondents and the third highest percentage of contractors (60%) in this study, teamwork and collaboration is also consistently recognized as a top process improvement needed in other DD&A research, including the 2014 *Managing Uncertainty and Expectations in Building Design and Construction SmartMarket Report*. Use of BIM directly supports collaboration across the project team, and most of the benefits associated with BIM are enhanced when an integrated project team is engaged early in the process of design.

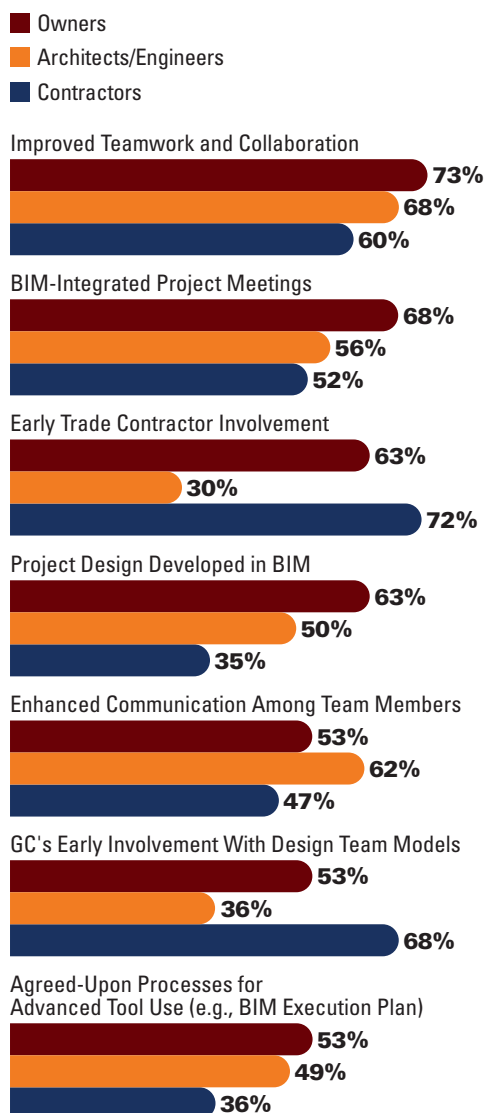
However, far fewer design team respondents (30%) place equal value on early trade contractor participation in projects than owners (63%) or contractors (72%) do (see below). This suggests that there is a need to create a more productive model-based relationship between designers and trade contractors during design.

BIM-INTEGRATED PROJECT MEETINGS

The second highest percentage of owners consider this a critical success factor, and over half of design team respondents (56%) and contractors (52%) do as well. Project meetings incorporating BIM enhance opportunities for collaboration and help increase shared knowledge and the ability to make project decisions effectively.

Project Processes That Contribute Most to the Success of Complex Projects (According to Owners, Architects, Engineers and Contractors)

Dodge Data & Analytics, 2015



Processes Identified as Important by Contractors

The highest percentage of contractors select early contractor and trade contractor engagement in projects as a critical part of the success of complex projects. The much lower percentage of design team respondents who also consider this important is notable and suggests that the value placed on collaboration and teamwork does not extend to full project integration for many of these respondents.

EARLY TRADE CONTRACTOR INVOLVEMENT

Not surprisingly, nearly all (96%) trade contractors consider this an important contribution to the success of a project, and nearly two thirds (64%) of general contractors agree.

Equally notable is the owner response. A higher percentage of owners (63%) see the contribution of early trade contractor involvement in the success of their projects than early involvement by general contractors in the development of the model (53%).

GENERAL CONTRACTOR EARLY INVOLVEMENT WITH DESIGN TEAM'S MODELS

It is also a natural expectation that more general contractors (76%) highly value their own early involvement in design than trade contractors (46%) do. It is notable, though, that more than half of owners (53%) recognize the importance of this factor, and that owners are more likely to recognize it than design team respondents (36%), some of whom may be concerned about ceding control during the early phases of the project.

Processes Identified as Important by Design Team Respondents

More design team respondents (62%) consider enhanced communication among team members important than owners (53%) or contractors (47%).

The fact that a similar percentage considers improved teamwork/collaboration important (68%) is telling, and it may suggest that enhanced communication, rather than an integrated team approach, may be the means most highly valued by design team members to achieve improved teamwork/collaboration.

BIM, Communication and Project Team Integration

Taken as a whole, the differences in responses among owners, design teams and contractors reveal some challenges and opportunities when it comes to BIM, communication and integration of the project team.

- **They reveal a core conflict around the true value of full collaboration through integration.** That conflict is evident in the widespread, general recognition of the need for collaboration/teamwork and indications in the findings of a persistent, traditional mind-set that favors players' individual contributions rather than an emphasis on creating an integrated project team.
- **They suggest a leadership role for the owner in encouraging greater project integration.** While individual players seem to place the greatest value on getting their own perspectives reflected throughout the process, owners place strong weight on most of the processes that directly encourage collaboration. They are also best positioned to drive collaboration as a goal on their projects.

Most Significant Ways That Owners Impact the Success of Complex Projects

MEASURING THE IMPACT OF BIM ON COMPLEX BUILDINGS DATA

Owners can have a major influence on the success of projects. For complex projects in particular, owner leadership and engagement can be critical for team cohesion and clarity of scope.

Owners, design teams and contractors were asked to select the factors related to owner engagement that contribute most to project success, and they were allowed to select up to four of seven possible responses. As a whole, they generally agree that the approach owners take in assembling teams for complex projects has a significant influence on the success of those projects.

- **Selection of Design/Construction Firms Experienced in Using Advanced Tools/Methods:** DD&A research consistently demonstrates that companies with greater experience with BIM consistently reap greater benefits from its use. Advanced methods involving collaboration also require skills that must be honed through use. Therefore, a team's degree of BIM experience directly impacts project success. Not surprisingly, a higher percentage of respondents from firms using BIM on 50% or more of their projects (67%) consider this a critical success factor than those using BIM less (48%).
- **Openness to Innovative Team Structures, Agreements, Work Processes:** About half of all respondents believe innovative approaches can be effective. It is important to note that owners need to understand, be staffed for and be prepared to implement a new approach in order to receive benefits.

