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Prefabrication and Modularization:

Increasing Productivity in the Construction Industry

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Prefabrication and Modularization: Increasing Productivity in the Construction Industry SmartMarket Report

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McGraw Hill CONSTRUCTION

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Introduction

Prefabrication and modularization are construction processes that the industry has used for centuries. So why in 2011 is McGraw-Hill Construction conducting forward-thinking market research on what many consider to be old, well-established methods used on construction projects?

Well, to paraphrase the song, everything old about prefab and modular is new again. This reemergence of prefab and modular as a “new” trend is tied to the rise of BIM and green building, critical new trends identified by McGraw-Hill Construction and other industry leaders.

The emergence of building information modeling (BIM) is influencing design and construction processes and how project teams collaborate. In the *Business Value of BIM SmartMarket Report* (2009), we found that a key benefit of BIM is enabling the increased use of prefabrication and modularization, which in turn improves worksite productivity and overall project ROI. Contractors were especially excited, with 77% believing that BIM would allow them to use prefabrication on larger, more complex projects in the future.

The phenomenal growth in green building has also had an undeniable impact on the construction industry. Just last year, in *Green Outlook 2011* we estimated that up to 35% of new nonresidential construction is green, representing a \$54 billion market opportunity that will grow to \$120 billion or more by 2015.

Last year, in the *Green BIM SmartMarket Report* (2010), we looked at the convergence of the BIM and green trends and found that construction professionals who use BIM on green projects are more likely to do model-driven prefabrication than non-green BIM practitioners. These green BIM practitioners saw model-driven prefab as a way to design and construct greener buildings and have a greener site.

Now, in this *SmartMarket Report*, we take a new look at prefabrication and modularization and their impact on a major initiative within our industry—improving productivity. Through an Internet survey of hundreds of AEC professionals, we gathered data on the impact of prefabrication and modularization on key industry productivity metrics including project schedules, costs, safety, quality, eliminating waste and creating green buildings. Some of the most significant productivity findings from prefabrication and modularization users include the following:

- **66% report that project schedules are decreased—35% by four weeks or more.**
- **65% report that project budgets are decreased—41% by 6% or more**
- **77% report that construction site waste is decreased—44% by 5% or more.**

We would like to thank our premier partners including NIST, the Modular Building Institute, Island Companies, and Syntheon; and our other corporate & association partners for supporting this study.



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The Summit at Queens College
Student Residence Hall, Queens, NY

From left to right:
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Executive Summary

Everything Old Has Become New Again!

Building information modeling (BIM), modern manufacturing methods, sustainability goals and recognized productivity gains rejuvenate centuries old-construction processes.

Prefabrication and modular construction are processes that have been used by generations of construction professionals. Over the past century, these processes have developed a stigma of “cheapness” and “poor quality.” However, through modern technology, that image has changed. Now it’s a key component of the drive to improve construction industry productivity.

Adoption and Usage

Prefabrication and modular building processes are not new activities—63% of those that are using these processes have been doing so for five years or more. Given that prefabrication/modular construction has been around for many years, it is not unexpected that 85% of industry players today are using these processes on some projects—including 90% of engineers, 84% of contractors and 76% of architects.

By 2013, nearly all players (98%) expect to be doing some prefabrication/modularization on some projects. Among users, usage today is fairly low. Only about a third of users (37%) have been using it at a high or very high level (more than 50% of projects). Over the next two years, usage on projects is expected to moderately grow, with high or very high usage reaching 45% by 2013. Among all players surveyed, the highest level of current and future usage is among fabricators, mechanical contractors and design-builders.

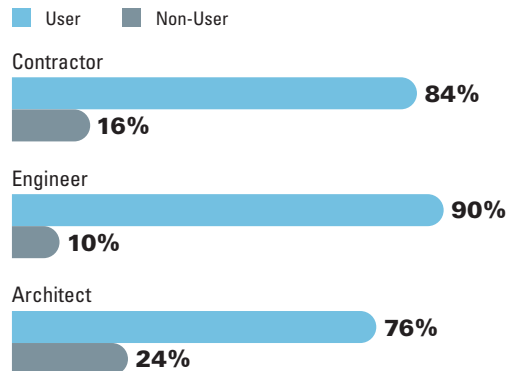
Among all players, the primary reason they are not using prefabrication and modularization on some or all of their projects is that the architect did not design it into their projects. Owner resistance was the primary reason given by architect users (39%) and non-users (54%) for not including prefabrication and modularization into their designs.

BUILDING SECTORS AND AREAS OF USAGE

Adopters are using prefabrication/modular building processes on a wide variety of commercial building projects. In particular, respondents today are using it on healthcare facilities (49%), college buildings and dormitories (42%) and manufacturing buildings (42%). These respondents see the most future opportunity in healthcare facilities (14%), hotels and motels (11%), commercial warehouses (11%) and other building types (10%) that included data centers, prisons, power plants and oil refineries. These opportunities do vary by player type.

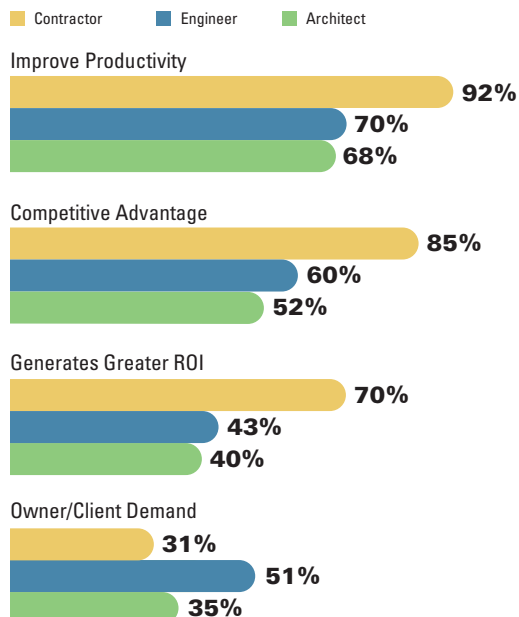
Percentage of Prefabrication/Modularization Users Today (2011)

Source: McGraw-Hill Construction, 2011



Current Drivers to Use of Prefabrication/Modularization (By Player)

Source: McGraw-Hill Construction, 2011



Within a building, prefabrication and modular construction are used in a variety of areas but most often in the building superstructure (27%), mechanical, electrical and plumbing (MEP) systems (21%) and exterior walls (20%).

When deciding whether or not to use prefabrication or modularization, the most important factor is the job site accessibility (58%) followed closely by the number of building stories (53%) and the type of building exterior (52%).

USAGE DRIVERS

The most important driver to current usage of prefabrication and modularization is its ability to improve productivity (82%). This is particularly important to contractors (92%). All players also see these processes as making them more competitive in the marketplace (75%).

Productivity Improvements—Primary Future Driver

Architects, engineers and contractors are also very closely aligned in the belief that the primary drivers to future usage will be the improvements that prefabrication and modularization can provide to elements of productivity including project schedule, cost, safety and quality.

IMPROVED PROJECT SCHEDULES

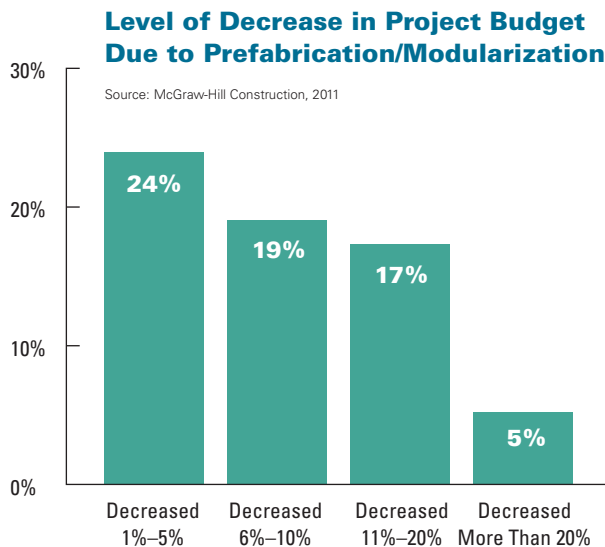
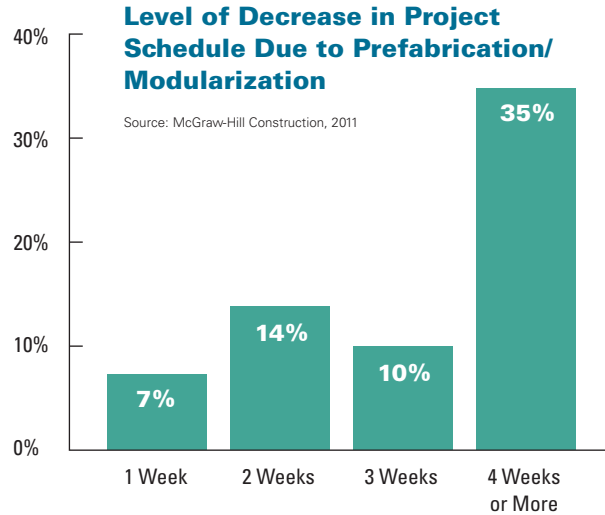
A key metric of productivity is the project schedule. 66% of user respondents indicated that prefabrication/modularization processes have a positive impact on project schedules, with 35% of those respondents indicating that it can reduce the project schedule by four weeks or more.

REDUCED COST AND BUDGETS

Another key productivity metric is project cost as measured by the project budget. 65% of user respondents indicated that the use of prefabrication/modularization had a positive impact on project budgets, with 41% indicating that it reduced project budgets by 6% or more.

SITE SAFETY

More respondents (34%) believe that prefabrication and modularization can improve site safety versus those who think the practices reduce safety (10%). Most users believe that these processes are safety neutral (56%).



GREEN BUILDING AND WASTE REDUCTION

Green was not a major driver to prefabrication and modularization adoption. However, when asked about elements of green, including site waste and amount of materials used, a different story emerges. 76% of respondents indicate that prefabrication/modular construction reduces site waste—with 44% indicating that it reduced site waste by 5% or more. In addition, 62% of respondents believe that these processes reduce the amount of materials used—with 27% indicating prefabrication/modularization reduced materials used by 5% or more.

Recommendations

The research findings have varying implications for different industry players.

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

Owners:

Consider using prefabrication and modularization processes on your projects. This is not your grandpa's prefab! With the precision bestowed by BIM and the quality provided by modern materials and manufacturing facilities, prefabrication and modular construction offer the opportunity to obtain significant productivity gains on your projects. Owner demand is the primary driver for architects to include prefabrication / modular construction into their project design.

Architects:

Understand and educate clients on the benefits of prefabrication and modularization. As the initial interface with the client, the architect has the greatest influence during the design phase in determining if prefabrication and modular construction will be used in a project.

Understand the key benefits that prefabrication/modularization offer, such as improved project productivity, producing more sustainable buildings and ultimately increasing ROI for the client and other members of the project team. Architects should educate clients that using prefabrication/modularization can measurably:

- Reduce project schedules—sometimes by a month or more.
- Decrease purchase and installation costs of materials—ultimately decreasing the project budget.
- Increase construction site safety—resulting in fewer accidents and lower insurance costs.
- Eliminate significant amounts of construction site waste, making the project greener.
- Allow the specification and installation of better quality and more sustainable building materials.

Specify prefabrication and modularization in your design.

Once you get the client's buy-in, make sure you include prefabrication/modularization into your design. The early decision to bring it into the project allows for greater continuity of design maximizing potential productivity gains. The number one reason engineers and contractors give for not using prefabrication or modularization is that the architect did not include it in the project design.

Engineers:

As the professionals primarily responsible for the structural integrity and systems efficiency of buildings during their

design and construction, **engineers should evaluate the quality and availability of prefabricated/modular products and be the catalyst for their use.**

Many engineering firms today are already using prefabricated /modular elements for the building superstructure, exterior walls, roof and floor, and they view their use as a way to differentiate themselves from their competition.

General Contractors and Construction Managers:

Build prefabrication/modular efficiencies into your pre-construction planning and bids.

Prefabrication provides predictable results for your schedule and costs. The research shows that it can decrease the purchase and installation costs of materials and compress project schedules. These factors can ultimately decrease the project budget and allow GC and CM firms to be more competitive.

Include the green factor. It is clear that prefabrication and modular construction can help reduce waste and result in a greener construction site. Given that green has become a major factor in the construction marketplace, the fact that prefabrication/modularization can

help achieve green objectives should be promoted and emphasized in bids.

Specialty Contractors:

Adopt for competitive reasons. For some construction specialty trades, such as mechanical and electrical contracting, prefabrication/modularization has become an integral part of their business. With the inherent efficiencies and productivity gains and current projections showing increased usage on projects, specialty contractors need to acquire experience with prefabricated/modular processes in order to remain competitive.

Manufacturers:

Promote the green benefits of your products.

Although most architects, engineers and contractors do not view prefabricated and modular products as a primary way to achieve their green building objectives, all professionals agree that these processes reduce waste and the amount of materials used on projects. Manufacturers need to raise awareness of these green benefits.

Create BIM objects of prefabricated and modular products. BIM use continues to rise, and BIM is a driver to increased use of prefabrication/modularization. ■

Data: Introduction

Construction Trends

Driving Prefabrication/Modularization

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

Prefabrication and modularization are certainly not new to the construction industry. However, current influential construction trends, such as the increasing interest in lean construction, the rising use of BIM technologies and the growing influence of green construction have caused many practitioners to reconsider their appeal. In fact, the National Research Council's 2009 report on improving productivity in the construction industry recommends prefabrication/modularization as an "opportunity for breakthrough achievement."¹ These factors, combined with recent advances in prefabrication/modularization, make this a critical trend in the construction industry.

Lean Construction

The strong increases in productivity offered by using prefabrication and modularization fit squarely into the lean building model. The difficult economic conditions in the construction industry have increased the appeal of lean methods and practices. For more information on the use of prefabrication and modularization to achieve a lean approach, see pages 24 and 25.

BIM

The increasing use of BIM also contributes to the potential for increased use of prefabrication and modularization. In a recent study about the use of BIM on green projects, McGraw-Hill Construction (MHC) found that the use of BIM model-driven prefabrication on more than one quarter of their projects is expected to increase from 37% to 73% among practitioners who use BIM for green work. Even those who are currently not using green BIM expect an increase from 22% to 57%.¹ BIM helps enable prefabrication of tightly integrated MEP systems, allowing designers to maximize space for other uses in high-tech buildings like hospitals.

Green Building

Green building has grown into a substantial part of the overall construction market. MHC's *Green Outlook 2011* estimates that nonresidential green building will comprise 28%–35% of the total market by the end of 2010. This dramatic increase in market share, from less than 5% in 2005, reflects the fact that green building sustained steady growth throughout the recession, even as the overall construction market shrunk by nearly one-third.²

MHC also predicts that the growth of the market share for green will not abate as the construction industry recovers from the recession. By 2015, MHC projects that 40%–48% of nonresidential construction will be green.

As the results of this study demonstrate, this has strong implications for rising interest in prefabrication and modularization, which helps eliminate waste onsite and conserve resources.

Bringing the Trends Together

What is most striking about prefabrication/modularization is its ability to enable all these trends, in addition to being more prominent because of them. It brings all of them together to improve productivity in construction.

Note About the Data

The data in this report are based on an online survey of 809 contractors, architects and engineers. The contractors comprise 65% of the total respondents, while architects total 12% and engineers 23%. The large number of respondent firms in all three player categories provides a statistically meaningful sample for the study conclusions.

For full methodology, see page 52.

¹ National Research Council of the National Academies. *Advancing the Competitiveness and Efficiency of the U.S. Construction Industry*. Washington DC: The National Academies Press, 2009. ² *Green BIM SmartMarket Report: How Building Information Modelling is Contributing to Green Design and Construction*. McGraw-Hill Construction, July, 2010. ³ *Green Outlook: Green Trends Driving Growth*, 2011. McGraw-Hill Construction, October, 2010.

Data: Market Activity and Opportunity

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

Sectors with Opportunity for Prefabrication/Modularization

Currently, prefabrication/modularization is being used on many types of building projects demonstrating its applicability across nonresidential construction.

The five sectors using prefabrication/modularization in over 40% of projects are:

- **Healthcare (49%)**
- **Higher Education (42%)**
- **Manufacturing (42%)**
- **Low-Rise Office (40%)**
- **Public (40%)**

These sectors also present strong opportunities in the construction market, which bodes well for a vigorous prefabrication/modularization future market.

Healthcare

Healthcare is a sector that is well-suited for prefabrication/modularization techniques. The interior layout of hospital rooms allows for efficient use of modularization, and it is a sector highly responsive to strategies that shorten schedule—a particular benefit prefabrication brings to a project (See page 18).

According to McGraw-Hill Construction's economic forecast, the market activity for healthcare construction is expected to increase in 2011 and 2012 to become more than a \$28 billion market opportunity in 2012.

Dormitory and Education Projects

Like healthcare buildings, dormitories and school projects have features that are well-suited to prefabrication/modularization. Dorms and classrooms allow for use of modular room design, and these projects also benefit from faster construction schedules.

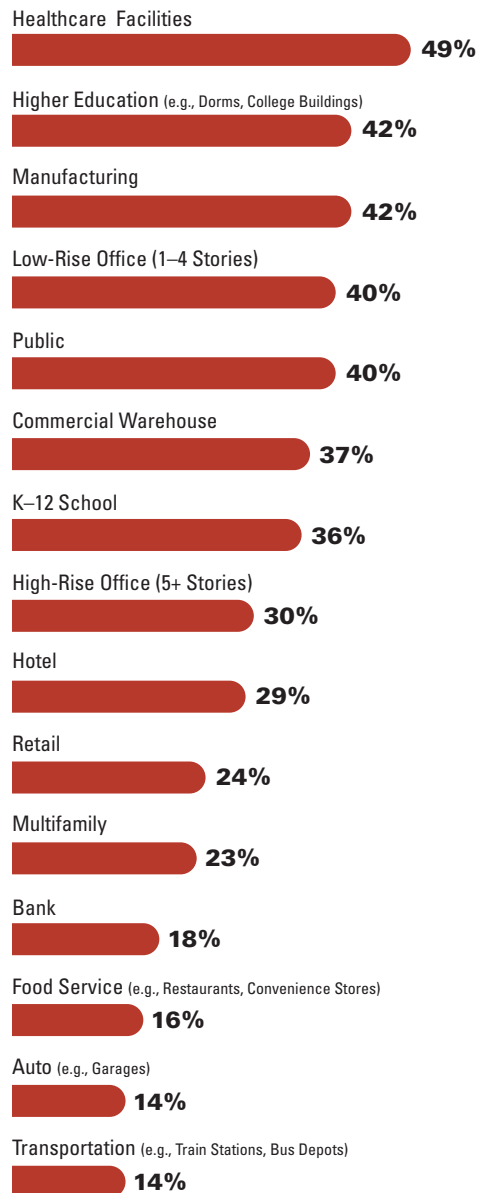
As the largest construction sector by value (over \$43 billion in 2011), education presents a significant opportunity for prefabrication/modularization—both currently and in the future (see page 10).

Variation by Player

- **Contractors:** Across the board, contractors report heavier current involvement in prefabrication/modularization, predominantly in healthcare (61%), dormitory/education (50%) and public buildings (46%).
- **Engineers:** Engineers are using prefabrication/modularization most often in manufacturing buildings

Building Sectors Using Prefabrication/Modularization

Source: McGraw-Hill Construction, 2011



(46%), followed by commercial warehouses (43%). Engagement in the other sectors is 30% or lower.

