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# Lean Construction

**Leveraging Collaboration and Advanced Practices  
to Increase Project Efficiency**

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# SmartMarket Report

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## Lean Construction: Leveraging Collaboration and Advanced Practices to Increase Project Efficiency **SmartMarket Report**

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## About McGraw Hill Construction

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## Introduction

While concerns about the inefficiency of the construction industry are not new, the devastating impacts of the long recession have made it clear that, even as the economy slowly recovers, business as usual can no longer be an acceptable approach in the construction industry. **Lean construction offers an alternative that allows companies to thrive in any economic conditions.**

In the last few years, McGraw Hill Construction has explored many ways in which the industry has addressed questions of inefficiency. Our series of BIM reports demonstrate, among other findings, that the collaborative approach BIM can help foster has strong impacts on productivity and profitability. Similarly, the 2011 *Prefabrication and Modularization* and *Mitigation of Risk in Construction SmartMarket Reports* reveal approaches that improve the process of construction, improving the bottom-line of projects. **This report builds upon those findings by demonstrating that taking a Lean approach, including the use of BIM and prefabrication, makes firms more competitive and yields strong business benefits.** In fact, these benefits can be so pronounced that one of the expert Lean contractors interviewed as part of this study states that, because of their Lean approach, "We didn't have a downturn."

Among contractors using the Lean practices included in the study, most report a wide range of benefits, including:

- **Higher Quality Construction (84%)**
- **Greater Customer Satisfaction (80%)**

- **Greater Productivity (77%)**
- **Improved Safety (77%)**

However, the most surprising result of this study is that, despite the experience of the last few years, **55% of firms that are not familiar** with Lean practices or Lean construction regard current construction processes as efficient/highly efficient. In contrast, 62% of Lean practitioners regard these same processes as inefficient/highly inefficient. In addition, Lean practitioners find lack of knowledge the biggest obstacle to implementing Lean, and non-practitioners familiar with Lean consider lack of industry support or understanding of Lean to be the biggest obstacle. **Clearly, education about Lean and the need for and benefits of increasing efficiency must be a major priority for the industry at large.**

Increasing industry knowledge about how Lean can improve construction is particularly vital because many Lean construction practices depend upon a highly collaborative approach. The emphasis on early planning and the commitments to schedule demand that all project partners collaborate to achieve the benefits offered. However, this study also suggests that, despite advances, the technologies currently in place must be improved to more fully support a collaborative approach. **The in-depth interviews with highly collaborative contractors reveal the lack of a system that fully supports the ability to collaborate with internal or external project team members.**

We would like to thank our premier partner Dassault Systèmes for their help in bringing this call to action to the industry.



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## Introduction

**D**assault Systèmes with McGraw Hill Construction is pleased to present this *Smart Market Report*, which provides insight into collaboration and Lean practices in the construction industry. The industry is undergoing an important transformation in the way work is performed and managed. Facility owners are demanding higher performance buildings delivered with greater economy. This requires all players in the industry to be more competitive to meet those demands by capitalizing on know-how to deliver projects on-time and on-budget while improving worksite safety and efficiency. To excel in the new construction industry, the entire team will need to examine their processes closely and find new ways to innovate and build with less waste.

### Collaborative Construction

Construction project teams are in search of coherence, where all project team members—from the owner to the office to the field—share a common view of objectives, plans and status. All parties need to share the same consistent set of data and to arrive at a shared understanding.

### Lean Methods to Industrialize Construction

A majority of Lean practitioners increase efficiency by undertaking offsite prefabrication (90%) and Just-In-Time material delivery (78%).

### Signaling a Cultural Change

This transformation is a cultural change for the industry. The survey findings point to changes in management philosophy. They point to the need to empower field superintendents and to champion new ways of constructing and planning. We are also struck by Lean practitioners' concern about the availability of skilled workers. All of these indicate a need for increased education and work instruction.

We would like to thank McGraw Hill Construction and especially those industry participants who shared their insights into the drivers of Lean and increased efficiency that signal the way towards a high performance construction industry.

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# Glossary

## Definition of Terms Used

**5S (for workplace organization):**

Part of the Just-in-Time Manufacturing approach, 5S is a workplace organization method built around five Japanese terms that begin with an “S” when translated into English. The five S’s are Sort, Straighten, Sweep, Standardize and Sustain, although Safety and Security are also considered under this approach when appropriate.

**A3 Report:**

A standardized approach used by Toyota and adopted beyond them of problem solving through a series of steps.

**Big Room:**

Part of the Toyota Way, brings project leaders together to use data to resolve issues that arise in a project.

**Choosing by Advantages:**

A decision-making process formulated in the late 1990s in which only contrasting advantages of various alternatives are considered when making a decision.

**Corporate Performance Management (CPM):**

Software that monitors and manages an organization’s performance, according to key performance indicators like revenue and operational costs.

**Enterprise Resource Planning (ERP) System:**

Software supporting the internal business processes of a company by providing an integrated real-time view of its core business processes such as finance, procurement and human resources.

**Just-In-Time:**

According to the Lean Construction Institute, Just-In-Time is a system of production that makes and delivers just what is needed, just when it is needed and just in the amount needed.

**The Last Planner System®:**

Developed by the Lean Construction Institute, this involves requiring commitments to schedules by all project team members. The five key elements of this system are master scheduling, pull planning, make work ready planning, weekly work planning and learning.

**Lean Construction:**

The elimination of waste from construction processes.

**Multi-Party Contracts:**

Contracts designed to encourage collaboration by sharing the risks and rewards across multiple project team members.

**Pull Planning:**

Definition and sequencing of tasks, working backward from a target completion date.

**Six Sigma:**

A set of strategies, techniques and tools for process improvement, by identifying and solving root problems.

**Stretch and Flex Meetings:**

Short warm-up drills conducted onsite to promote safety by stretching and flexing muscles prior to work.

**Target Value Design:**

A collaborative approach that involves a concurrent design process beginning with a project cost estimate and building the design around value as defined by the building owner.

**Toyota Way:**

According to the Lean Construction Institute, the system developed by Toyota Motor Corporation to provide best quality, lowest cost and shortest lead time through the elimination of waste.

**Value Stream Mapping:**

A Lean manufacturing technique that involves creating a map of all stages of a process in order to identify and evaluate potential improvements or efficiencies.

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# Executive Summary

## Executive Summary

**The construction industry must become better informed about the inefficiencies in current construction processes and about the opportunities offered by taking a Lean approach to improve their projects and keep their clients satisfied.**

There are still many firms that are not familiar with the term Lean construction, a problem which must be addressed. Even current Lean practitioners would benefit from wider industry awareness and adoption, due to the interconnected nature of construction work and the highly collaborative nature of many Lean construction approaches.

### Familiarity With and Use of Lean Practices

Because Lean is still an emerging practice in the construction industry, a broader sample of contractors familiar with Lean were actively sought out to participate in the survey. **Lean practitioners were identified as those that have implemented any of the following six practices at their company: Lean construction; Pull planning; Just-In-Time delivery; The Last Planner System®; Toyota Way; and Six Sigma.**

The survey sample was comprised of two groups: McGraw Hill Construction's Contractor Panel and members of the Lean Construction Institute. **When only considering the responses of the contractor panel, which is representative of the industry, 37% are not familiar with any Lean practice.** Clearly more education about Lean is still needed in the construction industry.

### Inefficiency of Current Construction Practices Is Not Widely Recognized

**Over half (55%) of contractors who are not familiar with any Lean practices find the construction industry either efficient or highly efficient, while 62% of Lean**

**practitioners recognize that the industry is inefficient.**

Given the cultural challenges posed in encouraging workers and project team partners to engage in a Lean approach, it is essential that there is a wider recognition of the problem of waste and inefficiency in the construction industry. While the benefits of using Lean practices, especially the ability to be more competitive, are evident in the study findings, these benefits alone may not be sufficient to persuade firms to adopt Lean if those firms do not recognize the inherent inefficiencies in the traditional design and construction processes that Lean practices are intended to reduce.

### Making Firms More Competitive Is the Most Important Benefit of Lean

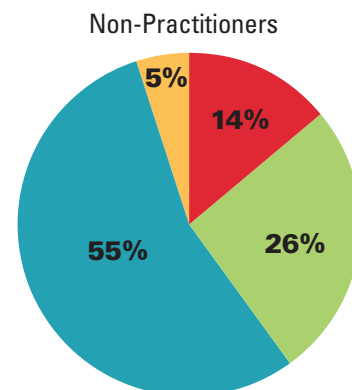
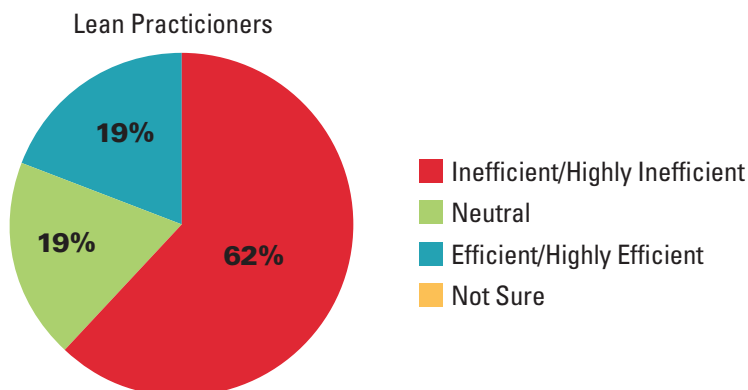
**Lean experts in the in-depth interviews agree that their ability to succeed in a competitive market is the most important benefit they gain from Lean,** due to a combination of factors such as improved reliability of outcome and profit margin, higher quality construction, greater customer satisfaction, and reduced costs and schedules.

The responses of Lean practitioners in the survey also demonstrate the business advantages of Lean:

### Efficiency of Construction Processes in the Industry

(By Level of Lean Engagement)

Source: McGraw Hill Construction, 2013





- **84% find that adopting Lean has led to higher quality projects.**
- **80% report greater customer satisfaction.**

In fact, as more owners become familiar with the impact of Lean, it may evolve from a competitive advantage to a necessity. **Eighty-six percent of Lean practitioners find that clients are increasingly expecting the shortened construction schedules enabled by a Lean approach.**

Case studies also reveal specific benefits of Lean.

- **Rosendin Electric’s value stream mapping study cost \$2,000 but saved \$50,000 in labor costs**
- **Boldt Construction’s active coordination of their prefabrication efforts for headwalls on a hospital project reduced the number of man hours per headwall by more than two-thirds, from 24 to seven.**

### Benefits That Will Encourage Adoption Among Non-Practitioners

Among firms that are familiar with Lean but have not yet implemented any Lean practices, **the highest percentage agree that knowing that they could have greater profitability/reduced costs (83%) and greater productivity (81%) would have a strong influence on the decision to adopt Lean practices.**

It is critical to note that while these are not the benefits reported by the highest percentage of Lean practitioners, **over three quarters (77%) have achieved greater productivity and almost two thirds (64%) have achieved improved profitability/reduced cost due to their adoption of Lean practices.** However, encouraging firms to recognize the impact on competitiveness, the greatest benefit of Lean, would help to align expectations and lead to better implementation.

### Challenges

**The most important challenges to Lean adoption and implementation reported by practitioners and non-practitioners alike reinforce the need for greater education about Lean in the industry:**

- **Lack of knowledge: Selected by 47% of practitioners**
- **Lack of industry understanding of Lean: Selected by 39% of non-practitioners**

Lean experts also cite employee resistance as a key challenge, although most acknowledge that employees grow very enthusiastic and engaged after they experience the benefits offered by Lean.

### Tools Supporting Collaboration

Lean experts in the in-depth interviews identify collaboration as critical to their Lean approach. Strategies like Last Planner depend on commitments from all project team partners to yield improved schedules and reliability.

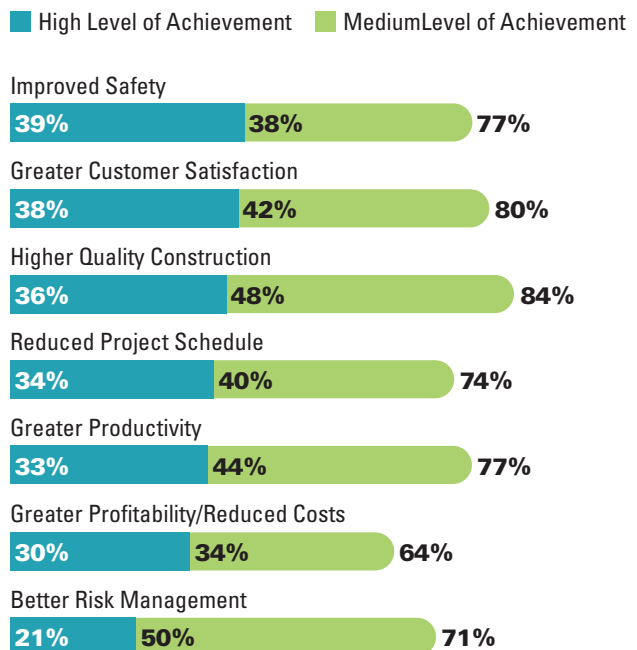
The ability to exchange data among project team members is critical to collaboration, as is the ability to analyze data to improve a firm’s performance. Enterprise resource planning (ERP) systems connect project data to business functions like finance and procurement. **Thirty-four percent of contractors use an ERP, and 65% of those firms find that it supports their efficiency efforts.**

Despite the advantages an ERP offers contractors seeking greater efficiencies, **in-depth interviews with highly collaborative contractors reveal that there is no tool that allows them to share data effectively both internally and externally.** Even internal data-sharing is best conducted on custom-built tools, but these do not enable data sharing with external partners. **Better tools are needed that allow more intensive data-sharing within and beyond individual firms, especially with owners and fabricators.**

### Benefits Reported by a High Percentage of Lean Practitioners

(By Level of Achievement)

Source: McGraw Hill Construction, 2013



# Recommendations

**The study findings demonstrate that the industry still needs to learn a great deal about Lean construction, why it is beneficial and how it will improve their ability to succeed, even in a challenging market.**

## Overall Recommendations

### ■ #1: PROVIDE EDUCATION ON THE NEED FOR GREATER EFFICIENCY

Fifty-five percent of those not familiar with Lean find that construction industry processes are efficient or highly efficient. This finding strongly suggests that, in order for contractors to recognize the need to adopt Lean practices, they must first recognize the inefficiencies inherent in a traditional design-bid-build project.

The industry overall can help address this problem. **Industry associations have a role to play by offering more information about Lean, by sponsoring research to demonstrate the need for greater efficiencies and by actively promoting the philosophy of continual improvement.**

### ■ #2: CREATE SOFTWARE THAT SUPPORTS THE NEED FOR EXTERNAL AND INTERNAL COLLABORATION

Collaboration is essential to the success of many Lean approaches (see the next recommendation), but collaborative efforts

must be supported with the ability to share and track information, both among project team members within a firm and with other firms working on the project.

However, it is challenging, even for highly collaborative contractors, to share information at the data level rather than the file level, unless they invest in custom solutions and work around ongoing interoperability issues. **Software firms have an opportunity to create better tools that support the trend toward greater collaboration in the construction industry.**

## Contractor Recommendations

### ■ #1: TAKE A COLLABORATIVE APPROACH TO LEAN TO MAXIMIZE GAINS

Many Lean practices require taking a more holistic view of the design and construction process. A construction project involves intensive coordination among teams from multiple companies, and decisions made to improve schedules and Just-In-Time deliveries of materials and services

have to include the entire project team. In addition, one Lean expert in the in-depth interviews affirms that increasing his workers' "relatedness," which includes understanding the work of other trades on a project, improves the overall project and his workers' experiences on it. **Firms must work collaboratively in order to achieve the full benefits of their Lean practices.**

### ■ #2: RECOGNIZE AND PLAN FOR THE CULTURE CHANGE NECESSARY FOR FULL LEAN ADOPTION

Lean construction is not limited to individual practices; it is a commitment to continuous improvement that must engage all workers involved in a project, from management to craft workers in the field. This means taking an entirely different approach to a project. For example, experienced workers may initially resist the idea that they are not working as efficiently as they can be. **Therefore, firms seeking to adopt Lean need to consider how to engage their employees as part of their strategy.**

Most of the Lean experts in the in-depth interviews report that they are still implementing Lean at the project level, but many are now considering a broader company-wide approach. Working on one Lean project can be a powerful way to encourage employee buy-in.

Several Lean experts also describe increased employee engagement and innovation as an important benefit of Lean adoption.

### ■ #3: TRACK AND SHARE DATA AT THE MOST GRANULAR LEVEL POSSIBLE

Improving efficiencies best begins at the worker level. According to Lean experts in the in-depth interviews, data collection at the most granular level is necessary, down to man hours dedicated to install individual components. **Firms seeking to improve efficiencies will benefit from understanding and analyzing processes at the worker level, tracking each step of the process to see where improvements can be made.** ■

# Data: Introduction

The construction industry is currently seeking ways to improve how it does business. McGraw Hill Construction has examined many of these rising trends, including improved risk management, the use of prefabrication, the support of collaboration through improved information mobility and the rise of BIM with its profound implications for altering existing design and construction processes. Lean construction and integrated data-enhanced collaboration bring together these elements and help to advance the industry.

**A simple definition of Lean construction is the elimination of waste from the processes of designing and constructing buildings**, but that definition does not capture the essentially transformative nature of Lean for the industry. As is clearly revealed in the qualitative study of Lean experts featured in this report, true adoption of Lean demands changing the culture of an organization and embracing a collaborative approach.

Because this level of commitment and change management is daunting, the industry needs to understand not only the need for Lean to address inefficiencies inherent in current construction processes, but also the range of potent benefits that come from pursuing a Lean approach. None of the experts find this process to be easy, but all find that their firms are not only more competitive as a result, but they also see increased levels of engagement and innovation as their companies dramatically improve.

Construction has always been an industry with tight margins, and the prolonged recession from which the industry has begun slowly to emerge has caused many to consider how to improve their businesses. In this environment, collaboration has become increasingly important. Most in the industry currently regard collaboration rather narrowly, confined to the key players in design and construction. However, a few advanced practitioners are looking beyond these traditional players to collaborative efforts with fabricators and building owners, not just in design and construction, but across the lifecycle of the buildings they construct.

For these collaborative efforts to bear fruit, an organization needs to be able to accomplish the following: analyze data across the breadth of its business; create accurate schedules based on an in-depth understanding of its processes; and share data effectively with project team members. These efforts depend on the use of data integration systems, which can improve processes in Lean and advance the construction industry into a new age of efficiency and profitability.

## Note About the Data

**The data and analysis in this report are based on two studies, conducted in September 2013.**

- A series of qualitative in-depth interviews conducted by phone and in person with 10 experts on Lean and four advanced users of technologies that support collaboration.
- A quantitative online survey of 193 contractors from the McGraw Hill Construction Contractor's Panel and from the Lean Construction Institute (LCI).

**The primary goal of the qualitative and quantitative Lean studies was to examine the experience of those who have engaged with Lean to understand how they are implementing it in their organizations, the sophistication and comprehensiveness of their approach to Lean, the challenges they encounter and the benefits they have experienced as a result of the use of Lean practices.**

- In order to gauge their involvement with Lean, respondents were asked whether they were familiar with or have implemented the following Lean practices: Lean construction, Toyota Way, Six Sigma, Last Planner System®, Just-In-Time delivery or pull planning.
- Firms were then analyzed in three groups based on their responses:
  - Implemented Lean Practices: Use at least one of the practices
  - Familiar with Lean Practices: Familiar with at least one of the practices, but has not implemented any
  - Not Familiar with Lean Practices: Not familiar with any of the practices

**The use of the contractor panel provided a representative sample of contracting firms for the survey. Among that representative sample, 28% have implemented at least one practice; 35% are familiar with Lean but not implemented any practices; and 37% are not familiar with Lean.**

**The qualitative study of technology-focused data integration concentrated primarily on technologies like Enterprise Resource Planning systems, which the experts participating in the research have used to enhance their ability to collaborate.**

# Data: Lean Practices

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY DATA

## Awareness and Use of Key Lean Construction Approaches From Manufacturing and Last Planner®

While there are many practices currently used in the industry to help the construction industry become more Lean, the core, central philosophies, such as Toyota Way, Six Sigma and Just-In-Time first emerged from the manufacturing sector. Many engaged in Lean construction actively employ the principles behind these approaches in their pursuit of Lean at their organizations, and they are also using tools created specifically for the construction industry, including the Last Planner System, developed by the Lean Construction Institute, and the strategy of pull planning included in Last Planner. See the glossary on page 3 for definitions of the specific Lean approaches.

The chart to the right represents the level of awareness and use of the core six practices by all the survey respondents. **The analysis of Lean practitioners throughout the rest of the data analysis from this survey is drawn from those who report having implemented at least one of the Lean practices represented in the chart.**

The main goal of this study is to consider the impact of Lean practices on firms that have adopted them. Therefore, it is important that 37% of the survey respondents are also members of the Lean Construction Institute, who have a broader awareness of Lean and are more likely to have initiated some of these practices at their organizations. (See page 56 for more information.) Including these firms allowed the overall number of Lean practitioners who participated to provide insights on this emerging trend.

The remaining 63%, on the other hand, provide a representative sample of the industry. **Only 28% of this representative sample have implemented Lean and 37% are not familiar with any of the practices.** The responses from this representative sample are provided in the discussion of specific Lean practices to reveal the state of awareness of the industry at large about these practices.