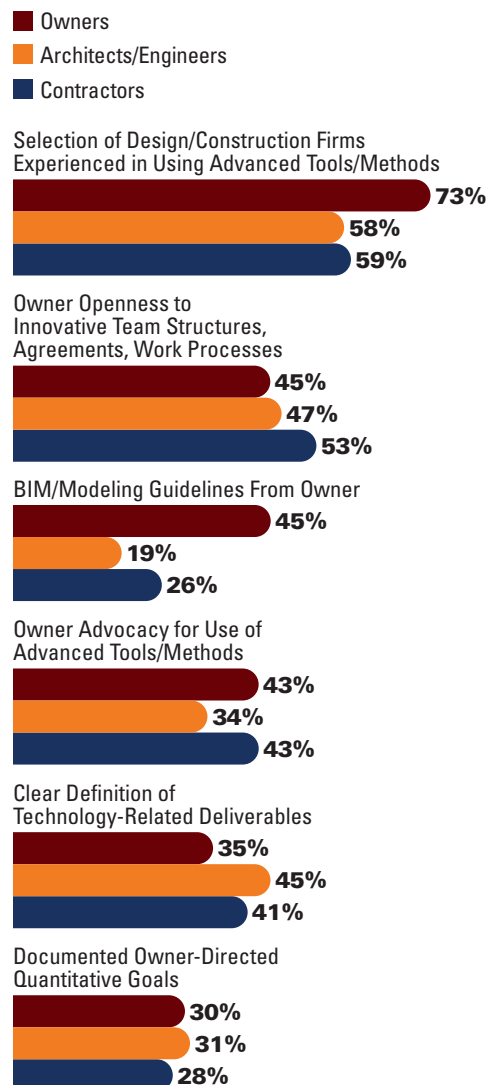
However, when it comes to owners providing direction, there is less overall agreement.

- **Fewer design teams (34%) state the importance of owner advocacy for tools/methods, perhaps because many will use BIM regardless of owner attitude.**
- **Conversely, design teams (45%) lead in wanting clearer definition of deliverables, and contractors (41%) agree, while owners demur (35%),** perhaps due to an inability to provide it.
- **Most (83%) owners in this study report having BIM standards (see page 38), and many (45%) highly value them.** Low design and contractor ratings may reflect perceived value for them.

These findings suggest that most industry practitioners are seeking owner support and clearly defined deliverables, but prefer greater freedom to establish the best approach to fulfill those deliverables and less direct guidance from owners on working with technologies.

Factors Related to Owner Engagement That Contribute Most to Project Success (According to Owners, Architects/Engineers and Contractors)

Dodge Data & Analytics, 2015



Data: Owner Insights

on Best Practices

Owner Insights on Best Practices

for Most Effective Use of BIM on Complex Projects

In-depth interviews with eight owners with a high level of experience with BIM provides insights into some best practices for the use of BIM on complex projects.

Employ Delivery Methods That Enhance Collaboration and Early Trade Contractor Involvement

Consistent with many of the findings in this study, the in-depth interviews with expert owners demonstrate that BIM is most effectively used on complex projects when it is combined with owner selection of delivery methods that enhance collaboration and engage early trade contractor involvement.

Joe Porostosky from Ohio State University explains that about two years ago, Ohio State switched from requiring all projects to have a design-bid-build delivery system to the use of other systems. This allowed them to see greater engagement from all project team members earlier on. "Because they were engaged from day one, there wasn't as much of that back and forth. It was 'We are all in this together, and we are going to collaborate.'"

For **Digby Christian from Sutter FPS**, the strength of taking a collaborative approach is that it helps create a "single source of truth" before construction begins.

An IDI participant at a large technology firm who requested to remain anonymous found initially that they, as the owner of the project, "did not garner that much benefit from BIM." He attributes this to their contractor selection and project delivery strategy, which wasn't "conducive for BIM" since

"The more you build your delivery model around the BIM, it definitely improves any opportunity to get value. You can't get the productivity [improvements] if you don't work collaboratively with the model."

their contractual arrangements did not allow benefits like reduced project schedule to accrue to the owner as well as the contractor. Therefore, he finds that **owners in particular benefit most from using integrated project delivery**, particularly when it includes trade contractor involvement. "[The trade contractors] have the shared risk and reward, and ... they feel like they are part of the team ... You see the trades help us come up with innovative ideas, and they also share the benefits when we see cost and duration reduction."

The value of early trade contractor involvement is echoed by other owners. **Meghan Ruffo from Carolinas Healthcare System** reports that they have developed an approach she calls "collaborate-bid-build, where we [engage] the key trade partners early on, we look at incentivizing them, doing some collaboration and then actually go out to bid with those trade partners, as well as similar competitors." Their approach allows them to ensure that they are getting low-cost bids while still benefiting from early collaboration.

Stuart Eckblad from UCSF sums up the need to collaborate as follows: "... the more you build your delivery model around the BIM, it definitely improves any opportunity to get

value. You can't get the productivity [improvements] if you don't work collaboratively with the model."

Other Best Practices

Other practices were reported that help owners to improve the positive impact of BIM on their complex projects.

- **Use of a third-party BIM manager** was reported by Christian to be a valuable strategy for large, complicated projects because a third party can "drive the correct behaviors in terms of how a model should be used to get design finished and get all the trade coordination done."
- **Consideration of impact of BIM on process and risk management as part of its implementation** was also considered by Christian to be fundamental to the successful use of BIM. He states, "BIM will save nothing unless you think it through from a process and risk management point of view [in terms of] what you are trying to do. If you think that through logically, you understand [that you] need BIM to increase the certainty that [you] will manage [your] risk and achieve [your] operational goals. ■"

Most Significant Project-Team-Related Obstacles to the Success of Complex Projects

Owners, architects, engineers and contractors were asked to select the top two project-team related obstacles out of a group of five possibilities. Notably, no single obstacle was selected by more than 50% of any group.

