Mortenson®

MAY 2014

Prefabrication Research Study Results

BENEFITS & DRIVERS FOR SUCCESSFUL IMPLEMENTATION

PREFABRICATION

FOREWORD

McGraw Hill Construction recently published a report on the impact of prefabrication and key industry productivity metrics such as project schedule, cost, safety and quality. The healthcare sector was reported to have the highest use of prefabrication among all types of building construction projects, as well as the sector with the highest opportunity in implementing such construction strategies. Currently, nearly half of all healthcare projects use prefabrication, and it is reported that schedule and costs are the largest drivers to use prefabrication, followed by safety and quality. [McGraw Hill Construction, 2012]

In this study, a value-based cost-benefit analysis was performed on an ongoing 831,000-square-foot hospital consisting of 360 patient beds, in which the above main performance drivers were analyzed to determine actual project performance results. Mortenson is currently under contract to build the new $380 million Exempla Saint Joseph Heritage Project with a construction schedule of 29.5 months.

The complexity of this project, combined with an extremely aggressive schedule, required creative solutions to be successful. Prefabrication was used extensively to tackle the problem. We are pleased to share with you the following insights regarding the use of prefabrication and its subsequent impact on the project.

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CURRENT STATE OF PREFABRICATION IN THE INDUSTRY

In recent years, the decision to implement prefabricated versus site-built building components has gained a tremendous amount of attention in the construction industry. This shift in construction strategy can be attributed to Building Information Modeling (BIM), new project delivery methods such as Integrated Project Delivery (IPD) and project management philosophies like Lean Construction. These new tools and strategies allow the industry to use proven methods that have effectively been used by other industries, particularly the manufacturing industry. Prefabrication has emerged as one of these driving methods that benefits construction projects, and the industry as a whole, by increasing efficiency and lowering cost.

The most common benefits of prefabrication include cost savings, schedule acceleration, improved quality and safer work environments. [CII, 2002]

Cost is typically the driving factor when considering the benefits of using prefabrication as a construction strategy, therefore, when considering other value components of using prefabrication, owners and CM/GC's ultimately translate these components into actual dollars. The table below summarizes typical value components for prefabrication decision-making and its intuitive expectation. [Cook, 2013]

PREFABRICATION VALUE COMPONENTS & EXPECTATIONS

[Cook, 2013]

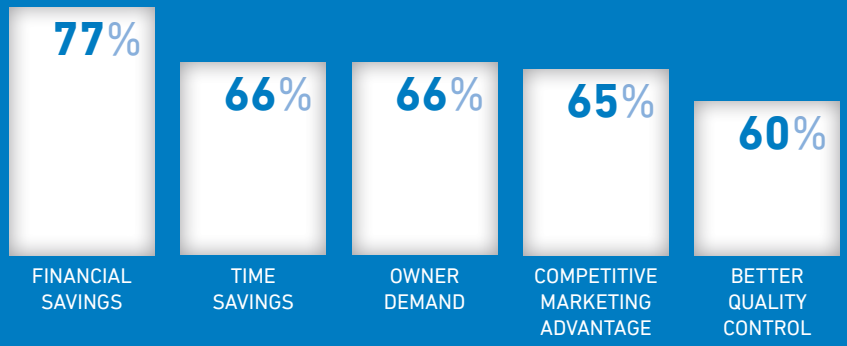
Value Component	Prefab Intuitive Expectation
Cost (Material & Labor)	Neutral or Lower
Time (Schedule)	Compressed
Design Flexibility	Difficult to Make Changes
CM/GC Coordination Time	Reduced
Quality	Equal or Better
Site Deliveries & Supplies	Reduced
Sub-Trade Activity On-Site	Reduced
Safety & Worker Health	Increased
Ergonomics	Better
Weather Conditions	Controlled
Environmental Impact	Reduced
LEED Certification	Mixed Pros & Cons
Waste & Disposal	Reduced
Public Relations	Favorable
Marketing	Favorable
Maintenance (Life Cycle)	Improved

The decision to use prefabrication has been shown to be based on anecdotal evidence rather than numerical data, primarily due to the fact that no formal measurement procedures or strategies are available. [Pasquire & Gibb, 2002]