- **Architects:** Their heaviest use is in low-rise offices (43%) and healthcare facilities (36%), with less than a third reporting use in other sectors.

Brief History of Prefabrication/Modularization

An early example of prefabrication/modularization use can be found in Britain's Great Exhibition of 1851, featuring a building called the Crystal Palace. Designed in less than two weeks, the building used light and cheap materials: iron, wood and glass. The construction period lasted only a few months and consisted of assembling the prefabricated components. After the exhibition, the palace was taken apart, piece by piece, and moved to another location.¹

Modern Beginnings

For the U.S., modern prefabrication/modularization is said to have started in the early 1900s. Housing started being developed using prescheduled procedures based on modern mass production. Aladdin and Sears Roebuck Company sold prefabricated houses that were delivered to customers as mail-order homes.²

Prefabrication/modularization was increasingly used during World War II due to the need for mass accommodation for military personnel. The United States used Quonset huts as military buildings. These all-purpose, lightweight buildings could be shipped anywhere and assembled without skilled labor.³

Following World War II, both Japan and Europe had massive rebuilding needs and turned to prefabrication and off-site construction to fill the demand. It is because of this early adoption and acceptance that European and Japanese companies are still considered some of the most advanced in terms of modular construction techniques.

In the U.S., commercial applications of modular construction like hotels, offices, hospitals and schools began to emerge throughout the '70s, '80s, '90s, and into the 2000s as demand exceeded the supply of existing structures.

Recent Evolution

Recent innovations over the past few decades have allowed the prefabrication and modular construction industry to make significant advances in developing processes and materials to build and deliver more sophisticated and complex facility types.

An example of this is the Hilton Palacio del Rio Hotel in San Antonio. Built by Zachry Construction Corporation for the Texas World's Exposition of 1968, the 500-room deluxe hotel was designed, completed and occupied in an unprecedented period of 202 working days. All the rooms were placed by crane in 46 days. Still in use, the hotel is believed to be the tallest modularly constructed facility in the United States. The project is a testament to the durability of modular construction.⁴

A current example of just how well accepted modular units have become is their use in the construction of the new cruise liner Queen Mary 2, which is one of the largest and most expensive cruise liners in the world. The ship owners chose to use modular passenger cabins to ensure all cabins were built to the higher standards that are available in a factory environment; even their VIP suites utilized the modular building process.⁵

Prefabrication/modularization is also becoming more widely recognized as a resource-efficient and greener construction process. A clear example of this is the use of modularization at the Fort Sam Military Barracks being built in San Antonio, Texas. The buildings are on track to meet LEED Silver certification due to reduced material waste and pollution and increased use of recycled materials (see page 16 for more information on this project).

The Time Is Right Now

Prefabrication/modularization has not had a steady increase in use over time; instead, it has fluctuated based on the level of drastic need during war and economic booms. However, technological advancements over the past 20 years have increased what prefabrication/modularization can achieve in the construction industry. BIM, quality modern materials and sophisticated manufacturing facilities now offer significant productivity gains on projects not possible before.

Recently a committee of experts appointed by the National Research Council identified "greater use of prefabrication/modularization" as a key breakthrough opportunity that could significantly improve the efficiency and competitiveness of the U.S. construction industry going forward.⁶

With a construction market facing acute shortages in onsite skilled labor and also where players are trying to be leaner, many believe the time is right now, more than ever, for widespread adoption of off-site prefabrication/modularization solutions on a major scale in the construction industry. ■

1 Kelly, Burnham. *The Prefabrication of Houses*. The Technology Press of The Massachusetts Institute of Technology; John Wiley and Sons, Inc., New York; Chapman & Hall, Ltd., London. 1951.

2 The Encyclopedia of Chicago. *Housing*. Mail Order. Web. April 8, 2011. 3 The Steel Master Building Systems. Quonset FAQ's. Web. April 8, 2011.

4 Modular Building Institute. "21-Story Modular Hotel Raised the Roof for Texas World Fair in 1968" Web. April 20, 2011. 5 Avalon Building Systems. "Interesting History of the Modular Construction Industry". Web. April 20, 2011.

6 National Research Council of the National Academies. "Advancing the Competitiveness and Efficiency of the U.S. Construction Industry". The National Academies Press. Washington DC. 2009.

Building Sectors with the Most Significant Future Opportunity for Prefabrication/Modularization

Not only is the industry using prefabrication/modularization on a range of projects (see page 8), it also views future opportunity coming from a wide variety of building sectors.

In fact, there is no consensus as to which sector offers the most significant future opportunity. Only healthcare was slightly higher than the other sectors, but that is likely due to the heavy focus on this sector by contractors, who comprise the largest share of respondents (see pages 8 and 11).

This distribution suggests that any building type can benefit from prefabrication/modularization activities.

Comparison of Current versus Future Prefabrication/Modularization Activity

It is notable that some sectors with lower levels of current involvement (see page 8) are seen as offering the greatest opportunity in the future.

This suggests that the industry, which has been using prefabrication for years, is seeing a change in future use, reinforcing the notion that prefabrication/modularization is on the cusp on more significant adoption across the industry.

HEALTHCARE

Healthcare is the sector currently showing the highest use of prefabrication/modularization (see page 8), and it is noted as the most important sector for future growth—especially for contractors (see page 11).

McGraw-Hill Construction’s (MHC) economic forecast reports that healthcare construction will steadily increase over the next five years. As the third largest nonresidential construction sector (behind education and office), healthcare projects pose an important area for prefabrication/modularization if owners can recognize its benefits.

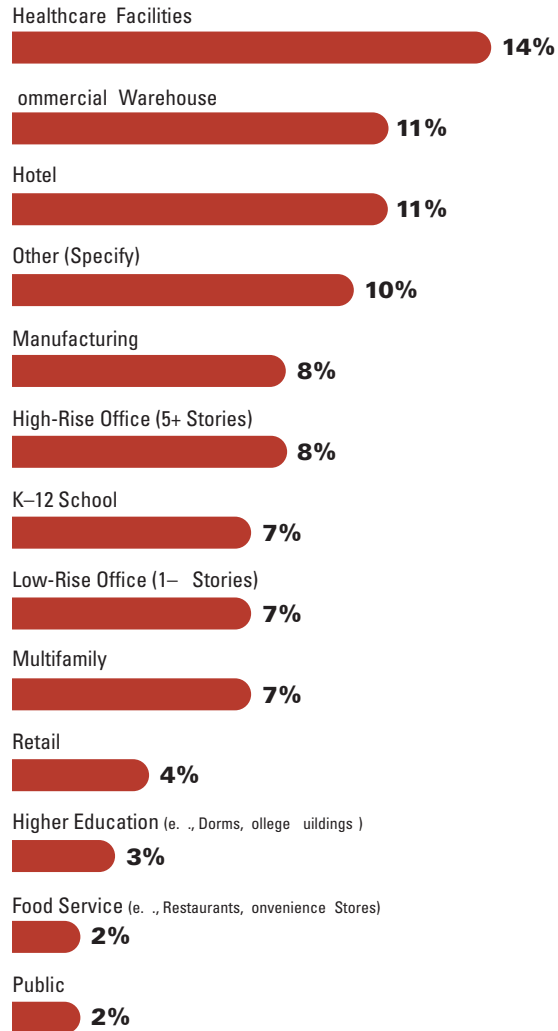
COMMERCIAL WAREHOUSES AND HOTELS

Though these sectors are not commonly using prefabrication/modularization now, they are considered strong opportunities for the future, cited as the next highest sectors for opportunity behind healthcare, despite being ranked #6 and #9 in current use. In fact, fewer than one third of prefabrication/modularization users are currently using these techniques on hotels.

Though these sectors represent lower levels of construction activity, MHC economists forecast

Ranked Building Sectors for Prefabrication/Modularization Opportunity

Source: McGraw-Hill Construction, 2011



significant growth over the next five years, making them an untapped opportunity for prefabrication/modularization.

EDUCATION

Though ranked lower than other sectors, it is important for the industry to continue to seek opportunities in the education sector because it has the highest share of nonresidential construction activity. Furthermore, after several years of decline, MHC’s economic forecast

Market Activity and Opportunity

Building Sectors with the Most Significant Future Opportunity for Prefabrication/Modularization CONTINUED

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

reports that school construction will begin to pick up in 2012, with dramatic increases in the longer term—projected to be a market worth over \$70 billion in five years.

Variation by Player

There is notable variation in how different players view the sectors with the most significant future opportunities for prefabrication/modularization.

Overall, the players agree that hotels are a major untapped market for prefabrication/modularization activity, but more architects and contractors emphasize its importance.

CONTRACTORS

Nearly a fifth (19%) of contractors believe healthcare offers the most significant future opportunity for prefabrication/modularization, notably higher than the next most important sectors—hotels (13%) and high-rise offices (10%).

This marks a shift from current use, where dorms and public buildings take the second and third spots, respectively.

ENGINEERS

Engineers view the most significant sectors for prefabrication/modularization opportunity to be warehouse and manufacturing projects.

In terms of construction activity, both the warehouse and manufacturing sectors are on the rise, but they are smaller by value as compared to other building types. In five years, they are forecasted to offer a combined \$30 billion opportunity. Perhaps they offer a niche market for engineers that is currently untapped.

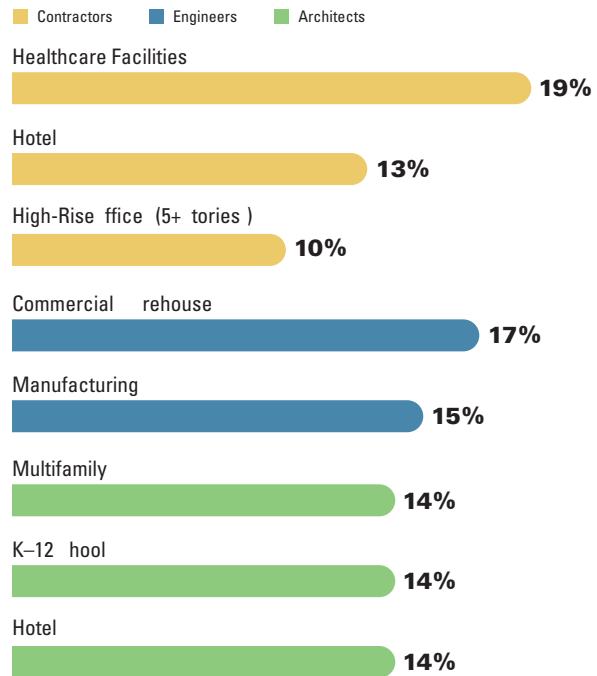
ARCHITECTS

There is an even split among the sectors that architects cite as having the largest levels of future activity: multifamily residential, K–12 schools and hotels. Multifamily residential is an especially important opportunity for prefabrication/modularization given that the combined value of starts is forecasted by MHC to be \$60 billion over the next two years.

As the largest nonresidential building type, education projects pose very significant opportunities for prefabrication/modularization, with a strong long-term forecast (see page 10).

Top Building Sectors for Prefabrication/Modularization Opportunity (by Player)

Source: McGraw-Hill Construction, 2011



Users of Prefabrication/Modularization

Overall Users of Prefabrication/Modularization

Today, there is broad use of prefabrication/modularization on building projects—85% of respondents are using these strategies to design and construct projects at some level.

While this level of use is encouragingly high, the activities that are included under the broad definition of prefabrication/modularization can range widely from entire modular rooms to floor planks to racks of mechanical ductwork. The impact on reducing site materials, labor demands, project budget and schedule and waste can vary significantly depending on how prefabrication/modularization is used on a project. (For more information on the definitions of prefabrication and modularization, please see page 51.)

VARIATION BY PLAYER

There is heavier involvement in prefabrication from engineers and architects, as compared to contractors—90% of engineers and 84% of contractors report using prefabrication at some level, while 76% of architects report usage.

Length of Prefabrication/Modularization Use

Prefabrication and modular building processes are not new activities.

- **Almost two-thirds (63%) of respondents are long-time users of prefabrication/modularization strategies, using them for more than five years.**
- **Only 8% are new users—using prefabrication/modularization for less than a year.**

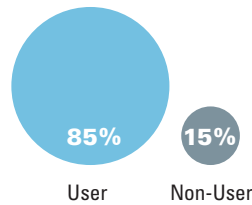
VARIATION BY PLAYER

Engineers have been using prefabrication/modularization for the longest, with over three-quarters (77%) reporting use for more than five years, significantly higher than architects (64%) and contractors (57%).

Contractors lag the other two players in length of use even though they are heavier users than architects (see above). However, the lag could be due to more limited architect involvement, given that contractors are driven to use prefabrication/modularization if it is designed into the project (see page 32).

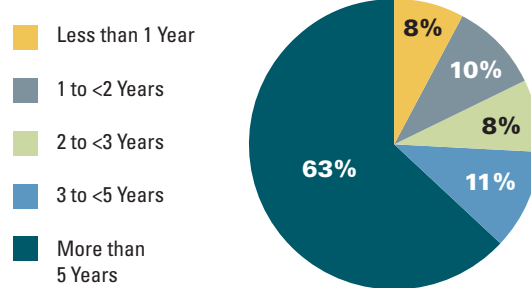
Percentage of Prefabrication/Modularization Users Today (2011)

Source: McGraw-Hill Construction, 2011



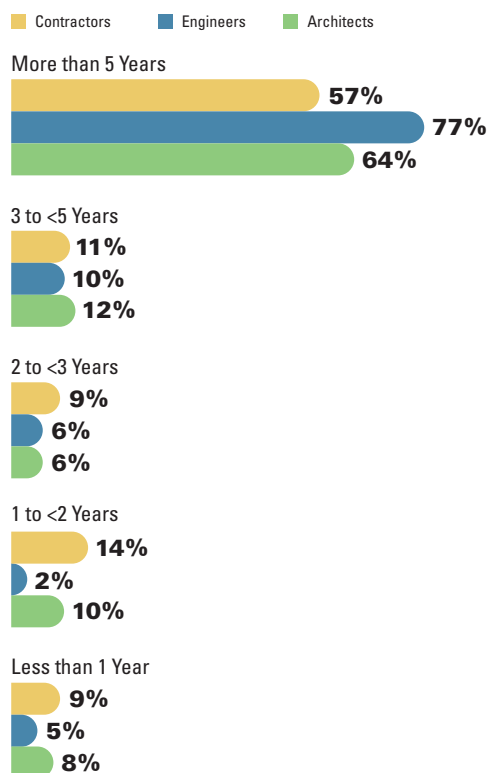
Length of Time Using Prefabrication/Modularization

Source: McGraw-Hill Construction, 2011



(by Player)

Source: McGraw-Hill Construction, 2011



Levels of Use of Prefabrication/Modularization: Today and in the Future for Current Users

While reported levels of prefabrication are already quite high (see page 12), a notable increase is still expected over the next two years—both in the percentage using prefabrication and in the intensity of use.

Future Use of Prefabrication/Modularization

By 2013, 98% of industry players (current users and non-users) will be users of prefabrication/modularization.

- **Current Users: Virtually all current users will still be using prefabrication/modularization in 2013.**
- **Current Non-Users: 87% of current non-users will become users over the next two years, resulting in a decrease in the overall number of non-users from 15% of the industry in 2009 to an insignificant 2% in 2013.**

Various factors are impacting this increased use, including growing concerns about construction productivity, advancements in prefabrication and the quality of prefabricated materials, and the wider adoption of BIM, which helps enable more intensive, productive use of prefabrication.

VARIATION BY PLAYER

Contractors, engineers and architects all report that their level of use of prefabrication/modularization will increase by 2013.

Architects report the highest increase in prefabrication/modularization use—from 76% in 2009 to 98% by 2013. However, because their levels were originally lower, this more dramatic increase is to be expected.

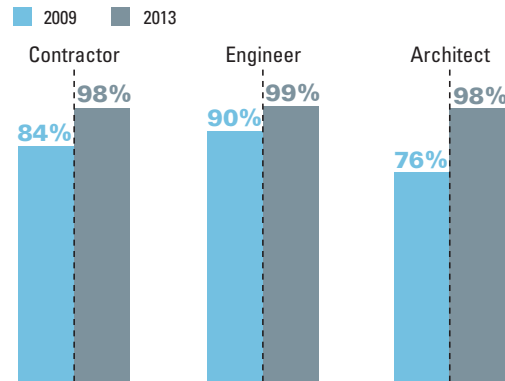
Level of Use

The level of use of prefabrication/modularization is also expected to increase. The number of players using prefabrication/modularization on over 50% of projects is expected to increase from 37% in 2009 to 45% in 2013.

Despite the level of activity increasing, these results do not indicate the complexity of the prefabricated or modular components used on these projects. And it is important to note that adoption needs to involve more than installation of simple prefabricated elements for the full benefits of prefabrication/modularization to be realized. For example, significant benefits are gained when prefabrication/modularization is used on major building components, resulting in a reduced need for scaffolding, coordination of multiple trades onsite and equipment use.

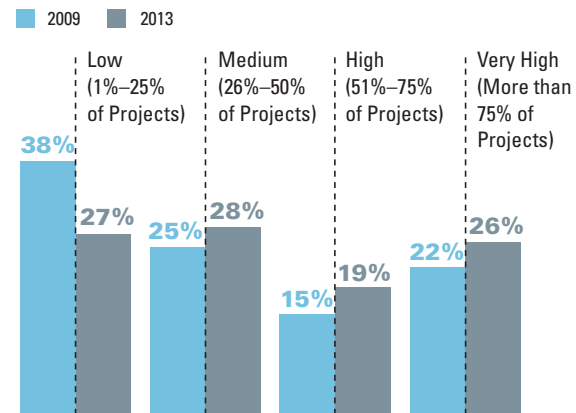
Percentage of Respondents Using Prefabrication/Modularization on Projects 2009 to 2013 (by Player)

Source: McGraw-Hill Construction, 2011



Percentage of Prefabrication Use for Current Users (2009 versus 2013)

Source: McGraw-Hill Construction, 2011



PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

Future Activity by Current Non-Users of Prefabrication/Modularization

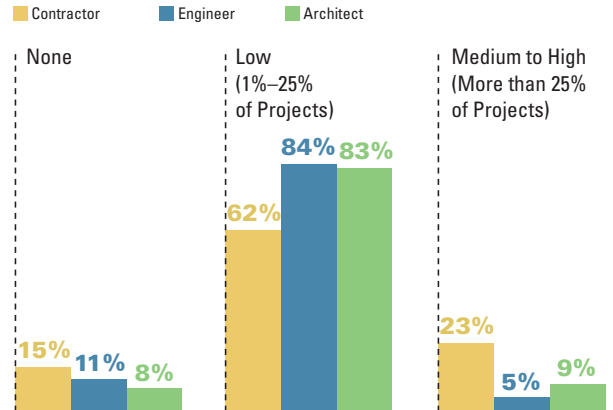
While most firms not using prefabrication or modularization expect to do so in the future, most expect to use these approaches on a low percentage of projects.

- An average of 70% of current non-users report they will engage in prefabrication/modularization on 1%–25% of future projects.
- Contractor non-users expect to engage in prefabrication/modularization at much higher levels than their industry counterparts—23% report they will use it on over 25% of projects by 2013, compared to much lower percentages of engineer (5%) and architect (9%) non-users.

This suggests that there is still significant market penetration that can be created with more education and awareness on the productivity, financial and green benefits associated with prefabrication/modularization.

Percentage of Future Prefabrication Use for Current Non-Users (by Industry Player)

Source: McGraw-Hill Construction, 2011



Firm Size of Prefabrication/Modularization Users

The size of firms using prefabrication/modularization vary dramatically by industry player, with architect and engineer users coming predominantly from larger firms (billings over \$5 million) and the reverse true of contractors where significantly more users are from smaller firms (revenues less than \$25 million).