All Respondents

The one factor that ranks relatively high for most players is the perception that some AEC team members only get involved in a project phase for which they are contractually required to perform work. The strong showing for this obstacle among all players suggests that a substantial portion of the industry values more integrated approaches, and regards the more traditional approaches as an active obstacle to success. On the other hand, over half still do not regard this as a serious obstacle, suggesting a still-developing perspective in the industry about the impact of integrated teams.

Owners

Owners differ from the industry practitioners in their ranking of other obstacles included in the survey. Only two percentage points separate their second, third and fourth most important obstacles, suggesting an equal focus on team attitude, team concern about cost and lack of a formal plan for technology use, all of which can be addressed by savvy owners.

It is notable, though, that only 15% of owners consider too few quantitative objectives for use of advanced tools/methods to be an obstacle, although it also ranks last for the other players.

Design Team and Contractors

The highest percentage of design teams and contractors are concerned about the lack of support for using advanced tools and methods by some AEC team members. This is especially strongly felt by companies using BIM on 50% or more of their projects (57%) versus those using BIM on fewer projects (44%). It supports the previous finding that an owners' selection of teams experienced with advanced tools is an important success factor (see page 44).

Among the other findings, it is notable that design team respondents who are focused on BIM deliverables, are more concerned with formal documentation on the use of advanced tools and methods on projects, while contractors, who are used to measuring outcomes, are more concerned about the need for quantitative objectives for the use of advanced tools/methods.

Most Significant Project-Team-Related Obstacles to Success for Complex Projects (Top Two Obstacles According to Owners, Design Teams and Contractors)

Dodge Data & Analytics, 2015

■ Owners

■ Architects/Engineers

■ Contractors

Some AEC Team Members Only Get Involved in Project Phase Where Contractually Required to Perform Work



Some AEC Team Members Not Supportive of Using Advanced Tools/Methods



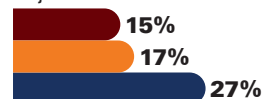
Perception by Some Project Team Members of Additional Costs for Advanced Tools/Methods



Lack of Formal Documentation for How Project Team Will Use Advanced Tools/Methods



Project Team Has No/Too Few Quantitative Objectives for Use of Advanced Tools/Methods



Most Significant Owner-Related Obstacles to the Success of Complex Projects

The highest percentage of owners (58%), architects (66%), engineers (50%) and contractors (59%) all agree that a significant owner-related obstacle to project success is when the owner organization does not sufficiently understand the value of advanced tools/methods.

Second to that is lack of owner involvement in the use of tools/methods, voiced most strongly by owners themselves (45%), who realize the importance of embracing the model and related processes as the center of the project process.

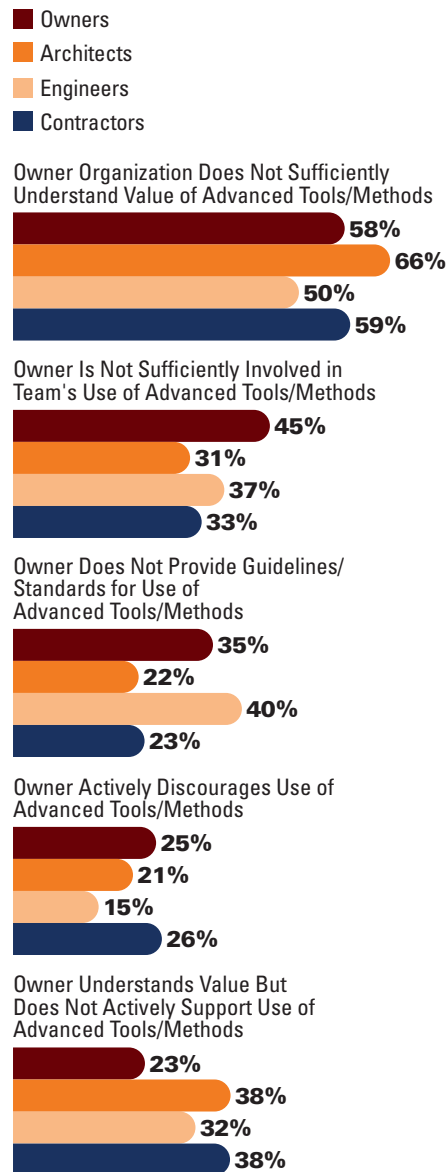
Other key findings include:

- A higher percentage of owners (35%) and engineers (40%) consider the lack of owner-provided guidelines and standards for using advanced tools and methods an issue than architects (22%) and contractors (23%). The lower level of concern from architects and contractors is consistent with the findings that they are not seeking direct owner engagement in the use of tools/methods indicated in the owner-related project success factors (see page 44).
- A relatively low percentage of all players find active owner discouragement of the use of advanced tools and methods to be a significant obstacle. Given the importance of owner recognition of the value of these tools and methods, this suggests that few firms actually experience this issue. Apathy and lack of awareness toward these tools and methods is apparently a far greater issue than direct hostility, which perhaps offers AEC firms an opportunity to advance BIM use by further educating their clients on its advantages.
- A much higher percentage of AEC firms consider the lack of owner support of the use of advanced tools and methods a significant obstacle than owners. Again, this is further support that owners can play an important role in promoting the effective use of these tools on projects. The relatively low percentage of owners who recognize this (23%) suggests that many owners may not understand the importance of their recognition and advocacy of the use of these tools.

Most Significant Owner-Related Obstacles to Success on Complex Projects

(Top Two Obstacles According to Owners, Architects, Engineers and Contractors)

Dodge Data & Analytics, 2015



Most Significant Technology-Deployment Obstacles to the Success of Complex Projects

MEASURING THE IMPACT OF BIM ON COMPLEX BUILDINGS DATA

The only obstacle related to technology deployment selected as having a significant impact on the success of complex projects by more than half of owners, architects, engineers and contractors is lack of team member skills at using advanced tools and methods. A high percentage of engineers in particular (63%) consider this obstacle significant.

The second most significant obstacle for AEC firms is insufficient technology training for inexperienced team members. The two top obstacles for AEC firms demonstrates that knowledge of how to use the technology across the project team, rather than the technology itself, is the most important obstacle for these firms.

