OFFSITE ARCHITECTURE

CONSTRUCTING THE FUTURE

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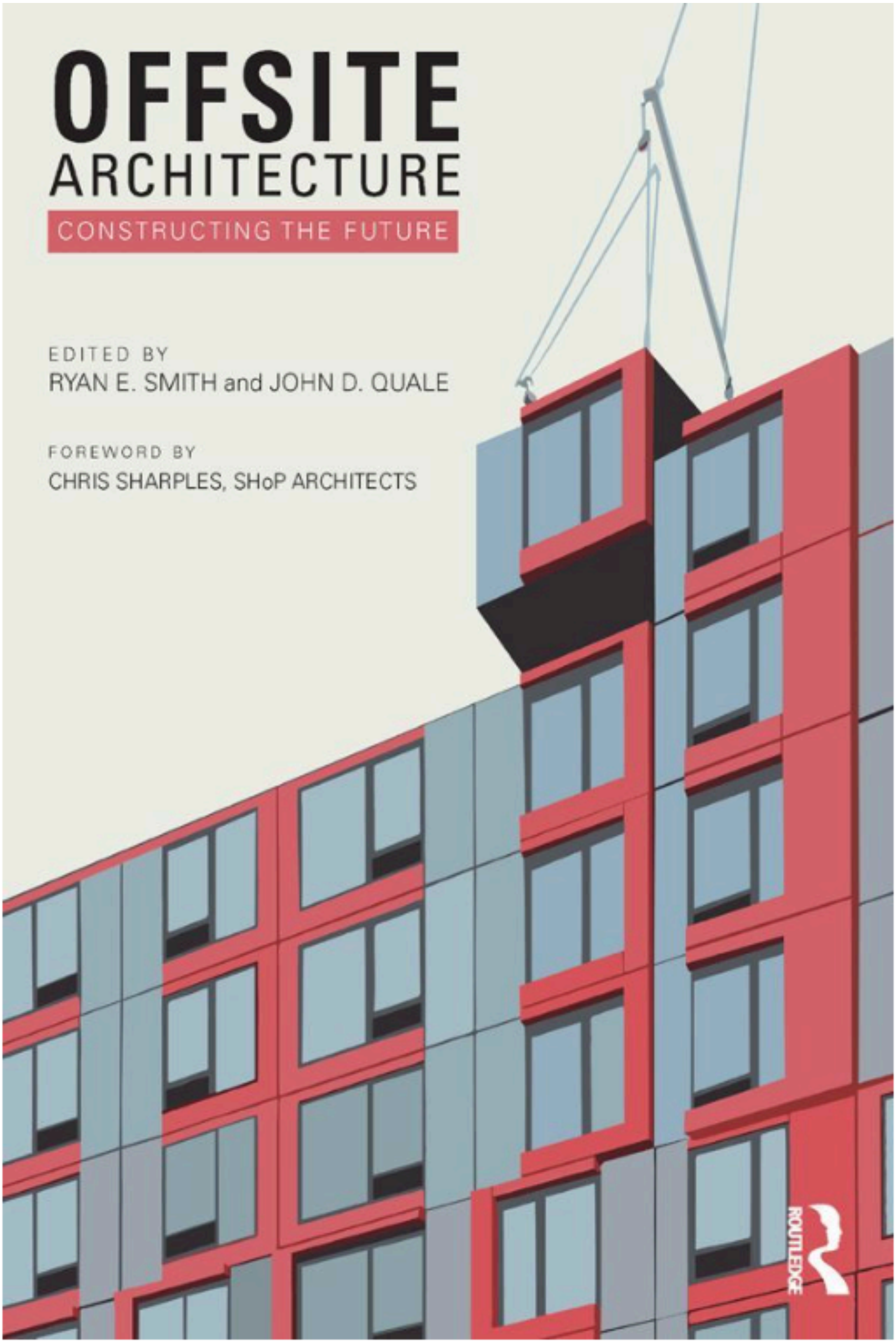

ROUTLEDGE

Conclusions and next steps

These three surveys are positive first steps to gathering data and substantiating the claims of the offsite industry. Cost and schedule savings are among many factors that have a significant impact on the adoption of offsite construction practices for a construction project. While these reports do support some of the industry's claims, there is further work to be conducted to unravel the nuances of offsite construction. For example, in the McGraw-Hill Construction report, 65 percent of respondents found a decrease in project budget and 66 percent of respondents found a decrease in project schedule. However, there were some respondents who found an increase to both parameters (6 percent in project schedule and 8 percent in project budget). It is unclear what portions of the supply chain are contributing to this increase or decrease in cost and schedule. More in-depth analysis of construction performance is needed to clarify the added value of offsite construction given project-specific context and parameters. The Integrated Technology in Architecture Center at the University of Utah conducted one such study, which begins to unfold the subtle nuances in practicing these offsite techniques through case study evaluation (see Chapter 7 in this volume).