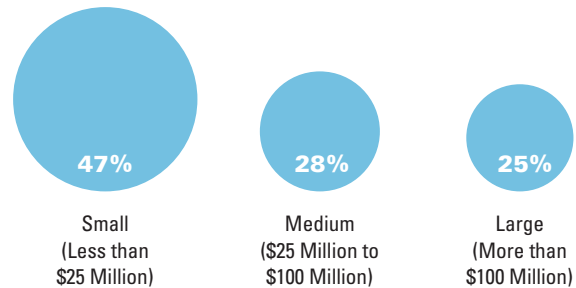
This is consistent with the roles and functions of each player. Many contractors engaging in prefabrication/modularization are specialty contractors, such as mechanical contractors, electrical contractors and fabricators, that tend to be smaller in size.

Architectural firms engaging in prefabrication/modularization are likely those engaged in more expensive, complex projects where designing for prefabrication/modularization can yield greater savings.

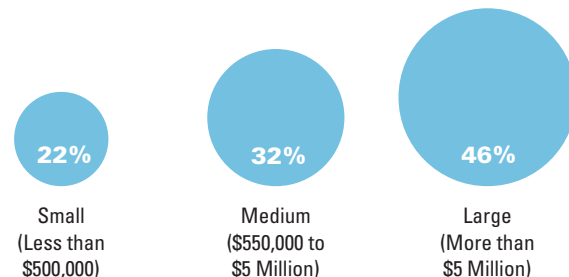
Share of Prefabrication/Modularization Users by Firm Size

Source: McGraw-Hill Construction, 2011

Contractors (by Revenue)



Architect and Engineering Firms (by Billings)



Interview: Thought Leader



Improving productivity to enhance our quality of life and our ability to compete globally.

**J. Doug Pruitt, Chairman and CEO
Sundt Construction**

Doug Pruitt emphasized the need to improve productivity in the construction industry as a central theme of his term as president of the Associated General Contractors of America in 2009. Today, Pruitt continues to pursue industrywide initiatives to address productivity issues through task forces and research groups.

Why did you create a call to action around productivity?

The construction industry plays an important role in our economy and our society. Do we really want to be an industry that—because of our inability to improve productivity—is doing damage? In the private sector, if we aren't productive that drives [private-sector clients'] capital costs higher. By not improving, we're not helping private-sector companies compete in a global economy. In the public sector, a lack of productivity means we pay more and more for fewer and fewer assets. We're not helping taxpayers get more for their tax dollars. This is about our quality of life and our ability to compete in a global economy. We want to be the industry that helps drive that, not hinder it.

How bad is the problem?

If you look at construction industry statistics over a 40-year span, we've had no productivity improvement as an industry. If you look at other industries, they've had significant productivity improvements. Every industry should strive as a collective

body to improve itself. Are we being responsible as an industry if we can't improve productivity?

Is the industry making significant improvements?

A small percentage of our industry is making a dent. But what percentage of our industry uses integrated project delivery? What percentage uses design-build? What percentage uses lean practices? What percentage leverages BIM to improve productivity? I would suggest it's a small percentage. The ones that do are making gains, but it needs to spread to the masses.

What are some key issues that hinder productivity today?

When you look at improvements being made today, innovation is being driven primarily through technology companies, not through construction companies. Look at contracts and contract language; that's a productivity issue. If you look at the lack of collaboration between designers, engineers and contractors, that's a productivity issue. Delivery methods are a productivity issue. Regulatory issues that create tremendous costs and do very little in terms of value added also drive productivity down. You spend extra dollars and the endgame doesn't change productivity. There are a whole host of things that need to be addressed by construction companies. One reason is that we're too fragmented. We need a forum

where we can discuss these issues and create solutions.

If companies are unwilling to change themselves, can owners drive change that will improve productivity?

Just like they did with safety, owners can insist on change. There are things owners can do now to influence change. Owners can select the delivery method. They can make contracts fair or onerous. They can define how we work together as a team. There can also be incentives versus penalties. A lot of owners approach productivity with penalties. They want a job done fast, and if you don't get it done on schedule, you pay damages. So as a contractor, you spend all of your time trying to protect yourself, and there's a cost associated with that. That's going at the problem the wrong way. We want to do [projects] better and faster, so there should be incentives to do so.

Can prefabrication and modularization play important roles in improving productivity?

Ultimately, their use can be widespread. There's a lot of prefabrication that can be done and is being done already. [Sundt Construction] has done some modular work for the Navy. There's a lot of potential out there to use it, especially with standardization [of military projects]. The technology to design and build it is there and getting better. You just have to avail yourself of it. ■

Speeding Delivery to Meet a Military Mission

Fort Sam Houston Medical Education and Training Complex Barracks

SAN ANTONIO, TEXAS

In an attempt to meet the massive workload of such programs as the Base Realignment and Closure Act of 2005, the Army Corps of Engineers and others have adopted transformative approaches to improve the delivery of buildings, including modularization. At the Fort Sam Houston Medical Education and Training Complex Barracks project, crews are installing more than 1 million square feet of permanent modular construction.

Decision to Use Modular

The basic project scope called for facilities to house a total of 6,000 soldiers, as well as a mix of administrative offices and classrooms. In order to meet the tight schedule of 42 months and budget constraints, general contractor Hensel Phelps of Greeley, Colorado, and subcontractor

the Warrior Group of DeSoto, Texas, devised a plan that heavily leverages permanent modular construction.

The team worked with designer Carter Burgess (now part of Pasadena, California-based Jacobs) to assist in reimagining the design. The new plan calls for five four-story buildings, roughly 320,000 square feet each, to be built using a hybrid of site-built construction and permanent modular components. All of the barracks use modular construction, representing nearly 220,000 square feet of space per building.

Mix of Modular and Site-Built Construction

Each building has a void form foundation sitting on piers that are driven between 65 feet and 70 feet deep. At the center of each facility's footprint, site-built steel structures

are used for a mix of classrooms, storage rooms, offices, elevators and mechanical rooms. Once that portion is completed, the modules are added, extending out as wings in the building. These wings turn in a series of 90-degree angles to form two courtyards. At each of the corners created by those 90-degree angles, site-built construction is again used to create classrooms, utility rooms and stairwells.

Standard barrack modules include two living quarters per module, separated by a central corridor. Each weighs 35,000 pounds and is 60 feet long by 13.6 feet wide. Some modules are installed with one living quarter.

The modules are "more than 85% complete when they arrive onsite," says Ed Zdon, senior project manager with the Warrior Group. The rooms in each module include the shell, sheet rock, doors, light fixtures, Corian vanities, ceramic bathroom tiles, all utilities, and even the poles and shelves in the closets.

Shipping and Installation of Modules

The modules are constructed at a facility in Belton, Texas, an approximately 2.5-hour drive north of Fort Sam. The manufacturer is able to construct and store hundreds of modules at no extra cost before they need to be shipped to the job site, according to Zdon.

Although shipping of the modules can be costly, Zdon notes that they can be built at the factory rain or shine, unlike site-built construction, which is subject to weather delays.

Each module is trucked to the site and lifted from the carrier bed by a 250-ton crawler crane. First-floor



At the center of each facility's footprint, site-built construction. Once the site-built portion is completed, the modular components are added, extending out as residential wings in the building. At each of the corners, site-built construction is used to create mechanical rooms and stairwells.

Fort Sam Houston Medical Education and Training Complex Barracks

SAN ANTONIO, TEXAS

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY



Modules are picked from a carrier bed by a crawler crane and stacked on top of each other with no additional structure. Crews install eight to 12 per day.

modules can be set directly to the foundation. Modules are stacked directly on top and next to each other with no additional structure added. The factory-installed utilities are routed to the corridor in each module, so onsite crews are easily able to access them and tie them into the appropriate lines. After work inside each module is complete, finishes like carpet and paint are added. In each corridor, drop-ceiling grids and lighting fixtures are added.

Zdon says the build team has seen minimal errors within the factory-built modules. In Building 1, every corridor wall lined up within designed tolerances. In Building 2, two corridor walls had to be adjusted.

The team is able to install between eight and 12 modules per day, Zdon says. Installation for an entire building—each housing 341 modules—takes about eight weeks.

Meeting Green and Resiliency Goals

Buildings must meet a minimum LEED Silver certification and exceed ASHRAE standards by at least 30%. EPDM roofing makes each module more airtight, which helps the building achieve its high-performance goals. Other contributing factors include the insulation used, the recycled-material content of products used and the U-factor of windows.

The buildings are also designed in accordance with the military's uniform facilities code to meet requirements for progressive collapse and blast resistance.

When completed in December 2011, crews will have installed 1,705 modules. Zdon says that the modular plan made the project possible. "[Modular] was the perfect fit with the schedule, the needs of the Corps and the budget," he adds. ■

stats

Project Facts and Figures

Owner

U.S. Army Corps of Engineers

Architect

Jacobs (Carter Burgess)

General Contractor

Hensel Phelps

Subcontractor (Modular)

The Warrior Group

Size

1.6 million square feet (total)

Number of Buildings

5 (roughly 320,000 square feet each)

Height

4 stories

Number of Modules

1,705 (total; 341 per building)

Data: Productivity

Impact on Project Schedule

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

A shorter project schedule is the most commonly reported productivity benefit of prefabrication/modularization, as well as the one with the largest reported payback.

Two-thirds of firms who currently use prefabrication/modularization experience reduced project schedule, with 35% experiencing decreases of four weeks or more.

Prefabrication can yield time savings through the ability to conduct work simultaneously onsite and off-site, as well as helping with better coordination among different trades. In addition, less onsite staging, such as scaffolding, is frequently involved. Regionally, the ability to avoid weather impacts can reduce construction time. Site conditions factor significantly in the ability of prefabrication to impact schedule.

Additional time may be spent in the design phase on complex projects to coordinate the use of prefabrication and modularization. However, the time saved onsite typically reduces the overall project schedule.

Benefits of Project Schedule Reduction

Since construction onsite is both labor-intensive and expensive, this time savings can yield significant cost savings as well. Prefabrication can also provide critical assistance with scheduling in sectors like higher education where project deadlines are frequently inflexible. Also, for buildings on active sites, like a new building in a hospital complex, a reduced schedule minimizes the impact on the rest of the business.

Variation by Player

A slightly larger percentage of contractors experience benefits compared to other players. The difference is not large in any one category, but it is consistent through each:

- **Decrease by two weeks: Contractors—15%;** Architects—10%; Engineers—12%
- **Decrease by three weeks: Contractors—12%;** Architects—9%; Engineers—8%
- **Decrease by four weeks or more: Contractors—37%;** Architects—31%; Engineers—31%

Because extensive use of prefabrication/modularization can involve a more intensive, coordinated design period, contractors may be more likely to see the schedule gains because their involvement typically occurs later in the project lifecycle.

Variation by Firm Size

More medium to large firms (47%) report achieving a schedule decrease of four weeks or more compared to large firms (44%).

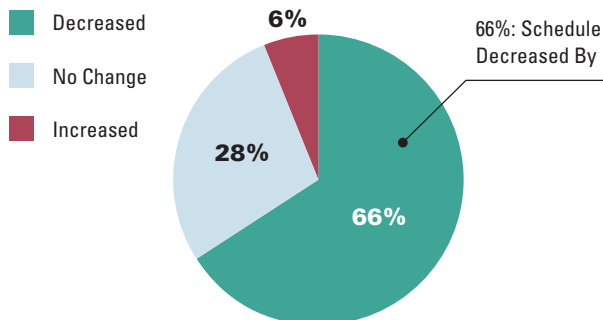
Firms Using BIM

50% of the respondent firms that use BIM on more than 50% of their projects experienced a schedule decrease of four weeks or more due to their use of prefabrication.

Use of BIM can support a smoother process and better communication between members of the project team.

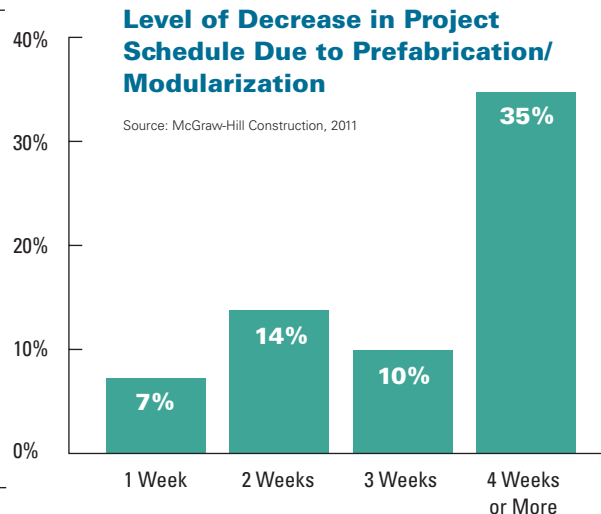
Total Impact of Prefabrication/Modularization on Project Schedule

Source: McGraw-Hill Construction, 2011



Level of Decrease in Project Schedule Due to Prefabrication/Modularization

Source: McGraw-Hill Construction, 2011



Impact on Project Budget

65% of firms who currently use prefabrication/modularization report that it reduces their project budget. 42% of the total respondents find that these techniques reduce their budget by 6% or more.

Construction work often has very tight profit margins, so even relatively small reductions in cost can make a strong impact on the firms involved.

Source and Value of Reductions

While prefabricated materials can cost less, in general the cost savings are due to secondary issues, such as reduced reliance on expensive onsite labor, the ability to avoid overtime pay and other unexpected labor costs, and the ability to reduce onsite resources required. With labor off-site, even basic site support facilities like portable toilets can be reduced.

Several owners interviewed for this report also discussed the value of having a guaranteed, fixed cost. Project budgets on traditional construction projects are infamous for their increases due to change orders during the construction process. Even when prefabrication appears to be slightly more expensive at the outset, the avoidance of unexpected costs during the process is valuable, especially for owners with inflexible budgets like those in the public sectors. This reliability increases in value when combined with the guaranteed, high-quality workmanship also offered by prefabrication/modularization.

Variation by Player

More contractors experience budget savings due to prefabrication/modularization than architects or engineers. (See chart on page 20.) This may be influenced in part by role that the schedule improvement plays in the overall reduction of project budget offered by prefabrication, since contractors also experience slightly larger schedule reductions.

Budget savings are reported by:

- 74% of Contractors
- 42% of Architects
- 52% of Engineers

The biggest difference between the savings experienced by contractors compared to the other players occurs in lowest level of savings (1%–5%), with approximately twice the percentage of contractors (30%) in that range than architects (16%) or engineers (15%).

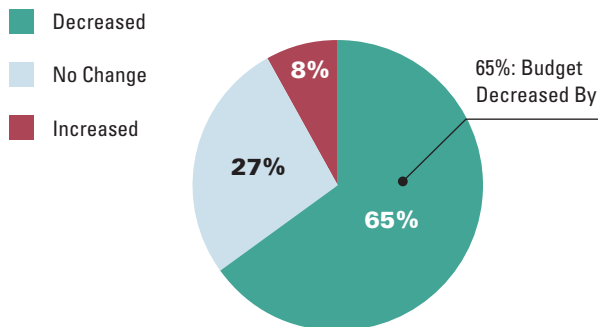
CONTRACTORS

■ Design-Build Firms

Design-builders experience a very different pattern of budget savings compared to other kinds of contractors. **18% experience budget decreases of more than 20%, compared to a 4% average across all contractor types.**

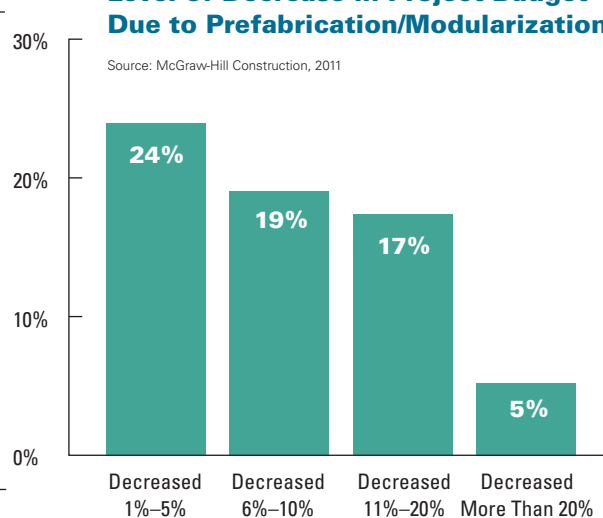
Total Impact of Prefabrication/Modularization on Project Budget

Source: McGraw-Hill Construction, 2011



Level of Decrease in Project Budget Due to Prefabrication/Modularization

Source: McGraw-Hill Construction, 2011



CONTINUED

Productivity

Impact on Project Budget CONTINUED

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

Design-Build firms also report more budget increases than other firms. Only 8% of total respondents report budget increases (see chart on page 19). However 22% of Design-Build firms have experienced an increase.

Design-Build firms carry the most risk and are positioned to achieve the strongest rewards on a construction project compared to contractors with other delivery methods. Therefore, it is not surprising that they are able to reap the greatest rewards and also occasionally suffer the greatest losses when employing prefabrication and modularization.

Impact on Site Safety

Even with the slowdown in overall construction, the fatality rate in the construction industry has remained constant.¹ Improving safety continues to be a challenge industrywide, which the benefits offered by prefabrication/modularization can help address.

Over one third of the survey respondents (34%) who are currently using prefabrication/modularization find that they have seen site safety improve as a result.

Reasons for this result may vary from site to site, but factors that contribute to increased site safety include reduced need for workers on scaffolding or ladders, as well as avoiding close work in tight spaces.

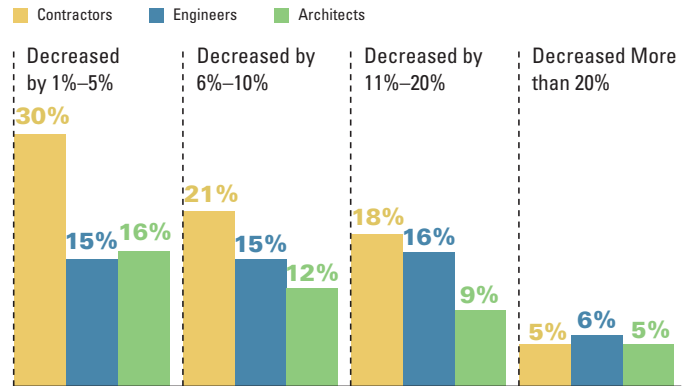
However, 10% found that safety actually decreased onsite. Prefabricated pieces are frequently large, and the approach to their installation needs to be carefully considered to avoid a negative impact on overall site safety.

Variation by Player

Not surprisingly, the percentage of contractors reporting site safety increases (37%) and site safety decreases (12%) were significantly higher than design firms. Contractors are more likely to bear the financial and legal responsibility for site safety than design firms and therefore would be more aware of and concerned about this issue.

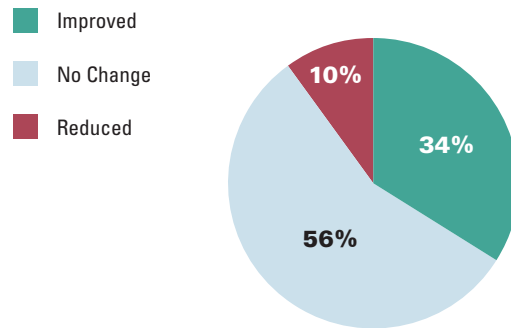
Level of Decrease in Project Budget Due To Prefabrication/Modularization (by Player)

Source: McGraw-Hill Construction, 2011



Impact of Prefabrication/Modularization on Site Safety

Source: McGraw-Hill Construction, 2011



CONTRACTORS

In general, a larger percentage of subcontractors are experiencing site safety improvements than general contractors, construction managers or design/builders. More mechanical contractors and fabricators in particular find their work to be less hazardous when conducted in a fabricating facility off-site.

