OFF-SITE STUDIES

PERMANENT MODULAR CONSTRUCTION

PROCESS
PRACTICE
PERFORMANCE

National Institute of BUILDING SCIENCES

MODULAR BUILDING INSTITUTE

ITAC
INTEGRATED TECHNOLOGY IN ARCHITECTURE CENTER
UNIVERSITY OF UTAH COLLEGE OF ARCHITECTURE + PLANNING

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CONTENTS

EXECUTIVE SUMMARY

ABSTRACT

This research studies off-site modular production processes using case studies in international permanent modular construction (PMC). The PMC projects documented herein provide a research test bed to evaluate the performance metrics attributed to off-site construction and the contingent qualitative contextual factors by which PMC in building design and construction may be realized. The study therefore:

1. Evaluates the construction performance of PMC including –

    a. Researching and documenting PMC projects to identify successful performance metric parameters: economics, schedule, scope, quality, risk & worker safety;

    b. Comparing this data to traditional site built construction to determine the estimated added value or negative impact of PMC;

    c. Identifying the qualitative contextual parameters for successful PMC deployment;

2. Reports on an industry survey that identifies the construction industry view on the benefits and barriers to PMC;

3. Runs a return on investment assessment of three discrete developer pro-formas to determine the impact of reduced schedule on initial cost; and

4. Synthesizes holistic best processes and practices guide for firms in the construction industry looking to engage in off-site work and suggests future research.

KEY FINDINGS

Quantitative Analysis

Cost	• 16% Savings
Schedule	• 45% Savings
Quality	• 5.4 Average Change Orders
Safety	• 0.25 Average Safety Incidents

Qualitative Analysis

Why Chosen	• Cost control • Schedule Reduction
Software	• AutoCAD: 62% • Revit: 23% • Other: 15%
Challenges	• Permitting schedule overruns • Transportation schedule overruns
Lessons Learned	• Early engagement of modular builder • Design-build contract • Design phase modular research
Successes	• Schedule advantage • Quality

Survey Analysis

Benefits	• Schedule reduction during construction phase • Quality of product • Site Operations
Barriers	• Design and construction culture • Transportation costs and logistics • Distance of factory to site • Industry knowledge • Labor unions
Collaboration	• Increased collaboration between stakeholders through project lifecycle • Decision to go PMC at schematic phase or later has negative impact
Decision Makers	• CM/GC first, AE second and owners last

Return on Investment

25% Schedule Reduction	$5.81/SF Average Savings
50% Schedule Reduction	$10.93/SF Average Savings

NEXT STEPS

During the study, next steps for continuing construction performance evaluation of PMC were identifed.

1. Develop alternative methods of comparative analysis including:

    a. Performing a PMC bid and schedule outline for a completed site built project as-built and specification documents; and

    b. Evaluating a side by side comparison of a stick built project and PMC built facility that are near similar (i.e. hotel chain built at the same time in different locations).

2. Continue to maintain metrics standards that are consistent with ASTM, NIST and ISO.

3. Collect labor hours in the PMC industry, and construction industry more broadly to determine productivity in construction.

4. Conduct a survey annually to seek current benefit and barrier perceptions of PMC in the industry.

5. Continue to codify research areas that others are working toward and prioritize these areas for greatest impact of uptake of off-site construction.

6. Develop an implementation guide for owners, designers, and fabricators to provide how-to knowledge of off-site delivery.

INTRODUCTION

PURPOSE

It is uncertain how much of the construction market permanent modular construction (PMC) constitutes in volume; however modular broadly is estimated to make up 3-5 % of the total construction industry. (MBI, 2011) Permanent Modular Construction "PMC" is an innovative, sustainable construction delivery method utilizing off-site, lean manufacturing techniques to prefabricate single or multi-story whole building solutions in deliverable module sections. PMC buildings are manufactured in a safe and controlled setting, and can be constructed of wood, steel, or concrete. The structures are 60% to 90% completed in a factory-controlled environment, and transported and assembled at the final building site. (MBI Website) PMC, as an off-site solution, has been marketed as a higher quality, faster to market and greener solution than traditional stick built, site built construction.

The added value of PMC, although conceptually strong, has yet to be significantly substantiated. The lack of qualitative or quantitative research data on PMC has been identified as a barrier to its adoption. As a disruptive technology, without grounded research for its use, PMC will have difficulty increasing its market share in the traditional construction sector. In addition, there does not exist a standardized method for collecting data on PMC projects in order to build to empirically evidenced arguments. Finally, there is a lack of qualitative information about the context in which successful PMC is realized including addressing issues of project delivery.