Notes

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Chapter 7

Permanent modular construction

Construction performance

Ryan E. Smith and Talbot Rice

Introduction

Permanent modular construction (PMC) has been marketed as a more cost-effective, higher-quality, and faster-to-market solution than traditional stick-built construction (MBI). The added value of PMC, although conceptually strong, has yet to be significantly substantiated. This research aims to provide data to fill this void. The study quantifies the added value of PMC and evaluates the contextual factors by which PMC in building design and construction may be realized in North America and beyond. The research leverages 17 case studies, listed in Table 7.1, and compares a portion of them to traditional site-built benchmark projects for performance parameters including cost and schedule. The data was collected through literature review, questionnaire, and interviews. In addition, qualitative data was collected to determine the project-contextual parameters that exist to realize success in PMC delivery. Finally, a return-on-investment study is included to demonstrate some of the lifecycle benefits of PMC.

Methods

The case study method

This study utilizes the case study method for investigation. This method is a common strategy in the study of humanities, law, and business (Yin, 2014). More recently, built environment research has used the case study method, by which completed project data is collected and analyzed for generalizable results (Groat & Wang, 2013). The case study project pool was established in consultation with the Modular Building Institute Education Foundation and Canadian Foundation and the National Institute of Building Sciences Off-Site Construction Council. The selection of 17 cases documented was based on:

- access to available archival data and willingness of the stakeholders to participate and offer additional data;
- diversity of project sizes, locations, and building types, in order to evaluate PMC across sectors, countries, and cultures; and

Table 7.1
Case study projects and their geographic locations

PROJECT	LOCATION
Xstrata Nickel Rim South	Greater Sudbury, ON, Canada
High Tech High	Chula Vista, CA, USA
SOMA Studios	San Francisco, CA, USA
STEM School	Redmond, WA, USA
Nicholson Village	Melbourne, Australia
Old Redford Academy	Detroit, MI, USA
MEG Pirate's Cove Lodge	Conklin, AB, Canada
CitizenM Bankside	London, England
Mercy Hospital	Joplin, MO, USA
Starbucks	Marysville, WA, USA
Victoria Hall	Wolverhampton, UK
Whistler Athletes Lodge	Whistler, BC, Canada
Inwood Apartments (The Stack)	New York City, NY, USA
Manresa Student Housing	Manresa, Spain
Wells Fargo	Phoenix, AZ, USA
Kirkham Child Care Center	San Francisco, CA, USA
The Modules	Philadelphia, PA, USA

- architectural significance, in order to demonstrate PMC performance with respect to buildings that have a greater opportunity for continued cultural investment.

A ranking system considering these three factors was devised and provided a rudimentary process for determining the final list. Data was gathered from the architect, general contractor/construction manager, and modular manufacturer/supplier for the respective projects. For projects where there was not a response from all three parties, at least two were consulted. A questionnaire was developed and peer-review-edited to identify the quantitative data including cost and schedule. This was disseminated online and through PDF response form. Reponses were limited and therefore follow-up interviews were conducted to gather additional and clarifying metric data as well as qualitative information. Limited forthcoming data led to exclusion of some cases in portions of the study. In total, there are ten cases among the 17 that have substantial cost and schedule information. Of these ten cases, seven of them could be compared in schedule and eight could be compared in cost to traditional stick-built construction benchmark projects.

The comparative method

The data from the PMC projects was compared to benchmark projects developed by Cumming Corporation, a cost consultancy firm. Key parameters in developing these benchmark comparisons included the following:

- Data for both the PMC cases and traditional benchmark comparison cases was normalized to first quarter 2014 in US dollars and Washington DC as the building location.

- Units of cost were calculated in $/SF and it was assumed that all of the benchmark projects use a design–bid–build delivery system. When possible, estimates for the comparisons were based on actual items of work. When data was not available, precedent values from other projects were interpolated for these comparative projects.
- Unit costs were based on current bid prices in Washington DC and subcontractor overhead and mark-ups were included. General contractor overhead and profit were excluded.
- The values determined were based on the probability of cost of construction at the programmatic design stage.

For estimating the values to construct the benchmarks, the following sources were referenced: *US Department of Labor Prevailing Wage Resource Book* (US Department of Labor, 2014), *Building Construction Costs with RSMeans Data* (Gordian, 2014), and *Cumming Corporation Internal Economic and Market Report* (Gray, 2014). The items not covered in this comparison included: hazardous material abatement, utility infrastructure improvements, design/consulting fees, building permits, testing and inspection fees, and land acquisition costs.

Comparisons were developed into case study cut sheets, each serving as a stand-alone example of PMC versus traditional building benchmark counterparts. Three examples of case study cut sheets are included in the Appendix.

Limitations

The study has several limitations. The first limitation is the fact that there are few PMC cases to date that have been built relative to traditional construction. The ability to quantify a trend or make a statistical argument is difficult without more cases. Furthermore, the amount of information that was provided for particular projects by stakeholders was also limited. More often than not, participants did not share information such as cost and labor hours. With the small amount of information on the already minimal amount of case studies, it is challenging to report statistically significant results. Regardless, these cases provide timely evidence of project-specific performance.