¹ Buckley, B. & Ichniowski, T. (2010, August 30) Fatalities Down But Rate Stays Flat. ENR, 265 (6), 13.

Impact on Purchase and Installation Costs for Materials

Almost half (47%) of the respondents who are current users of prefabrication/modularization find that the combined purchase price and installation cost for prefabricated components is lower than the regular purchase and installation of materials onsite.

This result demonstrates that the savings to the project budget attributed to prefabrication are not solely due to schedule improvements. Not only is the project schedule reduced, but the actual cost of procuring and installing materials is found by a significant percentage to be less than the cost of traditional construction.

This is particularly important given the perception that prefabricated materials are more expensive. While the cost of the materials alone may be greater, a large percentage of respondents recognize that the total costs of materials and installation is reduced.

Degree of Change in Materials Purchase and Installation Costs

Most respondents find their costs to be significantly reduced.

■ Reduction in Materials Purchase and Installation Costs:

- Less by greater than 10%: 12%
- Less by 6%–10%: 18%
- Less by 1%–5%: 16%

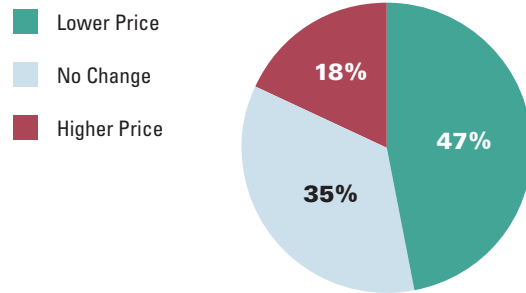
■ Increase in Material Purchase and Installation Costs:

- More by 1%–5%: 8%
- More by 6%–10%: 7%
- More by greater than 10%: 3%

Interviews with owners (see page 43) suggest that many owners find that prefabrication also yields measurable quality improvements compared to materials installed onsite, so that even when a significant cost savings is not achieved, there are still compelling reasons to employ prefabrication.

Impact of Prefabrication/Modularization on Purchase and Installation Prices for Materials

Source: McGraw-Hill Construction, 2011



Variation by Player

There is little variation in the percentage of architects (45%), engineers (45%) and contractors (47%) who experience reduced materials purchase and installation costs.

However, fewer architects (10%) report cost increases than engineers (20%) and contractors (18%). In addition, no architects reported an increase greater than 10%.

CONTRACTORS

■ Only 7% of mechanical contractors report increased costs, far lower than any other category of contractors.

■ Fabricators are less likely to see a cost decrease than other types of contractors:

- 37% of fabricators report seeing costs decrease, compared to 45%–53% of all other contractor types.

■ 28% of electrical contractors and design/build contractors report cost increases.

- Most of the design/build contractors (23%), however, report increases of 1%–5%.
- 18% of electrical contractors report increases of 6% or more.

Expected Impact on Project Schedule According to Prefabrication/Modularization Non-Users

Expectations of firms not currently using prefabrication/modularization reveal the industry's current predisposition towards these strategies.

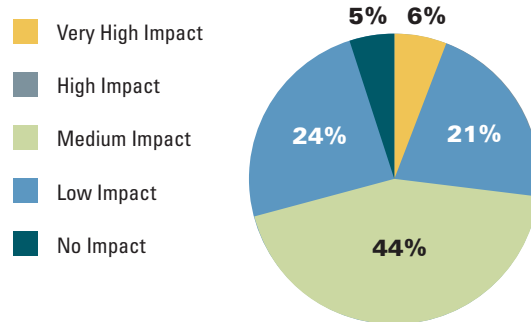
71% of firms not currently using prefabrication/modularization recognize that these methods have at least a moderate impact on the project schedule. This result demonstrates that key benefits of prefabrication/modularization are recognized by the industry as a whole.

However, those not using these techniques also underestimate their impact. Only 27% expect a high/very high impact on schedule, but 45% of those using prefabrication/modularization report a reduction of three weeks or more in project schedule as a result.

This result demonstrates that the industry would benefit from increased information about the true schedule benefits offered by prefabrication. In particular, sectors like education, where schedule is highly impactful, need to consider whether their projects are good candidates for using prefabrication/modularization.

Impact of Prefabrication/Modularization on Project Schedule (According to Non-Users)

Source: McGraw-Hill Construction, 2011



Impact on Project Budget According to Non-Users

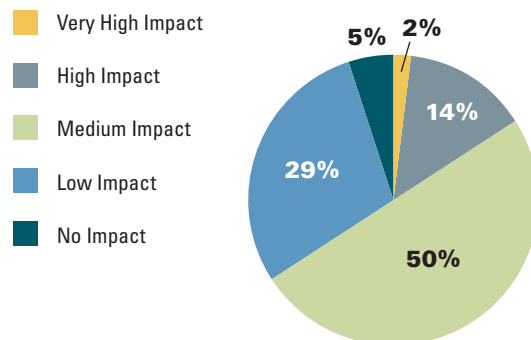
Firms not currently using prefabrication or modularization are still aware of their potential impact on the project budget. **Two-thirds (66%) expect the use of these approaches to have a medium to very high impact on the budget.**

Only 5% expect prefabrication/modularization to have no impact at all. This is in contrast to those currently using prefabrication/modularization, where 27% actually experience no notable change in their project budget.

This suggests that the industry as a whole may have overly optimistic expectations about the direct savings associated with prefabrication/modularization beyond the savings due to a shortened schedule and decreased materials and installation costs. **Therefore, the prefabrication/modularization market may benefit by educating the industry about other advantages beyond budget impact, including quality, safety and sustainability improvements.**

Impact of Prefabrication/Modularization on Project Budget (According to Non-Users)

Source: McGraw-Hill Construction, 2011



Impact on Reducing Onsite Resources

According to Non-Users

83% of firms not currently using prefabrication or modularization expect their use to have a medium to very high impact on reducing onsite resources such as manpower and equipment.

In fact, the case studies and owner interviews show extensive reductions in site resources needed, such as scaffolding, staging areas and material storage (due to just-in-time delivery) and portable toilets.

This result demonstrates that the industry believes that prefabrication/modularization has a positive productivity impact, so this point can be effective in making the case for these strategies.

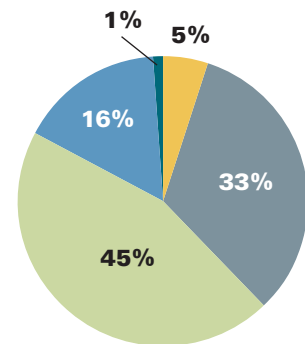
Variation by Player

Architects are the most optimistic about the impact of prefabrication/modular construction on reducing onsite resources. Strikingly, 54% expect a high to very high impact.

Impact of Prefabrication/Modular Construction on Reducing Onsite Resources (According to Non-Users)

Source: McGraw-Hill Construction, 2011

- Very High Impact
- High Impact
- Medium Impact
- Low Impact
- No Impact



Impact on Improving Project Quality

According to Non-Users

65% of firms who are not currently using prefabrication or modularization expect them to have at least a medium impact on project quality. Quality of the materials is one of the major benefits of prefabrication. In owner surveys, even those who find no compelling cost benefit to prefabrication/modularization often choose to use it because of the dependable quality. As with budget, owner interviews also indicate that the reliability of the quality is an important factor in their decision.

Reasons for Quality Improvement

Factory conditions offer the ability to do extensive quality control checks on each piece produced. Prefabricated concrete, for example, can avoid the imperfections frequently found in concrete poured onsite. The lack of exposure to the elements also increases the quality, as does the ability to fabricate in factory conditions rather than on ladders or from scaffolding.

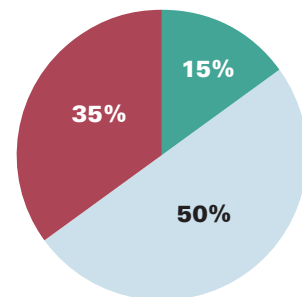
Variation by Player

Architects expect the greatest impact on quality, with one quarter (25%) expecting high to very high impacts, versus 16% of engineers and 12% of contractors.

Impact of Prefabrication/Modular Construction on Improving Project Quality (According to Non-Users)

Source: McGraw-Hill Construction, 2011

- High to Very High Impact
- Medium Impact
- No to Low Impact



One factor that may influence higher architect recognition of this benefit is that prefabrication may also allow the architect greater input into the final materials selected for the prefabricated component. While an architect can specify particular types of materials, contractors seeking a cost-effective project may select materials they think are comparable that cost less money. If prefabrication is included as part of an integrated project design process, the architect will have greater influence over the selection of the final products.

Interview: Thought Leader

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY



Rethinking management systems to create leaner projects

**Gregory Howell, Cofounder and Managing Director,
Lean Construction Institute**

Greg Howell cofounded the Lean Construction Institute with Glenn Ballard in 1997 to reform the management of production in design, engineering and construction. Among LCI's primary initiatives is the creation of a new operating system to replace the traditional critical path method used for project management. LCI developed its Lean Project Delivery System, which includes its Last Planner system, for production control.

Why do you believe the critical path method is flawed?

The current operating system is activity centered. The critical path method is the heart of that traditional operating system. That's the tool used to manage projects as a series of contracts. It's a logical system of one activity after another after another. In that operating system, you optimize the project by optimizing each of the pieces. It sounds good, but the problem is that it doesn't produce predictable workflow from one crew to the next. A lean operating system focuses on workflow as opposed to each activity. We put our attention on making the workflow predictable.

How can you make workflow more predictable?

We know that it's an uncertain world out there. There's a significant amount of complexity, and it's difficult to map everything out. We don't propose that we can get it right

at every moment, but rather that we can learn consistently through the life of a project. In current practice, the scheduler is supposed to get it right from the start. The schedule is what's supposed to happen. In our system, we want to get as good a schedule as we can, but we recognize that we'll need to learn and adjust throughout the life of a project. The current system pretends that we can know everything in advance, and if you don't, you're making an error. We believe you can make an estimate and continuously improve it as you go through the project.

Your approach is very collaborative. How can different team members work together to keep the schedule dynamic?

One example: We invented a planning system that is designed to create predictable workflow and rapid learning, but what took us into "lean" was the realization that it didn't work unless the foreman could say no and decline to make a bad assignment. Traditionally, the foreman is told by the superintendent what work they are supposed to do this week. And the foreman says he'll try, but in the end the work doesn't get done because the materials he needed weren't there. So if you want your planning reliability to be higher, you need to stop making bad assignments. It's a really radical act for a foreman to say no.

LCI has been around for 14 years, but the lean movement only gained steam in recent years. What has made the difference?

People didn't pay attention to what we were doing until the integrated form of agreement came out and changed the commercial terms of projects. That was a big step. On those first projects that used an integrated form of agreement, we saw trades agree to share one fuel truck coming out to the site every day rather than several. They agreed to share certain pieces of equipment and coordinate the usage instead of everyone having their own. Then you saw things like trades coordinating so they could prefab pipe racks. It took people out of their silos.

What is your view of prefabrication and modular components in lean construction?

It's a new structure of work, which means you have to rethink how you are managing tolerances. We don't pay a lot of attention to tolerances in construction. When you're doing stick built, everyone can adjust things in the field. When you do prefab and modular, the game is different because pieces that are out of tolerance can stack up. They build on each other and create a situation where things are out of tolerance at a bigger level. You have to be careful if you work ahead because you don't want to get stuck with a large inventory of [prefab and modular] components that are flawed. That's waste. ■

Lean Construction

Tools and techniques for reducing waste lay the groundwork for expansion of prefabrication and modularization.

Lean construction is a big buzzword among contractors these days, and some are leveraging those principles to gain impressive results. With a focus on eliminating waste, lean contractors report significant savings in both schedules and budgets.

Collaboration and Integration

At New York City-based Turner Construction, lean is an increasingly common practice, particularly on complicated jobs. James Barrett, national director for integrated building solutions at Turner, says the company uses a variety of techniques in achieving lean projects, but keeps a few primary tools in its kit. Collaboration and integration in particular are paramount to any lean job.

"We use the big room concept," he says. "We get everyone in a room to work together rather than launching things back and forth over the fence. We go through weekly schedule meetings and drill down to excruciating detail to see who is doing what and when."

The Turner approach to scheduling isn't top-down, but rather sets milestones in the field, then looks upstream at the dependencies between parties and finds common solutions. To help achieve that goal, Turner uses BIM extensively as an integration tool.

With improved integration among subcontractors, Turner sees added opportunities to use prefabrication for waste reduction. On traditional healthcare projects with onsite

fabrication, metals waste average 15% to 25% of total recycled materials. On healthcare projects employing lean principles with BIM-enabled prefabrication, metals waste average only 5% to 10% of total recycled materials.

At the \$340-million, 1.3-million-square-foot University of Kentucky Patient Care Facility in Lexington, crews used BIM and lean construction to facilitate the installation of 1.2 million pounds of prefabricated sheet metal in six months. Nineteen miles of 3-inch to 6-inch conduit was also installed in six months, and all pieces were bent off-site by the subcontractor, Gaylor Electric. Electrical deliveries were made using a small trailer pulled behind a pickup.

Overcoming Multitrade Obstacles

Skanska USA's Nashville, Tenn. office pushed the traditional limits of prefabrication on the \$152-million 484,000-square-foot Miami Valley Hospital addition in Dayton, Ohio. Multitrade prefabrication was used to create 178 patient rooms and 120 overhead corridor utility racks. Marty Corrado, project executive at Skanska, estimates that prefab cut two months from the schedule and trimmed up to 2% off the budget.

Corrado says original estimates called for a peak workforce of 700 workers, but by using off-site fabrication, peak workforce was less than half of that estimate. "The quality is better, your workers are happier, and you have less workers onsite so your safety numbers are better," he says.

Although trying to bring together multiple trades for a prefabrication project could be problematic in traditional construction, Corrado says that through BIM-enabled coordination and team integration, it's not only possible, it's necessary. "The industry needs to change," he adds. "This is a real movement. You can't go anywhere in the healthcare industry and not hear people talk about prefabrication. Multitrade is the next step."

Making the Move to Modular

Specialty contractor Limbach Facility Services of Warrington, Penn. not only creates multitrade prefabricated components, it is also teaming on multitrade modular projects. The firm worked with Lebanon, NJ-based Kullman Offsite Construction on the Cheyney University New Student Housing Project in Cheyney, Penn., a 133,000-square-foot four-story facility that will be built primarily with modular units.

Although prefabrication is a technique that is often driven by specialty contractors, Kevin Labrecque, senior vice president of operational excellence at Limbach, says that multitrade prefab and modular need a top-down approach.

"If it's a full-blown modular building, the owner has to be engaged in selecting that route," he says. "If it's multitrade prefab, the general contractor and owner need to define an approach and work closely with trade partners on collaborative coordination and installation. It has to be an integrated approach." ■

Pushing the Envelope in Prefabrication

Texas Health Harris Methodist Alliance Hospital

FORT WORTH, TEXAS

From the start, Texas Health Resources (THR) approached the Texas Health Harris Methodist Alliance Hospital project with the goal of improving the process for constructing hospitals moving forward, for THR and for the industry as a whole. The two main opportunities the project team has found were in using integrated project delivery and in maximizing use of prefabrication, including seeking prefabrication best practices in Europe.

Creating a Learning Opportunity

According to Denton Wilson, the director for facilities development at THR, the development team was charged with using this project as a test case for future work: "One of the tasks that THR put to this team was to get outside the box. Go out and find other things in other industries that would benefit our process."

In a previous project, Wilson had begun to experiment with the use of BIM tools and an integrated design process. He took the opportunity to fully embrace these approaches in the Alliance project because of the benefits he had observed: "If you align the people together that actually build things as units and cohesive parts and pieces, it just opened up the world to do that. All the metrics [demonstrated] more value, quicker [work], fewer change orders." Thus the Alliance project began with a full commitment to an integrated design process and use of BIM.

The team at the Beck Group, the construction manager, shared THR's goals. Dominick Calabrese, the director of healthcare services



The Texas Health Harris Methodist Alliance Hospital in Fort Worth Texas

at the Beck Group, affirms that the opportunity to improve the construction process was the main benefit sought rather than immediate cost or schedule savings: "I don't think we'll see a huge savings [on this project], but what Beck is interested in, what our subcontractors and THR mainly are interested in, is what can we learn? How can we learn to do prefabrication on this project so that we'll improve the industry and how we deliver [future projects]?" He clarifies that the cost and schedule gains of using prefabrication on a small 188,000-square-foot hospital like this one can be minor, but the experience that they gain on it will pay off on larger projects.

Integrated Project Delivery, BIM and Prefabrication

For Wilson, using prefabrication in an integrated design process has

an impact on the process itself; he argues that it encourages "the design philosophy of how to do the right thing from the beginning." The need for accurate, buildable specifications early in the process reinforces the collaborative nature of the process between the designers, the fabricators and the builders.

Wilson affirms that an open, collaborative design approach, especially one using BIM technology, can also increase the use of prefabrication. "When you have a technology-based, strong project team who are BIM modeling, you are going to test prefabrication."

Calabrese also finds this connection. He states, "Because IPD allows [the project team] to come together early in the design process, we are able to use the collaboration, our BIM technologies and other 3D modeling technologies to work with the architect, the owner and the major trades

Texas Health Harris Methodist Alliance Hospital

FORT WORTH, TEXAS

to identify what can be prefabricated." He cautions that "if you go through the traditional process and design everything first without considering prefab, you are just creating a whole lot of rework [if you ultimately want to implement prefabrication]."

Jeff Ratcliff, project manager with the Beck Group, points out the particular value added by working in BIM. "If it wasn't for BIM, we would not get the level of prefabrication we are doing. We are coordinating so much in such detail, [and BIM allows us] to really maximize the prefabrication and go into the detail that we need to."

BUILDING TEAMS

The greatest challenge associated with IPD is building the team's sense of trust and cooperation, but that is also its greatest opportunity. Calabrese argues that one challenge for any new team is to get everyone, especially the subcontractors, to adopt what he dubs "the IPD mindset," a recognition that it is the productivity savings for the project as a whole rather than for their own individual piece that matters.

"When Jeff and I were interviewing subcontractors for this project," reports Calabrese, "we would talk about prefabrication. Invariably, everyone we talked to [said], 'No, I don't want to do prefab. I can do it faster in field,' or 'Yes I do prefab, so I don't need to do anything differently.'" However, each contractor was only regarding their own individual trades, "looking at what is best for them as far as manpower and productivity, but not what is best for the project." He explains that working in a factory setting may not save any of the

individual contractors anything, but "that is better and more productive for the overall project than it may be for one singular entity." He reports that once the subcontractors adopted this mind-set, "that is when they really got excited about the project."

The adoption of the IPD mindset was particularly critical for the success of their most unusual use of prefabrication: the creation of multitrade racks for the hospital corridors.

CROSSING THE LINE

According to Wilson, team members were regularly surveyed to find out how well the process was working. One question asks whether the team is working with true trust and respect, while another asks, "Are the parties on the team actually crossing the line?" For Wilson, that ability to participate beyond the traditional boundary of their specialty is a good measure of the success of this project. However, the process of collaborating and seeking better approaches takes longer than simply doing what has worked in the past.