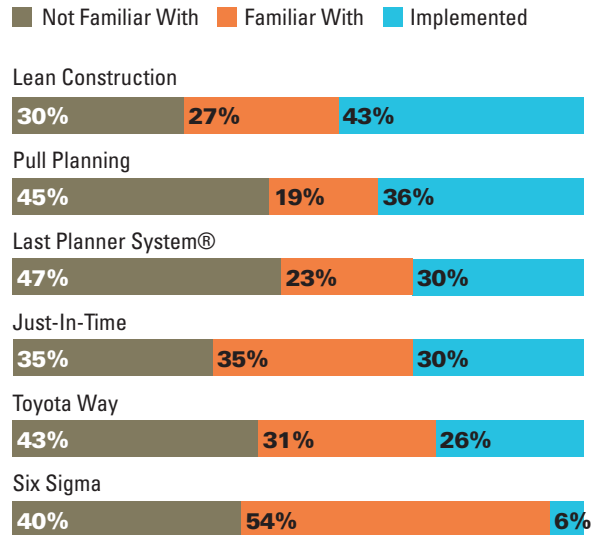
### Lean Construction

Given the variety of Lean practices currently used by firms in the construction industry, it is not surprising that **the overall category of Lean construction has the widest level of implementation of any of these approaches.** In fact, nearly half (43%) report that they have implemented Lean construction in some way at their organization.

However, it is worth noting that, **among a representative sample of the industry, 48% are not familiar with the broad, overarching concept of Lean construction.** This finding is important because it demonstrates that for much of the industry, Lean is at best still an emerging

### Familiarity With or Implementation of Lean Practices

Source: McGraw Hill Construction, 2013



trend. Because of the intensively interrelated nature of construction processes on a jobsite, lack of overall industry familiarity or understanding of Lean can have a significant adverse effect on companies attempting to implement a Lean approach. **In fact, one of the Lean experts who participated in the in-depth interviews commented that one of the biggest changes he hopes to see in the next five years is a reduction in the necessity for him to proselytize about Lean to other project team members.** (See page 25 for more information.)

### Lean Approaches That Originated in the Manufacturing Sector

**One key distinction of most of the approaches to Lean that are based on the manufacturing sector, compared to those developed for the construction industry, is that there is a much higher awareness of these approaches, but not a higher implementation.** One reason for this may be suggested by the experts from the in-depth interviews, who suggest that approaches like Toyota Way and Six Sigma offer philosophies that underpin their efforts, rather than practices they directly implement.

However, this finding is also a point of caution. Application of construction-specific tools without the rigor inherent in the manufacturing-derived approaches can be too limited.



## Awareness and Use of Key Lean Construction Approaches from Manufacturing and Last Planner®

CONTINUED

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY DATA

The interviews with the Lean experts demonstrate that without a companywide adoption of a Lean philosophy, the benefits to be achieved from Lean are truncated. They also reveal that this paradigm shift within their company is one of the biggest hurdles they face in encouraging Lean adoption.

- **Just-In-Time:** Just-In-Time is the most widely implemented of the manufacturing approaches. This may be due in part to the fact that this is a defined system that is more immediately applicable to construction, rather than a philosophical approach underpinning a firm's approach to Lean.
- **Toyota Way:** For many serious Lean practitioners, Toyota Way has informed many of the ways they approach Lean, including the adoption of specific Japanese terms associated with this approach.
- **Six Sigma:** Over half the respondents (54%) are familiar with Six Sigma, a much higher percentage than those familiar with Just-In-Time and Toyota Way. Among the representative industry sample, Six Sigma is also more broadly recognized, with 38% reporting familiarity with it. This is no doubt due to the permeation of Six Sigma terminology and discussion throughout businesses in the U.S. However, despite the broad familiarity, only 5% of all respondents actually have implemented Six Sigma at their firms, suggesting that the industry is not convinced of the applicability of this approach to construction.

### Construction-Specific Lean Approaches

Two of the most popular and far-reaching of the construction-specific approaches to Lean are the Last Planner System and pull planning. The level of implementation of these approaches is roughly equivalent to the Just-In-Time approach, but a far larger percentage of the remaining firms are not familiar with these approaches than are familiar with Just-In-Time. This suggests that contractors who become familiar with Last Planner and pull planning are more likely to implement it than the manufacturing approaches.

Interestingly, a higher percentage of firms report using pull planning (36%) than Last Planner (30%). Since pull planning is one step in the Last Planner System, this finding is very telling. It suggests that firms are picking and choosing among options within approaches, finding the ones that they prefer, whether that is due to the ease of implementation or the results they see. It again suggests that most firms are not at the point of a broad

implementation of Lean principles companywide, and instead are at the point where they are adopting useful tools. If this is the case, then the opportunities offered by Lean to eliminate waste in the construction industry are still largely untapped.

The industry as a whole is also not well informed about these practices, as is evident from the responses of the representative sample of respondents:

- 70% are not familiar with pull planning
- 73% are not familiar with Last Planner System.

### Variation by Type of Firm

It is notable that there is no statistically significant variation between general and specialty trade contractors on the percentage that implement any of these practices, which demonstrates their broad applicability in the construction industry.

### Variation by Size of Firm

A significantly higher percentage of firms with annual revenues of \$100 million or more have implemented at least some of these practices than firms with revenues under \$100 million, except Six Sigma. This finding demonstrates broader use of Lean in larger companies, although the in-depth interviews with Lean experts suggests that all these practices may not be implemented companywide.

### Variation by Location

Lean construction and Last Planner System are more widely implemented in the West than in the rest of the country.

- **Firms Implementing Lean Construction:**
  - West: 63%
  - East: 32%
  - South: 35%
  - Midwest: 39%
- **Firms Implementing Last Planner System®**
  - West: 45%
  - East: 12%
  - South: 31%
  - Midwest: 21%

## Elements That Define a Lean Approach

Both Lean practitioners and the respondents who are familiar with Lean but have not implemented any Lean practices were asked to suggest project-specific elements that define a Lean approach. The results demonstrate that those who are engaged in Lean think of it strategically, with a focus on its main objectives, and those who are familiar with but not engaged in Lean think of it tactically, with a focus on specific tools and strategies.

### ■ Project-Specific Elements that Define Lean According to Lean Practitioners

- 32% mention waste reduction
- 29% mention collaboration or project teams
- 22% mention efficient scheduling

### ■ Project-Specific Elements that Define Lean According to Those Familiar with Lean But Not Implementing Lean Practices

- 29% mention materials management
- 25% mention crew sizing
- 25% mention project planning

Other elements mentioned by less than 20% of both include labor/subcontractor scheduling, materials procurement, better communication and pull planning.

## Expected Use in the Next Three Years of Key Lean Construction Practices

Among the construction firms that report being familiar with Lean practices but that have not implemented them, the Last Planner System® and pull planning have the highest level of future adoption, with over one third of the firms expecting to implement Last Planner and 28% implementing pull planning in the next three years. Both practices have been specifically developed for the construction industry, which provides further support for the previous finding (see above) that firms not yet engaged in Lean are most interested in tools that can be added to their existing processes and in a tactical adoption of Lean on a project-by-project basis than in broader, companywide Lean philosophies. Even the broad, general category of Lean construction sees slightly lower adoption than these tools.

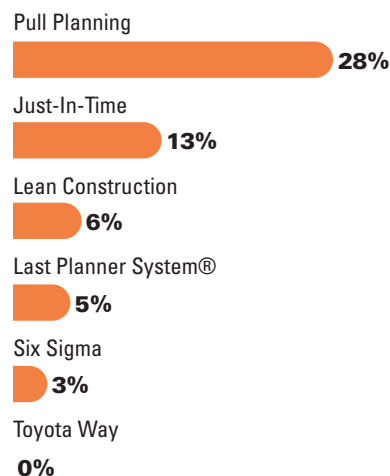
Last Planner is also a highly collaborative process, which may increase the awareness of non-Lean practitioners that have worked with firms using this approach of the benefits it offers.

Few firms are interested in the Lean practices drawn from manufacturing, including Just-In-Time and Six Sigma, and none expect to use Toyota Way in the next three years.

### Firms Planning to Implement Lean Practices by 2016

(According to Those Familiar with But Not Currently Implementing Practices)

Source: McGraw Hill Construction, 2013



## Awareness and Use of Additional Lean Practices

A Lean construction approach encompasses many different practices to eliminate waste from the construction process, including but not exclusive to tools that aid with good decision-making, engaging collaboratively with other project team members and seeking efficiencies in specific work processes.

Respondents were asked about their familiarity with or implementation of a select group of these practices. **The findings demonstrate that, despite the fact that 38% of the respondents are members of the Lean Construction Institute and thus more familiar with Lean than the industry as a whole, a large percentage, ranging from 39% to 64%, are not familiar with these individual approaches.** This clearly demonstrates the need for the industry to aggressively promote the tools that specifically help with the construction process.

### Practices That Enhance Collaboration

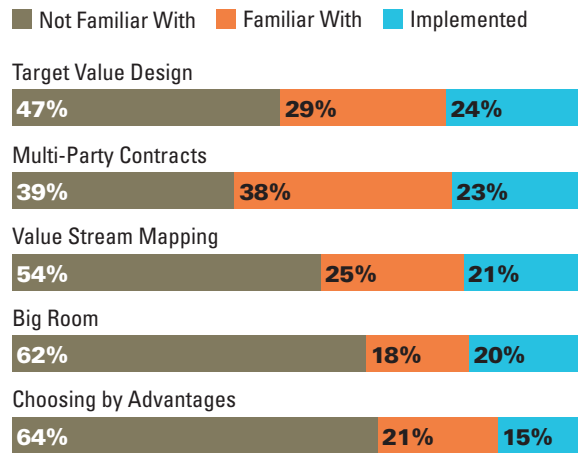
While none of the practices are widely known, the greatest level of awareness and use occurs for the practices that emphasize collaboration. Three out of five of the additional practices included in the survey encourage firms to be more collaborative, and two out of those three are the most widely known of the five practices.

**This finding is reinforced by the findings of the in-depth interviews with Lean experts, who recognize collaboration as critical to the practice of Lean.** It also supports a general trend in the construction industry toward greater collaboration, especially among contractors. In fact, the findings of the recent *Information Mobility SmartMarket Report* reveal that both general and specialty trade contractors are expecting to collaborate more with design firms and owners than they currently do, demonstrating their recognition of this growing trend. (See page 55 for more information.)

One possible reason that the practices that enhance collaboration may be more widely recognized is that many firms that have not adopted Lean practices themselves may have worked with Lean companies that have, especially in these collaborative ways. **As the in-depth interviews suggest, Lean firms are often advocates for the Lean process among other construction companies, either actively to improve their own processes, or by example in the benefits they reap from their Lean approach (see page 24).**

### Familiarity With and Implementation of Additional Lean Construction Practices

Source: McGraw Hill Construction, 2013



### TARGET VALUE DESIGN (TVD)

TVD is a collaborative approach in which the entire project team uses the owners' targets for budget, life-cycle costs, sustainability, operations and other factors as the basis around which to build the design for the project. **The percentage of respondents using TVD edges out multi-party contracts, but it also has the second highest level of recognition of the practices surveyed,** which suggests that many who know about it are still not actively engaged in using this approach.

### MULTI-PARTY CONTRACTS

**Multi-party contracts, in which all project team members share the risks and rewards of the entire project, are the most well known of all the practices.**

This is no doubt due to the level of attention given to encouraging greater collaboration by all sectors of the construction industry, from design to construction associations.

**However, despite the fact that the highest percentage of respondents are familiar with multi-party contracts of all the practices included in this question, the percentage that have used them (23%) is roughly equivalent to three out of the remaining four practices.** This finding is not surprising, given the debate around some existing multi-party contracts that they favor one player over the rest and the concern over increasing their exposure to risk that many firms associate with legally binding collaboration.

Trade contractors that participated in the in-depth interviews note that having a contract that favors Lean, which would include one that shares risk across multiple players, is a critical factor for improving efficiency in the construction industry (see page 19).

### **BIG ROOM**

This practice, which involves physically co-locating an entire project team in one location to enhance collaboration, whether for the duration of the project or for initial project planning, has a very high percentage of contractors (62%) that are not familiar with it. **On the other hand, it has the lowest percentage of firms (18%) that are familiar with it but have not used it, and it is utilized by almost the same percentage (20%) as the other two practices, which are far more widely known.** This suggests that it is possible that once firms become familiar with this practice, they typically engage in it, at least to some degree.

This finding does imply that wider adoption can be expected in the future, as firms not familiar with this practice get invited into the big room by more advanced Lean practitioners. Direct experience of the benefits gained can be a powerful way to promote a new approach like using a big room.

## **Other Practices**

### **VALUE STREAM MAPPING**

Just under half of the respondents are familiar with value stream mapping, a technique for finding efficiencies in individual work processes. (For an example of value stream mapping, see the case study on page 20.) The remainder are nearly split between those that are familiar with it and those that actually have used this approach.

Like many Lean practices, value stream mapping requires a commitment of additional time before construction and therefore before the full benefit can be experienced. While these benefits can far exceed the investment of time required, a firm must be able to commit the upfront man hours, which may often require that they have other Lean practices already in place to effectively manage the project schedule.

### **CHOOSING BY ADVANTAGES**

Choosing by Advantages is an approach to decision-making first published in 1999. It has the lowest level of familiarity among the respondents and the lowest level of implementation as well.



## Practices Adopted to Increase Efficiency

While taking a formal Lean approach is relatively new to the construction industry, many of the practices that are intended to increase efficiency have been adopted for a longer period of time. **Long before they considered themselves to be pursuing Lean, firms have been using frequent, regular meetings with workers onsite, prefabrication and optimization of crew sizes, and the data reveal that a large percentage of respondents have been employing these practices for more than three years.**

### Practices Undertaken for More Than Three Years by Most Respondents

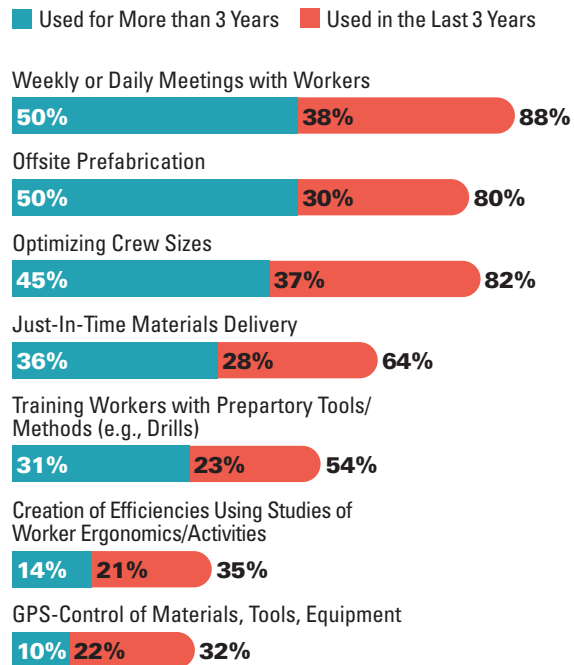
The wider industry adoption of these three practices is also evident among the firms that have not implemented Lean. (See chart on the following page.)

- **Weekly or Daily Meetings with Workers:** Site meetings used to bring efficiencies to the worker level may be associated with Lean, but firms seeking to improve safety practices rather than eliminate waste may also focus on frequent site meetings.
- **Prefabrication:** The *2011 Prefabrication and Modularization SmartMarket Report* revealed that 84% of the contractors included in that study used prefabrication or modularization. This is roughly consistent with the findings of this report, with 80% of contractors using prefabrication. Clearly, with such a high percentage of firms, this is not a practice associated solely with Lean. **However, as the Lean expert in-depth interviews reveal, many Lean firms find prefabrication to be an essential strategy to eliminate waste in their construction processes. (See page 17.)**
- **Optimization of Crew Sizes:** It is not surprising that most contractors, especially those not familiar with any Lean practices, would feel that they optimize the size of their crews. However, to truly gain efficiencies, there are clear advantages to gathering additional input from approaches such as pull planning and to rely on data rather than previous experience. Firms implementing Lean may be more likely to make this distinction, which may explain why the highest percentage that report engaging in this practice are those unfamiliar with Lean.

**One additional practice reported widely by firms that have not implemented any of the key Lean practices is training workers with preparatory tools and methods.** While the percentage of Lean practitioners is slightly higher, the difference is not statistically significant. A larger percentage also report having used this approach

### Advanced Practices to Achieve Efficiency Used by Contractors

Source: McGraw Hill Construction, 2013



for more than three years versus those that have been using it a shorter period of time.

Again, these kinds of preparations may not always be focused on eliminating waste, even if they help achieve that. Contractors may also prepare workers for safety reasons, and some firms with an advanced green/sustainable practice may also spend additional time preparing workers to handle green technologies for maximum impact on building performance.

The one practice that has a higher level of use among Lean practitioners that is statistically significant and that has also been in use for more than three years by a larger percentage of respondents is Just-In-Time material delivery. This finding suggests that this is one of the earlier Lean practices to be adopted in the industry.

### Practices Adopted by More Respondents in the Last Three Years

**Not surprisingly, the practices that have been adopted more recently—studies of worker ergonomics/activities and GPS tracking of materials, tools and equipment—are also those more reliant on effective data gathering.**

The 2013 *Information Mobility SmartMarket Report* suggests that the ability to gather and analyze data from the construction site has been increasing with new tools and systems supporting those efforts, although it also reveals that better tools are still needed to support these efforts.

■ **Studies of Worker Ergonomics/Activities**  
Analyzing data on worker ergonomics/activities can be a time-consuming, manual task without the right tools. **It can also be critical to find efficiencies at the worker level and to find new processes, as the the Lean experts in the in-depth interviews reveal. (See page 18.)** This may explain why 50% of Lean practitioners report engaging in this activity, more than double the percentage of respondents that have not implemented Lean.

■ **GPS Tracking of Materials, Tools and Equipment**  
The data suggest that this is still an emerging practice among Lean practitioners and non-practitioners alike. Again, to use this information to find efficiencies, it is essential to be able to analyze this data, not just to gather it on individual projects.

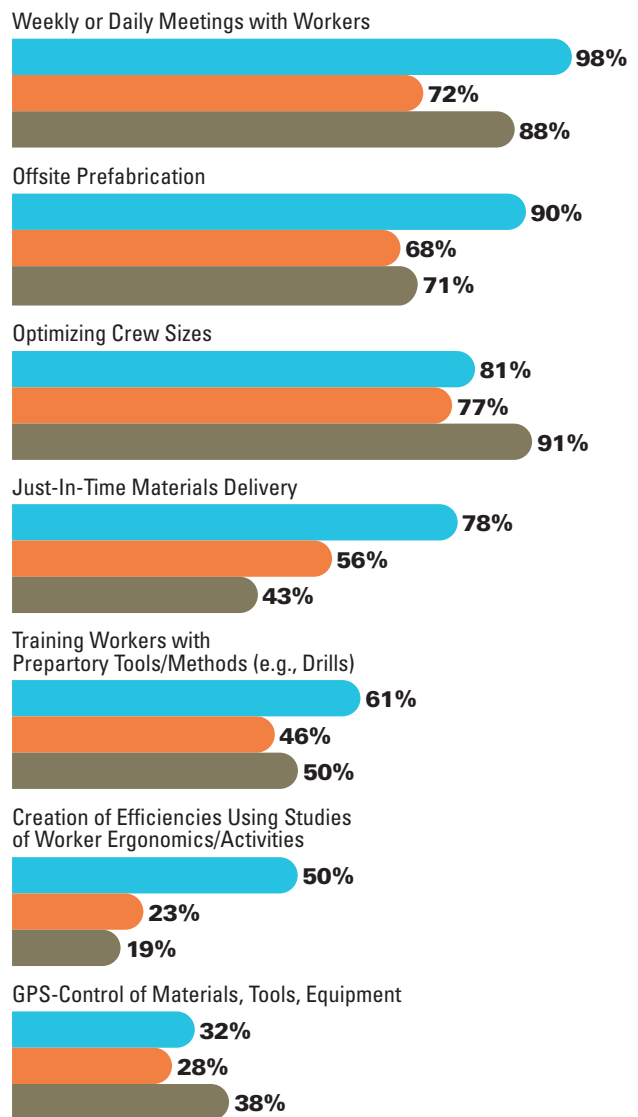
**Practices Not Undertaken by Respondents**

It is noteworthy that, even among the Lean practitioners, none of the respondents report using 4D schedule modeling or 5D cost modeling. **The Lean experts interviewed in the in-depth interviews frequently mention the importance of BIM to implementing Lean at their firms. (See page 17.) While a few of these experts do report doing 4D schedule modeling, the larger survey results reveal that this is still a highly limited practice.**

**Advanced Practices to Achieve Efficiency Used by Contractors (By Level of Lean Engagement)**

Source: McGraw Hill Construction, 2013

- Implemented Lean Practices
- Familiar with Lean Practices
- Not Familiar with Lean Practices



## In-Depth Interview Findings: Adoption of Lean Practices

**In-depth interviews with Lean experts reveal efforts that they have used to improve efficiency, the opportunities they see for further improvement, and the specific Lean systems and tools that they adopted.**

In the effort to bring Lean to the industry, contractors are employing a broad mix of principles, processes and tools for Lean construction. While there are some more commonly adopted means and methods, many companies are seeking their own unique solutions. Lean principles are also being applied by companies at various levels—from the field to the back office. Given the broad and diverse approaches, companies are learning that there is “no silver bullet” for being Lean.