A major issue in conducting comparative evaluations and analyses on traditional and prefabricated building components is that these methods do not typically account for all of the factors that affect cost (indirectly) and other recognized benefits. Typical evaluations of this issue are cost-based instead of value-based analysis. [Blismas, 2006]

FACTORS DRIVING FUTURE USE OF PREFABRICATION

[McGraw Hill Construction, 2011]



EXEMPLA SAINT JOSEPH HERITAGE PROJECT

By using these existing methodologies, this study has taken an approach that holistically evaluates the actual results experienced by the Exempla Saint Joseph Heritage Project using actual data as experienced by the CM/GC and subcontractors involved in the project. The evaluation method implemented has taken a value-based approach, to be discussed in the body of this white paper, and has performed a detailed cost-benefit analysis of prefabrication.

EXECUTIVE SUMMARY:
RESEARCH STUDY RESULTS

1.13 BENEFIT-TO-COST RATIO

For every dollar spent on prefab, approximately **13%** of the investment is expected to be returned as a **quantifiable benefit to the project.**

EXEMPLA **ST. JOSEPH** HERITAGE **PROJECT**

PREFAB ELEMENT	SCHEDULE REDUCTION	INDIRECT COST SAVINGS	DIRECT COST	REDUCTION IN REQUIRED LABOR	DIVERTED OFF-SITE LABOR	SAFETY INCIDENTS REDUCED	JOBSITE PRODUCTIVITY LOSS PREVENTION
Exterior Wall Panels	41 Days	$2.4 M	3.7% Savings	5,000 Hours	33,000 Hours	2	$0.5 M
Bathroom Pods	52 Days	$3.1 M	4.6% Premium	27,700 Hours	78,000 Hours	4	$1.4 M
Multi-Trade Racks	20 Days	$1.2 M	21.7% Premium	N/A	24,000 Hours	1	$0.4 M
Patient Room Headwalls	0 Days	$0	7.6% Premium	1,300 Hours	16,000 Hours	1	$0.3 M
TOTAL	**72** Days	**$4.3 M**	**6.0%** Premium	**29,500** Hours	**150,500** Hours	**7**	**$2.6 M**

SCHEDULE & COST CERTAINTY

Commit to an aggressive schedule and budget with more confidence.

18% SCHEDULE COMPRESSION ENABLED **29,500** HOURS OF SAVINGS IN LABOR **6%** DIRECT COST PREMIUM

ON-SITE LABOR DENSITY

Improved productivity, flexibility, housekeeping and safety.

$2.6M JOB PRODUCTIVITY LOSS AVOIDED **150,500** LABOR HOURS DIVERTED OFF-SITE

FEWER **SAFETY INCIDENTS**

Reduced congestion and schedule demands, improved positions and spaces.

7 SAFETY INCIDENTS AVOIDED

MANPOWER **CONSISTENCY**

Enhanced efficiency reduces training costs and reinforces cost certainty.

376 HEAD WALLS **346** EXTERIOR WALL PANELS **440** BATHROOM PODS **166** MULTI-TRADE RACKS

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PROJECT OVERVIEW: PREFABRICATION EFFORTS

Mortenson has been charged with building the 831,000-square-foot, 360-patient-bed Exempla Saint Joseph Heritage Project in 29.5 months. As reported by the Denver Business Journal [Proctor, 2012], the fact that the hospital must open by January, 2015, drove Mortenson to determine how to accelerate construction while maintaining the highest quality standards. The traditional on-site linear approach would have resulted in a 36-month schedule; however, an overall 18% schedule compression was required.