Results

Quantitative analysis

Cost

It has been claimed that the cost of PMC is less expensive than traditional methods of construction. Further analysis in these cases demonstrates that the cost is not necessarily always lower. In fact, the cost is sometimes at a premium. Overall, the study suggests that PMC projects are on average 16 percent lower in vertical construction cost compared to conventional methods of construction (Figure 7.1).

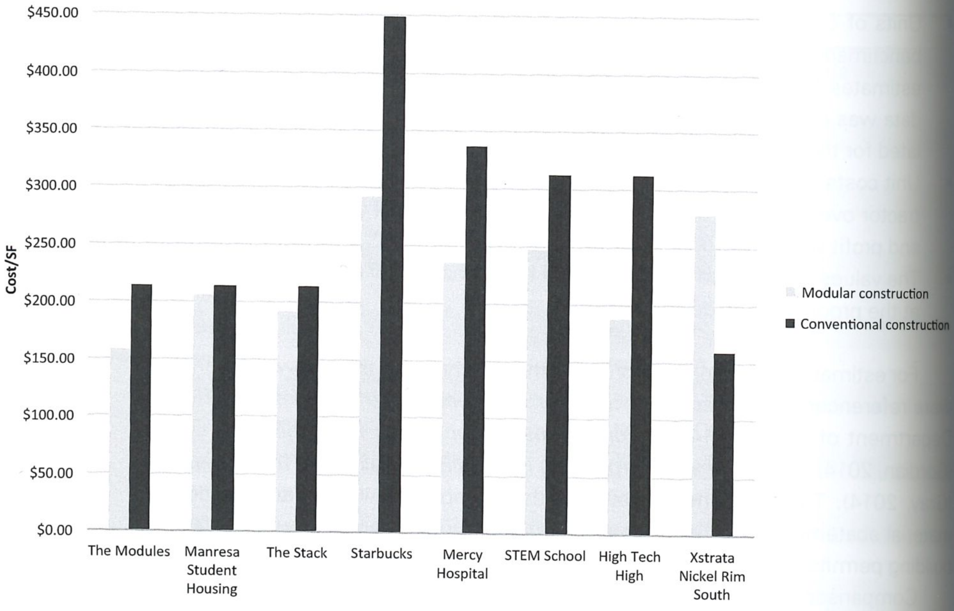


Figure 7.1
Cost of PMC vertical construction compared to benchmark projects

It is important to note that most stakeholders reported PMC offers a greater control of cost compared to traditional build. This is attributed to the inherent ability to reduce the number of change orders in any given PMC project. In a recent study conducted in Montgomery County, Maryland, the Office of Legislative Oversight (2014) studied 17 county government projects that reached substantial completion between 2009 and 2013. The study found an 8 percent overall increase in contract costs due to change orders. Respondents concluded that the reason why modular construction is cost controlled is because the design must be nearly complete before modular production, driving the number of change orders down.

When the cost was at a premium, respondents listed the following reasons:

- additional materials required for structure and transport;
- transportation costs for large load permits and lead cars;
- time lost due to permitting;
- time lost due to transportation over long distances.

Schedule

The validity of the industry's claim that schedule reduction is a clear advantage of PMC has been demonstrated by precedent research (Smith, 2011). Across the case studies documented, the schedule was reduced by an average of 45 percent (Figure 7.2). Respondents indicated that this is due to the fact that a PMC project is built in a factory and site work is conducted concurrently. This reduces the lag time compared to traditional methods of construction, according to which onsite built work must be carried out sequentially. The time saved with PMC is also an opportunity for additional cost savings.

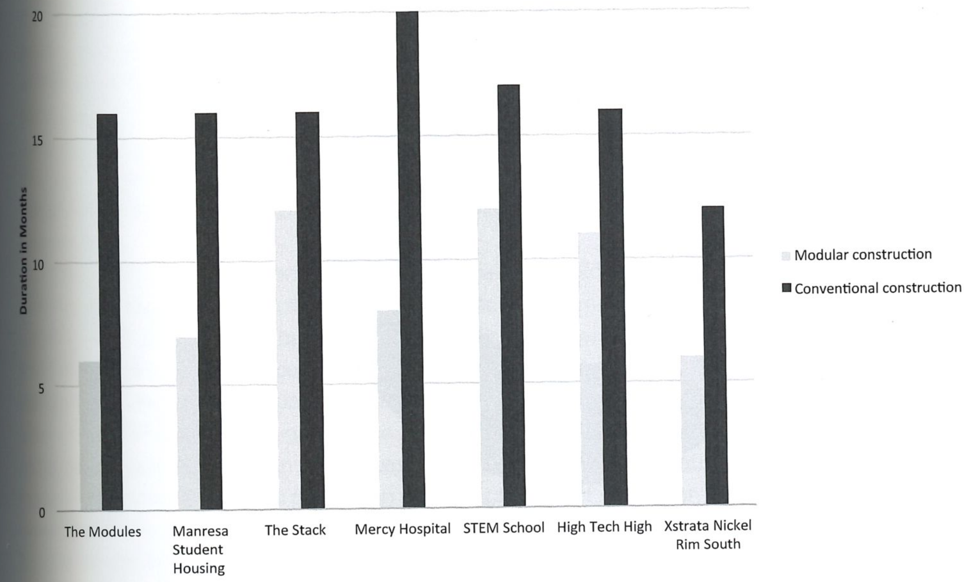


Figure 7.2
Schedule comparison between PMC projects and benchmark projects

Qualitative analysis

Project stakeholders were asked for qualitative information about a range of issues to get a better understanding of how PMC performs against conventional construction methods. This information is intended to give some understanding of how PMC can be improved.