### Efficiency Efforts

#### GENERAL CONTRACTORS

During the past five years, general contractors (GCs) who have adopted Lean principles and practices have focused their efficiency efforts mostly in the field. However, some advanced users are applying those principles to their business processes as well. In the coming years, these GCs expect to expand those efforts at the corporate level. Examples of efficiency efforts mentioned by GCs include:

- **Better planning:** All GCs said that improved planning efforts were central to their Lean strategies. All had used The Last Planner System® for production planning in the field.
- **Advanced modeling:** BIM has become an increasingly common tool among GCs, and some emphasize that advanced uses of BIM facilitate Lean efforts when

planning and detailing work. In particular, GCs noted that detailed modeling is central to coordinating and detailing offsite prefabrication.

- **Prefabrication/modularization:** Most GCs said they were pushing for more offsite prefabrication on their jobs, either from their own craft workers or subcontractors.
- **Centralized data:** At both the project and company level, GCs are looking to centralize their data so that it can be easily shared. Most struggle with integration issues, and some employ custom solutions to enable sharing.
- **Better preconstruction:** Most GCs focus on improving their preconstruction processes. **Two GCs said they had reduced the time from start of preparation to site mobilization by more 75%.**
- **Collaborative delivery:** Beyond being Lean in their own practices, GCs push for collaboration among multiple partners on the project team to improve the level of efficiency for the entire project. Some GCs note the need for more owners to embrace these delivery methods.

#### SPECIALTY TRADE CONTRACTORS

Specialty trade contractors are engaged in many of the same approaches to improve efficiency as the GCs, including better planning, advanced modeling and collaborative delivery. **The trade contractors also place even greater emphasis on prefabrication as a critical portion of**

**their efficiency efforts than the GCs do,** with nearly all the respondents emphasizing this as a key strategy.

**A critical difference between the general and trade contractors is that trade contractors place more emphasis on the work of the employees.** Daily work or project assessments are also mentioned by trade contractors as key strategies, and these efforts are typically linked with an emphasis on improving safety as well as efficiency.

### Areas of Opportunity for Greater Efficiency

#### GENERAL CONTRACTORS

While GCs are making improvements in their field efforts, most say they see a lack of company-level efficiencies in their approaches. Areas that GCs say could be improved include:

- **Internal process improvement**
- **Better top-down support to facilitate widespread adoption**
- **Better integration with partners**
- **Better automation of business processes and reporting**
- **Company reorganization to align with Lean strategies**

#### SPECIALTY TRADE CONTRACTORS

Trade contractors also express concern about consistent, company-wide application of the practices to increase efficiency. At least one attributes this concern to the fact that they still consider themselves relatively early in the process of adopting these more efficient practices.

Another factor highlighted as hugely impactful by one respondent is the lack of full commitment to scheduling and to the use of appropriate scheduling tools by other project team members. (See the discussion of the Last Planner System on page 19 for more information.)

Other areas mentioned by trade contractors for improvement include:

- **Making office work processes more efficient, similar to their efforts in the field**
- **The process of work acquisition**

## Means of Improving Efficiency

### GENERAL CONTRACTORS

To improve existing processes and capitalize on future opportunities, contractor strategies include:

- **Creating more “Lean champions” in the company to help spread adoption**
- **Increased training at the level of company and project**
- **Better collaboration with suppliers and subcontractors**

### SPECIALTY TRADE CONTRACTORS

Trade contractors seek more “collaborative and coordinated involvement among all the stakeholders,” without which projects do not see the full benefits of more efficient approaches. One notes that having a contract that supports Lean behavior can be a critical means of improving the types of practices engaged in on their projects.

They also agree that company management plays a crucial role in the adoption and implementation of efficient practices in their firm. For them, the biggest opportunity is leadership support for building an efficient culture, which can eventually

lead to “bottom-up” engagement as well.

In general, though, trade contractors focus more on factors outside their firm than within it as the necessary means for improving efficiency. This includes the need for more examples of the successful adoption of efficient practices, especially on the office side of the business, and the need for owners to mandate adoption of Lean practices. The schedules of trade firms depend on those of other trades, which may account for their heightened attention to the impact of other firms on their efficiency.

### Field Studies

GCs have mixed views about examining field efficiency. Two GCs say that they do work observations to examine things like flow and ergonomics. Two say that they have examined workers as part of studies on prefabrication. At a higher level, GCs note doing production studies in conjunction with efforts to improve planning, but they do not mention taking a detailed look at workers.

Two of the four trade contractors report conducting field study at a detailed level. One has done value stream mapping of individual tasks (see glossary on page 3), while the other conducts first-run studies, which involve having workers complete a cycle and then inspecting the process, having them complete a second cycle and inspection, and then continuing to double the number of cycles between checks, from 2 to 4 to 8 and so forth, in order to continue to seek improvements.

## Lean Construction Approaches

### GUIDING PRINCIPLES

As Lean has its roots in manufacturing, some have turned to approaches that are rooted in those industries. (For a definition of these terms, see the glossary on page 3.)

- **Toyota Way:** While most experts said they are familiar with the set of Toyota Way principles, they tend to “pick and choose” aspects of it that apply to their businesses. For example, some mentioned that respecting individuals and striving for continuous improvements—which are central in Toyota Way—are important precepts in their organizations. Other principles of Toyota Way, like solving root problems, can be seen in the systems they use, such as Last Planner.
- **Six Sigma:** Similarly, Six Sigma strives to identify and solve root problems. Although Six Sigma is a system that offers tools and strategies for process improvement, there is limited adoption of it by companies. Again, some say they may follow certain aspects that relate to their businesses, but not others. “Six Sigma tends to be a bit more manufacturing, and I don’t think we find it as applicable in our business,” says one contractor. A trade contractor also notes that while industrial construction has embraced Six Sigma, “the commercial industry isn’t sophisticated enough to really embrace it,” and he notes that instead they rely on systems like Last Planner.



**SYSTEMS AND TOOLS**

Other Lean approaches have seen strong adoption.

■ **Just-In-Time delivery:**

Also rooted in manufacturing, Just-In-Time delivery has been adopted by all of the expert GCs and trade contractors, with some saying that they have been using it for more than a decade. Trade contractors point out that a collaborative approach with the application of Lean principles by all stakeholders is essential to the success of Just-In-Time.

■ **The Last Planner:**

Developed as a production planning system for the design and construction industry and licensed by the Lean Construction Institute, The Last Planner is a critical tool in Lean construction, according to experts.

- All have either adopted it widely across their respective companies or have used it on some projects.

Users identified a few challenges with using The Last Planner system.

- Resistance from other stakeholders
- Pushes more planning effort upstream/time-consuming for management
- Lack of education
- Users not fully implementing all aspects of the system, leading to incomplete analysis.

**Trade contractors are particularly impacted by firms not implementing all aspects of the Last Planner System.** One respondent cautions that many firms “stop short” in their use of Last Planner. They create a schedule but then do not make firm commitments or do not get it into their project management software. Both of these omissions prevent their

efforts from fulfilling the Last Planner requirements, and changes are not cascaded to other players in ways that allow them to factor them into their planning for the project.

**Advanced Lean Approaches**

**GENERAL CONTRACTORS**

Examples of more advanced tools and techniques discussed that can be applied to Lean construction include:

- **Value stream mapping**
- **5S for workplace organization**
- **A3 for problem-solving**
- **Multi-trade prefabrication**
- **Modularization**

When it comes to implementing practices in the field at the worker level, GCs say that while they may put weekly or daily work plans together for crews, particularly as part of The Last Planner System, there is limited direct engagement with workers about their tasks.

- **Two GCs say field staff conducts short daily meetings with workers to outline project activities and point out safety concerns.**
- **One contractor says it took part in a university study looking at the work of individual laborers.**
- **One contractor says it rehearses tasks with workers to prepare them for tasks**

**SPECIALTY TRADE CONTRACTORS**

Many of the factors identified by the GCs as more advanced tools and techniques are included by the trade contractors as their key efficiency practices, including multi-trade prefabrication.

**Most critical to the trade contractors, though, is working with the field.** In addition to “stretch and

flex” daily meetings and formal value stream mapping of field work, several report looking at the work done in the field, down to component-level data. One reports doing work packaging, in which the packages are created for just a week’s worth of work for one or two people. This level of detail allows the crew to predict their percentage of completion of tasks with great accuracy, which allows for better use of a CPM schedule.

One firm tests each new hire to determine their skillsets, capabilities and limitations. This provides them with a baseline for making immediate worker assignments and reveals opportunities for training.

**The trade contractors also report creating value through collaborative approaches with other trades on their projects,** which one defines as “optimizing the whole and increasing relatedness.” As one contractor explains, “For our pipe fitter to be more efficient, we have to be in-sync with how the sheet rocker is doing their work because they can ruin our efficiencies in a heartbeat.”

**For at least one trade contractor, though, the issue isn’t the adoption of a specific practice but the opportunity to take a more holistic approach.** Rather than just pursuing incremental improvements of the existing process, he is attempting to redesign processes fundamentally by looking for a “radically different way to work.” To tackle this approach, he reports that they have run pilot experiments in their engineering group, in which they capitalize on the younger employees, who are not only less “embedded in the current processes,” but who can also think differently in terms of the ways technologies, like apps, might transform the current process. ■

# Achieving Savings Through Value Stream Mapping

## UCSF Cardiovascular Research Building

SAN FRANCISCO, CALIFORNIA

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY

Rosendin Electric was challenged by the project owner to look at ways to bring their projects even more under budget. As a firm that prides itself on innovation and one that strives to remain on the cutting edge of technology, Rosendin tasked one of its in-house study groups to come up with ideas that would be able to save time and cost. As a result, one of the approaches they decided to pursue was Value Stream Mapping (VSM).

### Process Improvements Identified Through Value Stream Mapping

VSM, in its simplest term, sets out to observe every step of a process and identifies areas where improvements can be made to eliminate waste. The technique was first originated by Toyota and is a lean tool that employs a flow diagram documenting in high detail every step of a process.

The process they chose to study was the installation of pendant-hung

fluorescent lights at the Cardiovascular Research Building at the University of California in San Francisco (UCSF). As a first step, they needed communication to come from upper management to let the workers know that the VSM study was looking for improvements in the process and that it was not a judgment on anyone's work. The communication also let the workers know that they were open to their ideas and feedback on how the process could be improved.

Joseph Leoncavallo, assistant project manager and one of the leaders of the VSM study, says, "We communicated to them that we didn't want them to install the lights any faster than they normally would just because we were there watching them with a stopwatch and a piece of paper and writing down everything that they did. So it's really important to have that honest conversation with the guys working in the field, first."

The management team, as a result, got very positive feedback from the

field. They were excited to be part of a process and to see what could be done going forward. Bob Weisman, senior estimator at Rosendin states, "The field team want to be successful and to do things the best way for themselves and the company. And we're giving them buy-in. We're not telling them they have to do this; we're saying: 'what do you think?' And that's a big, big deal when you ask people what they think."

### Each Step Taken Into Account to Identify Waste

The VSM started with setting up an observation record where a list of every activity was recorded along with notes. The group started documenting every step of the process, including activities that workers might not ordinarily consider when they are estimating time spent, including answering a question from someone, bathroom breaks and grabbing a wire nut. The whole

Light fixtures installed through a more effective process



Photographs Courtesy of Rosendin Electric

CONTINUED

## UCSF Cardiovascular Building SAN FRANCISCO, CALIFORNIA

process from start to finish was recorded. The group repeated the process four or five times to get a good understanding of the installation process.

As a next step, the current state map was created, which involved taking the observation record and putting it down as a process map. The map essentially provided a high-level overview of every step of the process. After all the steps were mapped out, the group went back and looked at the amount of time each step took. Two levels of time were recorded, non-value-added time and value-added time. Value-added time is considered time that is spent directly contributing to the installation of the light fixture, such as physically hanging the fixture. Non-value-added time, on the other hand, is considered something that could be done in the factory such as installing an end cap, or it could be opening a box, a necessary activity, but one that does not directly contribute to the light fixture being hung.

The team then analyzed each step in the process and identified areas where processes could be improved and waste eliminated. These areas of improvements were displayed on the map in highlighted yellow, a Lean technique known as Kaizen bursts. The areas of improvement that were identified included nine steps in the process that could be eliminated as a result of getting the fixture prefabricated by the manufacturer.

### Prefabricating Provides Key Opportunity for Savings

Next, the team incorporated the Kaizen bursts into a future state map that displayed the improved process

for installing the pendant-hung fluorescent lights. According to Leoncavallo, "We were looking at about 22 minutes of time that could be eliminated from each fixture installation, most of it due to eliminating the on-site [work on just one component of] a single fixture. Some of that time was non-value added, and some of it was value added."

Rosendin communicated to the manufacturer their need to prefabricate the desired fixture and were not met with resistance. The manufacturer had the capability to undertake this for them and wanted to maintain Rosendin's business, so in the end, they included the additional steps in their agreed-upon scope of work with no additional charge. While the advantage of being a big player was certainly a factor in the manufacturer's cooperation in this process, this is potentially an approach that any firm could benefit from. Leoncavallo says, "I think [the decision of the manufacturer to cooperate is made on] a case-by-case basis, but I think the biggest lesson there is, if you don't ask for something, you'll never know."

### VSM Study Results in Project Budget Reduction

The time saved on this project as a result of prefabricating the light fixture resulted in the opportunity to reduce the project budget as the team had set out to do. Weisman says, "I was convinced that we could at least save 15 minutes per fixture on 2,000 fixtures. So 15 minutes times 2,000 comes to 500 man hours, and our labor rate is close to \$100 an hour. So I was able to lower my budget by \$50,000."

According to Weisman, the

\$50,000 savings against an overall project budget of \$100 million was still considered significant by the owners. Especially when taking into account that overall only approximately \$2,000 was spent on the VSM study, the time spent by the person conducting the study.

### Value of the Process

Leoncavallo finds the value of this process exceeds the cost savings. "It gives you an opportunity to go out there, observe, really see what's going on and eliminate waste, which is going to improve your flow and productivity. It deepens the knowledge of the installation process .... And the other thing is, it really improves communication between the field and management because you're collaborating together on this solution." ■

#### Project Facts and Figures

**Electrical Contractor**  
Rosendin Construction

**Type of Project**  
Research Building (Higher Education)

#### Impact of Using Value Engineering

- Investment in conducting study: Approximately \$2,000
- Savings resulting from improved process for installing light fixtures: \$50,000

stats

# Data: Lean Benefits and Drivers

## Efficiency of Construction Processes

in the Industry and at Individual Firms

### Efficiency of Construction Processes in the Construction Industry

Much of the discussion around the need for greater adoption of Lean in the construction industry presumes a shared belief that the industry suffers from inefficient processes. The assumption that the industry needs to improve its processes underlies the efforts to encourage cultural change in organizations and to invest in greater upfront costs in planning and scheduling.

The study results, however, reveal a strong contrast in the perception of the efficiency of the industry between Lean practitioners and firms unfamiliar with Lean. **Sixty-two percent of the firms that have implemented Lean practices find that the industry as a whole is inefficient, compared with just 14% of firms that are not familiar with Lean.** In addition, 55% of firms not familiar with Lean find the industry to be efficient/very efficient.

**This finding is significant because it demonstrates that to encourage wider Lean adoption across the industry, simply demonstrating the benefits of using Lean practices may not be enough.** The industry as a whole is unlikely to be willing to commit to the paradigm shift involved in full Lean implementation unless most contractors agree that the need for such an approach is evident.

### Efficiency of Construction Processes at the Respondents' Firm

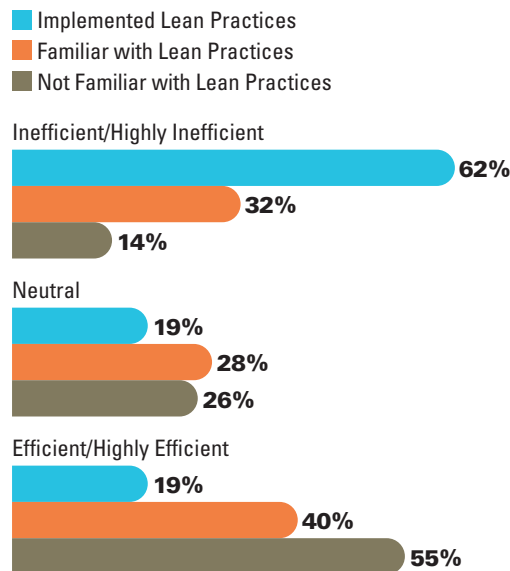
**Sixty percent of all respondents consider their firms efficient or very efficient.** In contrast to their evaluation of the industry, there is also no statistically significant difference in the firms' evaluation of their efficiency, based on their level of engagement with Lean.

It is worth noting that Lean practitioners are more skeptical about the efficiency of their firms than the other respondents, with 55% finding their firms efficient compared with 69% of those not familiar with Lean. This may at first seem surprising since these are the firms that have implemented practices designed to eliminate waste. However, not only are these firms more attuned to the waste inherent in construction processes, many are also gathering data on the effectiveness of their current processes. Therefore, **Lean practitioners may have a greater awareness of the inefficiencies they still need to tackle. This conclusion is supported by the in-depth interview with Lean experts, most of whom are still actively engaged in seeking out opportunities for greater efficiency.**

### Efficiency of Construction Processes in the Industry

(By Level of Lean Engagement)

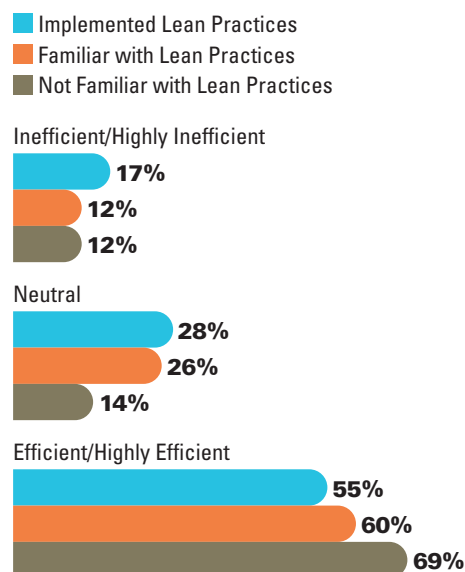
Source: McGraw Hill Construction, 2013



### Efficiency of Construction Processes at Respondent's Firm

(By Level of Lean Engagement)

Source: McGraw Hill Construction, 2013



LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY DATA



## Influence of Concerns About Skilled Worker Availability on the Decision to Undertake Lean

Nearly all (92%) of the Lean practitioners express at least some concern about the availability of skilled workers. The severe level of layoffs in the construction industry during the recession masked the growing shortage of skilled workers entering the field, and in the long run, the recession no doubt exacerbated the problem. The factors contributing to this workforce shortage, discussed in the 2012 *Construction Industry Workforce Shortages SmartMarket Report*, are many and include the retirement of the current generation of leaders and the lack of interest in construction as a profession by the next generation.

Over two thirds (67%) of those that are concerned about the availability of skilled workers agree that these concerns had an impact on their decision to pursue Lean. Lean approaches reduce the need for a skilled workforce in a couple of ways.

- **Less skilled work required onsite:** The use of prefabrication can result in the use of a “kit of parts” onsite, rather than assembling complicated components from scratch, and putting together a kit of parts can be done with fewer skill requirements.
- **Fewer workers:** The precision of planning and improved efficiencies in worker activities ultimately can result in requiring fewer workers to complete individual projects.

It is notable that one quarter of the contractors find that these concerns had a major impact on their decision to implement Lean practices. **However, this finding is at odds with the responses of most of the experts from the in-depth interviews. None of the general contractors regarded workforce concerns as major drivers. Among the trades, the responses were divided, with some regarding this as the least important factor driving them to Lean and another reporting that the reduction of their workforce needs through Lean was necessary for them to pursue work in certain, labor-constrained markets.**

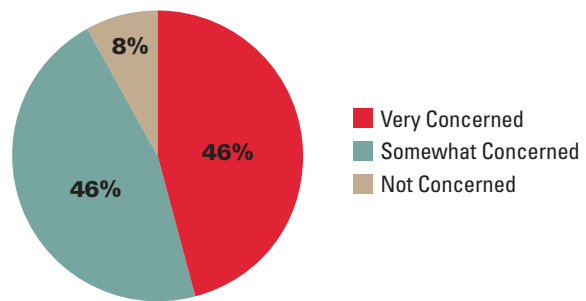
For the Lean practitioners in the survey, though, the alternative of using unskilled workers with some additional training has limited appeal. Twenty-three percent are unwilling to do so, and 53% are only somewhat willing to take this alternative. This finding suggests that, as workforce concerns increase, it may become a more significant driver for firms to pursue Lean in the future than it has been for the companies now implementing Lean practices.

### Influence of Concerns About Skilled Worker Availability on the Decision to Undertake Lean

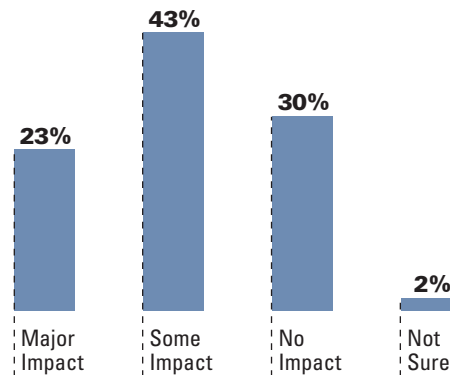
(According to Lean Practitioners)

Source: McGraw Hill Construction, 2013

Degree of Concern About Availability of Skilled Workers (According to Lean Practitioners)



Impact of Concerns about Skilled Worker Availability on Decision to Undertake Lean (According to Lean Practitioners Concerned About the Availability of Skilled Workers)



## In-Depth Interview Findings: Drivers for Lean

**Client satisfaction, improving their firms, being seen as leaders and specific business benefits all have a high degree of impact as drivers of Lean. In addition, while efforts to employ Lean need to be instituted by firm leadership, field workers need to actively adopt these principles for implementation to be successful.**

**B**usiness goals drive Lean adoption. Among the varied reasons that companies adopt Lean practices in construction, many are related to how a company is perceived in the marketplace, including the need to stay ahead of the competition and the desire to be seen as a leader in this area. These reasons, along with client influence, could also help companies secure contracts.