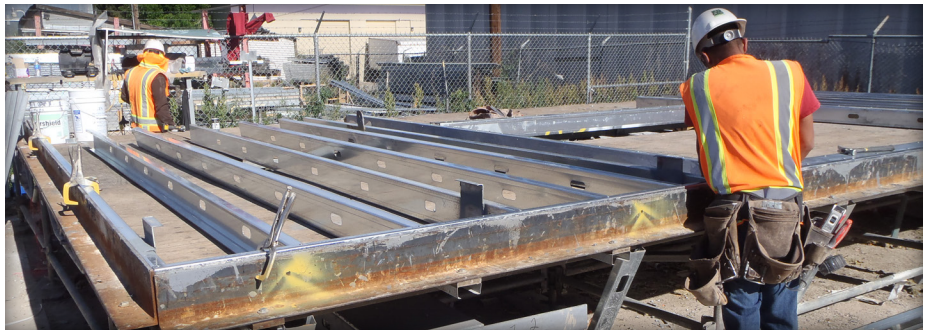
36-MONTH CONSTRUCTION SCHEDULE COMPRESSED BY 18%

Prefabrication quickly became the solution. Prefab allowed for some building elements to be built off-site, simultaneous with construction of the hospital. This also allowed for a significant number of trades to be pulled forward. Under a traditional approach, those trades would not begin on-site work until later in the schedule.

The project team searched for all possible components in the facility that would be conducive to the repetitive prefabrication process. The four major prefabrication efforts included:

PATIENT & ADMINISTRATIVE BATHROOM PODS
EXTERIOR WALL PANELS
MULTI-TRADE UTILITY RACKS
PATIENT ROOM HEADWALLS

The research behind this white paper heavily examined the numerous pros and cons of each prefabricated component. However, the main objective was to determine if prefabrication was beneficial to cost, schedule and safety.

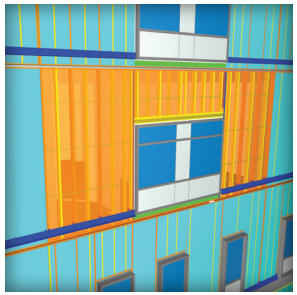


EXTERIOR WALL PANEL RESULTS

Prefabrication vs. Site-Built Construction

Schedule Reduction	41 Work Days
Indirect Cost Savings	$2.4 Million
Direct Cost	3.7% Savings
Overall Required Labor	5,000 Fewer Hours
Diverted Labor Off-Site	33,000 Hours
Reduced Safety Incidents	2 Incidents
Productivity Enhancement Savings On- and Off-Site	$500,000

1.74 BENEFIT-TO-COST RATIO



EXTERIOR WALL PANELS

The upper four floors were chosen to receive prefabricated exterior panels in a typical size of 30 feet long by 15 feet tall. The panel size and details were the result of BIM and coordination between the framing subcontractor, structural engineer, architect and Mortenson. The lower three floors proved to have too much variation to reap the benefits of prefabrication and were built traditionally on-site.

The off-site fabrication was located eight miles from the project site, along with the exterior framing subcontractor and its supplier. The production line included numerous jigs and templates, and it allowed craft workers to fabricate the walls at a comfortable height on elevated tables. The fabricated panels were complete with framing, brick ledge, sheathing, air barrier, mineral wool, brick ties and spray-foam insulation. The only remaining on-site activity was completing the detailing on the connections between panels.

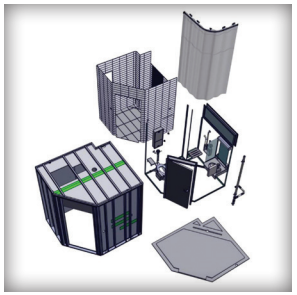
Exterior wall panel prefabrication proved to be extremely valuable, as shown in the resulting benefit-to-cost ratio.

BATHROOM POD RESULTS

Prefabrication vs. Site-Built Construction

Schedule Reduction	52 Work Days
Indirect Cost Savings	$3.1 Million
Direct Cost	4.6% Premium
Overall Required Labor	27,700 Fewer Hours
Diverted Labor Off-Site	78,000 Hours
Reduced Safety Incidents	4 Incidents
Productivity Enhancement Savings On- and Off-Site	$1.4 Million