Wilson believes that the process change led to a different product: 50% implementation drawings are weaker than a normal set of construction documents because in this kind of IPD project, "you are not building the drawings, you are building shops." The entire process is fundamentally changed because it is geared toward implementation as a whole rather than just completing a set of documents, focusing on the end result rather than on the individual steps to achieve that result.

stats

Project Facts and Figures

Owner

Texas Health Resources

Architect

Perkins + Will

Construction Manager

The Beck Group

MEP Engineer

CCRD Partners

Structural Engineer

LA Fuess Partners Inc.

MEP Subcontractor

DynaTen Corporation

Drywall Subcontractor

Lasco Acoustics & Drywall

Construction Cost

\$60,439,735

Size

188,124 square feet

Height

4 stories

Started

December 2010

Scheduled Completion

August 2012

Green Certification Sought

LEED Silver

Multitrade Prefabrication

The most promising and challenging application of prefabrication on this project is the multitrade prefabrication of the racks in the hospital corridors. Since that approach is not common in the United States, the team went to the United Kingdom to learn how it could best be applied.

Scott Brady, the president of DynaTen, the mechanical/plumbing subcontractor, describes a typical process in the U.K. for creating these racks: —"mechanical contractors hire [independent prefabrication firms] to

Texas Health Harris Methodist Alliance Hospital

FORT WORTH, TEXAS

do the BIM model for these horizontal systems, and [the prefabrication firms] have developed software that converts the BIM model into a bill of materials on a prefab rack by prefab rack basis." These racks combine the work of multiple trades, including duct work, medical gas mains, hot water supply and return for comfort heating, domestic water piping, electrical conduits, communication system pathways and low-voltage systems. Typically, in the U.K. these racks are assembled in factory and shipped to the site.

Since there are no equivalent prefabrication firms in the United States, Brady explains, "DynaTen developed a strategic relationship with a company in the UK ... They are doing the BIM model work for the areas where we will be installing the rack, and then they are using the software they've developed to send us a kit of parts for each rack." The racks will be assembled in a fabrication shop adjacent to the project site, with all the trades coordinating their assembly together.

Brady sees three clear advantages to following this approach: reduction in the manpower peak, safety and quality.

MANPOWER

He states, "If you look at the normal manpower curve on a project, there is a distinct peak, and we think we'll be able to reduce that peak by as much as 20% and move it forward so we are doing that work earlier."



The hospital will feature multi-trade prefabricated racks in the corridors, an approach that is still new in the U.S.

SAFETY

According to Brady, the workers will be able to do at least 90% of their work with the racks at waist level rather than working from ladders in a multi-story building.

QUALITY

Working in a controlled environment also typically yields better, more consistent results than those produced by workers on ladders.

Of course there are challenges associated with this process as well, especially when it comes to installing the fully loaded racks. "These racks weigh in excess of 2,000 pounds and they are 20 feet long, seven feet wide," states Brady, "but we've developed methods for lifting them, and we have made special lifts to get them in place."

Other Prefabrication Opportunities

The multitrade racks were the most innovative use of prefabrication, but not the only example of this approach. The patient rooms will also have prefabricated bathroom modules and headwalls. Wilson states that "those two components are a win on every facility we will ever do" because of the efficiency and quality of the construction.

He mentions the ability to conduct sound attenuation studies of the headwalls at the factory as a factor that contributes directly to patient satisfaction. "Who wants to hear the patient next door? Now we get to do all those studies in a warehouse ... and we get to do multiple scenarios to [measure the benefits]."

Finally, there will likely be few deviations from the schedule. Wilson notes that dependability—knowing exactly when the project will be completed—is a major benefit of prefabrication. ■

Data: Influence Factors

Drivers for Use of Prefabrication and Modularization

Factors Driving Current Use

Productivity is the top driver of prefabrication/modularization use among all firms.

As the findings on pages 18 and 19 reveal, reductions in project schedule and project budget are key productivity benefits reported by all firms. Time savings and even small cost reductions make a big difference for players in the construction industry, where profit margins are slim due to the labor-intensive and expensive nature of onsite construction.

VARIATION BY PLAYER

- **92% of contractors see productivity as a stronger driver to use prefabrication/modularization, compared to engineers (70%) and architects (68%).**
- **Competitive advantage (85%) and generating greater ROI (70%) are stronger drivers for contractors than they are for architects and engineers.**

This difference may be influenced in part because contractors experience reductions in project budget due to schedule improvements more than architects and engineers do; also in part because the very competitive market in which contractors operate make them highly responsive to potential cost savings and gains in market share.

Anecdotal feedback from owners also indicates that improving productivity is the biggest driver for using prefabrication/modularization. Owners report project schedule reductions of 10% to 30% resulting from off-site work.

Factors Driving Future Use

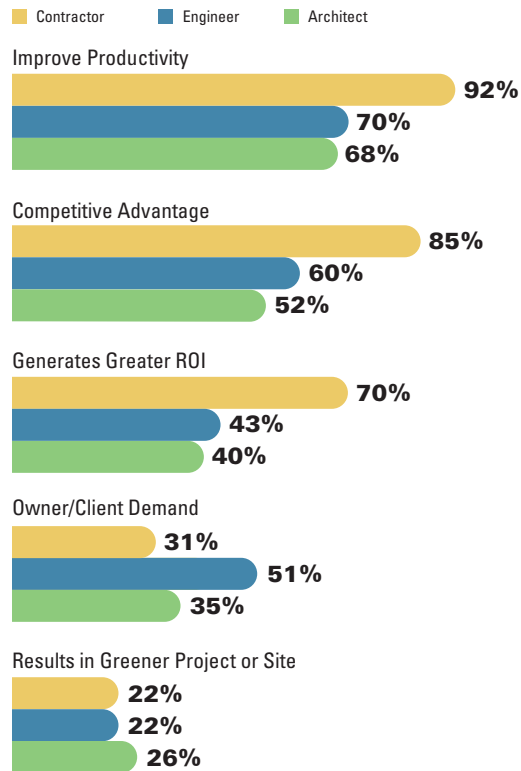
Lower project costs (85%) and project schedule improvements (84%) are the top drivers behind current users' decisions to use prefabrication/modularization in the future. Other top factors driving future use:

- **Project quality improvements (70%)**
- **Cheaper labor costs (69%)**
- **Project safety improvement (58%)**

These drivers are also consistent with anecdotal information from owners—most report that they plan to use prefabrication/modularization in the future because they see cost, schedule and quality benefits.

Current Drivers to Use of Prefabrication/Modularization (By Player)

Source: McGraw-Hill Construction, 2011



CONTRACTORS

Improving productivity is reported as the top driver for using prefabrication/modularization by construction managers, general contractors and design-builders.

- Design-builders report competitive advantage (82%) as a stronger driver, compared to general contractors (73%) and construction managers (78%).
- Design-builders also see generating greater ROI (64%) as a stronger driver, compared to general contractors (54%) and construction managers (55%).

SUBCONTRACTORS

Improving productivity is also reported as the top driver by mechanical contractors, electrical contractors and fabricators.

- **Mechanical contractors (94%) and electrical contractors (96%) report competitive advantage as a bigger driver than fabricators (63%).**

Factors Driving Future Use of Prefabrication/Modularization For Non-Users

Saving money is the top driver, identified by 77% of current non-users as a factor influencing their decision to use prefabrication/modularization in the future.

Firms report these other top drivers:

- **Saving time (66%)**
- **Owner demand (66%)**
- **Competitive market advantage (65%)**

These findings indicate that in this down economy, firms that decide to use prefabrication/modularization in the future are mainly concerned about what will help their bottom line and allow them to be more competitive. In the construction industry, where profit margins can be slim, any reduction in project time and cost can be critical.

The fact that owner demand (66%) is a significant influence factor suggests that with more owner education on the benefits of using prefabrication/modularization, more adoption is likely in the future.

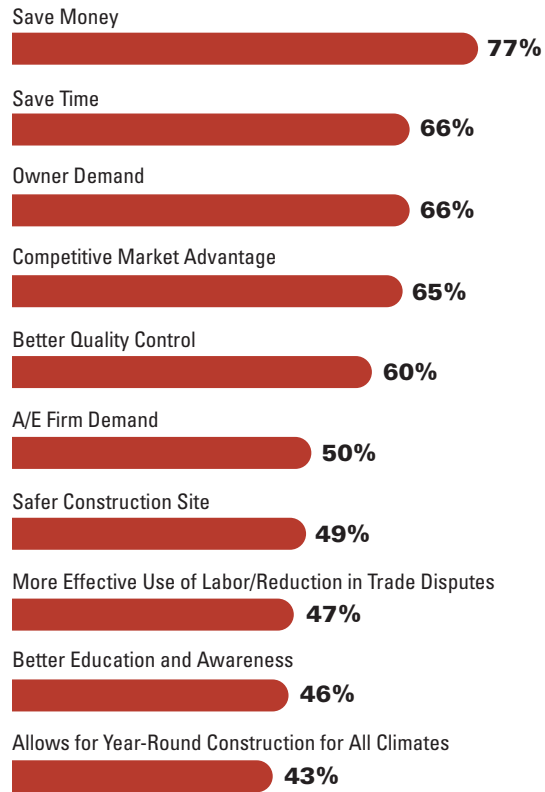
The majority of firms (60%) also report better quality control as a significant driver, demonstrating that in a competitive market, being able to distinguish your product is highly important.

Although it is not a top factor, 46% of firms see better education and awareness as a driver for future adoption of prefabrication/modularization. This is currently needed, as it will help the industry as a whole understand the key benefits of prefabrication/modularization and ways it improves project productivity.

Factors Driving Future Use of Prefabrication/Modularization

(For Current Non-Users)

Source: McGraw-Hill Construction, 2011



Non-Users' Current Reasons For Not Using Prefabrication/Modularization on Projects

46% of non-users report not using prefabrication/modularization because the architect did not design it into the project.

- **Not being familiar with the process ranks second highest, tied with project type not being applicable, according to 34% of non-users.**
- **Higher cost is the least reported reason (10%) for not using prefabrication/modularization.**

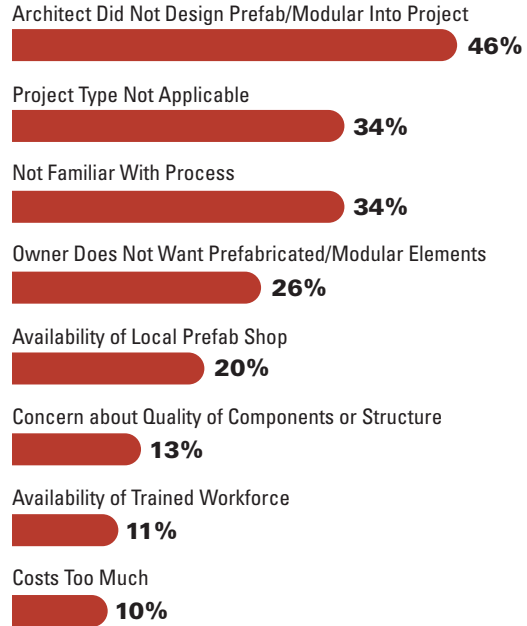
These results are similar to those of current users that are not using prefabrication/modularization on some of their projects. One exception is that being unfamiliar with the process ranks considerably higher with non-users.

The findings suggest that the cost benefits of prefabrication/modularization are better known while there is still a need for understanding the processes and the wider applicability of prefabrication/modularization.

Anecdotal evidence from owners demonstrates that various challenges exist, such as the need to commit to design work at an early stage and to figure out the logistics of shipping components to the site. However, once those obstacles are overcome, owners report that multiple benefits can be achieved in addition to schedule and cost improvements, such as increased safety, waste reduction and overcoming skilled workforce shortages.

Non-Users Current Reasons for Not Using Prefabrication/Modularization on Projects

Source: McGraw-Hill Construction, 2011



Users' Current Reasons For Not Using Prefabrication/Modularization on Some Projects

The top reason for current users to not use prefabrication/modularization is because the architect did not design it into the project.

Other top reasons for current users deciding not to use prefabrication/modularization on some projects:

- **Project type is not applicable (29%).**
- **Owner does not want prefabricated modular elements (32%).**

These findings show that the use of prefabrication/modularization in some cases is particularly dependent on the decisions of the owner and the architect. Reported by owners anecdotally, some of the challenges to using prefabrication/modularization include having to commit to a well-defined scope early in the planning stage, increased transportation and logistics requirements, and the limited number of providers of off-site fabrication.

VARIATION BY PLAYER

- **Almost half of contractors (48%) and engineers (44%) report not using prefabrication/modularization because the architect did not design it into the project.**
- **More architects (39%) report that the owner does not want prefabricated modular elements than do contractors (21%) and engineers (35%).**
- **More architects (29%) also indicate concern about quality of the prefabricated/modular component or structure than do contractors (10%) or engineers (19%).**

The fact that architects show concern over quality suggest that they need more information on the benefits of prefabrication/modularization other than cost, since one of its major advantages is being able to produce better quality work under controlled conditions.

These results, in general, demonstrate that the industry as a whole could benefit from more education on the processes, the use of materials and labor, and the wider applicability of prefabrication/modularization.

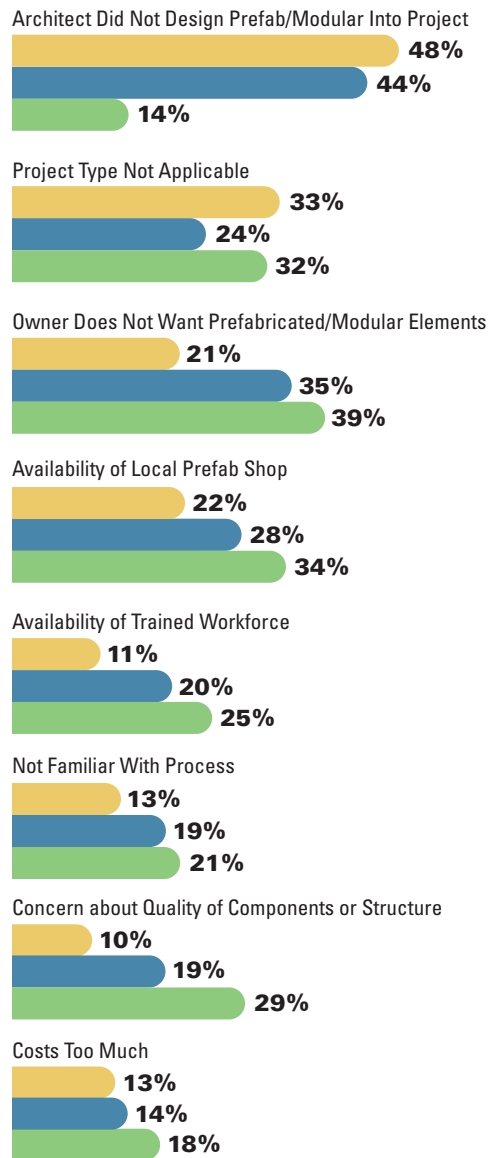
Armed with the right knowledge architects can use prefabrication/modularization in more creative and innovative ways in their designs as well as educate and influence owners to use prefabrication/modularization in the future.

Users Current Reasons for Not Using Prefabrication/Modularization on Some Projects

(By Player)

Source: McGraw-Hill Construction, 2011

■ Contractor ■ Engineer ■ Architect



Data: Prefabricated and Modular Building Elements

Influence of Job Site Conditions

Job site conditions are an important factor in the decision to use prefabrication/modularization, with over half of respondents influenced by job site accessibility (58%), number of stories (53%) and type of building exterior (52%).

JOB SITE ACCESSIBILITY

This factor influences around 50% of architects and engineers, and it is selected by 62% of contractors, the largest percentage for any of the job site conditions. For sites with severe restrictions, prefabrication can prevent job site congestion.

NUMBER OF STORIES

The number of stories can influence the decision to use prefabrication for structural elements or exterior walls. However, with the rise of BIM and with taller buildings with complex mechanical and electrical systems, prefabrication in taller buildings is becoming more common. In fact, although low-rise offices currently see more activity according to respondents, high-rise offices are selected by a slightly greater percentage as a strong future opportunity (see pages 8 and 10).

LAYOUT OF BUILDING INTERIOR

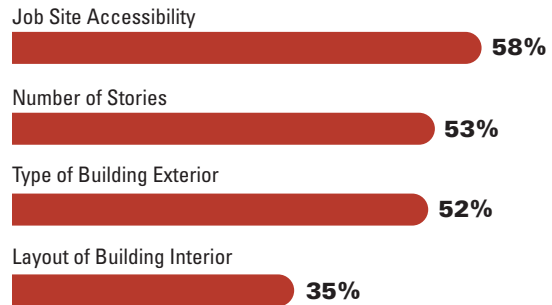
At 52%, this factor is deemed influential by the highest percentage of architects. A relatively repetitive layout for a large number of rooms makes the modularization of whole rooms a cost-effective approach in building types such as hospital or dormitories. Not surprisingly, this element influences contractors the least (27%) since the decision on room layout comes earlier in design.

TYPE OF BUILDING EXTERIOR

A larger percentage of engineers (61%) are influenced by this than architects (40%) or general contractors (50%).

Percentage of Respondents Influenced by Job Conditions

Source: McGraw-Hill Construction, 2011



Most Commonly Used Prefabricated and Modular Building Elements

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

Nearly half of all respondents (48%) use prefabrication and modularization for mechanical, electrical and plumbing (MEP) systems and the exterior walls. Prefabrication and modularization are used for the building superstructure by 44%.

Those same three building elements are also used the most by individual respondents, with the building superstructure the most highly ranked, at 27%.

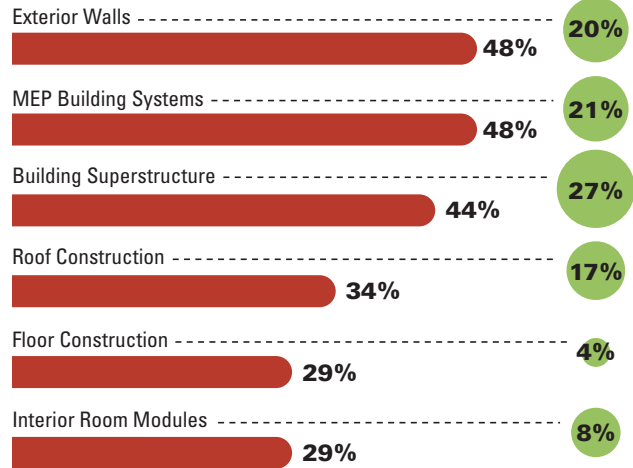
The benefits to be gained help account for their widespread use:

- **MEP Systems:** Prefabrication of complicated MEP systems can help reduce the space required for the ductwork. In addition, assembly off-site can positively impact the overall project schedule and keep ductwork cleaner for sensitive projects like high-tech or biomedical facilities.
- **Exterior Walls:** Prefabrication of exterior walls can significantly reduce the time required to assemble a building onsite. Also, some owner interviews revealed that reducing exposure to the elements during construction by assembling the walls in a controlled environment has benefitted the overall quality.
- **Building Superstructure:** Constructing all of the building above the foundation with prefabricated or modular units is most likely to yield the strongest cost and schedule benefits, which is probably why those who use this strategy also report that they use it most extensively.

Percentage of Respondents Using Prefabrication/Modularization for Building Elements

Source: McGraw-Hill Construction, 2011

Ranked #1 in Use



Variation by Player

The specific building elements constructed with prefabrication/modularization used by the highest percentage of architects and engineers differ dramatically from those used by the highest percentage of contractors. Only exterior walls are reported by a relatively large percentage of all three groups.