Trade contractors also mention the desire to work collaboratively and the ability to ensure constant improvement as key drivers for their businesses.

Other drivers relate directly to the desire to reduce waste, such as cutting costs and reducing projects schedules.

### Important Drivers for Lean

#### CLIENT INFLUENCE

Clients play a critical role in driving the use of Lean practices on construction projects. All GCs cite client influence as a driver with one third identifying it as the most important driver. Some note that healthcare clients have taken a lead role in pushing teams to pursue Lean. While client influence is important, one GC says that client influence plays a much stronger role when a company launches its initial Lean pursuits. “We’re implementing [Lean] regardless of whether our clients ask for it or not,” the contractor said.

One trade contractor regards client influence as a critical factor now,

but finds that this is the result of an industry shift over the last 10 years.

#### NEED TO INCREASE PROFITABILITY/CUT COSTS

GCs are split on the importance of using Lean to cut costs. Two identify it as the most important driver of Lean adoption. Since the recession, fees for GCs have been depressed, and GCs need to cut costs to stay competitive, according to one contractor. Another says that while cutting costs through Lean is always a factor, it is not a primary driver of its use. One contractor says cutting costs is not a driver at all and ranks it last among the list of potential drivers.

For trade contractors, the need to stay competitive is a far more prominent influence than the desire to increase profitability or cut costs.

#### LEADERSHIP INTEREST IN THIS AREA

All GCs interviewed would like to be seen as leaders in Lean construction, in large part as a way to demonstrate that they are innovative firms, developing new means and methods. Clearly, this could be beneficial when pursuing work from clients who are committed to Lean principles. Trade contractors place less emphasis on this area.

#### NEED TO KEEP UP WITH/AHEAD OF COMPETITION

All GCs report that staying ahead of the competition is an important driver for adopting Lean construction practices. “Anytime we get an

RFP and it has something Lean in there, we have to show proficiency because we know other bidders will as well—it’s absolutely a driver,” one contractor said.

Trade contractors are unanimous in the importance of this factor as a driver for them, the only factor with that much influence across all the trade respondents.

#### CONCERNS ABOUT WORKER SAFETY

Over the years, GCs have paid increasing attention to safety concerns, and the prospect that Lean practices could improve safety is appealing to many experts. Three GCs identified safety as a driver for adopting Lean practices. But opinions are mixed. One notes that while the company recognizes that improved safety can be an outcome of Lean, that factor does not drive its pursuit of Lean means and methods.

At least one trade firm attributes their initial interest in improved safety as a prime driver for their adoption of Lean practices because the approach to eliminating safety issues is to examine processes closely, and it therefore yields efficiencies as well. Otherwise, their response to safety mirrors that of the GCs.

#### NEED TO DECREASE PROJECT SCHEDULE

Through focused and detailed planning, many GCs aim to tighten up project schedules. Three GCs identify it as a driver with one saying it is

a factor in its approach “especially in using Last Planner and production planning.” One contractor argues that it was not a driver for them and added that it “would be a silly reason to do it.”

Only one trade contractor considers decreased project schedule as a key motivator for their adoption for Lean, but only in terms of the way in which it allows them to compete more effectively and be less impacted by schedule changes foisted on them by firms upstream in the construction process.

#### **IMPROVED SUSTAINABILITY/ BETTER GREEN RESULTS**

**While improved sustainability can be an outcome of Lean practices, GCs are divided in their views of it as a driver.** Two identify the prospect of improved sustainability as a driver. One contractor notes that his company has reduced its construction site waste by half since adopting Lean methods.

One expert, who oversees Lean adoption at his company, says he regularly works with executives in charge of sustainability measures. “We’re trying to take sustainability to this [higher] level. You need new methods to get there and this is one of them,” the contractor said. Two GCs report that while it is an outcome, it’s not a driver. “Sustainability and green are important to us but for different reasons than Lean,” said one contractor.

#### **WORKFORCE CONCERNS (AVAILABILITY OF SKILLED LABORERS)**

**GCs generally do not see workforce concerns as a driver for Lean adoption today.** No GCs identifies it as a driver. One says that while availability of skilled labor is a long-term

### **“Our superintendents need to be the ones driving [Lean]. If not, you can forget it.”**

concern, it is not a short-term driver of Lean.

**Trade contractors are more divided.** While one regards this as the least influential factor discussed, while another describes the specific example of a project in which, without the ability to reduce their workforce onsite, the scarcity of skilled laborers would have prevented them from pursuing the job.

#### **Drivers to Pursue Beyond Typical Lean Construction Practices**

As companies look to expand the menu of options available to make their projects and organizations more efficient, many of the same drivers apply. Experts noted that their reasons for adopting these principles have evolved over time. For many companies that have pursued Lean construction projects for several years, the initial efforts were focused on the field. **As those practices have taken hold, some firms note that they are doing more to drive Lean principles at a company level.** “There’s an understanding that you have to get beyond the cookbook Lean approach and the focus on tools,” said one GC. “It’s about looking at it as a management philosophy, which means you apply that to your entire organization.” A trade contractor concurs, “Early on, it was about using tools, and today it is about culture.”

In the coming years, some GCs predict that their drivers will evolve, especially as clients become more knowledgeable about Lean and expect it on their projects. Trade

contractors expect similar drivers to be in place, but with more data, less proselytizing will be necessary by firms engaged in Lean to persuade their project partners.

#### **The Role of the Field in Pursuing Lean**

General and trade contractors recognize that workers in the field play a critical role in driving use of Lean construction practices. Companies have taken a variety of paths to adoption. In some cases, project managers and superintendents independently pursued Lean concepts. In other cases, upper management initiated the strategy, calling on the field to implement Lean.

**Whether it was a top-down or bottom-up approach to initiating the pursuit of Lean, all contractors generally recognize that field workers have to champion the cause for it to be effective.** “Our superintendents need to be the ones driving it,” said one expert. “If not, you can forget it. We absolutely have field leadership who believes it. They’ve seen the benefits on project sites, and they are insisting on continuing the path forward.” Simultaneously, management serves to support those efforts, providing the necessary tools and training resources.

As field workers become more proficient in Lean practices, GCs expect workers in the coming years will refine their processes and make more incremental improvements to these means and methods. ■

## Benefits Achieved From Implementing Lean Practices According to Lean Practitioners

Over 70% of Lean practitioners report that they have achieved at least a medium level of achievement on six benefits included in the study, all of which have significant business implications. In order by percentage selected, they are higher quality construction, greater customer satisfaction, improved safety, greater productivity and better risk management. Four other benefits rank in the high sixties. This is clear evidence that investments in Lean see strong returns.

Higher quality construction is reported by a larger percentage of those doing four or more Lean practices (92%) than those that are doing three or less (75%). This finding suggests that a more comprehensive approach to Lean allows better achievement of this benefit.

In addition, over one third note high levels of achievement for four of the top benefits. Safety tops this list. In the in-depth interviews with Lean experts, many find that the careful attention to planning and process to eliminate waste and the focus on the work of the individual worker also have strong safety impacts. One trade firm also reports that their efforts to improve safety initiated their Lean implementation (see page 25).

The percentage that report improved customer satisfaction is also quite high. This is not surprising since many of the other factors on which a large percentage report a high level of achievement, such as higher quality construction, reduced project schedule and reduced cost often directly impact their clients. (See pages 29 and 30 for more information on how contractors view the degree to which project owners are the beneficiaries of reduced schedules and costs.) This finding aligns with the key finding in the in-depth interviews with Lean experts that increasing their overall competitiveness is the main benefit that firms achieve by adopting Lean, significantly more important than schedule or cost savings on individual projects (see page 33).

The benefits gained by the owner rather than the contractor may explain why greater profitability/reduced costs has a lower percentage of firms reporting a medium level of achievement than many other benefits, but a comparatively greater percentage reporting a high achievement. This may suggest that firms either rate this highly because the savings from eliminating waste accrue to their bottom line or they are less likely to rank it well at all because they do not see the direct benefits. As owners gain in familiarity with Lean, it is likely that their expectations of performance in this area will continue to increase, so it is important for the industry to recognize

### Benefits Achieved From Implementing Lean Practices (According to Lean Practitioners)

Source: McGraw Hill Construction, 2013

■ High Level of Achievement ■ Medium Level of Achievement



that greater competitiveness rather than greater profitability is a critical benefit of Lean.

A significantly higher percentage of those implementing four or more Lean practices also report seeing improved sustainability/reduced waste (78%) and improved lifecycle cost (58%) than those doing three or less. These findings suggest greater awareness of benefits less commonly associated with Lean by more sophisticated Lean practitioners.

## Benefits Expected by Lean Practitioners When They Implemented Lean Practices

Lean practitioners initiated Lean practices at their firm with a high expectation of achieving greater productivity. Nearly all (98%) expected to see at least a medium level of improved productivity, and 81% expected to see high productivity improvements. It is critical to note that a large percentage of contractors (77%) do report achieving productivity improvements (see page 26), but that productivity also ranks much lower in terms of the benefits achieved than factors like higher quality construction and customer satisfaction, especially when considered at a high level. It is critical that companies interested in adopting Lean practices in the future have a more tempered expectation when it comes to productivity.

On the other hand, contractors' expectations are more strongly aligned when it comes to the importance of quality and customer satisfaction. Both of these rank highly in the achieved benefits and the expected benefits. Clearly, gaining a competitive advantage is recognized from the onset by these firms as an important benefit they can expect from their Lean adoption.

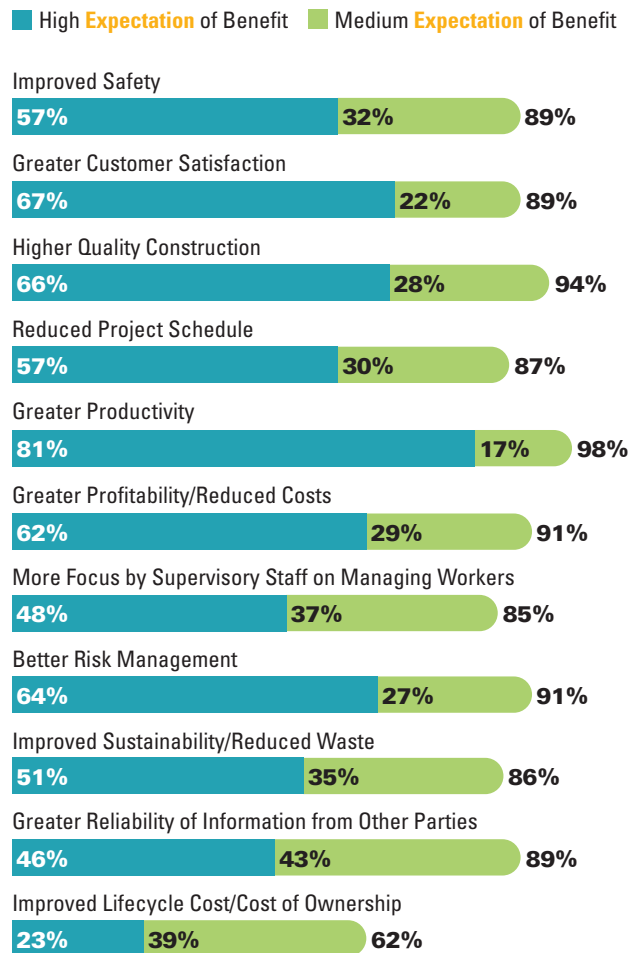
One benefit with a higher level of achievement than expected relative to the other benefits is safety. While the greatest percentage of contractors report a high level of improved safety from their use of Lean practices, safety ranks seventh in the percentage of firms that have a high expectation of achieving improved safety.

Two other factors that are ranked more highly in the percentage expecting a high level of benefit compared with the percentage that have achieved a high level of results are profitability/reduced costs and risk management. While strong results are reported by both of these factors, they also are heavily impacted by the influence of other players. Cost savings on Lean projects may land up accruing to the owner, depending on the type of contract used for the project (see page 33). Given the interrelatedness of processes on a construction site, a Lean firm may not be able to be in control of all their risks if they are not working collaboratively with other project partners. **This conclusion is supported by the in-depth interviews with Lean experts, many of whom consider collaboration to be an essential component of a successful Lean project (see page 17).**

Overall, the findings on expectations demonstrate that increased knowledge about the benefits Lean is most likely to provide will improve the industry's experience with and adoption of these practices.

### Benefits Expected by Lean Practitioners When They Implemented Lean Practices (By Level of Expectation)

Source: McGraw Hill Construction, 2013





## Potential Benefits With a High Influence on Non-Practitioners for the Adoption of Lean Practices

Over half of the firms that are familiar with Lean but are not using any Lean practices find that nine different benefits from achieving Lean would be highly influential on their decision to use a Lean approach. While some factors do appear to influence a wider range of companies, this finding does suggest that emphasizing the range of benefits to be achieved by implementing Lean will be an effective way to engage a broad swath of the industry. Firms appear to be influenced most by factors that impact their bottom line and their competitiveness, but factors that help them improve the way work is done at their company—from improving safety to the ability of supervisory staff to focus on managing employees—are also important.

The potential benefits with the greatest degree of influence on these firms are similar to the benefits expected by practitioners when they first implemented Lean. Greater productivity and profitability are considered the most influential drivers. The study results clearly demonstrate that most contractors who have implemented any Lean practices are experiencing these benefits, but firms considering Lean need to make sure the level of achievement they expect coincides with what others in the industry have achieved.

Other critical benefits to encourage wider Lean adoption among those familiar with Lean are greater customer satisfaction and higher quality construction. These directly impact a firm’s reputation and their ability to be competitive, and they are among the highest of the benefits reported (see page 26). To encourage wider Lean adoption, capturing these benefits in clear, quantifiable terms and widely publicizing them is likely to have a broad impact in the industry.

### Variation by Type of Firm

While the number of specialty trade contractors who are familiar with Lean but not implementing any Lean practices is too small to draw definitive conclusions, there is a clear trend for three factors to have a higher influence on trade contractors than on general contractors: greater productivity, improved safety and greater customer satisfaction. Trade firms have a greater focus on individual workers in general, as is revealed in the in-depth interviews with Lean experts, which is why improved productivity and safety are particularly critical to them.

### Potential Benefits with a High Influence on Non-Practitioners for the Adoption of Lean Practices

Source: McGraw Hill Construction, 2013



In addition, even more than general contractors, trade contractors frequently rely on their reputation and shared experience with general contractors to be selected for work. Building satisfaction among the general contractors is a strong way for them to become more competitive.

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY DATA

## Cost Savings From Lean Projects and Contractor Profit Margins

Given the importance of project profitability in helping to drive the adoption of Lean practices (see page 28), it is critical to understand how individual players benefit from the efficiencies achieved in pursuing Lean. Do the savings achieved improve the bottom line of the firm implementing Lean, or do they get passed along to their clients, whether that is general contractors or owners?

**General (71%) and trade (72%) contractors who have implemented at least one key Lean practice agree that the savings they see from using Lean practices contributes to their bottom line and project profitability.**

Less than 10% of either general or trade contractors disagree that the savings are contributing to their bottom line. **In addition, 59% of general contractors find that the adoption of Lean practices by their subcontractors increases their profit on projects.** This finding makes sense, given the fact that the best approach to Lean is when all project team members participate, which makes scheduling and other factors more reliable.

**Trade contractors in the in-depth interviews value their ability to be competitive and win business more highly than increased profit margins, so their business benefits from their ability to help the general contractor achieve a higher profit margin. One also reports that instead of increased profit margins, they now experience a consistent, reliable profit on projects, which they find to be even more valuable (see page 33).**

**In the survey, general contractors also place a high value on their ability to compete. Forty-one percent agree that they benefit more from competitive pricing to owners on their Lean projects than they do from a direct increase in profitability,** compared with just 14% who disagree. This is a critical finding because it demonstrates that even firms that do not experience significant increases in profit from their adoption of Lean still experience strong business benefits.

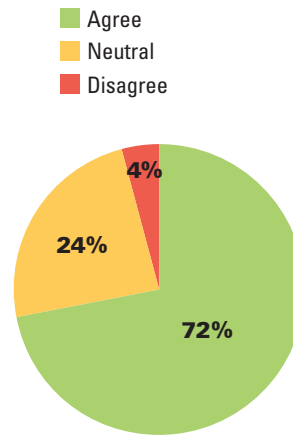
General contractors who self-perform their own trades, however, have very different opinions on a few key points than general contractors that do not. Even though the number of Lean respondents who do not self-perform some trades is too small to be statistically significant, there are clear trends that can be seen in the responses. They demonstrate that contractors who self-perform their own trades are more likely to see direct profits from their Lean efforts and more likely to find those profits valuable than the competitive edge they are afforded by Lean.

■ **Adoption of Lean Increases Profit Margins on Projects**

- Self-Perform Work: 68%

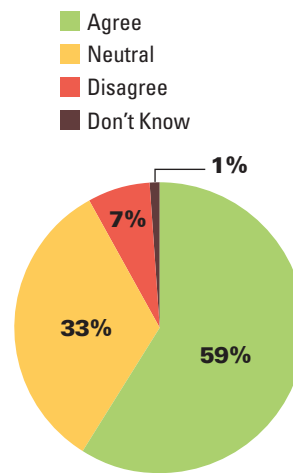
### Savings From Lean Contribute to Firm's Bottom Line/Project Profitability (According to GCs that Report Increased Profits/Cost Savings)

Source: McGraw Hill Construction, 2013



### Adoption of Lean Practices by Subcontractors Increases GC's Profit Margins (According to GCs that Report Increased Profits/Cost Savings)

Source: McGraw Hill Construction, 2013



- Do Not Self-Perform Work: 39%

It is possible that firms that self-perform their own trades are able to better control their profit margins, similar to the trade contractor in the in-depth interviews, than those that do not, which could account for this finding.

## The Impact on Contractors of Schedule Decreases Due to the Adoption of Lean Practices

Reduced project schedule is one of the top benefits of adopting Lean practices (see page 26), and saving time in the construction industry also cuts costs on projects and can increase profitability. However, the savings only accrue to the contractor if the owner has not already factored the reduced amount of time into their expectations of the contractor, especially in the case of a negotiated project, or if the contractor has not deemed it necessary to build those cost savings into their bid in order to win a project in a highly competitive market.

The study results suggest, though, that these options are not mutually exclusive. **About two thirds of contractors report that the schedule savings they experience due to their Lean practices do have a positive impact on the profit they experience in their projects, and just about the same percentage of contractors report that they are able to bid projects more competitively due to the schedule savings.** Clearly, there must be significant overlap of firms who both have schedule reductions feeding their bottom line and schedule reductions absorbed in their efforts to be more competitive.

However, **the findings also reveal that the industry is nearly unanimous about the growing expectations of owners that projects can be done in shorter time frames due to the adoption of Lean practices in the industry.** This aligns with the previous finding that increasing their firms' competitiveness rather than direct profits is the larger benefit from Lean.

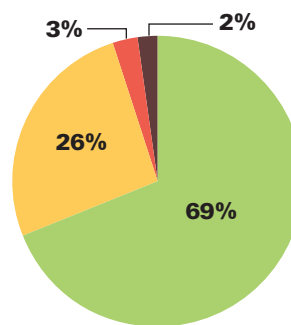
**The in-depth interviews with Lean experts shed further light on this finding. Experts report that, even just five years ago, most owners were not familiar with Lean, but they see a broad change occurring. Some believe that owner mandates will be the most critical driver of Lean construction in the industry in the future, a shift from what they currently see occurring, other than in one or two sectors like healthcare with engaged owners that have led the industry on Lean adoption (see page 24).**

### The Impact on Contractors of Schedule Decreases Due to the Adoption of Lean Practices

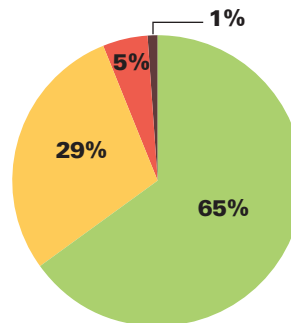
(According to Lean Practitioners)

Source: McGraw Hill Construction, 2013

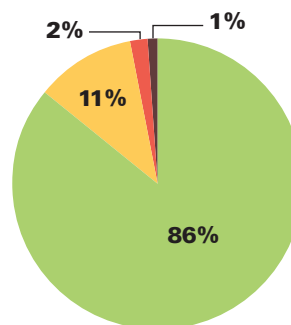
Agree Neutral Disagree Don't Know



Decreases in Project Schedule Due to Lean Practices Directly Increase Firms' Profit Margins on Projects



Decreases in Project Schedule Due to Lean Make Firms More Competitive by Helping Them Submit Successful Bids



Firms Use Lean Practices Merely to Stay Competitive Because Owners Increasingly Expect Shorter Schedules

# Increasing Industry Efficiency With Digital Configuration Multi-Product Assemblies

**Saint-Gobain**

HEADQUARTERED IN FRANCE

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY

Since 1988, building product manufacturers in the European Union have been working to comply with the “Construction Products Directive” (CPD), a piece of landmark legislation that “aims to ensure the free movement of all construction products by introducing a common technical language”<sup>1</sup> to describe and define product characteristics. Those could include mechanical strength, fire resistance, heat retention or any of a wide range of other properties critical to a product’s installed performance.