Drivers

Generally, there is a struggle to turn over construction projects on time and on budget. Based on the case studies, these survey results show that the use of PMC can mitigate cost and schedule challenges. When stakeholders were asked to name the drivers behind their use of PMC rather than conventional construction, the most common response was a motivation to reduce the construction schedule. LeRoy Stevens from Stevens Architects explained why he prefers PMC: "there is an ability to control the hard cost and schedule using PMC." All of the case studies included in this report not only met their construction deadlines but reduced the average construction schedule by an average of 45 percent when compared to traditional construction.

Software

The primary software used by all of the manufacturers, architects, and contractors are 2D drawing programs such as Autodesk AutoCAD. Remarkably, few are using BIM platforms, despite the construction culture software trend.

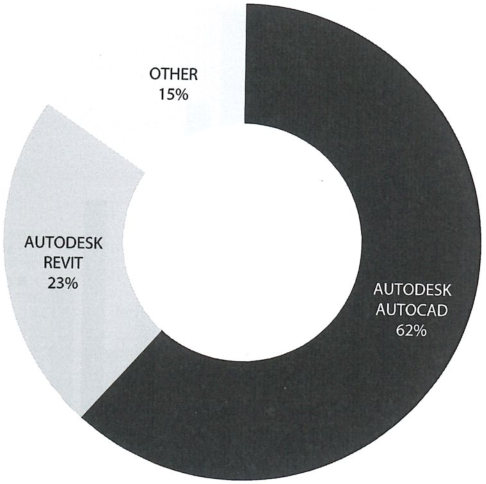


Figure 7.3
Software used in PMC delivery

Regulatory challenges

Of the six cases that acknowledged the issue of regulatory challenges, three noted that permitting and code issues delayed the project. Permitting and code officials are not familiar with or accustomed to this type of construction so it is imperative to start acquiring approvals and building/transportation permits early. An example of this is the Mercy Hospital in Joplin, Missouri. Because the factory was located in California, 1,500 miles and six states away, this project experienced ongoing transportation problems: "The transportation from California to Missouri was a huge hindrance to the schedule and oftentimes transportation was halted to acquire more permits" (McCarthy Building Company). Further study is needed to determine how a closer factory would impact the transportation and permit costs relative to an even faster construction schedule.

Benefits

The most significant benefit of PMC is its ability to be completed with reduction in schedule. Every survey respondent named meeting the substantial completion deadline as a success. The use of PMC, according to these case study interviews, does not entail a loss of quality compared to conventional construction. All interviewees were impressed with the substantial quality of the PMC buildings.

Early collaboration

The survey asked respondents if the utilization of PMC required earlier collaboration between project stakeholders. Only one respondent indicated that there was no need for earlier collaboration. All other responses indicated that earlier and greater levels of collaboration were necessary. There is a critical point in

the project schedule where all major trades need to be well versed in the project's needs and possible mishaps. This point is far before construction begins, as the modules must be completely designed before construction starts. Such an early critical point calls for major trades to either be involved as consultants very early, or under contract from the beginning. While it is still possible to achieve this level of collaboration with a design–bid–build contract, it is very difficult and not as inherently collaborative as its design–build or integrated project delivery counterparts.

The infancy of PMC compared to traditional site building makes for many prototype projects, in which the architect, contractor, and manufacturer are experiencing their first modular build. Because of this, it is likely that the number of PMC buildings will grow exponentially in the coming years. Thorough knowledge transfer between manufacturers, contractors, and architects is crucial to the success of each of these buildings; and the failure of such knowledge transfer seems to be the largest hindrance in the success of PMC. The fast-paced nature of PMC leaves little room for error in permitting and design, both of which can lead to the downfall of the project through change orders. These items must be finalized before construction begins; therefore, the need for all key trades to be involved at the beginning of the project is critical.

It is suggested, based on these case studies, that more collaboration at the beginning of the project would be easier if there was a project delivery method in place that is more conducive to this level of collaboration, such as design–build or integrated project delivery.

Return on investment

Using PMC, the cases in this study reduced their construction time by an average of 45 percent. To put this reduction of time in terms of cost benefit, a return on investment (ROI) method was developed to account for time savings. The ROI leveraged three discrete building type pro-formas from different developers: retail, office, and charter school buildings respectively. The developer data was assessed using a schedule improvement of 25 percent and 50 percent reduction from the actual schedule. This evaluation did not include the financial benefit of early return on operational business such as sales, or social/environmental impacts. The benefits included initial cost savings on general conditions and early lease rate income associated with schedule reductions.

The pro-formas included four sections:

1. the analysis of the schedule based on 0 percent improvement, 25 percent reduction, and 50 percent reduction;
2. the cost of construction;
3. the cost of the construction loan; and
4. the generated income.