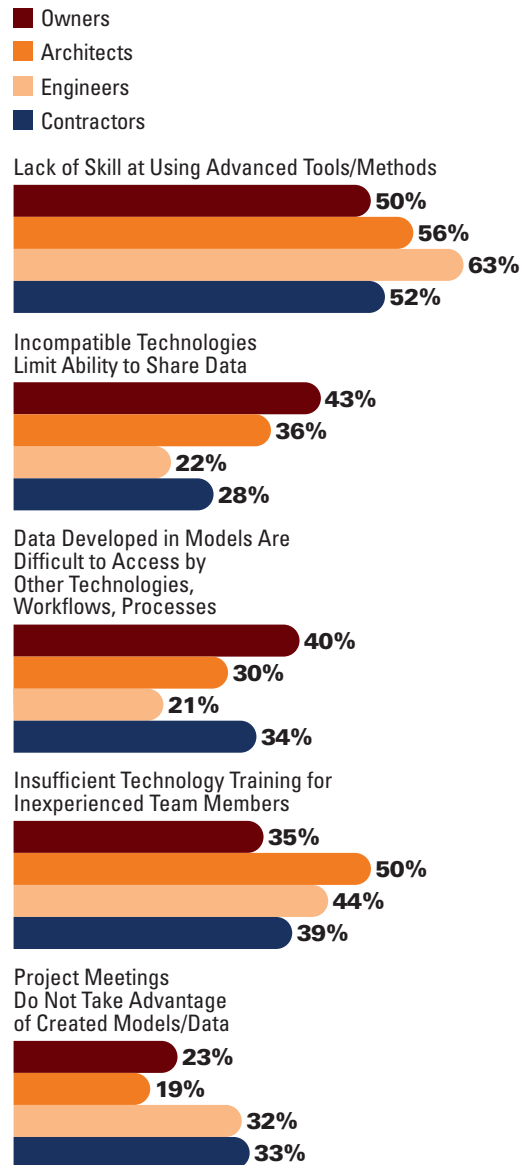
Owners, however, have greater concerns about incompatible technologies and the difficulties in extracting data from models. This may be the result of project team members referencing incompatible technologies with owners to explain sub-optimal leveraging of the value of certain models during a project.

Another contributing factor may be the challenge that owners face in using BIM for facility management after the project is complete. (See pages 36 to 41 for more information on using BIM for facility management.) A key part of that challenge is extracting data from BIM for input into typical facility management software, and owner frustration with this process may be evident in the technology obstacles they consider most significant.

Most Significant Technology-Deployment Obstacles for Complex Projects

(Top Two Obstacles According to Owners, Architects, Engineers and Contractors)

Dodge Data & Analytics, 2015



Top-of-Mind Obstacles Preventing Organizations From Achieving Greater Efficiency in Complex Building Projects

Owners, architects, engineers and contractors were asked an open question about what prevents their organizations from moving to greater efficiency in complex building projects. Interestingly, while there is some overlap in the top selections, each player has different obstacles that most frequently recur in their responses.

- **Owners: Change management is the top obstacle for owners.** This may demonstrate growing recognition among owners that improving efficiency involves process change that is supported by the adoption of tools like BIM. Other top obstacles for owners include:
 - Acceptance of advanced technologies/methods by other stakeholders
 - Cost, both overall and cost of hardware and software specifically
- **Design Team Respondents: Training/education in using tools is the most frequently mentioned obstacle among design team respondents.**

This emphasis on more training needed is also reflected in the main survey findings (see page 48). However, while other top obstacles for architects include owner buy-in and change management, engineers are more concerned about limitations with the software and its interoperability and the development of standards for the use of BIM. Since engineers typically have to work with many different architects and contractors and adapt to their BIM systems, it is not surprising that these challenges would be higher top-of-mind concerns for them than for other players.

- **Contractors: Owner buy-in is the top concern for contractors.** In contrast to the other players, though, contractors are more evenly divided among many top obstacles, which include:
 - Training/education in using tools
 - Acceptance by other stakeholders
 - Cost of hardware and software

Owner Insights on Obstacles to Using BIM Effectively on Complex Projects

Culture Change

Consistent with the top-of-mind survey findings (see above), more owners who participated in the in-depth interviews considered culture change/change management to be the biggest challenge they face in using BIM more effectively on complex projects. As Andy Reinach from Alexandria Real Estate Equities states, “I don’t think the issue is with software products. I think the limitation is with the people.”

Not surprisingly, using the tools to support greater collaboration is recognized as a critical challenge. Meghan Ruffo from Carolinas Healthcare System states, “One challenge is to get out of the design-bid-build mentality and actually look at collaboration earlier on, getting everyone into a different

mind-set when working on these projects.”

Joe Porostosky from Ohio State University is seeking to generate wider understanding of BIM among his staff, so that they can “communicate with the architects, engineers and contractors ... and be able to ask the right questions and be able to hold them accountable.”

Training and Skills

A couple of owners also see the need for improved training and skills as critical. For Denton Wilson of Methodist Health System, the key gap is the lack of knowledge about BIM at senior levels in companies. “[There is a growing need] to use more senior-level people to implement the BIM [in order] to have a properly coordinated model.”

The training identified by the large technology firm that participated anonymously corresponds to the need to change the mind-set discussed by Ruffo rather than just teach about the tool. That technology firm notes that many contractors are not BIM proficient, and when they first start using BIM, “they don’t really do BIM. They just create a 3D model. You’ve got to change the construction workflow into more of a manufacturing workflow.”

The main point expressed most by the owners who participated in the IDIs is that the true challenge is gaining proficiency in the process changes supported by tools like BIM, not greater proficiency in the tool itself.

BIM + Lean Integration: Organizing and Measuring Success on Complex Projects

Increasingly, firms are using BIM and Lean processes in tandem to create predictable workflows, provide better reliability of scheduling and deliver the most value from the client's perspective while consuming the fewest resources.

The Lean Construction Institute (LCI) defines Lean design and construction as “a production management-based approach to project delivery” that “maximizes value,” “minimizes waste” and is “particularly useful on complex, uncertain and quick projects”.