Saint-Gobain is a building product manufacturer headquartered in France with a global presence in over 55 countries. They manufacture a broad range of products, including insulation, gypsum, exterior products, pipe and industrial mortars as well as a number of prefabricated assemblies involving multiple products. According to Laurent Ortas, head of new construction technologies and Francois Pincemin, head of constructive solutions and prefabrication, the company has long been committed to supporting the CPD and is now leveraging that platform to support their leadership role in the emerging trend of highly efficient model-based design, fabrication and construction.

## Standardization of Product Descriptions

Anticipating their customers’ need for digital versions of Saint-Gobain products to function in model-based applications and workflows, the company has been working closely with the AIMCC, a French association of building product manufacturers, to create a European Standard Dictionary, available in French, German,

Swedish and English that would be a consistent reference as they, and others, developed parametric models of building products. AIMCC anticipates having a comprehensive European standard dictionary of product properties and an ongoing maintenance process in place by the end of 2014.

Using this dictionary, all building product manufacturers can harmonize their digital product offerings for greater interoperability, a key user-friendly goal of all organizations participating in digital design and construction.

## Impact on Industry Efficiency

Saint-Gobain is advancing the practice further by allowing design and construction professionals to search for products based on the characteristics they need, as well as to virtually configure more complex assemblies from complementary product lines. And to make their offering even more functional, Saint-Gobain is enabling the automatic creation by users of digital model versions of the selected products or configured assemblies. This avoids the need for manufacturers to invest in vast catalogs of pre-built digital models and have them waiting for users to find and download. Instead, a model based on a customer’s specific needs can be generated and delivered quickly, on-demand, from underlying product data that have been structured to comply with the standard dictionary.

Another common problem of pre-built product models is that they often either contain either too little or too much information for the user’s need at hand. Saint-Gobain addresses that by allowing users to

control how simple or complex their on-demand model will be, depending on its intended use.

To ensure that as many users as possible can take advantage of this capability, Saint-Gobain is working in alignment with the many other international organizations that are all promoting IFC (Industry Foundation Classes) as an interoperable standard for model exchange between various software tools.

The reliance on standardized digital descriptions of product characteristics also helps Saint-Gobain to engage in more efficient manufacturing by allowing computer-controlled cutting and finishing equipment to work directly from the data. This reduces waste, improves efficiency and provides assemblies that are faster to install onsite. In fact, products and assemblies for an entire project can be manufactured in sync with construction production schedules, to enable smaller “Just-In-Time” deliveries to the site, which can generate many benefits for time, labor, safety and project control.

## Conclusion

These efforts by Saint-Gobain are extremely encouraging because they demonstrate that enlightened manufacturers, along with contractors and industry organizations, are increasingly recognizing the contribution of standards, collaborations and partnerships to achieve the benefits of Lean principles industry-wide, not just for individual practitioners. ■

<sup>1</sup>. [http://europa.eu/legislation\\_summaries/other/l21184\\_en.htm](http://europa.eu/legislation_summaries/other/l21184_en.htm)

Eighty-eight percent of the respondents report using at least one of the measures provided in the survey to determine the benefits they achieve from Lean. The high level of measurement is likely influenced by the availability of data gathered in the course of eliminating waste from construction processes. It may also be impacted by the need to demonstrate the results of Lean since its implementation does typically involve more time-intensive processes at the beginning of a project.

Despite the wide range of use of these metrics, though, only increased profitability is measured by more than half of the respondents. Although all contractors are aware of their profitability, not all track it to gauge the success of their Lean practices.

However, the broad range of metrics used suggests that there is no standardized approach currently in place for companies to understand their Lean benefits. Factors measured are customized based on the work the firms do and the specific approaches to Lean they have implemented. As the use of Lean practices matures in the construction industry, the industry as a whole may need to consider the value of having more standardized ways of measuring the value obtained from Lean.

### Variation by Type of Firm

As the chart clearly indicates, specialty trade contractors are tracking metrics more widely on their use of Lean.

While there is a clear trend across multiple measures, the differences are statistically significant for increased profitability, reduced operating costs during construction and dollar value of work put-in-place per man hour.

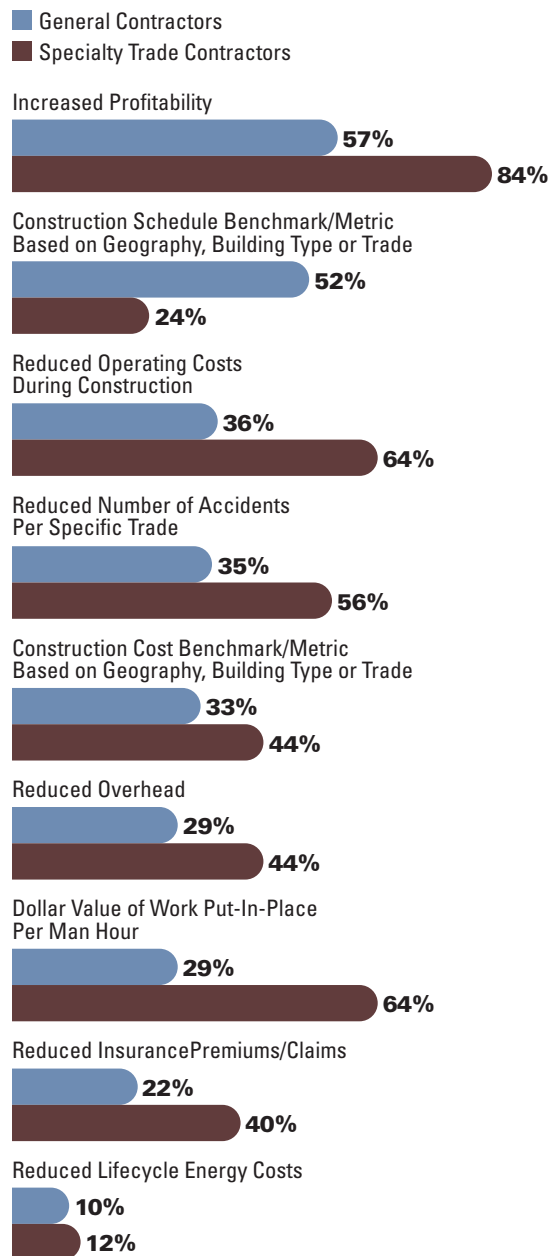
This finding is largely supported by the findings of the in-depth interviews with Lean experts.

- General contractors interviewed focus on subjective as well as objective measures to determine the success of their Lean efforts, with client satisfaction, employee engagement and removal of constraints being some of the measures they mention (see page 35).
- Trade contractors are far more focused on the rigor and usefulness of the measures they conduct to furthering their lean practices. One cautions that measures must be done at the lowest level possible, down to the component part being installed, and that he can then use that measure to work on continual process improvements (see page 35).

Thus, it is not surprising that trade contractors are conducting more of these specific, objective measures than general contractors.

### Objective Measures Used to Determine Benefits of Lean (According to Firms by Type)

Source: McGraw Hill Construction, 2013





## In-Depth Interview Findings: Benefits of Adopting Lean Techniques

**The greatest benefits reported by the Lean experts in the in-depth interviews include the improved ability to compete in a challenging market and higher levels of employee engagement.**

**F**irms that adopt Lean construction techniques at their respective firms realize a wide-ranging set of benefits.

**Most strikingly, experts in Lean construction believe that use of these techniques drives their success and their ability to compete in a challenging market.**

One expert says that Lean has been a contributing factor in the company's overall financial success in recent years. "I can point to jobs we've won because of our experience with Lean," he said. "We've gotten work with repeat clients where we implemented Lean, and they were absolutely thrilled with the results, and they just handed us work. There are examples where trade contractors who have worked with us, have had a better experience on our jobs and as a result we get better pricing." Another contractor states that "if we didn't do [Lean], we would have struggled [finding] work." Because they made that commitment, though, he was able to state definitively, "We didn't have a downturn."

**Others note that Lean construction promotes a higher level of engagement by staff and project partners.** "The biggest reward is that people get more engaged in their work," one expert said. "They get more excited about coming in and doing things everyday. That turns into higher quality, better safety and the things that are tough to quantify." Another impact that is hard to quantify but noted by a trade contractor is that the adoption of Lean practices "keeps

the culture of innovation [at their company] active and prospering."

### Benefits Achieved

All of the experts interviewed have realized significant benefits by using Lean construction techniques, and there is strong consensus among them that all of the following benefits are achieved from the use of Lean.

#### **GREATER PROFITABILITY/ REDUCED COSTS**

**GCs all agree that project costs could be reduced by cutting waste.**

For example, through better detailing, less materials could be used. Similarly, better modeling could lead to reduced rework. Notably, GCs say this does not necessarily translate to greater profitability, particularly those who operate under guaranteed maximum price contracts. "If there's a savings on the job, it goes to the owner," said one contractor.

Several trade contractors also agree that they see project costs reduced, but not all, and not consistently on every project. One advanced trade contractor, though, finds that, even if the profit margins are not frequently higher on Lean projects, they are more certain: **"Our margins have improved to expectation, so instead of taking a job at 4 or 5%, and being lucky to get 3%, we're taking the job at 4 or 5%, and we're making 4 or 5%—maybe getting a little extra, but not going below that."**

#### **IMPROVED SAFETY**

Numerous Lean techniques can contribute to safer worksites, including more predictable workflow, cleaner sites, improved ergonomics and better material handling. In particular, contractors note that prefabrication and modularization could improve safety by removing work from the field and executing it in a controlled environment. In fact, **half of the trade contractors find improved safety to be one of the top two benefits from undertaking a Lean approach.**

#### **GREATER ABILITY FOR SUPERVISORY STAFF TO FOCUS ON MANAGING WORKERS**

Better planning and greater predictability can lead to fewer conflicts in the field, freeing up staff for other activities. **A GC reports, "Previously to [adopting Lean techniques], 90% of the [field staff's] day was spent resolving conflicts and clashes between trades... That has been virtually eliminated..."** Now they focus on production planning, smoother workflow, how to get the project completed on time and working with the workers."

And a trade contractor concurs, "We have probably found a 60% increase in [a supervisor's] ability to directly manage the labor force," which he attributes to prefabrication and the ability to automate tasks like material takeoffs, ordering and logistics.

**HIGHER QUALITY CONSTRUCTION**

Some GCs note that by reducing rework, teams increase the likelihood that construction quality can be improved. Others note better design and preconstruction collaboration within an integrated team reduces or eliminates the need for value engineering.

Prefabricating in a controlled environment also promotes higher quality, according to both general and trade contractors.

One trade contractor considers improved quality one of the top benefits of Lean because the processes they have put in place help them to “deliver exactly what the customer wants—no more, no less.”

**GREATER CUSTOMER SATISFACTION**

This benefit carries greater weight with GCs than with trade contractors since half of the GCs interviewed say that customer satisfaction is the most significant benefit of Lean construction, a trend not found among the experts from trade firms. Customers may see some but not all the same benefits as contractors, such as lower costs, reduced schedules and higher quality.

Notably, many GCs also report that customer influence was a driver in adopting Lean techniques on projects. As such, successfully delivering a Lean project to a customer who requests it, naturally leads to customer satisfaction.

However, most trade contractors do see this as a benefit they achieve on projects, due to reliable outcomes, better adherence to schedule and higher quality.

**“I can point to jobs we've won because of our experience with Lean.”**

**GREATER RELIABILITY**

Through improved planning, some experts say that schedules are more reliable on Lean projects. As noted above, one trade contractor considers this to be the true outcome of Lean, rather than increased profitability. Another trade contractor notes that the reliability of outcome due to their Lean practices has changed from about 20% to about 80 to 85%. Other factors, such as better detailing, fabrication and preassemblies contribute to delivering a more reliable product.

**REDUCED PROJECT SCHEDULE**

Improved planning at both the project and craft levels, can lead to shorter construction schedules. “The first project I worked on... the superintendent thought it would take seven to eight months and he told the owner it would be done in six,” said one expert. “We did it in 4.5 months without any overtime.”

**GREATER PRODUCTIVITY**

In the spirit of cutting waste, firms are actively pursuing ways to remove obstacles and help workers be more efficient. For example, several note that use of the Last Planner System helped improve productivity in the field by creating more predictable workflow. However, some note that Last Planner, which requires more upfront and detailed planning on projects, could also increase the workload of project management

staff. This may be due to a lack of expertise with that system and could be less of an issue as users become proficient with the system.

**BETTER RISK MANAGEMENT ACROSS PROJECTS**

There are a multitude of risks on projects, and many can be addressed through Lean. Several of the benefits listed here can contribute to improved risk management, including better safety, greater reliability and higher quality. A couple of trade contractors consider this the most significant benefit of Lean.

**Impact of Lean Construction Techniques**

Although some firms track metrics, most admit that it is often hard to quantify those results. “When you measure it over a long period of time, we’ve made substantial progress,” said one GC. “When you’re measuring it one project at a time, you can see and feel the progress. It’s hard to have a perspective about how much impact it’s having.”

One equated quantifying Lean’s benefits to measuring the benefits of building information modeling. For example, when measuring the impact of improved clash detection through modeling, one has to compare project results against estimated theoretical clashes that might have occurred without BIM rather than hard data. The same could be said for many Lean techniques.

Some specific business practices did see benefits, such as supply chain management. Several experts report they had used or prototyped RFIDs on projects as a means to track products. One expert says that on a recent project, the company was able to save nine hours per week by using RFIDs to track materials onsite.

## Goals and Metrics

### GENERAL CONTRACTORS

**Through detailed planning, GCs are able to set goals and milestones.**

One contractor said it can set goals down to the craft level, such as how many bolts a millwright can tighten in an hour. Two GCs mention using key performance indicators on projects. **Most say that they do not have specific metrics for Lean projects.** One contractor reports that his company tracks such measures as change orders or requests for information on both Lean and non-Lean projects for comparison. At a company level, one contractor mentioned using a Lean checklist to determine the level of Lean implementation on projects.

### SPECIALTY TRADE CONTRACTORS

**For the most part, none of the trade contractors report having overarching goals,** with the exception of those with fabrication shops, for which specific goals are established. However, all report using metrics or benchmarks to track performance and engage in continuous, measurable improvements.

This may be due to the fact that many are still relatively new to Lean adoption. One firm does report that they are planning to set up company-wide goals around total cost or total time spent on an activity in 2014. This may suggest that the use of goals,

**“The biggest reward [of adopting Lean] is that people get more engaged in their work. That turns into higher quality, better safety and the things that are tough to quantify.”**

in addition to metrics, may be an emerging practice.

## Most Important Measures

### GENERAL CONTRACTORS

**GCs typically measure areas such as schedule, budget, quality and safety, but they do not necessarily see these as critical measures of Lean construction.** One contractor says that schedule is a critical measure for planning purposes, adding that projects that fall behind schedule are more likely to experience problems with budget, quality and safety.

GCs mention a variety of other ways that they gauge success with Lean. Some are specific and data-driven, while others are more subjective, including:

- Client satisfaction
- Employee engagement
- Removal of constraints
- Efficiency at the craft level

### SPECIALTY TRADE CONTRACTORS

**Safety is the most important measure for two out of four of the trade respondents of the in-depth interviews,** and speed/schedule is also frequently mentioned.

**Two respondents also emphasize the importance, not of a specific type of measure, but at conducting measurement at the level of specific tasks.** Highly granular measurements, which gauge efficiency

down to the level of the installation of specific parts, allow for more robust analysis. These measures are critical for supporting additional efficiency efforts. Another granular measure noted by a trade contractor as useful is dollar value of work put-in-place per man hour. ■



# Planning and Coordinating Prefabrication to Increase Project Profitability

**St. Elizabeth Hospital Five-Story Patient Tower and Connector Building**  
 APPLETON, WISCONSIN

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY



Headwall on the specially designed cart, prepped for installation

The Boldt Company has been using Lean project delivery for over a decade, and they have been able to bring many of the lessons they learned from the industrial side of their business to bear on their general building projects, according to Will Lichtig, vice president of business and process development at Boldt. As general contractors who self-perform many trades and work collaboratively with trade partners on others, prefabrication is one area where they have been able to find opportunities to improve cost, schedule and safety on their projects while sustaining or improving quality.

## Planning Approach Critical for Effective Prefabrication Use

Lichtig reveals that there are two factors that contribute to their success with intensive coordination of prefabrication on their projects: a disciplined planning process and an integrated approach to project delivery. He clarified that for each project, they first need to determine what level and kind of prefabrication makes sense. Being part of an integrated design process allows them to influence decisions during design. Lichtig reports that they use an A3 process to make sure that “when you are evaluating prefabrication as an

option, you are doing all the necessary research...rather than looking at assumptions or what may have happened on the last project, to try to make sound decisions.” (See page 3 for a description of A3.)

Part of that decision-making process is looking at the supply chain. The transportation of prefabricated items can impact schedule and quality, and they look at each individual element across the critical factors of schedule, safety, cost and quality in order to make their decision to use prefabrication and the degree to which it was useful.

For example, in a project they conducted in Moose Jaw, Canada, schedule became an important factor in the decision to prefabricate elements of the exterior enclosure of the building, because if the building was not enclosed before winter started, that would have significant implications for the remainder of that schedule. However, through prototypes and first-run studies, they also determined that the insulated metal panels that make up the skin of the building should not be included in the prefabricated components because they could not get the right seal in the shop during that process, increasing the risk to the quality of the project. Instead, that final element was installed onsite. They use a similarly rigorous process on all their prefabrication decisions.

## Impact of Logistics on the Selection of Trade Partners

For the fourth and final phase of the expansion of St. Elizabeth’s hospital in Appleton WI, they knew from the start that they would be looking at the gains they could obtain from

CONTINUED

## St. Elizabeth Hospital APPLETON, WISCONSIN

prefabrication because the owner of the project challenged them specifically to see what they could accomplish by taking this approach.

As Chris Waldron, field engineer and project engineer for Boldt on this project explains, this allowed them to explore options that they had not done on other projects, and it had an impact on their selection of the project team. Waldron states: “[Their prefabrication capacity] was part of what we evaluated [the trade contractors] on. Who’s pushing the envelope, in addition to things like price. We took tours of their shop to see how Lean their operations are, and their production facilities for doing this work also went into the evaluation.” Trade firms were also asked whether any had space that they could dedicate to additional prefabrication work should opportunities arise “to take it to the next level,” and the plumber they selected offered that opportunity, one which they are already taking advantage of.

### Tackling Logistical Challenges

As with their other projects, intensive planning was critical. Waldron describes how they conducted first-run time studies for each of the prefabricated elements, but they also made sure to include all the logistics of transportation as well, from how they get components on the truck to the bridges they need to clear. “We tested the build, we tested the delivery, and then we were able to either confirm or adjust our anticipated production.” Included in those calculations is an anticipated performance factor that comes from doing this work repetitively, which shortens the schedule.

Waldron also describes taking into account challenges that occur onsite and using the planning process as an opportunity to develop creative solutions: “We are making these headwalls ahead of time, and we had to figure out a way to get them on to the site [without damaging them.] So we thought about a way that accounted for corridor width and above-ceiling clearances. As a group, we came up with a sketch. We got buy-ins from everybody. Now we have this cart that we can put our headwalls on and can pick up with a forklift or a crane. We built one to see if it would work, and sure enough, it did.” Lichtig mentions that they are seeking opportunities to utilize this cart on other projects in Wisconsin.

Gaining buy-in from the foremen was a key part of this process, and it was a critical part of their overall process as well. They used the feedback from these workers to conduct a complete value stream analysis of both the traditional stick built conditions and the use of prefabrication. The process is intensive and attempts to capture all elements, such as the time needed to pick up scrap cutoffs and to go up and down stairs. The results of that process for two prefabricated components are featured in the table on the right.

Getting worker feedback is a critical part of gaining their buy-in for the process. As Waldron states, “We have these foreman in the room, and we need their buy-in because if we don’t have it, then they are not going to do it anyway.”

If the numbers from this initial process seemed favorable, they then conducted time studies by videotaping workers to confirm the findings of their initial interviews.

Finally, they consider the total cost of each solution, from the transportation logistics to the reduction of days onsite. Waldron points out that you need to consider what it costs “to have a crane on site, what it costs for all the overhead to be on the jobsite. If you are saving that time, you are saving money because every day you are on the jobsite, you are charging money.”

Without those extensive efforts, that take into account the specific logistical challenges and opportunities associated with that site, they would be making decisions on the use of prefabrication based on other projects, and that may not truly guarantee that they can save money and eliminate waste. ■

#### Project Facts and Figures

**Construction Manager**  
Boldt Construction

**Type of Project**  
Hospital Patient Tower and Connecting Building

**Construction Start**  
Fall 2012

#### Savings from Active Coordination of Prefabrication According to Time Studies:

##### Prefabricated Headwalls

- Total man hours reduced from 24 to 7 per headwall

##### Prefabricated Bathrooms

- Total onsite man hours reduced from 9.5 to 3, with an overall (offsite and onsite) man-hour reduction of 1 hour per bathroom



## Lean Strategies for Employing Prefabrication

Currently lean practitioners are demonstrating significant advantages in quality, safety, cost and project duration with prefabrication.