Market rate numbers for the ROI were taken from the Newmark Grubb ACRES *2014 Year End Utah/Mountain West Market Report*. The rental income numbers were based on the assumption that the building will be 100 percent occupied, reflecting the greatest possible opportunity for income. The pro-formas show two areas where there is an opportunity for cost savings using PMC. These areas include the cost of the construction loan and the money generated during the time saved.

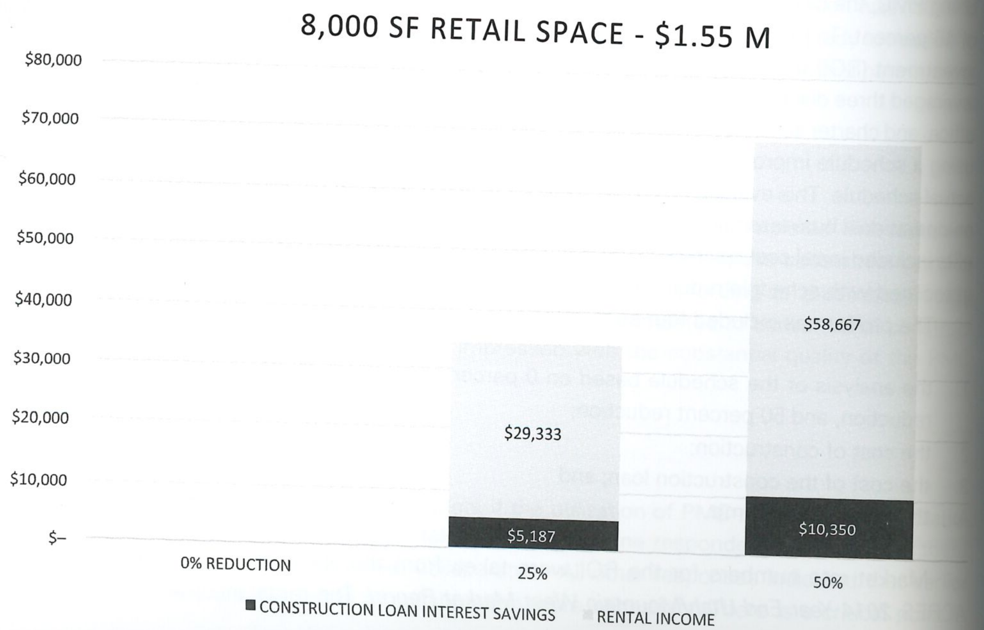
Retail space

- The retail space at 25 percent schedule reduction shows $5,187 in saved construction loan interest and $29,333 generated in rental income for an effective gross income of $34,520.
- At 50 percent schedule reduction, $10,350 was saved in construction loan interest and $58,666 generated in rental income, giving an effective gross income of $69,017 (Figure 7.4).

Office space

- The office space shows construction loan interest savings of $52,214 and a generated rental income of $292,333 for an effective gross income of $345,547 at 25 percent schedule reduction.
- At 50 percent schedule reduction, $78,147 was saved in construction loan interest and generated rental income was $440,000, giving an effective gross income is $518,147 (Figure 7.5).

Figure 7.4
ROI for an 8,000 SF retail space



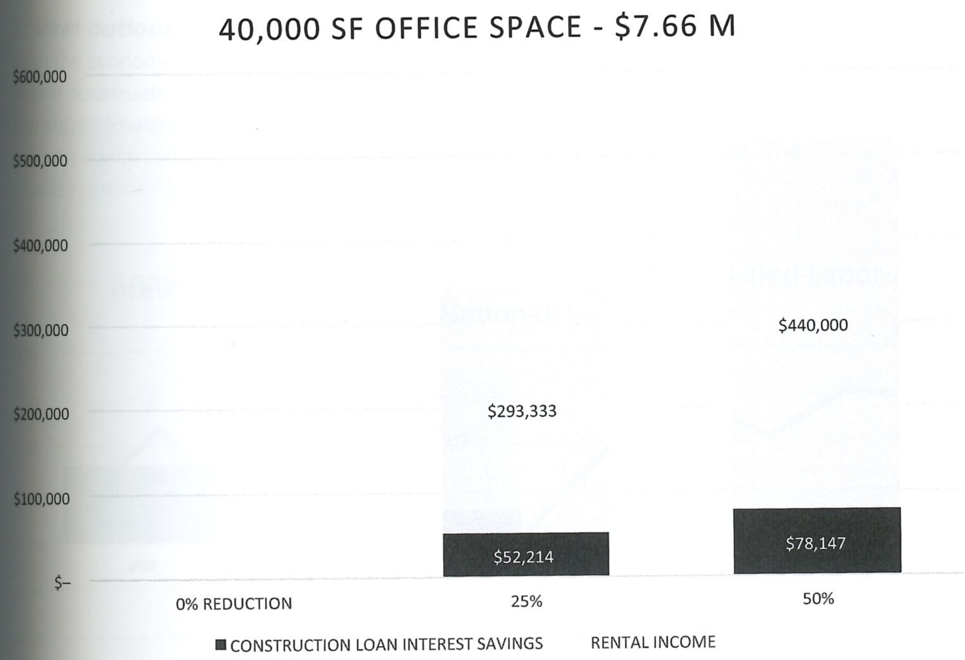


Figure 7.5
ROI for a 40,000 SF office space

Charter school

- $29,822 was saved in construction loan interest with a 25 percent schedule reduction. $134,030 was generated in rental income for an effective gross income of $163,852.
- There was a construction loan interest saving of $74,245 with a 50 percent schedule reduction. Adding rental income of $335,074 gave an effective gross income of $409,319 (Figure 7.6).