Many firms are beginning to leverage BIM as a Lean tool. They are using BIM to model owners’ process flows and to discover conflicts in design and construction documents, model site logistics issues and sequence construction to improve project workflow. BIM is also being used to effectively support Lean processes, such as collaborative planning. Further, BIM 3D and 4D visualization can help identify and eliminate potential planning problems. According to Kurt Gavalier, National Lean Manager

for Turner Construction, “with BIM you’re trying to find the problem, and Lean is about a problem-solving mind-set... find the problems early and get them solved.”

Better Builders

Turner Chief Innovation Officer Jim Barrett is an advocate of BIM and Lean processes. He says that “old command and control doesn’t work. Jobs are getting more complex, global supply chains, demanding schedules...that old style of doing things—it’s a relic of another age” that he believes they are addressing by using a Lean approach.

Turner Construction, a company with 5,200 employees based out of New York, NY, conducted its first BIM project trial in 2002 and first used Lean processes on a project in 2005. Both have subsequently become Turner formalized standards—BIM in 2008 and Lean in 2011. Since their introduction, Turner has used BIM on 741 projects valued at over \$60 billion, and Lean on 207 projects valued at over \$12 billion.

Two years ago Turner mapped out all of their major processes. What they found was very revealing. For example, project setup that took six weeks under traditional methods could be reduced to four days. Now they want to apply Lean principles to all of their internal processes, including purchasing, estimating and other support services. As noted by Gavalier, “We’re looking to get a Lean mind-set and culture ingrained into everybody.”

To implement their BIM and Lean initiatives, Turner hired dedicated BIM managers in all 11 of their regional offices, and will also soon have dedicated Regional Lean Managers. All of their upper management has received Lean leadership training, hundreds of employees have been trained through their BIM University and Advanced Lean programs, and they hold biweekly companywide Webinar Wednesdays alternating between BIM and Lean topics.

Turner National BIM Manager Jennifer Downey believes that BIM and Lean go hand-in-hand. She says that “all of our complex projects are almost always going to use both BIM and Lean because we need these tools to figure out how to build these buildings on time and on budget.”

Turner has many projects that have

Middle Tennessee Medical Center, Murfreesboro TN

General Contractor
Turner Construction

Size
555,000 sq. ft., 286-bed capacity

BIM + Lean Results

- Delivered GMP more than \$3M below owner’s target
- Nearly \$1M savings from BIM-enabled prefabrication
- Onsite labor savings of 14%
- Delivered more than 2 months ahead of schedule

Nintendo of America Headquarters, Redmond WA

General Contractor
Turner Construction

Size
380,000 sq. ft., 4 stories

BIM + Lean Results

- Delivered 3 months ahead of schedule
- Onsite labor 37% less than estimated
- Productivity 42% higher than average
- 7% of total budget returned as savings

benefited from integrating BIM and Lean. For example, on the 555,000-square foot, 286-bed capacity Middle Tennessee Medical Center located in Murfreesboro, Tennessee, they used BIM in tandem with Lean practices, including pull scheduling and extensive offsite prefabrication to deliver the GMP contract more than \$3 million below the owner's target and more than two months ahead of schedule.

Turner also used a combination of BIM and Lean techniques to construct the 380,000-square foot, four-story Nintendo of America Headquarters in Redmond, Washington. Through the extensive use of BIM and Lean construction methods, they were able to deliver the LEED Gold building over three months ahead of schedule while utilizing 37% less onsite labor than originally forecast. Productivity on the project was 42% above average, and Turner was able to return 7% of the total budget as savings.

**Edith Green Wendell
Wyatt Federal Building
Modernization, Portland, OR**

General Contractor
Howard S. Wright
(A Balfour Beatty Company)

Size
512,474 square feet, 18 stories

BIM + Lean Results

- 48-month delivery duration (GSA average 72–120 months)
- Zero lost time incidents in 663,736 manhours
- \$3 million design and construction savings

**Commitment-Based
Pull Planning**

Balfour Beatty Construction U.S., a 2400-employee company based in Dallas, is also an early adopter of BIM and Lean. BIM along with workflow practices such as 3D coordination, virtual mockups, site logistics planning, model based estimating and 4D visualization have now become standard practices.

Vice president Bevan Mace notes that over the last three to five years, there has been a significant uptick in the use of pull planning methods and in other integrated practices, including target value design and the use of big (co-location) rooms.

Last Planner® is the basis for their commitment-based planning approach. Last year they implemented a national pull planning standard with the expectation that it would be used on 100% of their major projects. Mace says, "Our primary focus right now is just getting folks into a commitment-based planning approach versus a critical path method scheduling approach." They are implementing this strategy across the company's eight divisions through the use of a national network of subject matter experts and "capability leads" that Mace describes as a blend of Lean, BIM and IPD (integrated project delivery) expertise.

Balfour Beatty has used Lean, BIM and IPD on a number of projects with notable results. For example, the modernization of the Edith Green Wendell Wyatt (EGWW) Federal Building, an existing 18-story, 512,474-square foot office tower located in downtown Portland, Oregon. Mace says that "the use of integrated delivery, Lean, BIM

resulted in design duration of 14 months versus a GSA average of 21–24 months and delivery duration of 48 months versus a GSA average of 72–120 months." The project had an impeccable safety record with zero lost time incidents in 663,736 manhours. The LEED Platinum building won an AIA "Top Ten" COTE award in 2014.

Another notable Balfour Beatty project is the construction of the new Parkland Hospital in Dallas. Balfour Beatty used pull planning and offsite fabrication extensively, and a BIM visualization room, which all resulted in a reduction in onsite manpower and subsequent safety benefits.