Lean design and construction focuses on improving total project performance, rather than reducing the cost or accelerating the delivery of single activities or phases. While the use of prefabricated components and modular construction is not new to the industry, their application has increased dramatically in recent years.

### Tangible Benefits to a Lean Prefab Approach

Greg Howell, co-founder of the Lean Construction Institute, points out that Lean prefabrication is particularly useful on complex, uncertain and quick projects, such as hospitals, data centers, semiconductor fabrication plants or other high-end manufacturing centers. Here the advantage is much more than speed. All trades (such as design architect, general contractor, mechanical, electrical, plumbing and fire protection) are involved from the beginning of the project, ensuring that well-coordinated design decisions are made at the “last responsible moment,” when uncertainty is lowest.

Victor Sanvido, senior vice president at Southland Industries, adds that a Lean prefabrication strategy delivers high performance on safety. By building components offsite rather than at the jobsite, the project can avoid some of the dangerous challenges that characterize building projects. For example, when prefabricated components are built offsite and purposely made too heavy to be

picked up manually, each unit is lifted and moved mechanically into position. Jobsite ladder and scaffolding accidents, as well as back injuries, are virtually eliminated.

### Working With Prefabricators

Well-sequenced object-based design is central to high-performance fabrication. Rebecca Bettler, national director of Lean construction and Mike Dennis, vice president, both for JE Dunn Construction, note that to maximize the benefits of prefabrication, you must identify the elements early in the design process. This allows the design to conform to the requirements of these elements. Without this focus, the design can sometimes preclude prefabrication. In short, designers need to allow for dimensional and spatial requirements that prefabrication may require.

BLOX CEO Chris Giattina emphasizes that his firm’s approach is “all about reduction in waste.” BLOX prefabricates medical modules. He explains that a typical hospital patient room bathroom contains 800 components field-installed by a dozen trades over a span of three months. BLOX removes that complexity from the site by completing the work in an offsite, Lean production line and inserting completed modules back into the site construction in a day. This works only if he is able to include all of the trades in design coordination discussions at the start of the project.

### Planning and Costing Logistics

Handling components as few times as possible reduces waste and minimizes safety hazards. Thus the decision on where to locate prefabrication and how to manage the logistics of transporting components to the jobsite are increasingly important considerations. How close to the jobsite is optimal?

Nick Loughrin, production manager for the Welty/Boldt Joint Venture’s Akron Children’s Hospital project, works with partners that have prefabricated components in warehouses just a few miles from the jobsite as well as those who ship the modules across hundreds of miles. Using the decision-making process, Choosing by Advantages, the decision for Loughrin is always case by case.

JE Dunn’s Bettler and Dennis point out that ideally the prefabrication shop is set up onsite or very close by. This lowers the complexity of Just-In-Time delivery.

BLOX’s Giattina counters that the distance from his prefabrication site in Alabama and the jobsite is not a major cost issue. Transportation accounts for less than 2% of his unit cost if shipping less than 1,000 miles. All waste counts, but transportation costs are modest and do not typically justify setting up offsite plants just to be closer to the project. ■

# Data: Challenges to Broader Lean Implementation

## Top Challenges Faced by Lean Practitioners in the Implementation of Lean Practices

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY DATA

Nearly half of the Lean practitioners find that lack of knowledge is one of the top three challenges they face as they implement Lean. As the Lean experts in the in-depth interviews make clear, this problem can be found internally and externally. It can extend from field personnel to senior management internally, and it can involve other firms that they need to work with externally. Because of the emphasis on intensive planning processes and the way in which their work depends on interaction with other project partners, firms attempting to implement Lean can be placed in the position of advocating for Lean, which can have an impact on their own effectiveness.

Four additional challenges selected by 39% to 43% of practitioners as among the top three they face all reflect that larger concern about lack of knowledge by internal and external partners. Internally, the perception that Lean is too complex is still a factor, along with employee resistance. Many of the Lean experts in the in-depth interviews cited employee resistance as a key factor, although most also acknowledged that employees also grow very enthusiastic and engaged when they experience the benefits offered by Lean (see page 41).

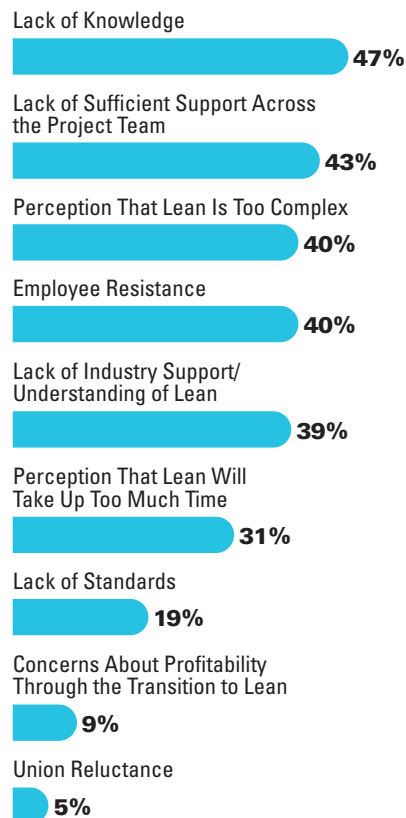
The experience with internal resistance is also the main differentiation between the responses of the challenges by those who are just familiar with Lean versus the Lean practitioners (see page 40).

Externally, they express concerns about their project partners and the lack of industry knowledge about lean, similar to those that have not yet implemented Lean. It is notable that there is no statistically significant difference between the percentages of general and trade contractors who find this to be a top challenge, even though trade contractors in the in-depth interviews tend to focus more on the impact of external partners on their effective implementation of lean practices.

One striking finding is the low percentage of firms that find profitability through the transition to Lean to be a challenge. This suggests that firms do see results from the Lean practices they adopt even from the start, despite the upfront investment of time and analysis most of these practices require.

## Top Challenges Faced in the Implementation of a Lean Approach (According to Lean Practitioners)

Source: McGraw Hill Construction, 2013



## Challenges That Influence Non-Lean Practitioners in Their Decision About Adopting Lean Practices

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY DATA

Two out of three of the challenges that carry a high degree of influence for the highest percentage of firms that are currently not practicing Lean but that are familiar with it both deal with lack of knowledge and understanding of Lean. The highest percentage (39%) find that lack of industry support and understanding of Lean is a highly important challenge, and 32% also find that a general lack of knowledge is problematic.

These findings demonstrate that more information and education on Lean must be provided to the industry. They are also supported by the findings of the group of respondents who are representative of the industry that over one third of them (37%) are not familiar with Lean construction or any of the main practices measured in the survey (see page 8).

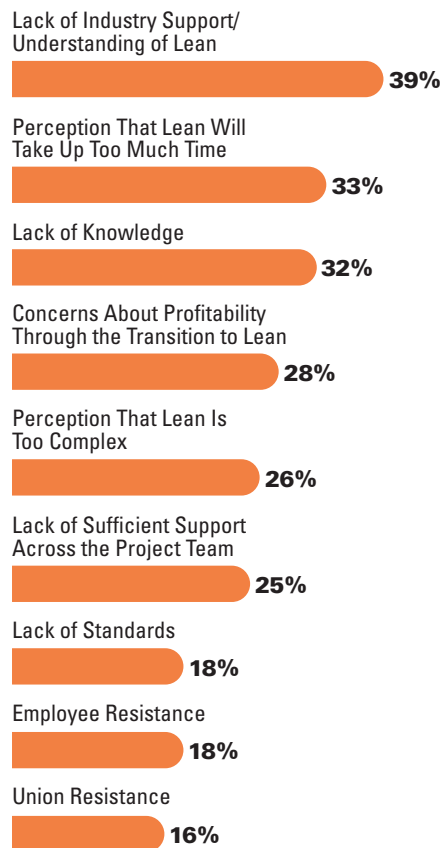
**The next most important obstacles are a series of concerns about the impact of Lean adoption on their firm and the challenge associated with implementing it.**

Top issues include the concern that Lean will take up too much time (33%), the concern about profitability during the transition to Lean (28%) and the concern that Lean is too complex (26%). Other than the notion that Lean is too complex, among those who have actually initiated Lean, the amount of time spent and the profitability of the transition to Lean are not considered among the top challenges. This also reinforces the call for more information on Lean, so that firms understand the full benefits and the biggest obstacles they face in implementing Lean practices and can make informed decisions.

**On the other hand, those who have not implemented Lean do not fully understand the challenges posed by working with project team members who are not engaged in Lean.** Practitioners tend to rank this factor much higher because they understand that other project partners can undermine even the most ambitious planning efforts at the start of a project. Of course, as Lean practices take hold in the construction industry, this is likely to be less of a problem. In fact, **one of the Lean experts from the in-depth interviews anticipates that in the next five to 10 years, they will no longer need to spend as much time encouraging their project partners to see the value in a Lean approach on projects as they do now (see page 25).**

### Challenges With a High Degree of Influence on the Decision to Use a Lean Approach (According to Non-Practitioners Familiar With Lean)

Source: McGraw Hill Construction, 2013



## In-Depth Interview Findings: Challenges to the Pursuit of Lean Construction Practices

**Top obstacles include concerns about lack of knowledge and a full understanding of Lean, including the employees in their firms, their project partners and the industry at large.**

In some ways, Lean philosophies represent a paradigm shift in how companies approach construction practices. Efforts to infuse new means and methods into a well-established industry are bound to be met by some resistance. Among the top obstacles, general and trade contractors cite concerns around education, training and implementation, including the perceived complexity of Lean practices, a lack of knowledge by users and resistance to transform one's approach to tasks.

### Challenges and Obstacles

#### TOO COMPLEX

Between the philosophies behind Lean and the tools used in its pursuit, GCs recognize that Lean practices can be difficult for beginners to grasp. **All GCs identify this as an obstacle, and one finds it to be the most important obstacle.** "Sometimes you can get overloaded on jargon and tools and Japanese terms. People's heads start spinning... It can be off-putting," said one contractor.

#### LACK OF KNOWLEDGE

**In keeping with the perceived complexity of Lean practices, education is a concern for general and trade contractors. All GCs also identify this as an obstacle, with one regarding it as the most important obstacle.** For larger companies that are spread out geographically, rolling out Lean concepts and providing proper

training across the entire organization can be challenging, notes one GC. A trade contractor notes that the learning cycle "can be the duration of a project," and another expresses the concern that all of their senior leadership is not uniformly trained on Lean.

#### EMPLOYEE RESISTANCE/ NEED TO TRANSFORM APPROACH

In an industry filled with seasoned workers, change can be difficult. Over time, workers learn traditional means and methods, and develop their own habits. Nearly all the experts recognize that teaching workers to rethink how they work can present a considerable challenge. **All GCs identify this as an obstacle, and one says it is the most important obstacle, while most of the trade contractors also express concerns about this issue.**

#### RESISTANCE/LACK OF INTEREST IN PARTICIPATING BY OTHER TEAM STAKEHOLDERS

**Many general and trade contractors see resistance by other team members of Lean projects.** Only one GC finds it was not an obstacle. Some GCs report that in areas where they see greater adoption of Lean practices—such as the West Coast—there is less resistance compared with areas with lower adoption rates—such as the East Coast.

One trade contractor reports that working with companies motivated financially to extend their schedule

on a project can create significant problems for his firm's ability to successfully pursue a Lean approach.

#### WILL TAKE UP TOO MUCH TIME

Some GCs report concerns early in the adoption phase that Lean can be time-consuming. However, **most recognize that as users become more proficient over time, Lean practices can save time and reduce the need for staff to focus on other tasks,** such as addressing conflicts. The challenge of finding the time for initial training appears to be the greatest concern for the trade contractors.

Factors generally considered less important include resistance from union stakeholders, lack of industry support/understanding of Lean and concerns about profitability through the transition. ■



# Data: Technologies Used to Support Lean

## Use of an Enterprise Resource Planning System to Support Improved Efficiency

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY DATA

An Enterprise Resource Planning (ERP) software system supports the internal business processes of a company by providing an integrated real-time view of its core business processes such as finance, procurement and human resources. For firms seeking greater efficiency, an ERP is most effective when it links data from business functions with project data. This provides the type of data necessary to understand better the cost and time implications of different processes and allows firms to make improvements based on data rather than on assumptions.

### Use of an ERP

Thirty-four percent of contractors report using an ERP at their company to coordinate their project data with their business management data, whereas 51% of those who have implemented Lean practices are using an ERP. This is a significantly higher percentage than the 17% of those not practicing a Lean approach that report using an ERP. **As one of the Lean experts in the in-depth interviews who is currently in the process of implementing an ERP system at his firm makes clear, use of an ERP will help him to analyze data that they currently gather but that they cannot currently query because they lie in different systems (see page 44).** If the systems are effectively coordinated, use of an ERP can help avoid manual use of spreadsheets to understand the implications of doing Lean.

### VARIATION BY SIZE OF FIRM

Firm size is directly correlated with use of an ERP.

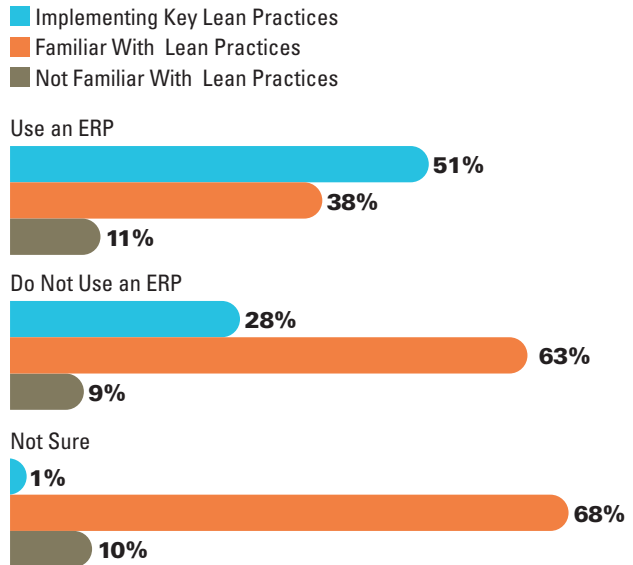
- \$500 million or more annual revenue: 70% use an ERP
- \$100 million to less than \$500 million annual revenue: 49% use an ERP
- \$10 million to less than \$100 million annual revenue: 18% use an ERP
- Under \$10 million in annual revenue: 6% use an ERP

This finding is consistent with other SmartMarket Reports that examine technology adoption, including the 2013 *Information Mobility* report and the 2012 *Business Value of BIM in North America* report, which demonstrate that large firms typically lead the industry in the use of new technologies. Large firms can dedicate more resources to new technology adoption and can even have dedicated staff to manage their technology, a challenge for smaller firms.

A significantly higher percentage of general contractors (39%) use an ERP compared with the percentage of specialty trade contractors (22%). It is likely that this

### Use of an ERP (By Level of Lean Engagement)

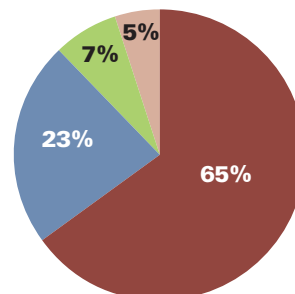
Source: McGraw Hill Construction, 2013



### Degree of Support for Efficiency Efforts Provided by an ERP

Source: McGraw Hill Construction, 2013

- Well Supported/Very Well Supported
- Supported
- Somewhat Supported/Poorly Supported
- Not sure



finding is largely due to the fact that the general contracting firms included in the study are generally larger than the specialty trade contractors, although general contractors may also benefit more in their role of coordinating data on projects across all trades from their use of an ERP.

### Supporting Efficiency

Given the importance of data in eliminating waste and measuring the effectiveness of specific approaches, it is not surprising that 88% of the respondents find that their ERP use supports their efforts to improve efficiency. In fact, 65% find that these efforts are well supported or very well supported.

Surprisingly, there is not a similar statistical difference between large and small firms when it comes to the percentage that consider their efficiency efforts well supported/very well supported by their ERP. Once a firm adopts an ERP, then size appears to be far less of a factor in the use they draw from it.

### ERP Use and the Adoption of Practices to Increase Efficiency

On page 15, the use of several practices to increase efficiency was reported by Lean practitioners and non-practitioners alike. However, respondents with an ERP system that connects their project and business management data are more likely to conduct the top two practices from that list:

#### ■ Weekly or Daily Meetings With Workers

- ERP Users: 94%
- Non-ERP Users: 58%

#### ■ Offsite Prefabrication

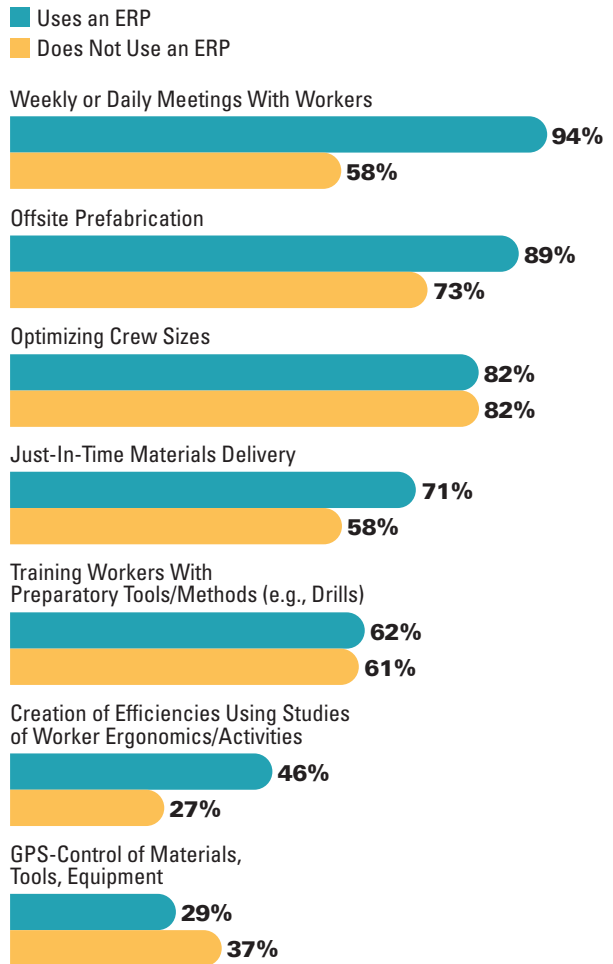
- ERP Users: 89%
- Non-ERP Users: 73%

One less frequently used practice is also in use for a significantly larger percentage of ERP users compared with non-ERP users: creation of efficiencies using studies of worker ergonomics/activities.

All three of these activities place an emphasis on coordination, and the investment by a firm into an ERP system represents a commitment to more effective coordination through better access to data. These findings demonstrate that, even among firms not formally pursuing Lean, investment in understanding their business coordination can allow them to take better advantage of opportunities to improve efficiency.

### Use of Practices to Achieve Efficiency (According to Those Using an ERP)

Source: McGraw Hill Construction, 2013



## In-Depth Interview Findings: Use of Enterprise Resource Planning Systems

**As part of their lean strategies, some companies employ ERP systems to help consolidate and integrate a variety of business and project-specific data, sometimes from disparate systems. The types of systems used and the levels of data integration realized in these systems vary greatly among the Lean experts interviewed.**

Some firms interviewed use databases such as Oracle or SAP as the backbone of their ERP systems. Others use construction-specific project management software such as CMiC, Meridian Prolog and Viewpoint as the core of their systems.

### Integration

General and specialty trade contractors pursuing Lean practices report highly varied levels of systems and data integration.

**Two experts say that their companies have full integration, enabling them to coordinate project data with business management data.** One refers to the company's system as its "single source of truth." To achieve this, users often develop custom solutions to gain the integration and functionality they need.

**Three experts report that they have systems but have not fully implemented them.** One firm says that since implementing a system three years ago, the company has discovered that its own internal processes did not match up well with the system. The company is currently reviewing its internal processes as part of an effort to make it more Lean, and the company reports that it is already seeing improvement during that process. When setting up a project in the system, "it was taking us 46 days to get boots on the ground. After a Lean workshop, we got that down to four days. It's a massive change," the contractor said.

**One trade contractor reports that they have developed a mobile-based solution that allows their teams to track materials from order to pre-fabrication to the jobsite, using BIM Field 360 technology.** This approach has reduced the cost of processing, tracking and validating installation. They also have a digital pre-construction planning application and a field personnel tracking program.

**One expert says that his company uses a variety of software for project and business functions, some of which is not integrated.** While he said the company is able to track things like productivity across multiple jobs, ERP integration is not a primary focus of its Lean approach. "Way too often we make it too complex because we can ... and we spend more time entering data than we do observing, measuring and improving," the contractor said. A trade contractor also believes that ERP integration was secondary to their Lean implementation: "If you are looking at efficiency, the crews need to be able to measure their work themselves. If they don't ... you'll be quite late." He reports that the office information is usually between two to eight days out-of-date.

**Two trade firms have not fully implementing data integration solutions, and both report heavy reliance on manual processes and spreadsheets currently.** One is in the process of getting a system now, which they consider essential to answering questions about installation

efficiencies for specific equipment. They are tracking all the data, but there is "no way to query our systems right now," which is what they hope to gain through the ERP.

### Supply Chain

While experts recognize the capabilities of ERP systems to aid in supply chain management, it has gaining limited use by these GCs. Some focus on supply chain at the project level, but not at the company level. Half said that improving supply chain management is a long-term goal.