1.29 BENEFIT-TO-COST RATIO

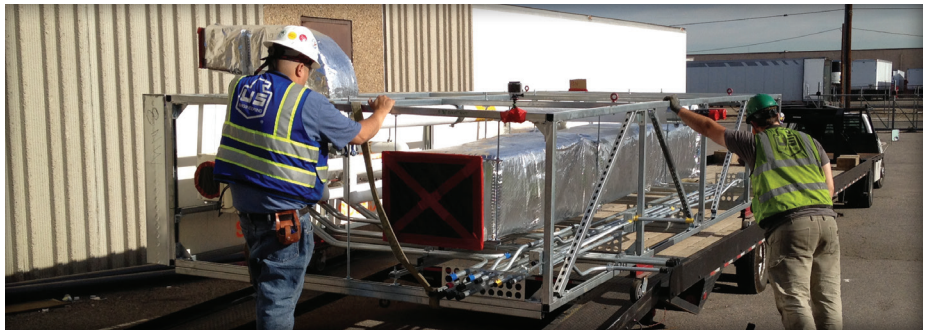


PATIENT & ADMINISTRATIVE BATHROOM PODS

All bathrooms in the hospital were considered for prefabrication. Taking shipping size and repetitive characteristics into consideration, 440 bathrooms were prefabricated while 122 bathrooms were built traditionally on-site. The vast majority of the bathroom pods (257 units) were represented in the patient rooms. Early coordination was required between the owner, design team, supplier and Mortenson to gain concept buy-in and to incorporate as many efficiencies into the design as possible. This demanded a significant team effort to finalize bathroom sizes, locations and finishes much earlier in the project than traditionally required.

The prefabricated bathrooms were manufactured by Eggrock Modular Solutions, a division of Oldcastle and a leading third-party manufacturer of prefabricated bathroom pods. The pods were shipped from Massachusetts, complete with all finishes including towel bars, mirrors and toilet paper holders. On-site crews received, hoisted and transported the pods through the building and set them in a floor slab depression. MEP and finish trades connected utilities and extended drywall partitions to provide a seamless transition.

The decision to prefabricate bathrooms was very beneficial for the project, particularly from a scheduling perspective.

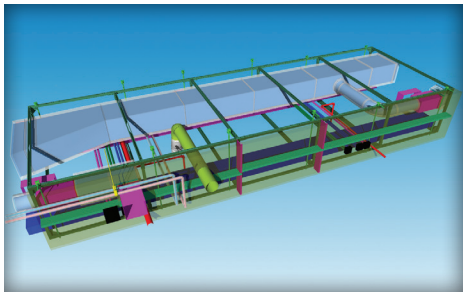


MULTI-TRADE RACK RESULTS

Prefabrication vs. Site-Built Construction

Schedule Reduction	20 Work Days
Indirect Cost Savings	$1.2 Million
Direct Cost	21.7% Premium
Overall Required Labor	4,700 Additional Hours
Diverted Labor Off-Site	24,000 Hours
Reduced Safety Incidents	1 Incident
Productivity Enhancement Savings On- and Off-Site	$300,000

1.22 BENEFIT-TO-COST RATIO



MULTI-TRADE UTILITY RACKS

The project team identified all areas of the hospital within utility corridors to utilize multi-trade racks (MTR). Based on repeatability and density of utilities, 166 MTRs were installed, representing nearly a mile of prefabricated racks. Typical MTRs are 25 feet long by 8 feet wide, consisting of hydronic piping, air duct, cable tray, conduit, pneumatic tubing and drywall. Heavy coordination was required between the owner, design team, mechanical subcontractor, electrical subcontractor and Mortenson to group and design utilities to ensure prefabrication was beneficial and efficient.

Off-site fabrication was performed at a 60,000-square-foot warehouse located four miles from the jobsite. The production line produced and stored up to two floors of MTRs ahead of on-site construction to substantially remove these trades from the critical path. The mechanical subcontractor, U.S. Engineering, transported, hoisted and installed the MTRs. On-site crews completed the system by tying together the 5-foot gap between racks.

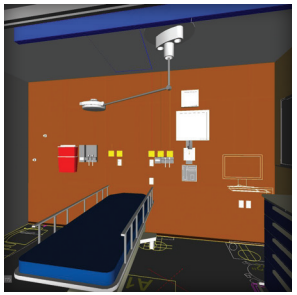
Multi-trade rack prefabrication was advantageous for the project, substantially due to the reduced congestion and diverted labor hours from the well-traveled main corridors.