This research is to study off-site production processes in the global construction industry. It quantifies the added value of PMC and evaluates the contextual factors by which PMC in building design and construction may be realized in the U.S. and beyond. The scope of this research focuses on commercial construction and does not include single family residential. The research uses a case study method to compare PMC projects to traditional site built projects globally for construction performance parameters such as cost, schedule, quality, and safety. Both quantitative and qualitative data is collected through literature review, questionnaire and interviews. In addition to the comparative analysis, this report shares the results of an off-site industry survey, and a return on investment assessment demonstrates the lifecycle value of reduction in schedule as a result of modular. The study concludes with lessons learned and next steps.

TABLE 1 - BACKGROUND LITERATURE

The following is a list of literature resources used to provide a basis for this report.

USA Papers, articles, reports
McGraw Hill study (2011)
NIST study (2007)
Reports by the Modular Building Institute
Manufacturer literature
UK studies as precedent
Standards for data collection: ASTM, ISO, NIST

TABLE 2 - AUDIENCES

This report is aimed at the following audiences in the construction industry.

Market Sector Audiences	Healthcare Housing/Dormitory Hospitality Retail Office
Stakeholder Audiences	Owner Design Team (A/E) GC/CM Modular Manufacturers Regulatory Bodies

TABLE 3 - CASE STUDIES

Case studies included herein are diverse in region and context.

PROJECT	LOCATION
Xstrata Nickel Rim South	Greater Sudbury, Ontario, 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, Alberta, Canada
CitizenM Bankside	London, England
Mercy Hospital	Joplin, MO, USA
Starbucks	Marysville, WA,USA
Victoria Hall Wolverhampton	Wolverhampton, UK
Whistler Athletes Lodge	Whistler, BC, Canada
Inwood Apartments "The Stack"	New York City, New York
Manresa Student Housing	Manresa, Spain
Wells Fargo	Phoenix, AZ, USA
Kirkham Child Care Center	San Francisco, CA, USA
The Modules	Philadelphia, PA, USA

METHODS

CASE STUDY METHOD

This research utilizes a case study method for investigation. The case study method is a common strategy used in built environment research wherein projects are identified and documented for quantiative and qualitative data through interviews and literature review. The case study modular project pool has been established in consultation with the Modular Building Institute membership and the National Institute of Building Sciences Off-site Construction Council. The selection of the 17 cases documented are based on the following:

- Access to available archival data and willingness of stakeholders to participate and offer additional data: The pool of projects started with dozens of samples. However, some project stakeholders were reluctant to share data. The pool of this study consists of projects for which stakeholders were forthcoming with information became the pool of the study;

- Diversity of project sizes, locations and building types in order to see PMC across sectors, countries and cultures: However, the majority of the projects are located in North America as continent based organizations and companies funded this study; and

- Culturally significant buildings were selected based on architectural impact. The goal of the study is to demonstrate how PMC performs with respect to different building types, sizes, and delivery methods.

A ranking system considering these 3 factors was devised and provided a rudimentary process for determining the cases.

Each case study was developed by gathering data from the architect, general contractor or construction manager, and the modular manufacturer and/or supplier. In cases which there was no response from all three parties, at least two were consulted. A questionairre was developed and peer review edited to identify the quantitative data including cost, schedule, scope, quality and safety for the PMC case studies. This was disseminated online and through PDF response form. Responses were limited and therefore follow up interviews were conducted to gather additional quantitative data. During the interviews, qualitative questions were asked to determine the context for successful PMC deployment. Limited information that was provided led to the exclusion of some case studies on portions of this study. In total, there are 10 case studies with substantial contributing cost and schedule information. From these 10 cases studies, 7 of them were able to be compared in schedule and 8 in cost.

DATA GATHERING METHOD

TABLE 4 - QUANTITATIVE DATA

Gathered through online literature, phone interviews and email response

General Information	• Geographic Location • Gross S.F. • Number of Stories • Number of Modules • Type of Modular Construction (i.e. wood, steel, hybrid) • Primary Program (i.e. housing, commercial, mixed-use, healthcare) • Percentage complete of modules in factory • Miles from factory to site • LEED Rating, if any
Cost Data	• Capital cost • Design cost • Construction cost • Modular contract
Schedule Data	• Projection Duration • Construction Start Date • Project Completion Date • Module in the factory duration • Erection time on site • Design Duration
Quality/Safety Data	• Change orders associated with modules • Safety incidents • Fatalities • Labor Hours*

**Labor hours information was not recorded or available from respondents*

TABLE 5 - QUALITATIVE DATA

Gathered through phone interviews and email response

- Why was permanent modular used on the project?
- What digital software was used on the project?
- Were there any permitting problems?
- What were the greatest successes of the project?
- What would you do differently next time?