"Leveraging BIM and Lean practices in integrated project delivery is a team sport. A project's ultimate success requires servant leadership and tight collaboration among all team members, and our experience on the new Parkland Hospital project certainly reinforces that," Mace says. ■

**New Parkland Hospital,
Dallas, TX**

General Contractor
BARA (Balfour Beatty Construction, Austin Commercial, HJ Russell & Co., Azteca Enterprises)

Size
1.9 million square feet

BIM + Lean Results

- Under budget \$5M–\$6M
- Project completed 11 days ahead of schedule
- 6.5 million manhours versus 10 million original estimate
- 1,400 manpower peak vs. 2,200 original estimate

Small But Complex: A Mechanical Contractor Uses BIM to Tackle Severe Site and Schedule Challenges

University of Massachusetts Boston
BOSTON, MASSACHUSETTS

MEASURING THE IMPACT OF BIM ON COMPLEX BUILDINGS



At the University of Massachusetts Boston, J.C. Cannistraro crews had to fit their work within a maze of existing services.

At the University of Massachusetts Boston, operations on the 175-acre campus run 24 hours a day, seven days a week. When the university moved ahead with plans to replace an existing 40-year-old central utility plant, the construction team needed solutions that would allow crews to work within an extremely tight schedule and keep the campus operating.

Elements of the major upgrade included four 2,000-ton centrifugal chillers, three 800-horsepower hot water boilers and one 400-horsepower hot water boiler. Trade contractor J.C. Cannistraro, which was responsible for plumbing, HVAC, fire protection and sheet metal, had to install temporary chillers and re-pipe the

400-horsepower boiler during the upgrade. Crews had one weekend to install system isolation valves for the boiler and 30-inch chilled water valves. Several systems—including electrical, domestic water and fire protection—had to remain undisturbed while Cannistraro upgraded the HVAC systems.

Adding to the complexity, crews had to fit their work within a maze of existing services. Colin Detra, systems designer/coordinator at J.C. Cannistraro, says that determining existing conditions—including what would remain and what needed to be demolished—was a daunting task. In addition, Detra learned that hanger rods could not be attached to the underside of the vault's concrete deck, only to the sides of concrete support beams.

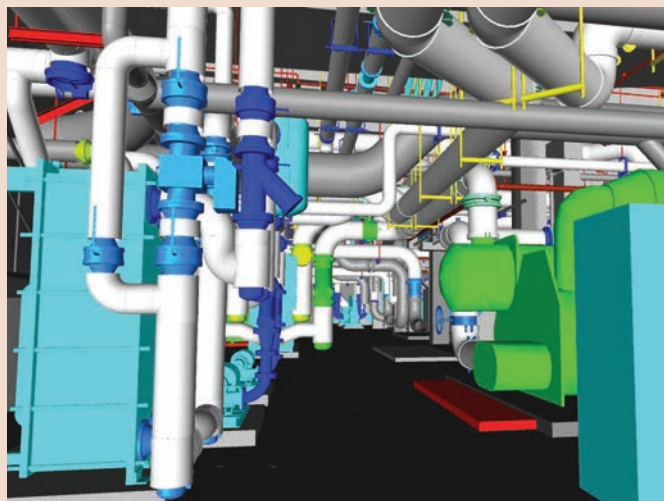
"I was borderline nervous when I saw what we were dealing with," he says. "I looked at it and thought, 'How do I get this done?' It looked impossible."

Laser Scanning Of Existing Conditions

Detra's solution was to laser scan the existing conditions, creating a point cloud to model new systems within the existing ones. Cannistraro was then able to use the model to help coordination and virtual layout. In addition to the 50-plus connections that need to be coordinated, Cannistraro was able to determine locations for hanger rods.

With an accurate model of both new and existing systems, the team was able to pursue BIM-enabled prefabrication.

University of Massachusetts Boston BOSTON, MASSACHUSETTS



J.C. Cannistraro generated laser scans of the existing conditions to create a point cloud. It then leveraged that info to model new systems and existing systems. The team used prefabrication to help reduce manhours in the field by 22% from estimate.

By prefabricating pieces, work is performed in a controlled environment, helping to improve quality and safety. Work can also be performed ahead of time with pieces delivered just in time for installation, potentially saving time in the schedule. This benefit was particularly important on the University of Massachusetts Boston project, where temporary installations had to happen within a two-day window.

Cannistraro employs prefabrication on its projects whenever possible, but Detra says that can be difficult on jobs with complex existing systems.

"It is very hard to catch everything in an existing environment and see all of the interferences," he says. "[These tools] allowed us to do that."

Cannistraro generated hundreds of spool sheets on the project, but by fabricating from the model, Detra says it took half the time it would with 2D drafting software. Data from the model was also used to

drive automated welding machines, translating to almost 9,500 inches of X-ray-quality welding.

Saving Schedule

Although the schedule allowed for a whole weekend to complete the temporary installations, crews were able to get the systems running within a day.

Even more compelling, Cannistraro crews were able to reduce manhours in the field by 22% from its original estimate. Detra says the firm's original estimate, created before the potential use of laser scanning was explored, called for 700 hours of coordination and 22,706 hours in the field. In the end, Detra logged 792 coordination hours—92 hours above estimate—but the field only needed 17,635 hours to complete work.

"I put in almost 100 extra hours for coordination, but it saved 5,000 hours in the field," he says. "All of that upfront effort was 100% worth it." ■

Project Facts and Figures

Trade Contractor
J.C. Cannistraro

Type of Project
Central Utility Plant

Major Components
Four 2,000-ton centrifugal chillers, three 800-horsepower hot water boilers and one 400-horsepower hot water boiler

Completed
2014

BIM-Related Results

J.C. Cannistraro crews were able to reduce manhours in the field by 22% from its original estimate.

- Coordination hours increased from 700 hours (original estimate) to 792 hours (actual).
- Field hours decreased from 22,706 hours (original estimate) to 17,635 hours (actual).

Prefabricating for Project Health

Healthcare has become a leading sector for the use of BIM-enabled prefabrication, allowing complex projects to achieve their qualitative goals while achieving tangible, quantifiable benefits.

Prefabrication of building components has emerged as a leading strategy on complex projects. Driving the shift is a convergence of enabling factors: BIM, integrated project delivery methods and project management philosophies such as Lean Construction. More than any other construction sector, healthcare projects are making the highest use of BIM-enabled prefabrication. That's because the modular elements typical of healthcare buildings make a strong fit for the strategy.

"I would say that is the No. 1 golden rule of prefabrication," says Brandon Bergholz, healthcare market leader with Mortenson Construction. "You have to have multiple repeatable items to really be successful."