The average cost saving for a 25 percent schedule reduction across the three pro-formas is $5.81/SF in total construction cost. The average cost saving for a 50 percent schedule reduction across the three pro-formas is $10.93/SF in total construction cost.

Conclusion

Summary of results

The results from these case studies and the comparative analysis of traditional stick-built projects demonstrate that PMC offers the following quantitative benefits (Table 7.2), qualitative benefits (Table 7.3), and return on investment (Table 7.4).

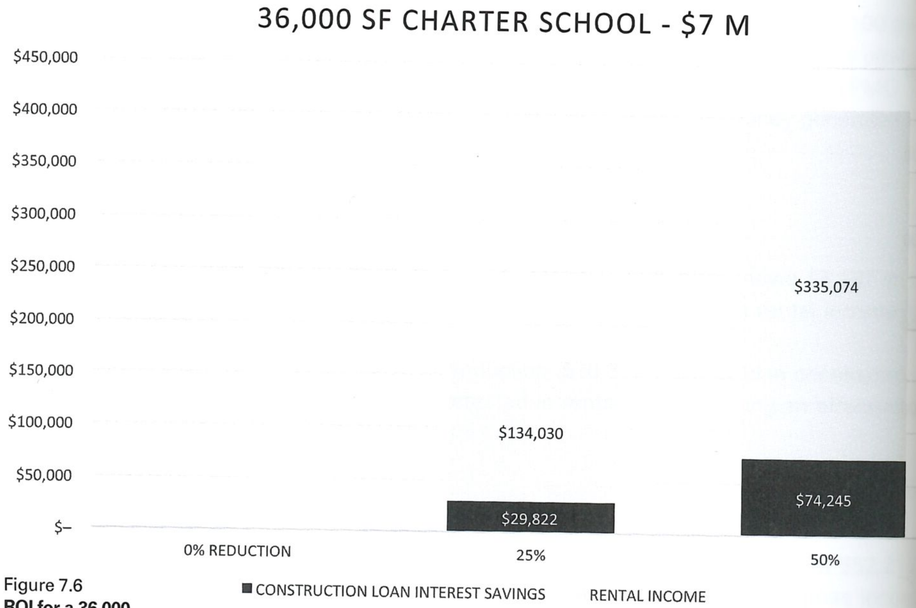


Figure 7.6
ROI for a 36,000 SF charter school

Table 7.2
Quantitative results of cost and schedule

Cost	16% savings
Schedule	45% savings

Table 7.3
Qualitative results of the comparative study

Drivers	Cost control and schedule reduction
Software	AutoCAD: 62% Revit: 23% Other: 15%
Challenges	Permitting and transportation schedule overruns
Lessons learned	Early engagement of modular builder, design–build contract, design-phase modular research

Table 7.4
Developer ROI results at 25% and 50% schedule reduction

25% schedule reduction	$5.81/SF average
50% schedule reduction	$10.93/SF average

Market outlook

After the economic downturn of 2008, the demand for construction and the supply of that construction followed suit. Construction demand is high again, yet supply has stayed low and cannot meet demand (Figure 7.7). This presents a gap where modular construction can take advantage due to its lower labor requirements. The time is right for PMC.

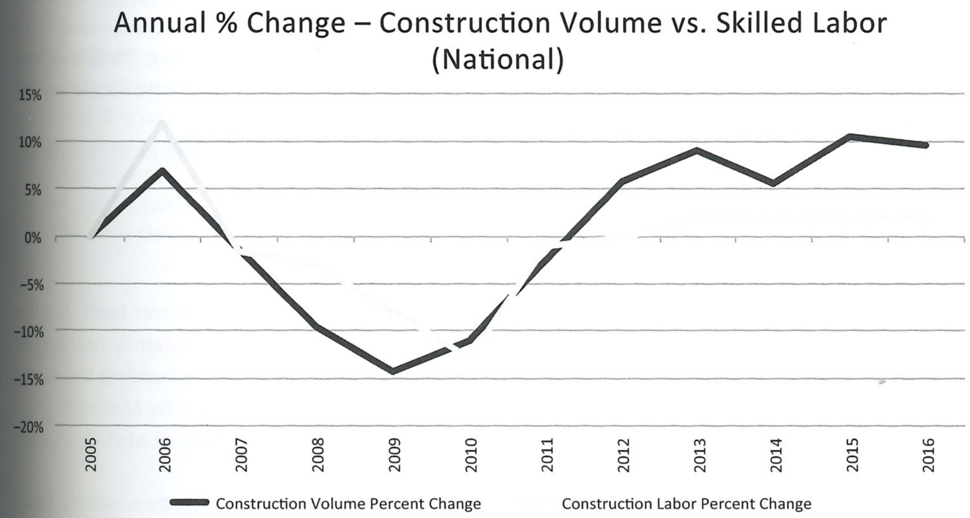


Figure 7.7
US construction volume versus skilled labor – gap potentially to be filled by modular construction (Credit: Cumming Corporation)