However, one trade contractor points out the challenge of using sophisticated systems for supply chain management when it comes to some suppliers they deal with. "Those poor people are in the Stone Age [with handwritten material requisitions faxed to the contractor] ... We are attempting to drag them into the 20th century .. to at least get them to use email, and maybe take some digital files on a spreadsheet now and then." This is a problem because it interferes with the firm's ability to track component-level data.

### Future Needs

- **Better integration:** Contractors need ERP systems that integrate data seamlessly across all project team members without having to invest in customized solutions.
- **Cloud-based systems:** Some GCs would like to move away from their own server-based database to cloud systems. ■

## Rise of the Super-Sub

**As producers of highly detailed models and critical project data, super-subs are being recognized as key players early in the project lifecycle, and on some projects as stand-alone players.**

**T**hrough advancements in modeling and production technologies, a new tier of trade contractors is emerging. Dubbed by some as “super-subs,” these firms combine construction with expertise in engineering and operations. They are deeply leveraging advanced tools to aid in greater collaboration, virtual construction and model-driven prefabrication and modularization.

### Integrated Project Delivery

Victor Sanvido, senior vice president of Southland Industries, a firm specializing in mechanical and electrical building systems, says Southland is increasingly integrated in project teams, often getting involved early in projects. “We recognize that 50% of the [project] cost is established during the program phase, 75% during schematic phase and the rest after that,” he says. “So we need to be involved in the programming and schematic phases to maximize the value of what we can bring to the table.”

As some firms and owners push for more integrated project delivery to improve cost, schedule and quality, the role of these major trade partners has become more critical, says David Mortenson, president of Mortenson Construction. As part of that approach, Mortenson is increasingly looking for subcontractors that can offer multi-trade prefabrication and modularization solutions on projects. “The suppliers and

subcontractors who adopt integrated delivery and use new manufacturing-based techniques will find their business growth accelerates over the next 5 to 10 years,” he says. “Those who don’t will find their opportunities limited.”

### Evolving Relationships With Other Players

Increased collaboration is causing an evolution in the relationship between trade contractors and engineers. Gerald Hartford, principal of Hartford Engineering, says he is working more closely with trade firms on designs and moving away from creating construction documents. Instead, he passes that level of design on to the contractors’ detailers.

“I’ll do the design and engineering, working closely with my contractors, and go right to their BIM models, which are suitable for their particular fabrication practices,” he says.

Sanvido also recognizes the value of advanced modeling and production techniques executed by trade contractors. “When we design a facility and we do significant prefabrication and modularization, our safety performance is about 15 times better than the industry average,” he says. “That’s a huge differentiator.”

The relationship between these subs and owners is also changing. Sanvido notes that on about one third of Southland Industries’ projects, the firm is involved in helping owners make the business case for a project or validate their business program.

### Beyond Construction

Multi-trade contractors with design/build and post-construction servicing capabilities can become the central hub of the project lifecycle process. David Morris, director of virtual construction with Emcor Group, says that as super-subs expand their capabilities, they are able to offer more of a one-stop-shop solution for owners, similar to EPC-style delivery in the industrial market. For example, if a client wants to completely overhaul a mechanical room, the super-sub may be able to take on all of the work without a general contractor or architect involved. “The super-sub concept works quite well in that scenario because you don’t need to have an additional tier of involvement by people that don’t have skin in the game,” he says. “Everyone there is performing a vital function.”

Morris sees this as establishing an ongoing relationship with owners, since trade contractors can provide services to owners beyond construction and into the operations and maintenance phase of the building. Just as general contractors are often retained by large institutional owners for years to address ongoing capital needs, super-subs could be contracted directly to assume these roles. ■

## In-Depth Interview Findings: Collaboration and Technology-Focused Data Integration

**As more firms aim to foster better collaboration among team members, integration of workflows and project-specific data is critical. Teams must find solutions to bring together disparate internal business functions as well as the capabilities of a wide-variety of external team members. In some cases, this raises technological challenges, but often teams are also faced with conflicting cultural issues or differing processes.**

**F**indings from in-depth interviews (IDIs) conducted with four general contractors that are committed to a collaborative approach on projects demonstrate that there are a few elements that support collaboration and impact its success beyond the commitment of the partners and their engagement with the process. Delivery method and systems support collaborative efforts and must be taken into account to advance an effective approach. However, **options for software and systems currently available limit the potential to have a truly positive impact on the collaborative process.**

### Collaborative Delivery

Established and emerging delivery methods are forging partnerships that foster collaboration, crafting contractual terms and establishing common standards and practices to streamline workflow between team members. **All firms interviewed are deeply engaged in collaborative projects, reporting that at least half of their projects use the collaborative delivery methods discussed below.**

The industry is significantly expanding its view of collaborative delivery methods, exploring new contractual schemes to better achieve project goals.

### DESIGN-BUILD

**For decades, design-build has gained acceptance and is now the preferred delivery method for many**

**contractors**, and the findings from the participants in the IDIs align with the broader industry. All four engage in design-build projects, and nearly all of their collaborative projects are design-build.

One contractor notes that half of the firm's current projects are design-build, but he expects that 60% to 70% of future projects will use that method. In anticipation of this, the firm "reached out to a number of design firms that share similar company cultures and values to forge memorandums of understanding for design-build projects. The agreements lay out a framework for how [the contractor] and specific design firms will approach a design-build project, spelling out basic protocols, team roles and responsibilities."

### INTEGRATED PROJECT DELIVERY

In recent years, some owners have pursued integrated project delivery (IPD) by using an integrated form of agreement to contractually align team members in this approach. As an emerging method, IPD has seen limited use to date, but two of the advanced group of contractors interviewed have worked on IPD projects. The firms used contractual agreements, such as an Integrated Form of Agreement, to create the framework of the collaborative delivery method.

As an emerging delivery method, a limited number of projects have been contracted using this scheme, but **IPD is expected to gain momentum in the**

**coming years, especially among early adopters in sectors such as health-care. For at least some of the respondents, increasing owner interest is critical to that growth.** "IPD seems to be the desire of clients, but clients sometimes fall short of that," said one contractor.

### CONSTRUCTION MANAGER AT RISK

Construction manager at risk is not always one of the delivery methods most associated with a collaborative approach, but one respondent, who is heavily involved in construction-manager-at-risk projects, considers them to be highly collaborative.

### DESIGN-BUILD-OPERATE

Design-build-operate (DBO), which is sometimes referred to as design-build-maintain, is another emerging collaborative concept. In the United States, it has gained some traction on public-private partnership projects, such as toll roads, but its adoption is limited to date.

**No firms interviewed are currently engaged in DBO contracts, but some are pursuing projects and discussing this option with owners.**

One firm reports that while it does not have any current design-build-operate projects, the firm is in the procurement and proposal phase on future DBO projects. This firm expects to become more involved in DBO projects in the next five years, particularly on large infrastructure projects.



- One firm has seen requests about DBO during preconstruction from some institutional clients, but “no one has taken the leap of faith to do it yet.”
- Given that there is limited adoption of DBO in the vertical building markets, three experts said their firms offered services to clients to aid in operations and maintenance after a project is commissioned. These firms are primarily leveraging data from BIM models to help clients with post-occupancy needs.

**Just as with all collaborative delivery methods, the adoption rate of DBO hinges on its acceptance by owners.** Contractors note that clients drive the choice of delivery method on a project, meaning that owners play the central role in promoting enhanced methods of collaboration in the industry.

### Fabricators and Detailers

Advanced modeling and production techniques are helping contractors produce detailed models that serve the needs of both contractors and fabricators. In forging this connection, contractors create a single source of data that is critical to the coordination process, while providing assurance that fabricated components will meet specifications.

**As this collaborative process can involve multiple team members—contractors, subcontractors and fabricators—it is critical that users find interoperable means of data collaboration.** Detailers and fabricators can work within silos on projects, but a more collaborative approach could improve efficiency and consistency of data. **Owners**

**can play a critical role in this process: some firms note that the level of detailing on a project may depend on a client’s willingness to pay for it.**

### INVOLVEMENT IN FABRICATION AND DETAILING ON PROJECTS

As general contractors, the firms interviewed may not be directly involved in fabrication and detailing, unless it is on their own self-performed work. More often, they are involved in coordinating between the trades that are doing these tasks. A general contractor may contractually require subcontractors to provide specific deliverables relative to detailing.

### FREQUENCY OF USE

Two contractors say they work with fabricators and detailers on all projects. Two say they work with fabricators and detailers on some, but not all projects.

**One contractor notes that decisions regarding the scope of models and level of detail can be driven by client requirements or the client’s willingness to pay for modeling.**

This decision could also be driven by the complexity of a project’s scope and the risk of field issues if modeling is not done.

Although owners and contractors can impose detailing requirements on subcontractors, one contractor notes that, for some subcontractors, 3D fabrication is integral to their existing process “to the point where they will produce a fabrication model regardless of if we ask them for one or not.”

### ROLES AND RESPONSIBILITIES

For general contractors, their primary role is to coordinate the

detailing done by its various subcontractors. This could include gathering digital models from all parties and coordinating those in a federated model to check for collisions or constructability issues.

### COMMUNICATION

Contractors use a mix of conventional and emerging digital tools to communicate with detailers and fabricators. Although direct communication by telephone and email are still very common, most also pursue multi-party connections to data and files. This could include FTP sites or other file-sharing systems. Several also used online meeting systems for multi-party data review in real time.

When considering these communication tools, contractors said they need these tools to be:

- Simple
- Customized and contextual
- Aligned with the users’ workflows
- Affordable

### Software/Systems Use

In a data-intensive environment, software systems are a critical tool in enabling collaboration. Whether focusing on internal functions or working with outside partners on projects, the functionality of the software and systems can either help or hinder the collaborative process.

In addition, contractors note that other non-technological factors can influence the team’s ability to work with integrated data, including culture issues, conflicting workflows and processes, and contractual terms.

The integration of internal and external data varies greatly among firms. **To date, none of the firms interviewed has found a single**

**solution that serves all needs.** Some create customized systems that cater to their internal needs. However, these firms can face challenges when using these unique systems while collaborating with other project team members. Some firms use a suite of third-party software. This approach may not meet all of a firm's internal needs, but it increases the chance that external team members can share data seamlessly, particularly if they use the same software. **Interoperable solutions for data exchange would significantly enhance a firm's ability to collaborate internally and externally.**

**SYSTEM TYPES USED BY RESPONDENTS**

■ **Database system**

Two of the firms interviewed use database systems as the backbone of their data integration strategy. The main advantage of a database is having a centralized source of data. This reduces the risk of redundant or unreliable data.

Respondents did not cite specific disadvantages, but some note that this data may not be easily shared with other project team members.

■ **Enterprise Resource Planning system**

One firm is in the process of implementing a new Enterprise Resource Planning (ERP) system across the company. This is being done in phases, so the system was not fully implemented at the time of this interview. Currently, its operations and accounting functions are connected to the system. Based on cost concerns, other departments, including marketing and estimating, do not have access to the system under the current deployment plan. However, in the future "those

barriers may break down." **In light of this, the contractor said that culture change is its main obstacle on the path to integration.**

■ **Third-party software**

Three use a variety of third-party software solutions for their internal and external needs. Some of this software may help enable collaboration, such as software that is part of a suite of BIM software. By using third-party software, a firm may find interoperability issues when trying to share data between disparate systems. However, the firm

used by various facets of the company.

**SYSTEM SUPPORT FOR INTERNAL COLLABORATION**

Internally, contractors generally support and connect the data from their business functions at multiple levels.

■ **Business development and finance:** Supported at both the corporate and project levels by all respondents.

■ **Constructability, estimating, human resources and safety:** Supported by most respondents at the corporate level. All but human

**"Change management is huge. How do you switch from one system to another? How do you get your team up to speed on a system that they don't necessarily use?"**

may improve its ability to share data externally, if other players use the same software.

**OPPORTUNITIES FOR IMPROVEMENT**

Contractors say that their ability to share data could be improved by:

■ **Reducing duplicate entries.**

■ **Keeping information digital: One contractor states that all data should be "born digital and stay digital. We can be so much more efficient when everybody shares and accesses the same single source of digital information stored in the cloud."**

■ **Standardizing data-sharing constructs: "There's a lot of information out there. The more consistent data you have, the more you'll be able to share it," one expert said.**

■ **Integrating individual systems**

resources are supported by all respondents at the project level.

■ **Procurement:** Only supported by half of respondents at the corporate level. Supported by all at the project level.

When a business function is supported at the project level, it is integrated at both the data and files levels. **However at the corporate level, most of the data is integrated at the file level only, demonstrating the need for better systems for sharing data internally.**

**SOFTWARE/SYSTEMS USED TO ENABLE INTERNAL COLLABORATION**

The firms interviewed use a variety of systems, third-party software and custom solutions to enable file-sharing internally. The choice of which approach to take may be driven by

the types of data being shared such as project management data or BIM models. The type of project and the players involved may also affect this decision.

While users were generally satisfied with their existing systems, **suggested areas of improvement included faster speeds, better reliability of service and improved ease of use.**

■ **Database system:** Two firms use in-house database systems as the primary source for file-sharing internally.

• **Advantages:** When sharing internally, respondents say that **speed and reliability of centralized data were the main advantages.**

• **Concerns:** **Consistency in how employees interact with the data is a primary concern.** One notes that further functionality may need to be developed in-house in the future.

■ **Third-party software**

Three use third-party software solutions that are part of their respective suite of BIM software.

• **Advantages:** When sharing internally, respondents say that the **ability to interconnect data from multiple offices was an advantage.** One notes that the ability to save documents locally for faster viewing was also helpful.

• **Concerns:** **Training and team buy-in are the main obstacles** to using these systems internally.

• **Improvements:** The main improvements that users would like to see are **faster speeds and more stable syncing between online cloud content and local syncing.**

### SYSTEM SUPPORT FOR EXTERNAL COLLABORATION

■ **Database system:** Two firms use in-house database systems as the primary source for file-sharing externally.

• **Advantages:** When collaborating with other firms, respondents say their systems offer **better reliability and tracking of how data is being used within the team.**

• **Concerns:** Contractors say the primary obstacle faced when collaborating with the team is **getting all parties to use their software.** “Change management is huge,” said one respondent. “How do you switch from one system to another? How do you get your team up to speed on a system that they don’t necessarily use?” **Contractual terms are an important factor in driving this approach across multiple project members.**

■ **Third-party software:** Three use third-party software solutions that are part of their respective suite of BIM software.

• **Advantages:** When collaborating with other firms, one respondent notes that its system is very secure and that it could set limitations based on login information. Another added “one-stop shop for everybody.”

• **Concerns:** The main obstacle to using this approach for collaboration is **potential incompatibility of software or workflow among team members.**

■ **File-sharing services:** Two use third-party cloud-based services for file-sharing. These services are available for general business use and were not developed for

construction-specific purposes. Despite this, one said that it was able to customize its services to better serve its needs.

• **Advantages:** Both internally and externally, one user notes that its service was **simple to use and integrated well with apps on the team’s mobile devices and desktops.**

• **Concerns:** Users note that the capabilities of these services were limited.

### SOFTWARE/SYSTEMS USE FOR PROJECT WORK

Project work requires both internal and external collaboration simultaneously. When applying data systems to project-related work, contractors deploy a wide variety of strategies and tools.

Some use multiple software, each focused on specific project-related functions. This approach works well in silos, but does not in a collaborative environment.

Others have taken a more integrated approach, using either custom or third-party solutions. These work particularly well for internal purposes, but may present challenges when collaborating with other project partners. **Custom databases appear to work best because they can be developed to the specific needs of construction, but industry tools with these functions would be beneficial for sharing data externally.**

■ **Custom solutions:**

Two firms reported that they use custom-developed systems that leverage centralized databases for consistent exchange of data. Users report that these systems work well for internal purposes and collaboration. Functions that work particularly

well include:

- **Seamless sharing of information** across multiple project-related functions within the firm.
  - **Ability to make their systems available to other project partners for data-sharing**, including subcontractors, fabricators, suppliers and others. Partners may need to implement these systems for the duration of the project. This could require training and may or may not work seamlessly with each partner's existing systems.
  - **Ability to link data from past projects**, such as supplier information, to new projects. "These histories are beneficial in making decisions for new projects in bidding," one contractor said.
  - Generation of **real-time project performance reports** across a portfolio of projects.
  - Ability to **leverage data from the BIM model** to assist in functions such as estimating efforts for procurement, extracting quantities and verifying take-offs.
- **ERP:**  
One firm has adopted an ERP system that allows data-sharing across multiple project-related functions within the firm.
- **Ability to share data:** The contractor shares data with multiple project partners, including subs, fabricators, suppliers and others. "Everything goes to everybody, and we hope people understand how to use the delete key when they get something they don't need. Try to make it as transparent as possible," said the contractor. As with custom solutions, using this system may require training and

may or may not work seamlessly with each partner's existing systems.

- **Leveraging data from past projects:** When leveraging supplier data from past projects to new ones, the contractor takes a legacy approach, using spreadsheets. "We tend to have the 'good old boy' group that works on our jobs. We see a lot of the same partners coming in with us job to job," the contractor said.
  - **Use of BIM data:** The firm works in BIM, but is not connecting its models to its procurement system.
  - **Real-time project reports:** The contractor is unable to run real-time project reports across its portfolio of projects at this time. The ERP system is in the process of being implemented across the company, so this function is not available at this time. "The desire is there and a lot of people are talking about it," the contractor said.
- **Third-party software**  
One firm uses a mix of software, each focused on different business functions, such as estimating, accounting, scheduling and other project management functions. The firm reports that "in practice our processes and tools are not set up to seamlessly tie this information together. This is a big hairy audacious goal for the industry as a whole."
- **Use of BIM data:** The contractor uses BIM on its self-performed work and is able to tie those models to its procurement systems, but he says this approach does not work as well as they would like.

## Conclusion

Collaboration is fostered at various levels within a project team.

- **The choice of delivery method helps establish the framework for collaboration on projects.**
- **Owners select the delivery method and therefore set the tone for how collaborative a project team can be.**

With a framework in place, contractors drive collaboration among its subcontractors. Subcontractors then work with other trades, and they may collaborate with fabricators. A team's ability to collaborate can be affected at all of these levels, but **respondents note that owners hold the most influence in encouraging collaboration, particularly as there may be costs associated with enhanced collaboration.**

The tools used by different firms on a project team also significantly impact a team's ability to collaborate within a data-intensive environment. **Firms currently use varied and often disparate means to produce and exchange corporate or project data, and there is an ongoing need to improve this process.** Some companies have addressed it by developing custom solutions that may improve their own processes, but these systems do not necessarily aid in collaboration with other firms. ■



## Collaborating for Sustainability

**Sustainability is, fundamentally, a holistic endeavor. The more integrative the processes around the design, construction and operation of a building, the greater the opportunities for generating environmentally effective decisions and practices.**

The most effective collaborations reach beyond the project development team to bring in perspectives from across the building lifecycle.

### Bringing the Users' Perspective Forward

PNC Financial Services Group has developed a fleet of LEED-certified bank branches, and its Tower at PNC Plaza, now under construction, is expected to be North America's tallest naturally ventilated office tower. PNC kicks off each project with an eco-charrette, which engages not only the architectural and engineering disciplines, but also construction managers, building operations staff, IT personnel, PNC's head of workplace and additional perspectives that can help shape the project's approach to sustainability.

The information generated helps align what gets built with how users actually behave. If everyone in a workplace uses cell phones and laptops, for example, the IT system will pose fewer electrical demands than the sum of the usual faceplates. And if a department tallies its real needs for me-space, we-space and flex-space, they may total less than an estimate based on square footage per person.

"There are so many links in the value chain, that any misalignment gets magnified," says Tom Paladino, PE, CEO at Paladino and Company, strategic advisor on the Tower at PNC Plaza's sustainability design process.

"For project teams wanting to push beyond LEED, highly integrated processes are what's getting them there."

### Tracking Design Intent Beyond Completion

By the time a building reaches completion, the owner may consider the development team's role complete. That could be a mistake. According to Andy Frichtl, PE, principal with Interface Engineering, "Almost every building has issues that need to be addressed."

For example, the Hood River Middle School Science and Music Building, an AIA-COTE Award-winning, LEED-Platinum, net-zero-energy facility, did not at first operate at net zero. When Frichtl conducted a post-occupancy review, he found equipment and controls needing fine-tuning and maintenance staff needing to understand the significance of propping open classroom doors in cold weather. Once those adjustments were made, the building not only achieved net-zero energy, it actually began producing more energy than it used.

Monitoring and commissioning may look like extra costs, says Frichtl, but having the design team track design intents, at least through the first year of building performance, confirms achievement of a project's sustainability objectives, establishes benchmarks for owners' reference in the future and brings a better return on investment.

### Hardwired for Collaboration

Operations and maintenance (O&M) costs, which can typically amount to three times a project's initial expense, are determined very early in the project's design. According to a 1994 analysis by Joseph Romm, FAAS, when just one percent of a project's upfront costs are spent, up to 70 percent of its life-cycle costs may already be committed.

The design-build-operate-maintain (DBOM) method of project delivery breaks down the distinction between project development and O&M phases, bringing them under a single, often decades-long contract, and hardwires a project for collaboration. With the contractor and O&M staff contributing from the start, and with environmental and financial implications brought together and forward in the decision-making process, DBOM builds in the holistic thinking that generates more sustainable solutions.