PATIENT ROOM HEADWALL RESULTS

Prefabrication vs. Site-Built Construction

Direct Cost	7.6% Premium
Overall Required Labor	1,300 Fewer Hours
Diverted Labor Off-Site	16,000 Hours
Reduced Safety Incidents	1 Incident
Productivity Enhancement Savings On- and Off-Site	Minimum $250,000

0.93 BENEFIT-TO-COST RATIO



PATIENT ROOM HEADWALLS

To take advantage of the repetitive nature of patient room headwalls, 376 units were built off-site for the project. This effort took place at the same 60,000-square-foot warehouse as the multi-trade racks. A total of 15 stations were established, allowing construction of two headwalls per station and 30 total headwalls at a given time. The sequencing established by the project team allowed each headwall to be completed to 100% in the warehouse, including tested utilities, casework and faceplates. ISEC, the casework subcontractor, transported, hoisted and set each unit on-site. Follow-on trades tied in utilities to complete the system and casework; drywall and ceiling grid completed the sequence.

Although significant cost or schedule savings were not achieved, the quality of work was exceptional. Though somewhat difficult to quantify, this reduction in risk gave the project team greater confidence in their product much earlier in the project timeline.

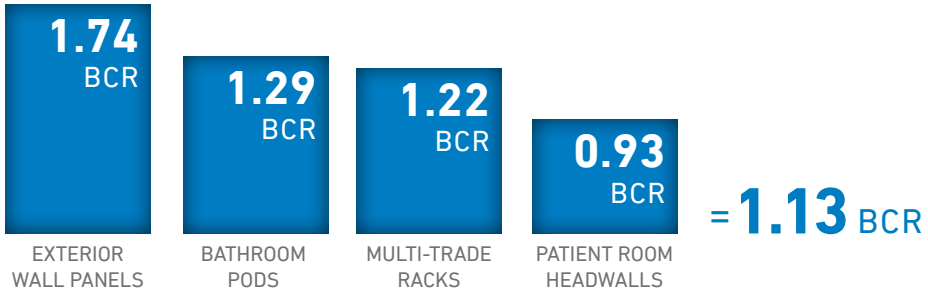
The positive result of prefabricating patient room headwalls is not visible in cost or schedule savings; rather, it was favorable for increasing quality and reducing overall congestion on the jobsite during a busy time of the project.

STUDY RESULTS

The use of prefabrication was, without a doubt, a major contributor to the success of the Exempla Saint Joseph Heritage Project and significantly reduced the typical risk of a highly technical, aggressively scheduled hospital project.

BENEFIT-TO-COST RATIO

Based on value-based cost-benefit analyses performed on the most significant performance drivers for prefabrication (schedule, cost and safety), the benefit-to-cost ratio of the project was 1.13. Approximately 13% of every dollar spent on prefabrication was expected to be returned as a quantifiable benefit to the project.



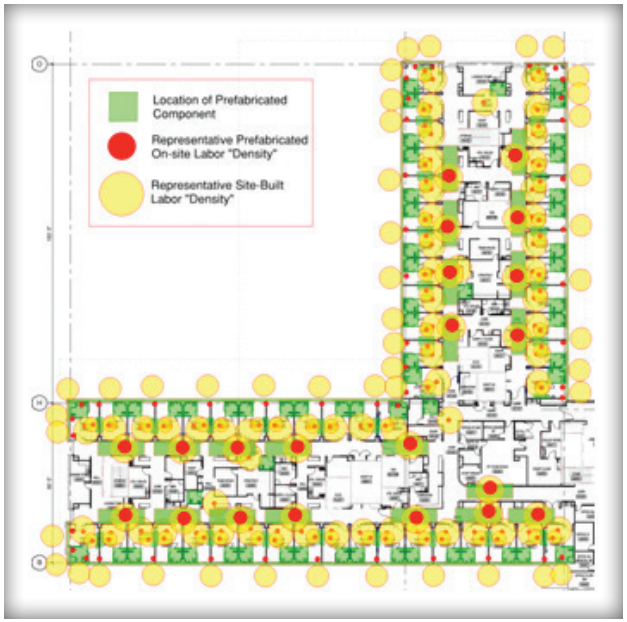
ADDITIONAL BENEFITS

In addition to the significant quantifiable results shown above, the use of prefabrication substantially decreased on-site congestion. Although difficult to put a number on this, it was immediately evident that hallways were less crowded, there were fewer lifts on the exterior and interior of the building and significantly less material, noise and dust. The use of prefabrication made the project safer and more predictable. Based on these reasons, the craft workers were excited to work in both