COMPARATIVE METHOD

Data from the PMC projects was compared to benchmark project data supplied by Cumming Corp., a cost consultancy firm. The data for both the PMC cases and the traditional comparison cases have been normalized to the first quarter of 2014 in US Dollars and Washington DC as the location. Units of cost are calculated in $USD/SF and it is assumed that in all of the traditional benchmark construction projects in comparison use a design-bid-build delivery system. When possible, estimates for the comparisons are based on actual items of work. When data has not been available, precedent values from other projects have been interpolated for these comparative projects. Unit costs are based on current bid prices in Washington DC with subcontractor overhead and mark-ups included. General Contractor overhead and profit has been separated.

The values determined were based on the probability of cost of construction at the programmatic design stage. The following parameters are compared using the Cumming Corp. database of projects in traditional construction. 10 of the PMC projects for which data was gathered were appropriate for draw comparisons regarding cost, schedule, quailty or safety. 8 of the 10 cases were used to compare cost performance and 7 for schedule comparisons.

For estimating the values, the following sources have been referenced:

- Davis Bacon Wage Rates
- RS Means Geographical Indices
- RS Means Standard Hourly Rates for Construction Industry Cumming Corporation Internal Economic and Market Report

The items not covered in this comparison include: hazardous material abatement, utility infrastructure improvements, design/consulting fees, building permitting, testing and inspection fees, and land acquisition costs.

The development of the data-gathering model has been in peer review with the National Institute of Building Sciences, Off-site Construction Council. ASTM and ISO standards for construction data referenced metric parameters for the model.

SURVEY METHOD

In addition to the PMC case study data, this study codifies an industry survey conducted in partnership with the National Institute of Building Sciences, Off-site Construction Council. A special council committee made up of industry and academic personnel authored the survey. It was peer reviewed by a small sample and then disseminated through the NIBS network, council contacts, *Engineering News Record*, and *Building Design & Construction Magazine* subscribers. 312 responses were collected. The data from the NIBS survey was filtered to reflect PMC project stakeholders' responses only, consisting of 53 responses and is reported herin.

RETURN ON INVESTMENT METHOD

By employing PMC, the cases in this study reduced their construction time by an average of 45% when compared with traditional construction. *Figure 3.7* shows the time of construction compared to their traditionally constructed counterparts. To put this reduction of time in terms of cost, a return on investment study was performed to account for the time saved by PMC.

The ROI leveraged three discrete developers pro-formas for a retail, office, and charter school building type respectively. The developer data was assessed using a schedule improvement of 25% and 50% faster than the actual schedule. This did not include the financial benefit of early returns on operational business such as sales, lease rates, or educational impacts. It was a construction duration cost benefit only. The buildings included in the pro-formas are finished structures located in Salt Lake City, UT. All metrics are represented in that geographical location as well.

The pro-formas include four sections:

1. The analysis of the total build, the build time reduced by 25% and then reduced by 50%;
2. The cost of construction;
3. The cost of the construction loan;
4. And the generated income. Market rate numbers are based off of the Newmark Grubb Acres 2014 Year End Report. The Rental Income numbers are based on the presumption that the building will be 100% occupied reflecting the highest possible opportunity for income.

LIMITATIONS

This study is limited in several ways. Because there are relatively few built PMC cases compared with traditional methods, it is difficult to make statistical arguments or identify trends. Information on costs and labor hours in particular projects is also limited by the willingness of the firms interviewed to share proprietary data.

The traditional stick built comparative benchmark projects were also limited. The study called upon the database from Cumming Corp., a cost consultancy firm that in some cases did not have similar projects by which to compare to the PMC cases. In any event, identifying like for like specified buildings is not possible. Alternative methods of traditional build and PMC comparative research are recommended in the conclusion to this report pg. 38-44.

The survey was limited by not being able to ensure a diversity of random sampling, as it was sent through media channels, to which not all construction industry professionals have access. It is not uncommon that surveys in general have this limitation of diversity in sample. Additionally, the survey results on PMC were part of a larger survey on off-site. 53 of 312 respondents indicated deploying PMC and therefore there were a limited number of respondents to make statically significant claims.

The return on investment study also needs more samples to make a significant claim as there were only 3 pro-formas from 3 unique developers referenced.

TABLE 6 - LIMITATIONS

Limitations to the methods included in this report.

Case Studies	• Sample Pool too small (10 comparable projects) • Lack of information or willingness to provide information from stakeholders
Comparative	• Database of projects limited • Difficulty to match constructed buildings like for like specification
Survey	• Ensuring the diversity of random sampling • Statistical significance based on number of responses (PMC 53 reponses)
ROI Study	• More samples needed (3 included)

RESEARCH

QUANTITATIVE

GENERAL

This study asks participants the following general information questions:

What is the building type and square footage?