Quantifiable Benefits

SCL Health's new St. Joseph replacement hospital, which opened in December 2014, made extensive use of prefabrication: 250 exterior wall panels, over a mile of multi-trade utility racks, 446 bathroom pods complete with fixtures and finishes, and 400 patient headwall assemblies. An analysis conducted by Mortenson as construction was nearing completion expected every dollar spent on prefabrication to return about 13% to the project in quantifiable benefits. Exterior wall panels' benefit-to-cost ratio of 1.74 made it the most valuable of the prefabrication strategies.

The most significant benefits of prefabrication for SCL, achieved at a direct cost premium of only 6%, included:

- **Schedule compression of 18 percent and labor savings of 29,500 hours**
- **150,500 labor hours diverted offsite for a productivity improvement of \$2.6 million from reduced onsite labor density**
- **Increased safety through reduced congestion and improved ergonomics and work settings**

Qualitative Goals

In addition to quantifiable benefits, prefabrication can also support qualitative goals. For example, one of the construction goals for the Medical University of South Carolina (MUSC)'s Children's Hospital and Women's Pavilion, currently in design, is to maximize local, and especially minority-group, participation. Steve Wiley, senior project manager at Robins & Morton, construction managers on the project, has found that prefabrication can facilitate local participation by portioning project components out among local businesses. Wiley speaks from his experience on MaineGeneral's Alford Center for Health, where prefabrication contributed to keeping 97% of subcontractor costs in-state.

Because prefabrication allows building envelope panels and bathroom pods to be built while foundation piles are still being driven, MUSC is also considering it

to help flatten the peaks and valleys of workforce planning and mitigate potential labor shortages.

Best Practices for BIM-Enabled Prefabrication

Whatever decisions the MUSC team makes around prefabrication, says Wiley, "we know we have to make them as a team." Integration is the signature advantage of BIM-based design, and a critical factor in successful prefabrication. Early integration of specialty trades allows the design to incorporate efficiencies that the trades identify and the model to provide the accuracy needed for successful prefabrication.

A closely related best practice is what Bergholz calls the "right of reliance": The model must at all times represent the current status of the design, so that team members can base their decisions on it with confidence.

Challenges

On healthcare projects, clients typically prefer to select equipment as late as possible, which affects utilities and their placement. That preference may represent a limit on the sector's opportunities for prefabrication, which requires design decisions to be finalized even earlier than in conventional construction.

Apart from that, the applications for prefabrication are "just a question of how far can we take it, how complete can we get it," says Bergholz. ■

Converging Technologies

Poised to Transform Construction

New technologies like robotics, drones and 3D printers are poised to increase the ability of BIM to address challenges and improve processes on complex projects.

The increasing complexity of construction projects may be a critical factor helping to drive the development and integration of new technologies. Just as BIM has proven to give new life to older approaches like prefabrication, the introduction of new technologies are likely to increase the value of BIM for construction projects. A few promising new technologies include robotics, drones and 3D printing.

Builder Bots

In March 2015, Construction Robotics, a New York State-based construction technology developer, won World of Concrete's Most Innovative Product award for a brick-laying robot called SAM (semi-automated mason). Designed to help with the repetitive and strenuous task of lifting and placing each brick, SAM offers reduced strain on mason and crew, increased consistency and estimated job savings of over 30%. BIM and SAM may be a match in the making.

Flying Eyes

Meanwhile, Japanese construction machinery manufacturer Komatsu recently joined forces with San Francisco-based Skycatch to integrate autonomous aerial data collection with automated heavy machinery. Komatsu plans to automate early foundation work on construction sites by deploying unmanned aerial vehicles (UAVs), or drones, to scan jobsites and send data to unmanned bulldozers and excavators. That interface will allow

comparisons of what the drones see with what the project calls for.

Drones are really just a special type of robot, one that flies. As the Komatsu-Skycatch enterprise suggests, taking advantage of their bird's-eye view for aerial data collection is an emerging role for drones on jobsites: scan-to-BIM surveys of existing site and building conditions to inform design, and remote inspections of work in progress. One scenario even predicts drones conducting fly-through verifications that trigger automatic weekly or bimonthly payouts to contractors.

Heavy lifting may not be a strength associated with drones, but Flight Assembled Architecture, a project mounted in 2012 at an art center in France, showcased a team of drones laying up a complex architectural form six meters high using some 1,500 lightweight masonry units. The drones collaborated according to mathematical algorithms that translated digital design data into actions. This elegant project conveys the poetic potential of channeling design intelligence through robotics.

Additive Manufacturing

Calling 3D printers robots might seem like a stretch, but that's just a matter of scale. A 20-foot tall, 33-foot wide, 132-foot long machine with a giant extruder arm, which Chinese company WinSun used last year to

print full-scale houses in concrete, and the even bigger one it used to print a five-story apartment building, seems a lot more like a robot than a printer.

In May 2015, engineering consultant Arup announced the 3D printing, or additive manufacturing, of a structural steel connector weighing 75% less than its conventional counterpart for the same loads. "On a construction project, that means we could be looking at an overall weight reduction of the total structure of more than 40%," says Arup team leader, Salomé Galjaard. "But most important, this approach potentially enables a very sophisticated design, without the need to simplify the design in a later stage to lower costs."

One of the most profound implications of these converging technologies, according to Mike Whaley of technology consultants Turis Systems, is waste reduction. Suppose, for example, resinous hospital countertops could be 3D-printed onsite direct from the BIM model; or a drywall installer could laser scan existing stud framing and openings with a cell phone and send the data to print drywall pieces onsite in just the right sizes. No extras, no off-cuts, no waste. "Yes, you can save money," says Whaley, "but you can also have a positive impact on the big picture without added cost. That is huge." ■

Methodology:

BIM for Complex Projects Study Research

Quantitative Online Research

Dodge Data & Analytics conducted this study to investigate the use of BIM for complex building projects among design and construction industry professionals in the US. This research sought to explore: 1) project stages when BIM is used; 2) impact of BIM during design and construction phases; 3) factors influencing BIM use in complex projects, such as triggers and obstacles; 4) BIM use in facility management; and 5) future developments in improving efficiency.