TOTAL STUDY RESULTS

Prefabrication vs. Site-Built Construction

Schedule Reduction	72 Work Days
Indirect Cost Savings	$4.3 Million
Direct Cost	6.0 % Premium
Overall Required Labor	29,500 Fewer Hours
Diverted Labor Off-Site	150,500 Hours
Reduced Safety Incidents	7 Incidents
Productivity Enhancement Savings On- and Off-Site	$2.6 Million
Benefit-to-Cost Ratio	**1.13**



This graphic represents a wing of the hospital and the associated on-site labor force with both traditional construction approaches (yellow) and prefabrication (red).

BUSINESS DRIVERS & LEARNINGS

Prefabrication provided substantial gains in reducing the project schedule, reducing on-site labor density and reducing safety incidents. However, it was clear that direct cost savings were not achieved given the current prefabrication approach. In fact, direct costs were elevated in order to realize the aforementioned benefits. This fact must be taken into consideration for future projects.

The four most significant benefits achieved on the project as a result of the prefabrication process include schedule, on-site labor density, safety and manpower.

SCHEDULE

Prefabrication allows multiple activities to be performed concurrently, where the same activities were previously required to have start-to-finish relationships on-site. The just-in-time delivery and rapid installation of prefabricated assemblies translates into substantial schedule gains. Additionally, subcontractors and suppliers can predict and commit to their costs earlier and with more assurance. The result is increased schedule and cost certainty, reducing exposure to overruns. It is now possible to commit to a historically aggressive schedule and budget with more confidence. Benefits that customers achieve from a project completed earlier include: reduced financing costs, reduced construction costs in the form of general conditions and earlier revenue streams.

ON-SITE LABOR DENSITY

Overall labor hours are not significantly reduced through prefabrication; however, a significant number of those hours are diverted off-site. The resultant reduction in on-site labor substantially decreases labor congestion, enabling increased productivity, increased flexibility, improved housekeeping and an overall safer environment for our craft. Had assemblies been built on-site, trade stacking, overtime and a congested worksite would have resulted in an established 30% minimum reduction in productivity.

BUSINESS DRIVERS & LEARNINGS

SAFETY

Significantly fewer safety-related incidents are encountered in a warehouse environment due to reduced congestion, better ergonomic positions, environmentally controlled spaces and reduced schedule demands. Recordable injury rates plummet in a warehouse compared to the construction site, and every labor hour diverted to the warehouse reduces the probability of a safety-related incident.

MANPOWER

Labor efficiencies are created based on the predictability of scheduling, allowing for consistent manpower planning, rather than peaks and valleys typically experienced during large projects. Though not quantified for this study, the efficiencies gained are expected to lower hiring expenses and reduce the project's training burden.

THANK YOU

We sincerely thank our customer, Exempla Saint Joseph Hospital, for instilling trust in Mortenson to deliver this extraordinary project. The project design team was instrumental in the success of the prefabrication effort. Our subcontractor and supplier partners believed in the benefits of prefabrication and executed the plan on- and off-site.

We would specifically like to thank the following participants who provided necessary data to quantify our results:

Colorado Doorways
Floorz
ISEC
Oldcastle – Eggrock
South Valley Drywall
U.S. Engineering
Encore Electric
Four Star Drywall
Marino Tile
Phase 2 Drywall
Specialties Contracting

Mortenson is committed to working closely with our customers and partners to continue to utilize and improve prefabrication on future projects. We are continually examining our processes with an eye to reducing waste, improving efficiencies and reaching for new and innovative solutions to successfully deliver all of our projects.

We welcome the opportunity to share more with you about Mortenson's prefabrication expertise and other unique capabilities to provide world-class quality, innovation and service to our customers.

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From local healthcare and education facilities, cutting-edge stadiums and state-of-the-art, LEED-certified mission critical projects to some of the most innovative renewable energy projects on the planet, Mortenson is building structures and facilities for the advancement of modern society®.

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