Next steps

This study is limited by the sample size, the scope of company participation, and the challenge of locating appropriate traditional construction comparisons. However, the research findings suggest helpful metrics to be developed by researchers in the future to demonstrate the value of PMC beyond initial reductions to cost and schedule. Although effective as a baseline report, construction performance metrics of cost and schedule do not take into consideration the full lifecycle benefits of offsite modular. This section discusses next steps in this research to demonstrate the performance of PMC.

The study took PMC projects and gathered quantitative data for each case through literature sources and questionnaires compiled by project stakeholders. This was followed by qualitative interviews with architects, contractors, and modular manufacturers. The data collected was compared to benchmark case studies by Cumming Corporation, a cost estimation consultant. The benchmark projects were traditional site-built projects completed in the last ten years. Although cost data was normalized so the location factor was similar, it was challenging to find projects that were comparable enough to PMC cases to draw feasible conclusions that demonstrate the performance of PMC.

Identifying a traditional site-built project of similar size in overall square footage, height, and number of stories, and with similar specification is difficult. Peer review of this study suggests that future research should use two comparative methods to determine performance.

Method A

1. Locate a built project whose type is appropriate for PMC. This may include multi-family housing, student dormitory, education, retail, or other.
2. Procure the building's as-built drawings and specifications from the project stakeholder team and their permission to evaluate the project.
3. Obtain three separate bids and construction schedules from PMC builders and partnering general contractors for the project in the same locale as the site-built work, including all vertical construction costs.
4. Compare the actual traditional site-built project to the bid project data for construction performance.

Method B

1. Locate two similar buildings that are going to be built in the near term. Ensure that the buildings are appropriate for PMC, including multi-family housing or office complex, or a corporate retailer or hotel chain that is building the same brand in two different cities (e.g. Starbucks or Fairfield Inn by Marriott).
2. Convince the building owners to build one using traditional stick-built construction and the other using PMC.
3. Document the construction performance data of cost, schedule, safety, labor hours, change orders, defects, and incidents of injury.
4. Interview the project stakeholders including owners, architects, and contractors on each project to gather qualitative data.
5. Compare the site-built project to the PMC project across the construction performance parameters and determine what contextual qualitative factors from the interviews lead to successful PMC delivery.

Acknowledgments

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Appendix

Appendix A

MANRESA STUDENT HOUSING
MANRESA, SPAIN

Architect: Xavier Tragant
Modular Builder: Compact Habit
Contractor: Constructora d'Aro

ABOUT

High quality is an inherent attribute of offsite construction. Manresa Student Housing boasts this trait while showing a schedule reduction of 56 percent and a slightly lower cost. PMC was chosen by the investor to meet a hard deadline.

GENERAL

HOUSING BUILDING TYPE

2008 YEAR COMPLETED

44,239 SQUARE FEET

75 CONCRETE MODULES

5 STORIES TALL

COST

€3.64M CAPITAL COST

€231.5K DESIGN COST

€2.34M MODULAR CONTRACT

SCHEDULE

10 MONTHS FROM START TO FINISH

7 MONTHS UNDER CONSTRUCTION

3 MONTHS FOR DESIGN

3 MONTHS IN FACTORY

10 DAYS TO ERECT

$204.91 PER SF

4% MORE COST-EFFECTIVE

56% FASTER CONSTRUCTION

LESSONS LEARNED

This building was largely a success because of the collaboration of all team members involved. It is an example of how a collaborative team can bring a complex project such as this to a more cost-effective and schedule-saving conclusion.

REFERENCES

Compact Habit.

Images: Compact Habit

	MANRESA STUDENT HOUSING	COMPARED PROJECT
CONSTRUCTION DURATION	7 MONTHS	16 MONTHS
STORIES AND CONSTRUCTION TYPE	5 STORIES CONCRETE	4 STORIES WOOD
SQUARE FOOTAGE	44,239	55,000
COST	$9M	$11.7M
COST/SF	$204.91	$213.33

Appendix B

THE MODULES
PHILADELPHIA, PA, USA

Architect: IS-Architects
Modular Builder: Build IDBS/Excel Homes
Contractor: Equinox Management and Construction

ABOUT
The Modules project is a great example of how PMC can be used to mitigate the costs of labor unions. This building was conceived and built during the recession in 2010. Aside from minor permitting problems and manufacturer difficulties, the project was a great success as it was constructed in only six months.