The research was fielded between March 2nd and April 13th, 2015, using an online survey, with 391 respondents. The total sample size of 391 has a margin of error of +/-5% based on a 95% confidence interval.

SURVEY PARTICIPATION

The sample list was drawn from the DD&A Architect and Contractor Panels, the Dodge construction database and association memberships.

Survey participants include:

- 40 Owners
- 183 Architects
- 68 Engineers
- 100 General Contractors

SCREENING CRITERIA FOR PARTICIPATION IN THE SURVEY

■ Criteria for all respondents

- Organization currently using BIM
- Experience with programmatically complex and/or systems-intensive projects
- Knowledge of BIM use at their organization: On a 5-point scale where 5 is very knowledgeable and 1 is not at all knowledgeable, owners needed a 3, 4 or 5, and architects, engineers and contractors needed a 4 of 5 score

■ Additional Owner Criteria: Has at least one of the following types of projects in building portfolio.

- Data centers
- Entertainment (e.g., stadiums, theme parks)
- Hospitals
- Industrial/manufacturing
- Laboratories
- Transportation buildings (e.g., airports, major railway stations)

VARIABLES USED IN THE ANALYSIS

■ BIM Use for Current Projects

- Less than 50% (108 respondents)
- 50% or more (283 respondents)

■ Architect Firm Size (2014 Billings)

- Less than \$5 million (59 respondents)
- \$5 million to less than \$10 million (40 respondents)
- \$10 million to less than \$50 million (42 respondents)
- \$50 million or more (42 respondents)

■ Contractor Firm Size (2014 Project Value)

- Less than \$250 million (40 respondents)
- \$250 million to less than \$1 billion (31 respondents)
- \$1 billion or more (29 respondents)

Qualitative In-Depth Interviews

DD&A conducted in-depth, 30-minute interviews with eight executives representing building owners in the healthcare, laboratory, higher education, high tech and transportation sectors, with the primary goal of finding out where they believed their company saw the greatest value from BIM.

The participants were selected based on their BIM expertise and on significant experience with complex projects. There were seven named participants and one participant from a major technology company who agreed to participate under the condition of anonymity. The seven named participants include:

- Digby Christian, Senior Program Manager, Sutter FPS
- Stuart Eckblad, Director, Mission Bay Hospitals Project, University of California San Francisco (UCSF)
- Ryan Marzullo, Director of New York Design and Construction, Delta Airlines
- Joe Porostosky, Senior Manager, Facilities Information and Technology Services, Ohio State University
- Andy Reinach, Vice President of Development and Construction, Alexandria Real Estate Equities, Inc.
- Meghan Ruffo, AIA, LEED AP, Contract BIM Manager, Facilities Management Group, Project & Construction, Carolinas HealthCare System
- Denton Wilson, Vice President of Design and Construction, Methodist Health System

Resources

Organizations and websites that can help you get smarter about the impact of BIM on complex buildings.

DODGE DATA & ANALYTICS

Dodge Data & Analytics

Main Website: construction.com

Dodge: construction.com/dodge

Research & Analytics:
[construction.com/dodge/
dodge-market-research.asp](http://construction.com/dodge/dodge-market-research.asp)

Sweets: sweets.com

SmartMarket Reports:
analyticsstore.construction.com

ACKNOWLEDGEMENTS:

The authors wish to thank our premier partner, the U.S. Department of Veterans Affairs—and, in particular, Rick Bond and Renée Tietjen at the VA—whose vision and support have made this report possible.

We would also like to thank the eight individuals who participated in the in-depth owner interviews, including both those who went on the record and those who spoke anonymously. Their insights bring greater depth and clarity to the findings of our study.

In addition, we thank Hal Jones at Skanska, Jim Barrett at Turner Construction and Doug Rowe at Lend Lease for sharing their expertise and insights and helping us to create an effective, meaningful survey instrument. We also thank the American Institute of Architects (AIA), including the AIA Technology in Architectural Practice Knowledge Community (TAP) and the AIA Large Firm Roundtable, as well as Microsol Resources and VDCO Tech, for helping us to widely disseminate the survey.

Finally, we would like to thank all the individuals who provided information and insight for our sidebars and case studies.

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U.S. Department of Veterans Affairs BIM Guide:
www.cfm.va.gov/til/bim/BIMguide/lifecycle.htm

Research Partners

The American Institute of Architects: aia.org

AIA Practice BIM, Standards & Interoperability:
[network.aia.org/technologyinarchitecturalpractice/
home/bimstandards](http://network.aia.org/technologyinarchitecturalpractice/home/bimstandards)

AIA Guide to Integrated Project

Delivery: www.aia.org/ipdg

Microsol Resources: microsolresources.com

VDCO Tech: vdcotech.com

Supporting Partners

buildingSMART Alliance: buildingsmartalliance.org

Skanska: www.skanska.com/group

Other Resources

Association of General Contractors ConsensusDOCS,
301 BIM Addendum: [www.consensusdocs.org/
Resource_/FileManager/301_Guidebook_08_12_13.pdf](http://www.consensusdocs.org/Resource_/FileManager/301_Guidebook_08_12_13.pdf)

BIMForum: bimforum.org

bimSCORE: www.bimscore.com

BIM Task Group (UK): www.bimtaskgroup.org

Lean Construction Forum: agcleanforum.org

Lean Construction Institute: leanconstruction.org

National Institute of Building Sciences: www.nibs.org

National Institute of Building Sciences "The COBie
Guide": www.nibs.org/?page=bsa_cobieguide

Penn State Computer Integrated Construction
"BIM Execution Planning Guide": bim.psu.edu

RICS (Royal Institution of Chartered Surveyors):
[www.rics.org/us/knowledge/bcis/about-bcis/
forms-and-documents/bim-downloads/](http://www.rics.org/us/knowledge/bcis/about-bcis/forms-and-documents/bim-downloads/)

U.S. General Services Administration, Building
Information Modeling: www.gsa.gov/bim

US National BIM Standard:
www.nationalbimstandard.org

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