In addition, a smaller percentage of contractors in general are involved in projects with specific elements prefabricated or modularized, with MEP systems as the only category reported by more than 50% of the contractors.

ARCHITECTS AND ENGINEERS

The largest percentage of architects and engineers report using prefabrication and modularization for:

■ **Building Superstructure**

- Architects—68%
- Engineers—71%

■ **Exterior Walls**

- Architects—68%
- Engineers—60%

■ **Roof Construction**

- Architects—62%
- Engineers—56%

CONTRACTORS

The highest percentage of general contractors use prefabrication/modularization for the following building elements:

■ **MEP Building Systems (62%)**

While this number is strongly impacted by the MEP subcontractors surveyed, it is still notable that 40% of construction managers rank these systems as the area where they most commonly use prefabrication/modularization, the largest for that group. Over a fifth (22%) of general contractors also rank MEP systems first, the second highest category for them.

■ **Exterior Walls (39%)**

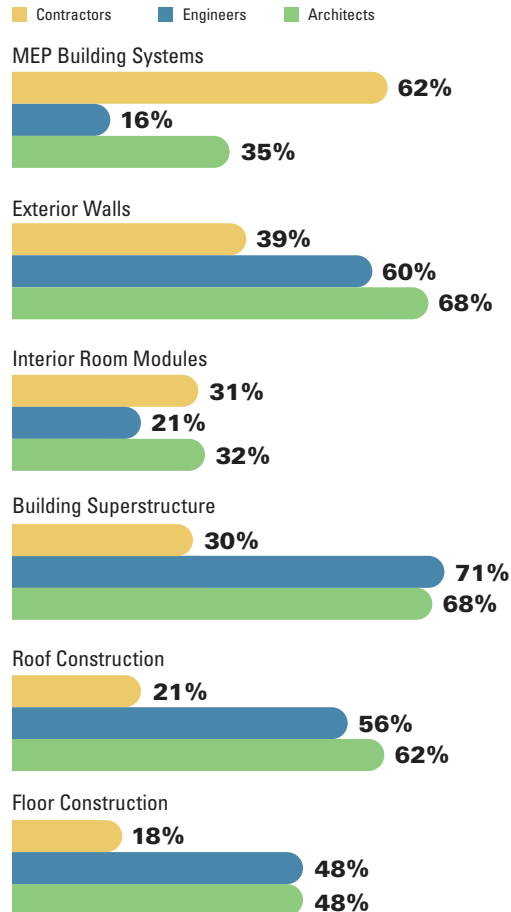
30% of construction managers and 35% of fabricators rank exterior walls as the building element for which they most commonly use prefabrication/modularization.

■ **Interior Room Modules (31%)**

Electrical contractors and design-builders report the highest use for interior modules, with 31% and 19%, respectively, ranking these as the highest categories.

Percentage of Respondents Using Prefabrication/Modularization for Building Elements (by Player)

Source: McGraw-Hill Construction, 2011



Firms with more than 75% Green Projects

10% to 15% more firms who primarily do green projects report using prefabrication in every category except MEP systems.

- **Building Superstructure—68%**
- **Exterior Walls—65%**
- **Roof Construction—56%**
- **Floor construction—47%**
- **Interior room modules—47%**

Innovation in Prefabrication to Achieve a Tight Schedule and Green Results

The Summit at Queens College Student Residence Hall

QUEENS, NEW YORK



The wall panels used to create the Summit project include a wide range of exterior materials, including brick and metal panels.

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

The Summit student housing project at Queens College in New York City employed extensive use of prefabrication, including innovative load-bearing exterior panels, to complete a high-quality building on time and on budget that achieved significant green goals.

Decision to Prefabricate

While the budget was always a consideration on this project, it was the tight 16-month construction schedule that led the project team to consider prefabrication. In part, the type of building contributed to the tight schedule; as Dr. Sue Henderson, the vice president for institutional advancement at Queens College, explains, “When you build a residence hall ... you only get one time of year to open it up. If you have it finished in September, that doesn’t quite work.”

In addition to the inflexible completion date, Bruce McKee, vice president at Capstone Development, describes additional schedule challenges: “We had a relatively challenging site. We had to move some things off the site. We had to put a garage underneath the structure, and with that part of the schedule, we knew it was going to take a substantial amount of time, more than we typically see.” And in fact, the site work and garage took even longer than they originally anticipated.

Therefore, the integrated design and construction team immediately considered prefabrication as a possible solution, and ultimately it proved effective. According to McKee, “The only way we were really able to get the project completed on time was by [making up time lost during the site work phase] through prefabrication of panels in the erection process.”

Innovative Use of Prefabrication

The project mainly employed prefabrication in two ways. The first was the use of prefabricated concrete floor planks, a relatively common practice.

However, they also decided to create lightweight, load-bearing prefabricated exterior walls, a new approach that the team developed just for this project. The system consists of wall sections that typically measure 30 feet. Each involves a metal stud structure with nearly all of the wall components factory installed, including glazing, exterior skin, insulation, vapor barriers—every component except the electrical wiring and interior sheetrock.

For the system to work effectively for a multistory building, it had to be lightweight, as Eric Goshow, a partner at Goshow Architects, explains. “We wanted to make it lightweight

The Summit at Queens College Student Residence Hall

QUEENS, NEW YORK

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

so that it could be easily transported, and would reduce the weight in the bottom of the building and the size of the footing." That goal led to the use of high-strength, lightweight metal studs in the panels. In addition, the brick used as the primary exterior finish for the building was one inch split tile as opposed to typical four inch face brick, which also significantly reduced the weight of the panels.

For Antoine AbiDargham, vice president at WSP Cantor Seinuk, the structural engineer, the main design challenge to this structure was "handling the stresses and distributing loads" around the openings and inserts in the facade. This challenge was increased by the fact that half of the building was going to be sitting on the parking garage. AbiDargham explains that they had to "make sure that [they] can place the loads through all these walls from top to bottom and minimize the deflection of the effect of the loads as you stack the walls on top of each other."

Early Research Was Critical

All of the team members, from the architects to the developer to the construction manager, credit the research they did early on to not only help them create a system that worked effectively but also to help them gain the buy-in of both the owner and the developer, a critical success factor for this approach.

To begin, the team considered many different structural options. AbiDargham describes how they "looked at various structural schemes to expedite construction," including steel frame and plank system, steel frame and cast-in-place

concrete, and metal stud load-bearing walls. None of these strategies were able to fully address concerns about schedule and cost.

Once they decided to consider a prefabricated, panelized load-bearing wall system, the project team's main concern was the capacity of the fabricator/manufacturer. As Goshow states, "The key with prefabrication is whether the prefabricator can develop enough panels on time?"

Before they committed to this strategy, the design team visited several prefabrication facilities. The entire team was impressed with Island International Fabricators, and they began to work with Island to develop the walls. Goshow points out that getting the manufacturer involved, even before they had been formally contracted, was important. "If you want to do something that is out of the ordinary, you want to bring in the people who are vendors and have some experience. These people are always willing to collaborate."

By the time the decision was made, the team involved included the architect, developer, owner, construction manager, structural engineer, civil engineer and panel fabricator. Because of the research they had conducted, there was broad support across this wide group for the strategy. "You have to have early buy-in from all the players that 'this is the way we are going to go, and we all have to work together to make this work,'" affirms AbiDargham.

Construction in progress on the load-bearing wall sections that even include the glazing.



The Summit at Queens College Student Residence Hall

QUEENS, NEW YORK

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

Benefits of Using Prefabrication

TIME SAVINGS

Doug Renna, project manager at T.G. Nickel & Associates, the construction manager, describes the result of their innovative system: “We erected a 175,000-square-foot building from January to April. We worked through the winter months with no holdup, and we put up a six-story building in less than four months.”

Eric Goshow estimates that this shaved at least six months off the construction schedule. Two inter-related elements contributed to these time savings. First, enclosing the building as quickly as possible “allowed the interior workmen doing the sheet rock and all the interior finishes to work much more efficiently,” according to Goshow. Manhar Bhatt, project manager at Goshow, also credits the phasing enabled by prefabrication of different sections of the building with contributing significant time savings.

FEWER ONSITE RESOURCES

No scaffolding was required because the brick was attached to a prefabricated wall in a factory, rather than laid on site. Several players involved in the project credit this with improvements in time, budget and safety.

In addition, only one crane was required for the entire project, another positive contributor to budget and safety concerns.

ACHIEVING GREEN GOALS

Amanda Langweil, the director of sustainability at Goshow Architects, finds that prefabrication assists with the following green goals:

- **Waste:** Prefabrication in a controlled environment creates much less waste. “Any stud material that is left over, any gypsum sheathing that is left over can be reused by that facility for another project.”
- **Materials:** The use of split tile brick, which is lighter than face brick, means less raw material use. It also has better tolerances to match the dimensions needed. Langweil estimates that the use of split tile brick resulted in savings of 70%–80% in raw material use compared to face brick.
- **Tighter Envelope:** Large prefabricated panels have fewer joints that need to be sealed on site.
- **Site Impact:** The lack of scaffolding reduced the site impact.

QUALITY

AbiDargham reports that the “perfect bearing of the metal studs” in the prefabricated panels minimizes deflection and thus helps the structural system.

McKee finds that “there is consistency across the building that we wouldn’t otherwise see [because] testing and certification can go on in a plant that are harder to replicate in the field.”

Henderson admired the sturdiness of the construction due to the metal braces, and also reports that both the wall panels and floor slabs do not contain the imperfections that are typical of onsite construction. In addition, two years into operation, she reports that students love the building and that they have experienced no problems at all due to the construction.

Goshow sums up the main response to concerns about quality: “People look at it, and they have no idea it has been prefabricated ... From an aesthetic point of view, just because it is prefabricated doesn’t mean it cannot look almost any way you want.” ■

Project Facts and Figures

Owner
CUNY Queens College

Developer
Capstone Corp.

Architect
Goshow Architects LLP

Construction Manager
T.G. Nickel & Associates

MEP Engineer
Goldman Copeland and Assocs.

Structural Engineer
WSP Cantor Seinuk

Exterior Load-Bearing Wall Contractor
Island International Fabricators

Interior Load-Bearing Wall Contractor
Godsell Contracting

Precast Plank Contractor
NY Precast

Project Cost (Construction Cost)
\$58 Million

Size
175,000 square feet

Height
6 stories

Started
June 2008

Completed
August 2009

Green Certification
LEED NC v2.2 Registered (Seeking Gold Level Certification)

Data: Green Building

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

Using Prefabrication/ Modularization on Green Building Projects

According to McGraw-Hill Construction's *Green Outlook 2011*, green projects comprised nearly a third of all new nonresidential construction activity in 2010, with that share expected to grow significantly over the next five years. Given this increase, it is important that the industry recognizes the contribution prefabrication/modularization can offer in meeting green goals.

Though the level of use of prefabrication/modularization in green projects is limited today, most of the industry (88%) is using it on at least one green project, with 19% using it on more than half of their green projects. This suggests that some industry players understand the value these off-site practices can contribute to green goals (see case study on page 36 for an example).

Use of Prefabrication/Modularization on LEED Projects

Currently, 31% of the industry believes that use of prefabrication/modularization can help projects achieve LEED credits under the U.S. Green Building Council's LEED green building certification program. However, there is still a majority that do not recognize that intersection.

There are several ways prefabrication can contribute to a greener project—and potentially to LEED credits. Aside from the waste reduction benefits (see below), off-site work could reduce habitat and site disturbance; protect some materials from rain and inclement

Construction Waste

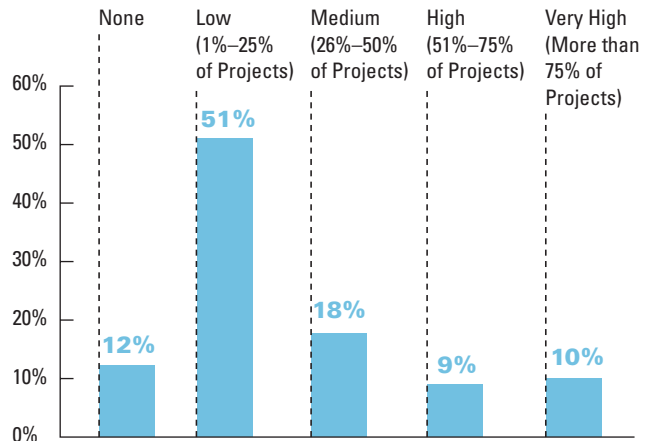
The impact of construction on the environment is significant. The US EPA estimates more than 135 million tons of debris from construction sites end up in landfills in the U.S. each year. According to the industry, that waste can be effectively minimized through the use of prefabrication/modularization.

According to Current Users

76% of current users report that prefabrication/modularization decreases the amount of their construction site waste, with 41% reporting decreases of 5% or more. Not only are these gains environmentally beneficial, but they also are financially beneficial, with less waste translating to cost savings and higher ROI.

Percentage of Green Projects Using Prefabrication/Modularization

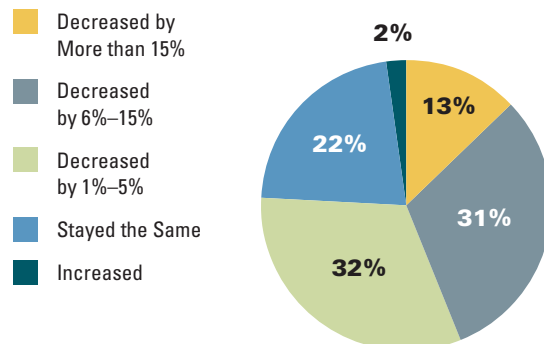
Source: McGraw-Hill Construction, 2011



weather—translating to less exposure to moisture and better indoor air quality; and offer flexibility—contributing to development of a more adaptive building.

Impact of Prefabrication/Modularization on Amount of Construction Site Waste

Source: McGraw-Hill Construction, 2011



CONTINUED

According to Current Non-Users

Non-users of prefabrication/modularization also recognize the green benefits that it can offer.

Nearly all (95%) non-users believe prefabrication/modularization can lead to a greener construction site, with a fifth reporting it can have a high or very high impact on creating a greener site.

VARIATION BY PLAYER

Architects have the most positive perception on the impact prefabrication/modularization can have on creating a greener construction site—33% of architect non-users believe it has a high or very high impact. Engineers lag, with 16% believing the same.

Materials

Not only does prefabrication help mitigate construction waste and lead to a greener construction site, it can also reduce material use, increase recycling and allow for greener material selection.

Materials Use

Currently, a majority (62%) of the industry recognizes that prefabrication/modularization can help decrease the use of construction materials, with over a quarter (27%) reporting decreases of 5% or more. The precise measurement possible in an offsite facility prevents wasted material, and the remnants of metals and other material can frequently be directly recycled back into the manufacturing process. However, more education is needed, given that over a third do not perceive a change in material use for prefabrication/modularization versus onsite construction.

Greener Material Selection

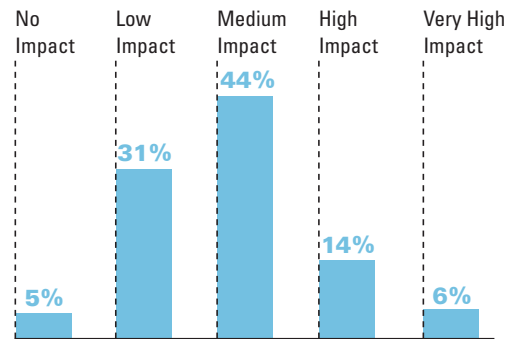
Nearly a third (31%) of firms find that prefabrication/modularization also enables greener building material selection.

However, it is clear that more education is needed in making the connection between prefabrication/modularization and green from a materials perspective. Given the increase in green building activity, firms that understand this connection can gain a market advantage.

Impact Prefabrication/Modularization Can Have On Creating a Greener Construction Site

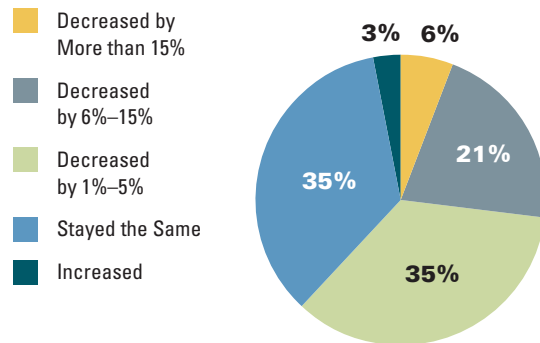
(According to Non-Users)

Source: McGraw-Hill Construction, 2011



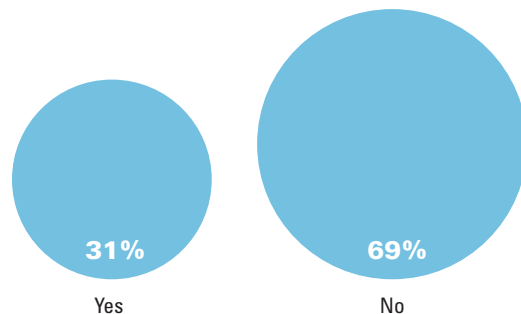
Impact of Prefabrication/Modularization on Project Material Use

Source: McGraw-Hill Construction, 2011



Percentage Finding that Prefabrication/Modularization Enables Greener Building Material Selection

Source: McGraw-Hill Construction, 2011



Data: Model-Driven (BIM) Prefabrication

Usage

PREFABRICATION AND MODULARIZATION: INCREASING PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY DATA

The use of Building Information Modeling (BIM) by industry professionals is on the rise, and this trend, in turn, is expected to drive high levels of use of model-driven prefabrication over the next two years.

Use of BIM

Nearly three-quarters of survey respondents (73%) indicated that they are using BIM on some projects, with nearly a third of BIM users (32%) indicating that they are using BIM on more than 50% of their projects.

Notably, prefabrication and modular construction users are significantly more likely to also be users of BIM. 78% of prefab/modular adopter respondents use BIM on some projects compared with only 48% of non-adopter respondents.

Use of Model-Driven Prefabrication

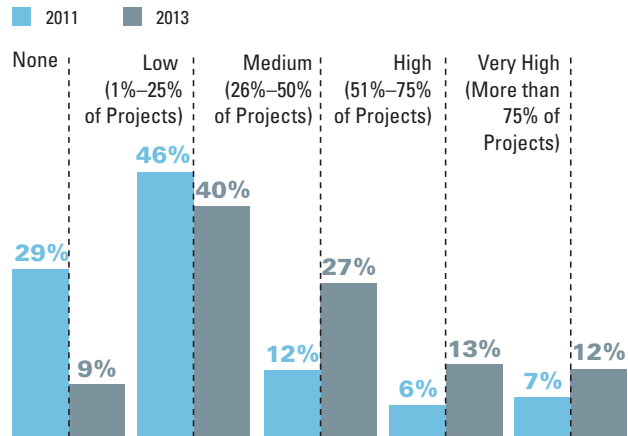
Model-driven prefabrication, where BIM models are provided to building product manufacturers to prefabricate building elements off-site, is projected to increase dramatically in the next two years.

Currently, 71% of prefabrication and modular construction users are doing model-driven prefabrication on some projects. However, this activity is expected to grow to 91% by 2013—with a quarter of users (25%) doing model-driven prefabrication on more than 50% of their projects.

Contractors are doing the most model-driven prefabrication today (76%) with nearly all (95%) expected to be doing some model-driven prefabrication in 2013.