GENERAL

HOUSING BUILDING TYPE

2010 YEAR COMPLETED

80,000 SQUARE FEET

89 WOOD MODULES

5 STORIES TALL

COST

$12.7M CONSTRUCTION COST

$300K DESIGN COST

$3.6M MODULAR CONTRACT

SCHEDULE

14 MONTHS FROM START TO FINISH

6 MONTHS UNDER CONSTRUCTION

9 MONTHS FOR DESIGN

2 MONTHS IN FACTORY

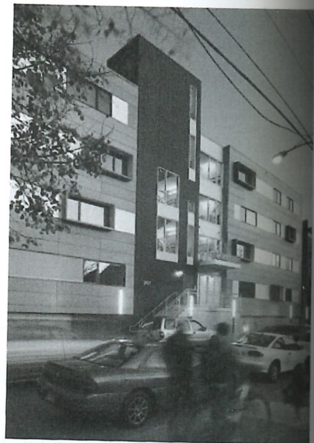
12 DAYS TO ERECT

$158.23 PER SF

25.8% MORE COST-EFFECTIVE

135 MILES FROM FACTORY TO SITE

63% FASTER CONSTRUCTION



LESSONS LEARNED

PMC served this building well as it was a large factor in the success of the project. A few things could have made the project run faster with fewer setbacks. First, up-front collaboration between the contractor, architect, and modular manufacturer would have avoided the issues of onsite stitching and vapor barrier installation. The up-front collaboration also provides all parties with thorough knowledge of designing and building with modular. Second, to avoid permitting problems, it is vital to decide on the use of PMC early. The nascent nature of PMC gives rise to the importance of starting the permitting and code approval process early. Third, the project team should work with code officials early in the design process. Finally, improvements need to be made to ensure factory-based operations and site operations are clearly coordinated and knowledge is communicated between stakeholders.

Images: is-architects.com/the-modules

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Wagner, Troy. IDBS

	THE MODULES	COMPARED PROJECT
CONSTRUCTION DURATION	6 MONTHS	16 MONTHS
STORIES AND CONSTRUCTION TYPE	5 STORIES WOOD	4 STORIES WOOD
SQUARE FOOTAGE	80,000	55,000
COST	$12.7M	$11.7M
COST/SF	$158.23	$213.33

Appendix C

THE STACK
NEW YORK, NY, USA

Architect: Gluck+
Mod Manufacture: Deluxe Building Systems
Contractor: Gluck+

ABOUT

In a highly dense urban environment such as New York, it is key to construct a building as fast as possible so that the negative impacts on the surrounding community are at a minimum. Building with modular provided such circumstances for The Stack.

GENERAL

HOUSING BUILDING TYPE

2013 YEAR COMPLETED · 38,000 SQUARE FEET · 8 STORIES TALL

COST

$5.4M MODULAR CONTRACT · $7.3M CONSTRUCTION COST

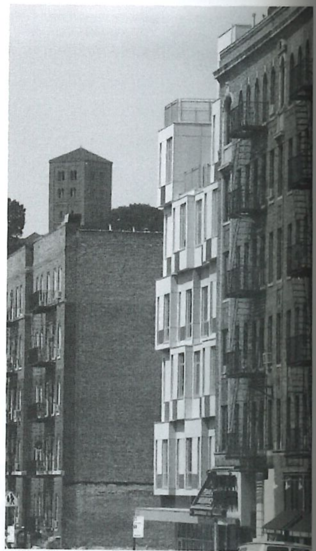
SCHEDULE

20 MONTHS FROM START TO FINISH · 12 MONTHS UNDER CONSTRUCTION

4 MONTHS IN FACTORY · 19 DAYS TO ERECT

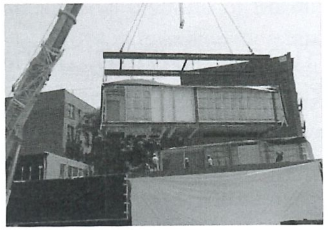
$191.84 PER SF · 10% MORE COST-EFFECTIVE

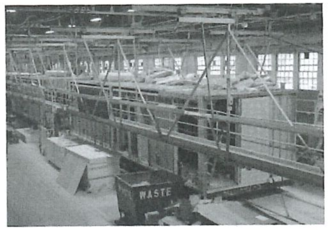
125 MILES FROM FACTORY TO SITE · 25% FASTER CONSTRUCTION



LESSONS LEARNED

The difficulty in constructing a building with such an accelerated schedule is the collaboration between trades for permits and deadlines. In this building's case, a simple fault in insurance renewal led to a delay in schedule. In the future, there will be more involvement in the drawing, fabrication, and stitching processes. Further, ignoring small details can delay the schedule greatly. Finally, there is a need for thorough communication of information between stakeholders, from fabrication to onsite stitching.





Images: Gluck+ and Amy Barkow

REFERENCES

Gluck, Thomas. Gluck+. Interview with Talbot Rice on 5.27.14

Erb, John. Deluxe Building Systems.

	THE STACK	COMPARED PROJECT
CONSTRUCTION DURATION	12 MONTHS	16 MONTHS
STORIES AND CONSTRUCTION TYPE	8 STORIES STEEL/CONC	4 STORIES WOOD
SQUARE FOOTAGE	38,000	55,000
COST	$7.3M	$11.7M
COST/SF	$191.84	$213.33