DBOM may be hardwired for collaboration, but other project delivery methods, including traditional design-bid-build, are capable of achieving similar levels of integration. They just require a more explicit commitment. "The type of contract doesn't matter all that much," says David Riley, associate professor of Architectural Engineering at Pennsylvania State University, "it's really about process. It's about having the right talent [who are] having exchanges at the right time." ■



# Collaborating on Prefabrication to Improve Schedule

## Exempla Saint Joseph Replacement Hospital

DENVER, COLORADO

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY

**F**aced with a daunting state-imposed deadline, the new Exempla Saint Joseph replacement hospital project in Denver needed to be on an extremely fast-track path. To meet the challenge, the project team devised a highly collaborative strategy that leverages multi-trade prefabrication and modularization to shave schedule. The plan would enable the team, led by Mortenson Construction, to deliver the 831,000-sq-ft facility in 30 months—five months ahead of an estimated traditional schedule.

“Prefabrication had to be a significant part of this strategy,” says Bill Gregor, construction executive for Mortenson. “It was the only way to meet the schedule restrictions.”

Gregor says the team needed to fast-track both interior and exterior elements to keep everything moving

ahead quickly. The team focused its efforts on four main elements for prefabrication—exterior wall panels, multi-trade corridor racks, bathroom pods and headwalls. By accelerating the exterior panels, crews could enclose the facility quickly and help the team maintain pace with prefabricated interior elements.

That process was enabled, in part, by the contractual framework. Although the project uses traditional contracting methods, integrated project delivery concepts were implemented. Stakeholders committed to a collaboration agreement, which includes incentives, as well as a BIM execution plan to map out the process.

Collaboration proved critical. To accelerate the schedule, designers and contractors worked together in the schematic phase—or earlier—to minimize redrawing.

“Early on we had prefabrication charrettes,” Gregor says. “There were brainstorming sessions with a lot of the players involved to work through all of the ideas of what we could accomplish.”

### Prefabrication and Modularization

For the enclosure system, Gregor says a joint venture of two local contractors were brought in during the design development process, allowing the design team’s work to be informed by the prefabrication process. “[The design team] drew it knowing how we would fabricate [the panels] so they could create modules in their drawings.”

Contractors prefabricated 346 exterior panels—most of which measure 30 ft. by 15 ft.—at a warehouse within five miles of the project site. Five to six panels could be brought in per truck for just-in-time delivery. Each panel was picked directly from the truck, lifted and installed. “On our best day, we placed 26 panels,” Gregor adds.

To help expedite the hospital’s 640 bathrooms, the team decided to create 440 of them as modular pods. The original design included 75 different bathroom configurations, but the team was able to rework it to establish 15 standardized pods. The custom pods were designed to a schematic level and then handed off to the manufacturer. “The manufacturer drew it, designed it in the model and transmitted it back to the design team as an element to insert into [the design] model,” Gregor adds.”

### Multi-Trade Prefabrication

One of the more unique aspects of

**Crews built 166 multi-trade racks that are built in a warehouse and trucked to the site for just-in-time delivery.**



Photograph courtesy of Mortenson Construction

CONTINUED

## Exempla Saint Joseph Replacement Hospital

DENVER, COLORADO

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY

the team's overall approach is the use of multi-trade corridor racks. Only a few hospital projects had used this technique prior to the Saint Joseph's job, but Gregor says Mortenson saw significant potential given that schedule was a primary driver. The 166 corridor racks, which measure roughly 25 ft. long, were constructed in a rented warehouse close to the site. Although each rack contained unique elements, the team worked to standardize and streamline the design as much as possible to improve efficiency.

Mechanical and plumbing contractor U.S. Engineering took the lead, first building the steel structure, then adding ductwork, piping and related elements. The racks were on wheels, enabling crews to move them from station-to-station within the warehouse. After U.S. Engineering's work was done, the rack was moved over to the electrical crews from Encore Electric to add their work. From there, insulation, drywall and framing were also added.

Dan Strait, vice president of project development at U.S. Engineering, says that compared with traditional methods, the multi-trade racks required significantly higher levels of collaboration and coordination, particularly in terms of logistics and constructability. "How do you, from a constructability standpoint, connect a rack to the lower wall sections?" Strait says. "From a logistics standpoint, how does that workflow go? Is it a benefit or not? There are a lot more conversations like that."

Strait said the trades created digital models for coordination and fabrication. U.S. Engineering could also generate a bill of materials for each rack as well as a set of instructions

for crews from its models.

The team also created a production schedule that allowed for a steady flow of racks. Strait says crews created the racks slightly ahead of construction, storing up to two weeks of racks in the warehouse. By using this method, Strait says contractors could maintain steady manpower needs, avoiding peaks and valleys. By allowing some limited storage, the team could accommodate for fluctuations in field installation.

Once shipped to the field, crews could install up to five units per day, creating roughly 125 feet of corridor space.

For the final piece of Mortenson's strategy, the team is creating 376 multi-trade headwalls, which include piping for medical gases, electrical, framing, drywall and finishes."

### Benefits

The project, which topped out in April 2013 and is scheduled to be completed in late 2014, is ongoing and Mortenson does not have final metrics in place, but clear benefits are emerging. As of October 2013, the project was a month ahead of schedule, five months ahead of a traditional schedule. Gregor also notes that, with so much prefabrication being done in warehouses at ground level, the work is exposed to much less risk. There were no recordable incidents on the prefabricated work, as of October 2013. Gregor notes that in some ways elements, such as the multi-trade racks can cost more in terms of direct costs, but that it is made up in other ways, such as reduced overall schedule. "We've been able to identify that it is cost-neutral," he says.

Strait says he also sees significant

benefits to the schedule. U.S. Engineering and Encore Electric partnered on multi-trade rack corridors for another project in Denver that completed this year, and they were able to build upon their collaboration in this project and work together effectively. He says that the team was able to install corridors on that project in one third of the time it would take for a traditional job.

"It's a great concept," he says. "The collaboration is a benefit in itself. It brings the team closer from both a cost and construction standpoint. You get just as good quality, if not better, and it's leaner construction in terms of workflow." ■

### Project Facts and Figures

**General Contactor**  
Mortenson Construction

**Type of Project**  
Hospital

**Size**  
831,000 sq. ft.

**Demolition**  
December 2011

**Completed**  
June 2014

### Collaborative Goals

**Reduce construction schedule by at least five months using collaborative techniques. Prefabricated/modular elements include:**

- 166 Multi-Trade Racks
- 376 Headwalls
- 440 Bathroom Pods
- 346 Exterior Panels

stats

## Other Research Studies Support Lean Conclusions

From renewed and more intensive use of long-standing practices, such as prefabrication and modularization, to the leveraging of new technologies, such as building information modeling (BIM), the construction industry is actively seeking ways to conduct work more efficiently and profitably.

Given the fact that over one third of the industry is not familiar with Lean construction or specific Lean practices (see page 10), it is clear that more information on the need for and benefits of Lean is important to help improve the construction industry process. However, Lean is not an isolated approach; it is the cornerstone in efforts to improve competitiveness, profitability and productivity in the construction industry.

In research since 2007, McGraw Hill Construction (MHC) has demonstrated the impact that individual practices and tools critical to taking a Lean approach—such as the use of BIM, improved information mobility, the use of prefabrication and the application of risk mitigation strategies—have had on productivity and profitability in the industry. The findings from these other research studies shed additional light on the value of adopting a Lean approach.

### The Importance of Collaboration

As the Lean experts in the in-depth interviews reveal, collaboration is at the heart of a Lean approach to increase efficiencies. Core practices like Last Planner System depend on collaboration among project team partners to be effective. Among the series of construction-industry specific Lean practices measured, two collaborative approaches—target value design and multi-party contracts—are the most widely known and adopted (see page 13).

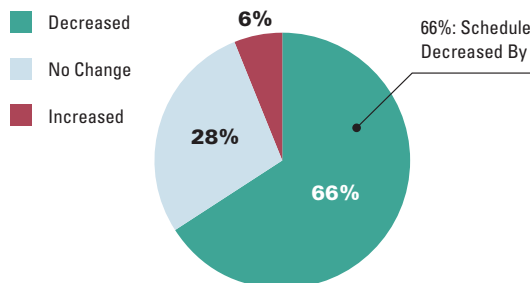
This study also demonstrates the challenges experienced by Lean practitioners in their ability to share data with project team members. A recent MHC study on information mobility<sup>1</sup> reveals that contractors find collaboration with owners and design firms to be increasingly important. Contractors in that study consider supporting collaboration to be among the most

important benefits of improved information mobility due to mobile tools and technology advances. In fact, **improved collaboration among team members is the most widely recognized benefit of improved information mobility by contractors, ranking even a little higher than improved productivity, with 81% of general contractors and 70% of specialty trade contractors perceiving it as an important benefit.** The study also reveals that the ability to share data with project team members is among the most important functions of mobile technologies and a key driver for firms to increase their information mobility.

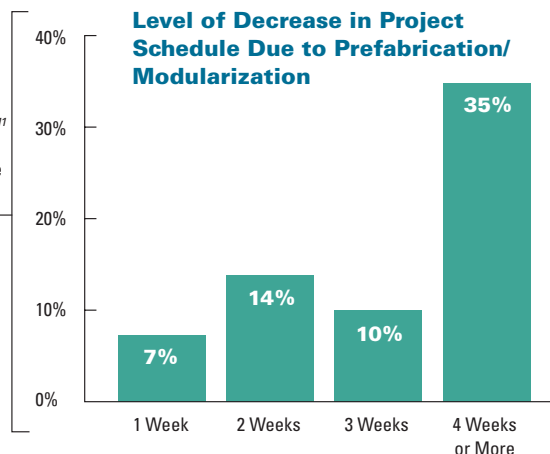
This finding has strong implications for firms taking a Lean approach. Since many Lean practices, such as the Last Planner System, depend on the full cooperation of all project team members, greater industry attention to and prioritization of collaboration supports

### Total Impact of Prefabrication/Modularization on Project Schedule

Source: Prefabrication and Modularization SmartMarket Report, McGraw-Hill Construction, 2011



### Level of Decrease in Project Schedule Due to Prefabrication/Modularization



the potential for better and more extensive Lean approaches. In addition, as firms work collaboratively on projects using a Lean approach, their exposure to the benefits companies experience because of Lean will help increase industry awareness and interest in Lean in the future.

An MHC study on the mitigation of risk<sup>2</sup> reveals at least one reason why the industry places greater importance on improving collaboration. **77% of the construction firms in that study agree that the use of an integrated team reduces construction project risk.** One of the greatest benefits of taking a Lean approach is greater reliability of results from a project, especially according to the Lean experts in the in-depth interviews. Effective collaboration is one critical element of that greater reliability.

### Benefits of Prefabrication and Modularization

**Eighty percent of firms in the Lean study report the use of offsite prefabrication to improve efficiency on their projects (see page 15).** The Lean experts in the in-depth interviews, especially the specialty trade contractors, also reveal that judicious use of prefabrication and modularization is a central part of their Lean approach (see page 17) and an important factor in their ability to achieve the benefits they experience. While prefabrication and modularization are widely applied in the industry and not solely used by Lean Practitioners, the focus on scheduling and the additional time spent in the planning stages to improve construction efficiencies allows Lean practitioners to capitalize on more sophisticated and complex

prefabricated assemblies. (See the Exempla Saint Joseph case study on page 52 as an example.)

While this study did not quantify the specific gains achieved from the adoption of prefabrication, an MHC study in 2011<sup>3</sup> did provide compelling evidence of the benefits of the broad application of prefabrication and modularization across the industry:

- **66% of contractors find that use of prefabrication/modularization shortened project schedules, with over half reporting savings of 4 weeks or more.**
- **65% find that use of prefabrication/modularization reduced project budgets, with over half reporting decreases of more than 5%.**

The 2011 study also revealed that the sectors on which prefabrication/modularization is most widely used are healthcare facilities (used by 49%), higher education (42%) and manufacturing (42%).

In addition, 63% of contractors in a 2013 MHC study on safety<sup>4</sup> report that the use of prefabrication and modularization has had a positive impact on safety for their projects.

These findings suggest the need for further research that provides more specific statistics on the benefits experienced by Lean practitioners, who are better positioned to utilize complex, multi-trade assemblies and can also take advantage of their advanced approach to scheduling to improve the effectiveness of taking this strategy.

### BIM Benefits

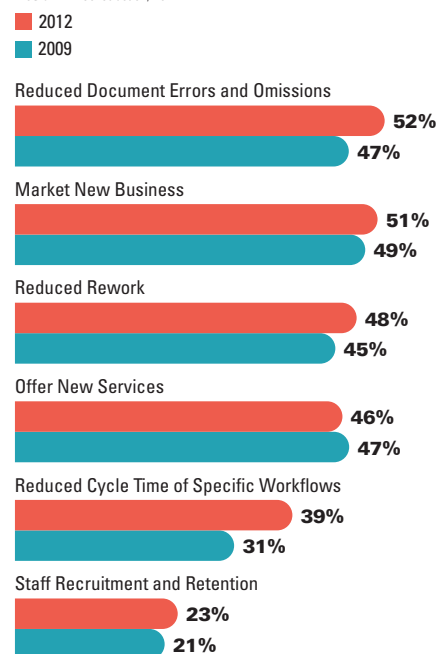
Advanced modeling practices are also cited by many of the Lean experts as a critical part of their attempts to improve efficiency at their companies. BIM is also a key

tool used by the industry to support collaborative efforts and to improve the efficiency of the process of prefabrication. An MHC 2012 study of BIM in North America<sup>5</sup> found a striking increase in the percentage of BIM users that report increased profits and improved ability to maintain repeat business, demonstrating that experience yields better results.

This finding corresponds to the findings in this report that adoption of Lean promotes the ability to be competitive and to increase customer satisfaction. It is likely that increased experience may also impact the number of firms able to achieve key benefits like profitability. This is particularly important because increased profitability and productivity are important drivers for non-practitioners to consider adopting Lean.■

### Short-Term BIM Benefits (2009 and 2012)

Source: *The Business Value of BIM in North America SmartMarket Report*, McGraw-Hill Construction, 2012



1. *Information Mobility SmartMarket Report*, McGraw Hill Construction, 2013. 2. *Mitigation of Risk in Construction SmartMarket Report*, McGraw Hill Construction, 2011. 3. *Prefabrication and Modularization SmartMarket Report*, McGraw Hill Construction 2011. 4. *Safety Management in the Construction Industry SmartMarket Report*, McGraw Hill Construction, 2013. 5. *Business Value of BIM in North America SmartMarket Report*, McGraw Hill Construction, 2012.



# Methodology:

## Lean and Data-Enhanced Collaboration Research

LEAN CONSTRUCTION: LEVERAGING COLLABORATION AND ADVANCED PRACTICES TO INCREASE PROJECT EFFICIENCY

The research in this report includes the results of a quantitative research study on Lean conducted online, and two sets of qualitative in-depth interviews—one also focusing on Lean and the other examining data-enhanced collaboration for contractors.

### Quantitative Lean Research

The 2013 Lean Construction Study was conducted online among U.S. general contractors and specialty contractors from selected trades to explore how the industry views Lean construction and the degree to which it is adopting Lean/efficient practices today and will be in the future.

A total of 193 qualified respondents completed the online survey including 120 respondents from the McGraw Hill Construction Contractor Panel and 73 respondents from Lean Construction Institute members. Data were collected from September 6–19, 2013. The total sample size of 193 benchmarks at a high degree of accuracy: 95% Confidence Interval with a margin of error of +/-7.1%.

The survey was open to all general contractors and the following types of specialty trade contractors:

- Concrete
- Curtainwall
- Electrical
- Glazing/panels
- HVAC, mechanical, plumbing, sheet metal/ducting
- Masonry
- Roofing
- Steel erection and fabrication
- Thermal and moisture control
- Vertical transportation

Among trade firms doing mechanical and electrical work, 50% do just electrical work and 25% do HVAC,

mechanical, plumbing and sheet metal. Only 3% do electrical and mechanical work.

The respondents' level of engagement with Lean was determined by asking about their familiarity with or implementation of the following six Lean practices:

- Just-In-Time
- Last Planner System
- Lean Construction
- Pull Planning
- Six Sigma
- Toyota Way or other Lean Manufacturing Approaches

Based on the responses, three groups were derived for analysis:

- 1) Lean Practitioner:** Those who implemented any of these six practices. Ninety-four respondents were practitioners, 49% of the total.
- 2) Familiar with Lean:** Those who were familiar with at least one of the six practices but have not yet implemented any. Fifty-seven respondents were familiar with Lean, 29% of the total.
- 3) Not Familiar with Lean:** Those not familiar with any of the six practices. Forty-two were not familiar with Lean, 22% of the total.

These definitions were used to direct respondents to specific sets of questions appropriate to their knowledge of or experience with Lean.

The following is the distribution of the respondents by size when measured by their revenues in 2012:

- \$250 million or more: 30%
- \$50 million to less than \$250 million: 21%
- \$10 million to less than \$50 million: 18%
- Less than \$10 million: 26%
- Prefer not to say: 5%

### Qualitative In-Depth Interviews

Two sets of in-depth interviews by telephone and in person were conducted, one for insights in the practice of Lean and the other to examine data-enhanced collaboration.

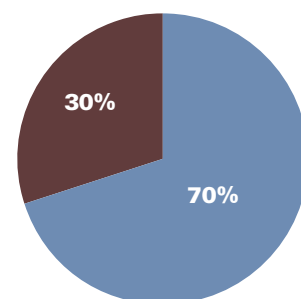
For the Lean study, expert Lean practitioners from six general contractors and four trade contractors were interviewed. The general contractors' annual revenues in 2012 ranged from \$150 million to \$9 billion, with most in excess of \$2 billion. The trade contractors interviewed were all MEP firms, and their 2012 revenues ranged from \$450 million to \$7 billion, with most under \$1 billion.

For the data-enhanced collaboration study, in-depth interviews were conducted by telephone with four general contractors that are actively engaged in using collaborative delivery methods on their projects. Each firm reported using a collaborative approach on at least 50% of their projects. Their 2012 revenues ranged from \$150 million to \$4 billion, with most in excess of \$2 billion. ■

### Respondents by Firm Type

Source: McGraw Hill Construction, 2013

- General Contractor
- Specialty Trade Contractor





## Resources

Organizations and websites that can help you get smarter about the use of Lean practices



### McGraw Hill Construction

Main Website: [construction.com](http://construction.com)

Dodge: [construction.com/dodge](http://construction.com/dodge)

Research & Analytics:

[construction.com/dodge/](http://construction.com/dodge/)

[dodge-market-research](http://dodge-market-research)

Architectural Record: [archrecord.com](http://archrecord.com)

Engineering News-Record: [enr.com](http://enr.com)

Sweets: [sweets.com](http://sweets.com)

SmartMarket Reports:

[construction.com/market\\_research](http://construction.com/market_research)

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Dassault Systemes  
[www.3ds.com](http://www.3ds.com)

### Premier Partner

Dassault Systemes: [3ds.com](http://3ds.com)

### Research Partner

Lean Construction Institute: [leanconstruction.org](http://leanconstruction.org)

### Other Resources

American Society of Civil Engineers: [asce.org](http://asce.org)

Associated Builders & Contractors: [abc.org](http://abc.org)

Associated General Contractors of America Lean

Construction Forum: [agcleanforum.org](http://agcleanforum.org)

BIMForum: [bimforum.org](http://bimforum.org)

BuildingSMART Alliance: [buildingsmart.org](http://buildingsmart.org)

Construction Industry Research and

Information Association (CIRIA): [ciria.org](http://ciria.org)

Construction Users Roundtable: [curt.org](http://curt.org)

Design-Build Institute of America: [dbia.org](http://dbia.org)

Intergraph: [intergraph.com/assets/pdf/](http://intergraph.com/assets/pdf/)

[LeanConstructionWhitePaper.pdf](#)

Karlsruhe Institute of Technology (Germany):

[tmb.kit.edu/english/1561.php](http://tmb.kit.edu/english/1561.php)

Lean Construction Forum on Linked In: [linkedin.com/groups/Lean-Construction-Network-2622826](http://linkedin.com/groups/Lean-Construction-Network-2622826)

Loughborough University (UK):

[construct-lean.org/index.php](http://construct-lean.org/index.php)

Michigan State University: [leanconstruction.msu.edu](http://leanconstruction.msu.edu)

National Electrical Contractors

Association: [necanet.org](http://necanet.org)

National Institute of Building Sciences: [nibs.org](http://nibs.org)

National Institute of Standards and Technology:

[nist.gov/lean-manufacturing-portal.cfm](http://nist.gov/lean-manufacturing-portal.cfm)

Sheet Metal & Air Conditioning Contractors'

National Association: [smacna.org](http://smacna.org)

University of California Berkeley: [ce.berkeley.edu/~tommelein/lean.htm](http://ce.berkeley.edu/~tommelein/lean.htm)

University of Salford (UK): [www.chairegp.uqam.ca/upload/files/conference-invitation/lean-construction-industry.pdf](http://www.chairegp.uqam.ca/upload/files/conference-invitation/lean-construction-industry.pdf)

■ Design and Construction Intelligence

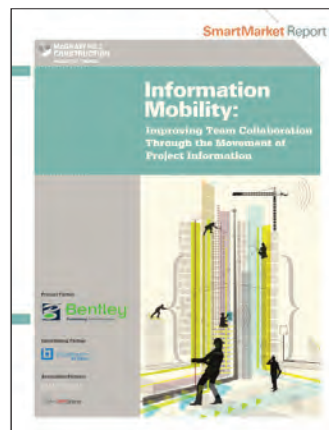
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