Use of Model-Driven (BIM) Prefabrication (by Percentage of Respondents)

Source: McGraw-Hill Construction, 2011

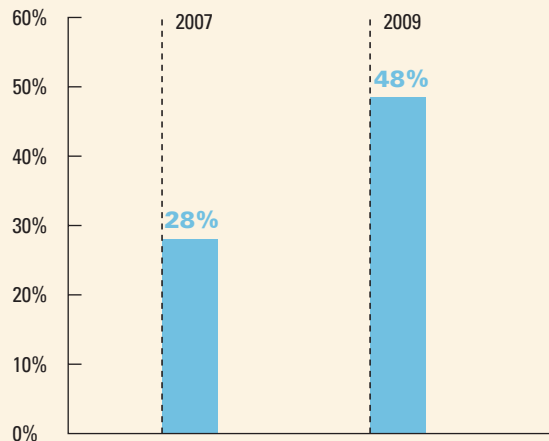


Sidebar:

McGraw-Hill Construction research conducted in 2009 (*The Business Value of BIM SmartMarket Report*) indicated that BIM use was growing rapidly with nearly half of survey respondents (48%) reporting use of BIM or BIM-related tools—a 75% increase in use compared with 2007 data. Further, in the 2009 study, one of the primary perceived future benefits, and driver of future BIM use, was the ability to do prefabrication on larger and more complex parts of projects.

Growth in BIM Use for Industry Players

Source: The Business Value of BIM SmartMarket Report, McGraw-Hill Construction, 2008



Drivers

Primary Reasons for Doing Model-Driven Prefabrication

Respondents report doing model-driven prefabrication for a number of nearly equally important reasons:

PRODUCTIVITY REASONS

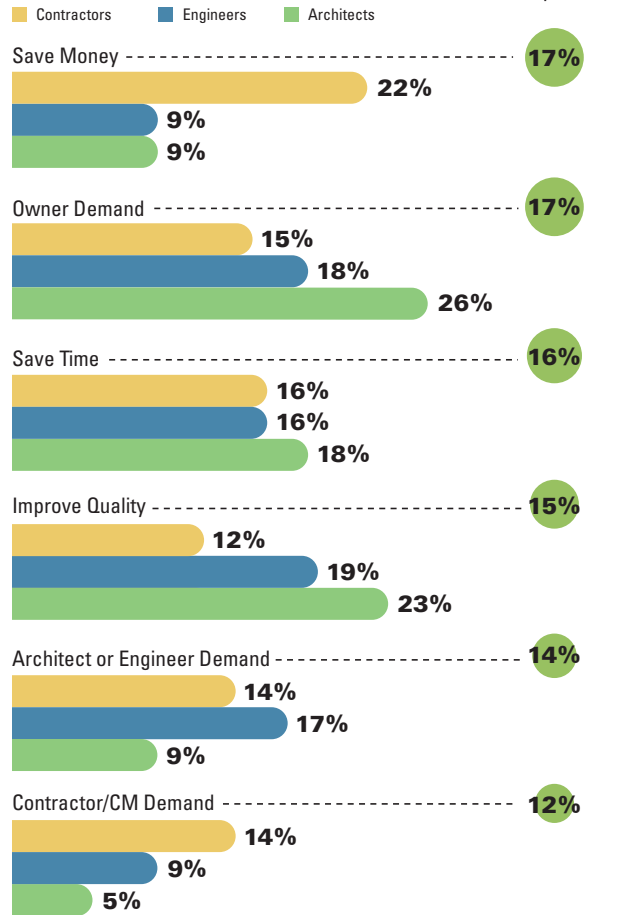
- 17% of users indicated that saving money was the primary reason for doing model-driven prefabrication. This was a particularly important reason for contractors (22%).
- 16% of users report that saving time was their primary motivation for implementing BIM-driven prefabrication. This was slightly more important for architects (18%).
- 15% of users report that improving quality was their primary driver to using model-driven prefabrication. This was a particularly important reason for architects (23%).
- Somewhat surprisingly, making the construction site/process safer (2%) and greener (1%) were considered much less influential reasons for doing model-driven prefabrication.

PLAYER DEMAND REASONS

- Owner demand for model-driven prefabrication was a highly rated reason for doing model-driven prefab. 17% of users indicated this was their primary reason, and it was particularly high among architects (26%).
- The architect or engineer specifying model-driven prefabrication was the second highest player demand reason (14%) with slightly more engineers (17%) indicating this was their primary reason.

Primary Reason for Using Model-Driven Prefabrication (By Player)

Source: McGraw-Hill Construction, 2011



Drivers Behind Owner Adoption of Prefabrication and Modularization

Propelled by new advancements in technology and the offer of potential significant cost savings compared to stick build construction, prefabrication/modularization has reemerged as an important construction option for building and plant owners.

As the data in this report points out, the reduced cost of off-site labor combined with the increased productivity of the fabrication shop is translating into compressed schedules and cost reductions, which owners are starting to recognize.

In-Depth Interviews of Owners with Commercial and Institutional Buildings and Industrial and Energy Plants

In February 2011, McGraw-Hill Construction conducted in-depth interviews with 15 leaders in firms that own commercial and institutional buildings and energy and industrial plants. (See the Profile of Owners box on page 45 for more information.) The respondents overall have favorable views regarding the use of prefabrication/modularization and expect its use to increase in the future as a result of the benefits being observed.

The interviews reveal the owners' perceptions of the drivers and the benefits as well as the various challenges facing the use of prefabrication/modularization across the industry.

Use of Prefabrication and Modularization

Over 90% of the owners interviewed report having used prefabrication/modularization in their projects

during the past two years. They report levels of use ranging from 5% to 80% in their project portfolios.

COMMERCIAL AND INSTITUTIONAL BUILDING OWNERS

Sectors of use:

- Offices
- Hotels
- Schools and campus buildings
- Retail and entertainment
- Mixed-use/multifamily residential
- Commercial warehouses

Most commercial and institutional building owners state that prefabrication/modularization lends itself well to building projects where stacking unit types and repetition is involved, which is where owners get the greatest benefits.

INDUSTRIAL AND ENERGY PLANT OWNERS

Sectors of use:

- Power generation facilities (fossil-fuel thermal and nuclear power)
- Oil refineries
- Chemical plants
- Control buildings

Industrial and energy plant owners indicate that prefabrication and modularization is used most commonly in the building of pipe racks, skid mounted units and combined cycle projects (gas turbine, front end, heat recovery steam generators).

Biggest Influence Factors on Decision to Use Prefabrication or Modularization

All of the owners expect to use prefabrication/modularization in their projects over the next two years at either current levels or increased levels of use.

The owners indicate that schedule and cost are the biggest drivers in their decision to use prefabrication/modularization, followed by safety. They see prefabrication/modularization positively affecting their projects in each of these areas.

SCHEDULE

All owners report reductions in their project schedules ranging from 10% to 30% as a result of using prefabrication/modularization.

CONTINUED

Overall, owners state that the on-site construction duration can be substantially shortened as a result of more work for a project being completed off-site. Prefabrication/modularization can lead to a compressed schedule because off-site work contains fewer inherent risks such as conflicting crews, weather delays or interference with ongoing operations.

COST

Owners report project cost reductions ranging from 2% to 40% as a result of using prefabrication or modularization.

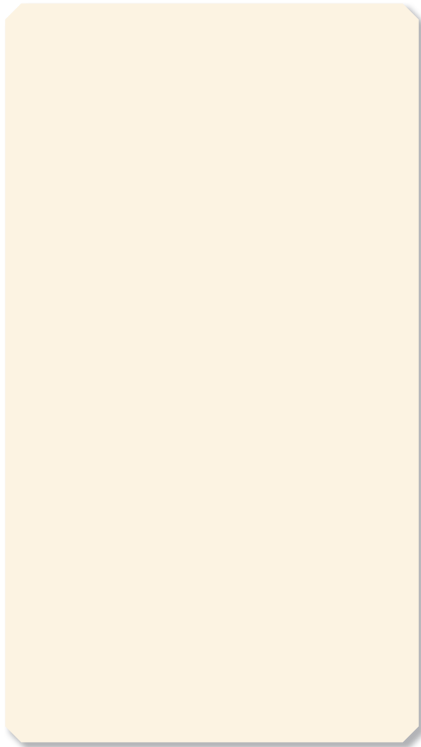
Several reasons for these reduced costs include:

- **Local labor for onsite work may be very expensive or inefficient.**
- **Unfavorable onsite conditions and weather problems may lead to costly delays.**

Several owners report that since some or all of the work is relocated to an off-site location, costs associated with onsite infrastructure and overhead can be reduced. Additionally, they mention that fewer workers onsite translate to fewer costs for accommodations, scheduling onsite work and other onsite logistics.

SAFETY

Almost all owners agree that overall project safety is improved through the use of prefabrication and modularization. The risk to owners from worker accidents and lost time is reduced when construction work is transferred away from the job site and into a controlled manufacturing environment.



Types of safety addressed by prefabrication/modularization include less exposure to:

- **Weather**
- **Heights**
- **Hazardous operations**
- **Congested construction activities**

Advantages Offered by Prefabrication and Modularization

Overall feedback from owners on the advantages of prefabrication/modularization confirms the responses from the other industry players reported in the data sections. Most owners believe quality can be improved through off-site work as a result of controlled factory and

production conditions and repetitive procedures handled by automated machinery.

LABOR

■ **Skills**

Owners indicate that it is not uncommon to encounter a lack of available skilled labor onsite, which becomes exacerbated the more remote the location of the site. This is a key factor in the decision to use prefabrication/modularization and a primary advantage according to owners. Owners can shift work to an off-site location where the supply of skilled labor is better.

■ **Costs**

Labor costs can also be a driver for prefabrication/modularization. Owners state that in areas where the local labor costs are very high, prefabrication/modularization offers a less costly alternative. Owners are able to shift some of the work to an off-site location and take advantage of cheaper labor costs.

QUALITY

Quality is cited by almost all owners as a significant advantage of prefabrication/modularization. Owners state that fabricating components away from the site allows higher quality due to the controlled environment provided by the manufacturing facilities.

OTHER ADVANTAGES MENTIONED

Less disruption of existing onsite operations was cited by several owners as an important advantage.

Several owners also emphasize the advantage of just-in-time delivery of building components. It allows for

less site disruption and less degradation of materials being stored onsite waiting to be constructed.

Challenges of Using Prefabrication and Modularization

While the drivers and advantages mentioned above help make the case, the decision to implement is determined by the owners weighing the benefits against the challenges of using prefabrication/modularization. Primary challenges listed by owners are: early commitment to engineering and design work, increased transportation requirements and the limited number of providers.

EARLY COMMITMENT TO ENGINEERING AND DESIGN WORK

Owners indicate that with prefabrication/modularization, the engineering

and design work have to be completed before onsite construction can begin, as opposed to conventional construction where only a portion has to be completed. Since this requires a well-defined scope early in the planning stage, some owners see this commitment as inflexible and a constraint on their delivery strategy.

INCREASED TRANSPORTATION LOGISTICS REQUIREMENTS

Owners cite the key role of transportation logistics in determining the feasibility of using prefabrication/modularization. Size and weight limitations, route restrictions, permitting requirements and the need for lifting equipment are factors that all need to be planned and coordinated before construction begins.

Owners emphasize the need to pay attention to transportation costs. Several owners cited cases where miscalculations were made up front which resulted in a substantially costlier project in the end.

LIMITED NUMBER OF PROVIDERS

The universe of providers of components via prefabrication/modularization is fairly small compared to the universe of providers of other kinds of components. This limited range of sourcing options is seen as a constraint and a risk factor.

Perceptions of the Role of Prefabrication and Modularization in Green Projects

At least half of the owners interviewed report having a green component to some or all of their projects, including both commercial and industrial projects. While a majority of owners believe that the

use of prefabrication/modularization leads to less waste onsite and as a result less energy use, many do not yet see green as a primary reason for choosing it, and only two owners are currently pursuing LEED certification for their projects. For examples of how prefabrication/modularization can be effective on green projects, see page 39.

Feedback from owners illustrates that more awareness is needed on the environmental benefits of using prefabrication/modularization: namely, fewer onsite environmental impacts because of reductions in material waste, air and water pollution, dust and noise, and lower overall energy costs. ■

Data: Contractors

Usage

The adoption of prefabrication and modular building processes is not a new activity for most contractors. 57% of contractors surveyed have been using these processes for five years or more.

Current and Future Usage

Given that prefabrication/modular construction has been around for many years, it is not unexpected that 84% of contractors today are using these processes on some projects. Further, by 2013, nearly all contractor respondents (98%) expect to be doing some prefabrication and modularization on a least some portion of their projects:

- By 2013, 73% of all contractors expect to be using these processes at a medium to very high level (more than 25% of projects). Two-thirds of mechanical contractors (66%) expect they will be using these processes on over 50% of their projects by 2013.
- 94% of large contracting firms (more than \$100 million in annual revenue) have adopted these processes compared with only 76% of smaller firms (less than \$25 million per year in revenue).
- Among contractors, design-builders (96%) are the highest adopters of prefabrication and modular processes, followed by construction managers (89%) and mechanical contractors (87%).

Building Sectors

Contractors are using prefabrication and modular building processes on a wide variety of commercial building projects. In particular, contractors today are using it on healthcare facilities (61%), university buildings and dormitories (50%) and public buildings (46%).

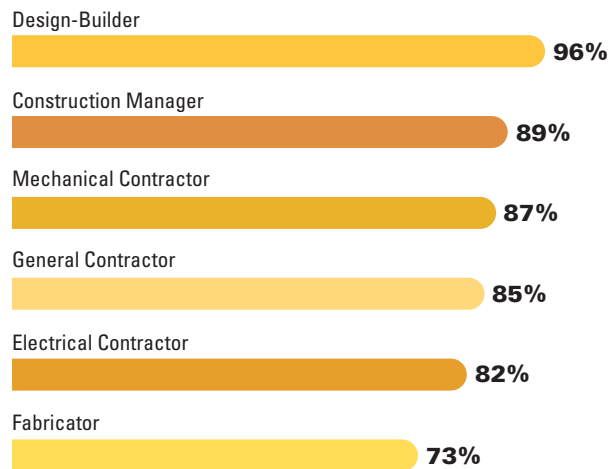
- Over 50% of mechanical contractors are using prefabrication on high- and low-rise offices and manufacturing buildings.
- Contractors see the most future opportunity in health-care facilities (19%), hotels and motels (13%), high rise offices (10%), commercial warehouses (9%) and other building types (7%) including data centers, prisons, power plants and oil refineries.

Building Elements

As part of commercial building projects, contractors most regularly use prefabricated/modular MEP systems (62%), exterior walls (39%) and interior rooms (31%).

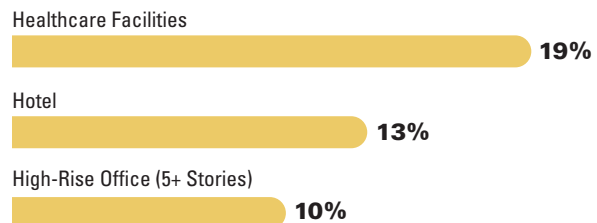
Current Use of Prefabrication/Modularization by Contractor Type

Source: McGraw-Hill Construction, 2011



Top Building Sectors for Prefabrication/Modularization Opportunity (Contractors)

Source: McGraw-Hill Construction, 2011



- Apart from expected occupational preferences (e.g., MEP systems for mechanical and electrical contractors), design builders (38%), fabricators (30%) and general contractors most often use prefabrication (24%) on the building superstructure.

Reasons for Not Using

The primary reasons contractors do not use prefabrication and modularization on projects is that the architect did not design it into the project (48%), followed by the recognition that the process was not applicable for the project (33%).

- Construction managers (49%) and general contractors (30%) also rated the lack of a local prefabrication shop as a key reason for non-usage.

Productivity

More than any other player group, contractors (92%) believe that prefabrication/modular construction processes can improve productivity.

Project Schedule

72% of contractors surveyed believe that use of prefabrication and modularization decreases project schedules by more than a week, with over one third (37%) believing that usage can decrease schedules by more than four weeks.

- **All contractor types agree on the positive impact that prefabrication/modularization is having on project schedules, ranging from 65% of electrical contractors to 79% of mechanical contractors.**
- **43% of construction managers believe that these processes can decrease project schedules by four weeks or more.**

Project Budget

Nearly three-quarters (74%) of contractors surveyed believe that prefabrication/modularization can help decrease project budgets, and nearly a quarter (23%) believe it can decrease project budgets by 11% or more.

- **Mechanical (85%) and electrical (81%) contractors are particularly convinced that it can reduce project budgets.**
- **Design-builders are the most optimistic about prefabrication's potential, with 18% believing that it can reduce project budgets by 20% or more.**

Site Safety

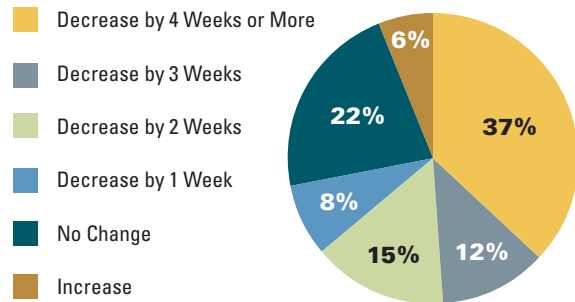
Contractors have very mixed views on the impact of prefabrication/modularization onsite safety. More than any other player, 37% believe that these processes improve site safety. However, more contractors (12%) than other players believe that it reduces site safety. Possibly this is due to the size of components and the need to have more cranes or other heavy equipment onsite to place these components. A majority of contractors believe that site safety stays about the same.

- **Mechanical contractors (46%) and fabricators (42%) believe that these processes improve site safety.**
- **Interestingly, a large percentage of fabricators (26%) believe that these processes decrease site safety, followed by design-builders (18%).**

Decrease in Project Schedule Due to Prefabrication/Modularization

(According to Contractors)

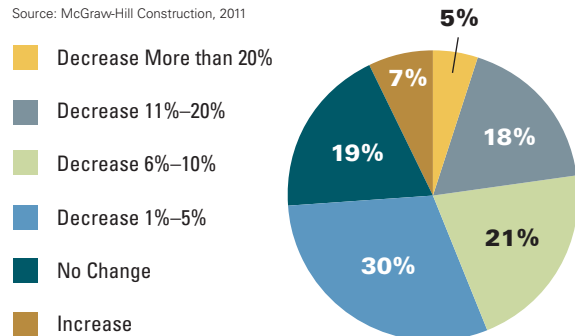
Source: McGraw-Hill Construction, 2011



Decrease in Project Budget Due to Prefabrication/Modularization

(According to Contractors)

Source: McGraw-Hill Construction, 2011



Purchase Price and Installation of Materials

Nearly half of contractors (47%) believe that the purchase and installation costs for prefabricated materials are lower than for regular building products. Over 10% of contractors believe that such costs are lower by 10% or more.

- **More than half of construction managers (53%) believe that purchase and installation costs are lower.**
- **Over a quarter of electrical contractors (28%) and design-builders (27%) believe that purchase and installation costs are higher.**

Drivers

Current Drivers

Contractors, like other industry players, are using prefabrication and modularization today because of the perceived productivity improvements (92%) and the belief that it gives them a competitive advantage (85%).

- **Nearly all mechanical contractors (98%) and electrical contractors (97%) see productivity improvements as the primary driver.**

Future Drivers

Contractors believe that by 2013 the primary drivers to future prefabrication/modular use will be their ability to employ these processes to decrease construction costs (85%) and produce improvements in project schedules (84%).

- **More than other contractors, construction managers (84%) and mechanical contractors (83%) believe that measurable improvements in project quality will be a key driver to future use.**

Model-Driven Prefabrication

Over three-quarters of contractor prefabrication and modularization users (76%) are also doing model-driven prefabrication. Most (50%) are doing it on only a low percentage of their projects. However, over half of contractors (55%) believe they will be doing it on more than 25% of their projects in 2013.

- **The primary reason why contractors are doing model-driven prefabrication is to save money (22%).**

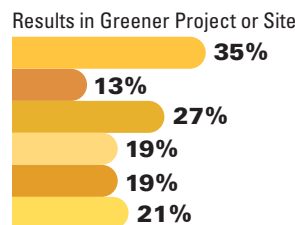
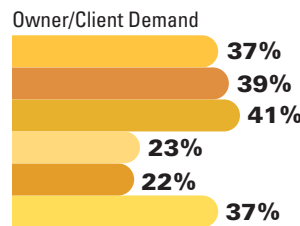
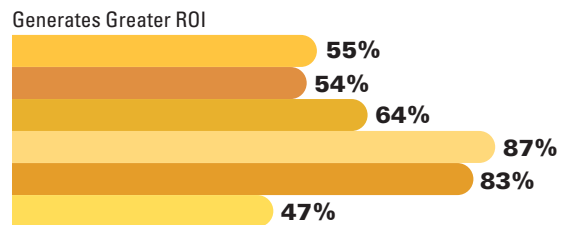
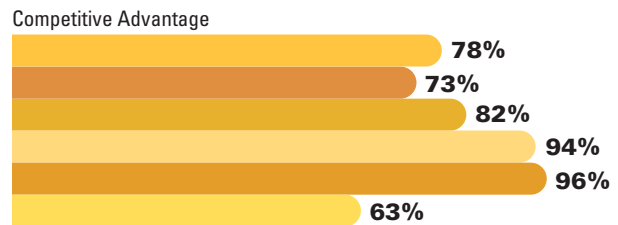
Green and Sustainability

Results show that contractors are not particularly aware of the overall green benefits of prefabrication. Less than a quarter (22%) view green as a key driver to prefabrication and modularization usage. However, when specific green aspects are considered, a somewhat different picture on green benefits emerges.

- **Reducing Onsite Waste: 83% of contractors believe that prefabrication reduces onsite waste. Nearly 40% believe it reduces onsite waste by 5% or more. Less than 1% believes that it increases onsite waste.**
- **Project Materials: Two-thirds of contractors (66%) also believe that prefabrication/modularization reduces the amount of material used on a project—over a quarter (29%) believes it reduces material use by 5% or more.**

Current Drivers to Use of Prefabrication/Modularization (By Contractor Type)

Source: McGraw-Hill Construction, 2011



Data: Architects and Engineers

Usage

Like contractors, architects and engineers are familiar with prefabrication and modular building processes. 64% of architects and 77% of engineers surveyed have been using prefabrication and modularization on some projects for five years or more.

Current and Future Usage

The long-term familiarity of architects and engineers with prefabrication and modularization translates into high current usage. 90% of engineers and 76% of architects are using these processes on some projects today. Further, nearly all architects (98%) and engineers (99%) expect to be doing some prefabrication and modularization on at least some portion of their projects by 2013.

- By 2013, 38% of architects and 43% of engineers that use prefabrication and modularization today expect to be using it on more than 50% of their projects.
- 97% of large engineering and 84% of large architectural firms (more than \$10 million in annual revenue) have adopted these processes, compared with only 76% of smaller engineering and 70% of smaller architectural firms (less than \$500,000 per year in revenue).

Reasons for Not Using

The primary reason that architects do not use prefabrication/modularization on a project today is because the owner does not want it (39%). The primary reason engineers are not using it on specific projects is because the architect didn't design it into the project (44%). Thus, there is a need for the industry to better educate owners on the benefits of prefabrication/modularization so that architects will include it when designing projects.

Building Sectors and Elements

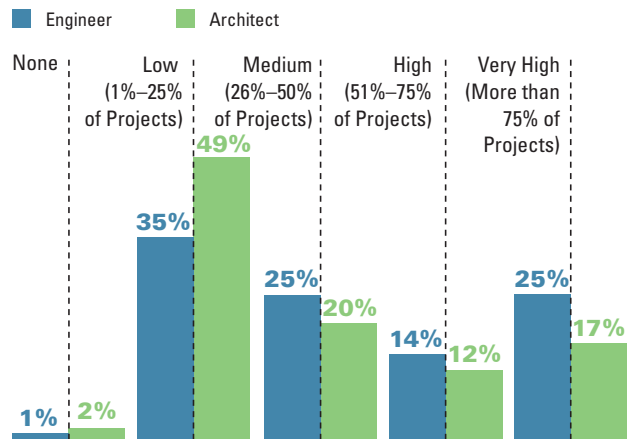
Today, both architects and engineers are using prefabrication/modularization on a wide variety of commercial building projects. Architects are currently using it most frequently on low-rise office buildings (43%) and health-care facilities (36%). Engineers use it most frequently on manufacturing buildings (46%) and warehouses (43%).

In terms of future sectors of opportunities, architects and engineers report the following:

- Architects see equal future opportunity in hotels (14%), K-12 schools (14%) and multifamily housing (14%).
- Engineers see the most future opportunity in commercial warehouses (17%), and manufacturing buildings (15%).

Percentage of Future (2013) Prefabrication/Modularization Use (for Engineers and Architects)

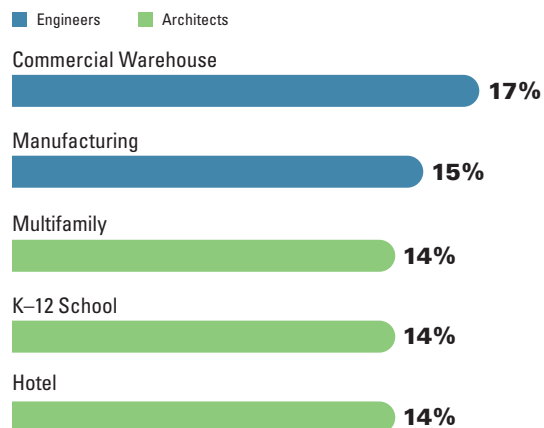
Source: McGraw-Hill Construction, 2011



Top Building Sectors for Prefabrication/Modularization Opportunity

(According to Engineers and Architects)

Source: McGraw-Hill Construction, 2011



- As part of commercial building projects, over two-thirds of architects (68%) and engineers (71%) are most likely to utilize prefabrication/modularization in the building superstructure. Over half of architects and engineers surveyed also use it in exterior walls and for roof construction.

Drivers and Productivity

Current and Future Drivers

Just like contractors, architects and engineers see the primary drivers for using prefabrication/modularization today to be productivity improvements and competitive advantage.

- **68% of architects and 70% of engineers are primarily driven by productivity improvements.**
- **60% of engineers and 52% of architects believe that these processes give them a competitive advantage.**

Architects and engineers are also closely aligned with contractors in the belief that the primary drivers to future usage will be the improvements that prefabrication and modularization can provide to project schedule, cost and quality.

- **90% of architects and 79% of engineers believe that in the future these processes will result in measurable improvements in project schedule.**
- **Over 80% of both architects (83%) and engineers (82%) believe these processes will reduce future construction costs.**
- **70% of architects and 66% of engineers believe that prefabrication and modularization will result in measurably higher quality on future projects.**

Productivity

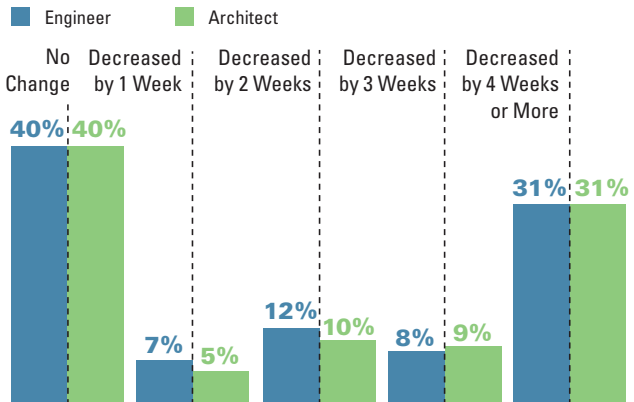
As noted above, both architects and engineers see productivity improvements as being the primary driver of current prefabrication/modularization usage and elements of productivity, including improving schedules and decreasing costs, as being primary drivers to future usage.

- **Project Schedule—Both architects and engineers see prefabrication/modularization as having a positive impact on projects schedules, but less so than contractors.**
 - 60% of both architects and engineers believe that the use of these processes reduces project schedules by one week or more, versus 72% of contractors.
 - 31% of both architects and engineers believe that it reduces project schedules by four weeks or more.
- **Project Budget—42% of architects and 52% of engineers believe that prefabrication/modularization has a positive impact on project budgets. This can be compared to 74% of contractors.**

Level of Decrease in Project Schedule Due to Prefabrication/Modularization

(According to Engineers and Architects)

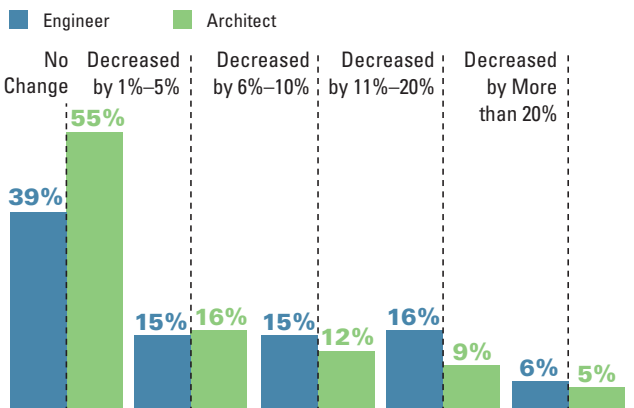
Source: McGraw-Hill Construction, 2011



Level of Decrease in Project Budget Due to Prefabrication/Modularization

(According to Engineers and Architects)

Source: McGraw-Hill Construction, 2011



- Most architects (55%) believe that prefabrication/modularization is budget neutral, while 26% see it reducing project budgets by 6% or more.
- 39% of engineers believe that project budgets are unaffected by use of prefabrication/modularization, while 37% see it reducing project budgets by 6% or more.

- **Site Safety—Most architects (77%) and engineers (62%) believe that site safety stays about the same. Very few architects (3%) and engineers (6%) believe that prefabrication/modularization reduces site safety.**

Glossary:

Definition of Terms Used

Building Information Model (BIM):

A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility and forms a reliable basis for decisions during its lifecycle from inception onward. BIM also refers broadly to the creation and use of digital models and related collaborative processes between companies to leverage the value of the models.

Building Superstructure:

All parts of the building above the foundation, including the building frame, roof and exterior walls.

Green Building:

A building constructed to LEED or other green building standards, or one that involves numerous green building strategies across several categories, including energy, water and resource efficiency and improved indoor air quality. Projects that only involve a few green building products are not included in this definition.

Integrated Design Process:

Active participation in all stages of design for all disciplines involved in the design, construction and, at times, the operation of the building. An integrated design team usually includes an owner's representative; architect; mechanical, electrical and structural engineer; and construction manager and/or general contractor. It can also include future building occupants, facility managers and maintenance staff, subcontractors and building product manufacturers.

Integrated Project Delivery:

The delivery of a construction project according to a contract that calls for an integrated design process and that clarifies the legal responsibilities and risks born by all members of the project team.

Lean Construction:

The Associated General Contractors of America (AGC) defines lean construction as a set of ideas based in the holistic pursuit of continuous improvements aimed at minimizing costs and maximizing value to clients in all dimensions of the built and natural environment: planning, design, construction, activation, operations, maintenance, salvaging and recycling.

Modularization/Modular Construction:

The manufacture and remote assembly of major interior or exterior sections of a building (e.g., wall, floor, roof) of one or multiple material types which may include portions of a system (e.g., electrical, plumbing). Examples include curtain wall, structural insulated panels and entire building modules.

Off-Site Fabrication:

The fabrication or assembly of components (no manufacturing processes) off-site or on the construction site but at a location other than the point of installation. The process is usually completed by specialty contractors (e.g., finish carpentry).

Permanent Modular Construction (PMC):

A design and construction process performed in a manufacturing facility, which produces building components or modules that are constructed to be transported to a permanent building site.

Prefabrication:

Manufacturing processes generally taking place at a specialized facility, in which various materials are joined to form a component part of a final installation. Examples include trusses, joists, structural steel and precast concrete. Model-driven prefabrication describes the use of the BIM model to enable prefabrication and assembly of building components both off and on the construction site.

Productivity:

Productivity is the ratio of output to all or some of the resources used to produce that output. Resources can include labor, capital, energy, raw materials, etc.

Project Budget:

The project owner or client will generally determine the construction project budget. It is the task of the project team to deliver a finished project to the owner maximizing project value within the budget.

Project Schedule:

The time for the events related to the project planning and construction. A construction schedule may also address the resources required to accomplish the tasks as well as the dependencies of the tasks to one another.

Methodology:

Methodology

McGraw-Hill Construction conducted the 2011 Prefabrication and Modularization Study to assess the level and scope of use of prefabrication and modularization construction processes and analyze how these processes can impact perceived productivity both now and in 2013.

The research in this report was conducted in two ways. The primary method was through an Internet survey of industry professionals between January 20 and February 22, 2011. This survey had 809 complete responses. The "total" category displayed throughout the report includes 101 architects (13%), 190 engineers (23%), and 518 contractors (64%). In addition, MHC conducted fifteen in-depth-interviews (IDs) of owners between February 18 and March 7, 2011, to collect detailed information on their perceptions and use of prefabrication and modularization and perceived impact on productivity on their construction projects.

The use of a sample to represent a

true population is based on the firm foundation of statistics. The sampling size and technique used in the Internet study conform to accepted industry research standards expected to produce results with a high degree of confidence and low margin of error.

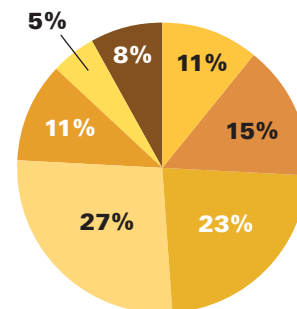
The total sample size (809) used in this survey benchmarks at a 95% confidence interval with a margin of error of less than 5%.

For the architects and engineers, the confidence interval is 95%, with a margin of error of less than 10%; and for the contractors category the confidence interval is 95%, with a margin of error of less than 5%. In addition, for the Contractors Perceptions section, all contractor categories, including general contractor (79), construction manager (55), mechanical contractor (119), electrical contractor (141), fabricator (59) and design-builder/other (65), benchmark at 90% confidence interval with margins of error of less than 12%.

Contractor Respondents

Source: McGraw-Hill Construction, 2011

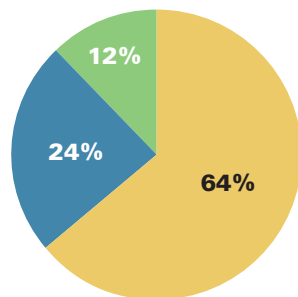
- Construction Managers
- General Contractors
- Mechanical Contractors
- Electrical Contractors
- Fabricators
- Design-Builders
- Other Contractors



Respondents by Firm Type

Source: McGraw-Hill Construction, 2011

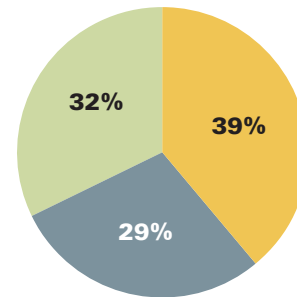
- Contractor
- Engineer
- Architect



Respondents by Firm Type

Source: McGraw-Hill Construction, 2011

- Small
- Medium
- Large



Resources

Organizations, websites and publications that can help you get smarter about prefabrication and modular construction.

McGraw Hill CONSTRUCTION

McGraw Hill Construction

Main Website: construction.com

GreenSource: greensourcemag.com

Research & Analytics:

construction.com/market_research

Architectural Record: archrecord.com

Engineering News-Record: enr.com

Sweets: sweets.com

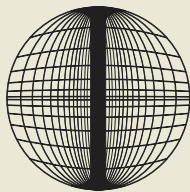
Green Reports:

greensource.construction.com/resources/SmartMarket.asp

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Modular Building Institute
www.modular.org

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

NIST
www.nist.gov

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Island Companies: islandcompanies.com

Modular Building Institute: modular.org

National Institute of Standards and Technology: nist.gov

Syntheon: syntheoninc.com

Partners

Autodesk: autodesk.com/bim

buildingSMART Alliance: buildingsmartalliance.org

National Institute of Building Sciences: nibs.org

Pinnacle Infotect: pinnaclecad.com

Research Partners

The American Institute of Architects: aia.org

American Institute of Steel Construction: aisc.org

American Subcontractors Association: asaonline.com

American Society of Civil Engineers: asce.org

Associated Builders & Contractors: abc.org

The Associated General Contractors
of America: agc.org

Construction Users Roundtable: curt.org

Design-Build Institute of America: dbia.org

International Code Council: iccsafe.org

Mechanical Contractors Association
of America: mcaa.org

National Electrical Contractors Association: neca.org

National Systems Contractors Association: nsca.org

Sheet Metal & Air Conditioning Contractors'

National Association: smacna.org

Society for Marketing Professional Services: smps.org

Other Resources:

BIMForum: bimforum.org

Lean Construction Forum: agcleanforum.org

Lean Construction Institute: leanconstruction.org

■ Design and Construction Intelligence

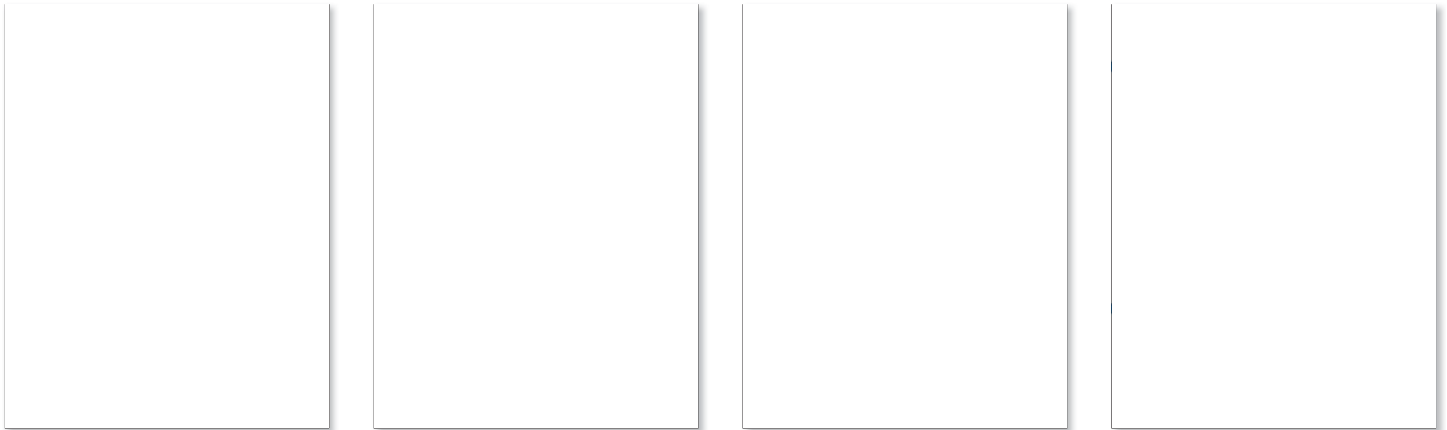
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