How many stories?

What is the context location of the building? (rural, urban, or suburban)

How many modules are in the building?

What is the distance from factory to the site?

What is the volumetric construction of the modules?

What was the percentage of module completion from factory?

This section includes all original 17 case studies as most of the information was found through website sources. However, information was left out of the study when it could not be located through literature or interviews.

Our method to find case studies attempted to gather the most diverse building types. See *Figure 1*. Most of these case studies fall within 40,000 to 80,000 square feet. See *Figure 2*. These metrics served as a basis to further explore the importance of the inclusion or exclusion of building types and square footages in future studies.

BUILDING TYPE

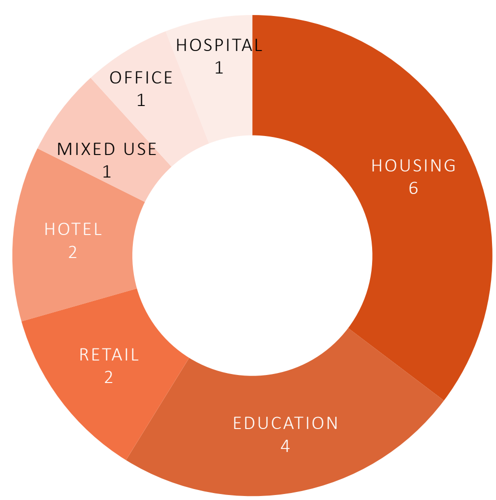

Figure 1
The type of buildings included in this report.

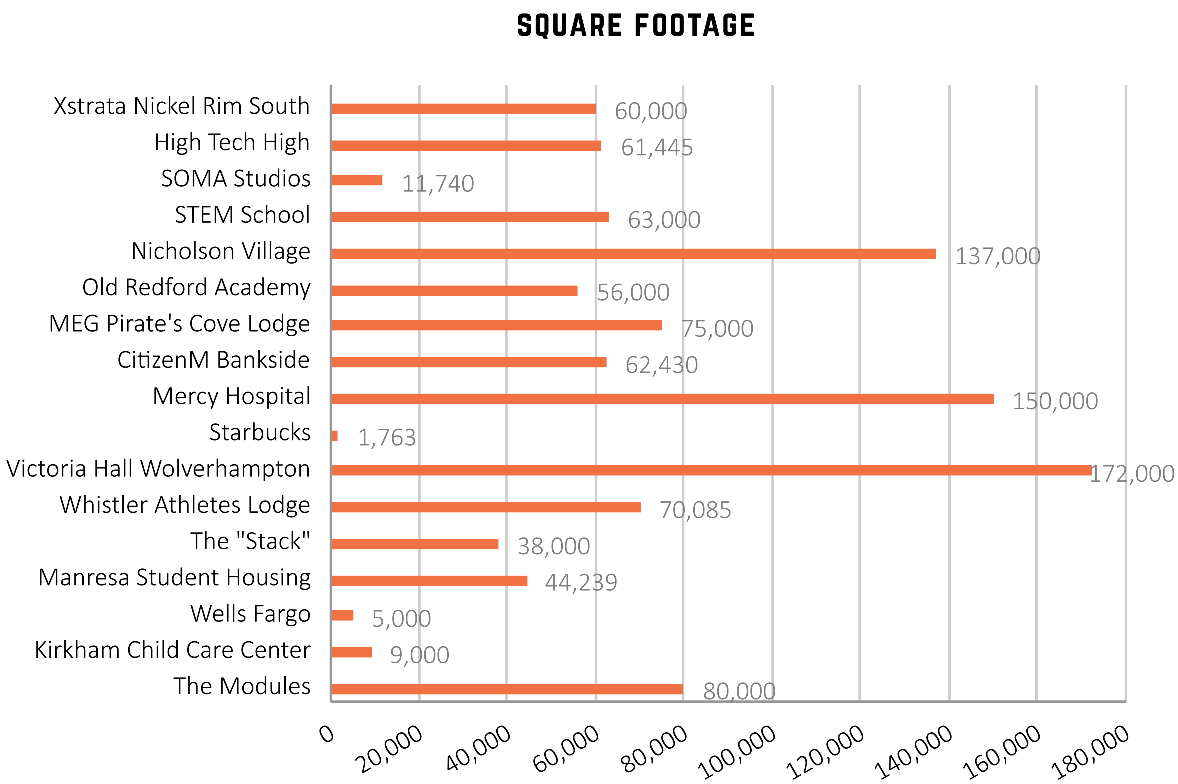

Figure 2
Square footage is measured in Gross Square Feet

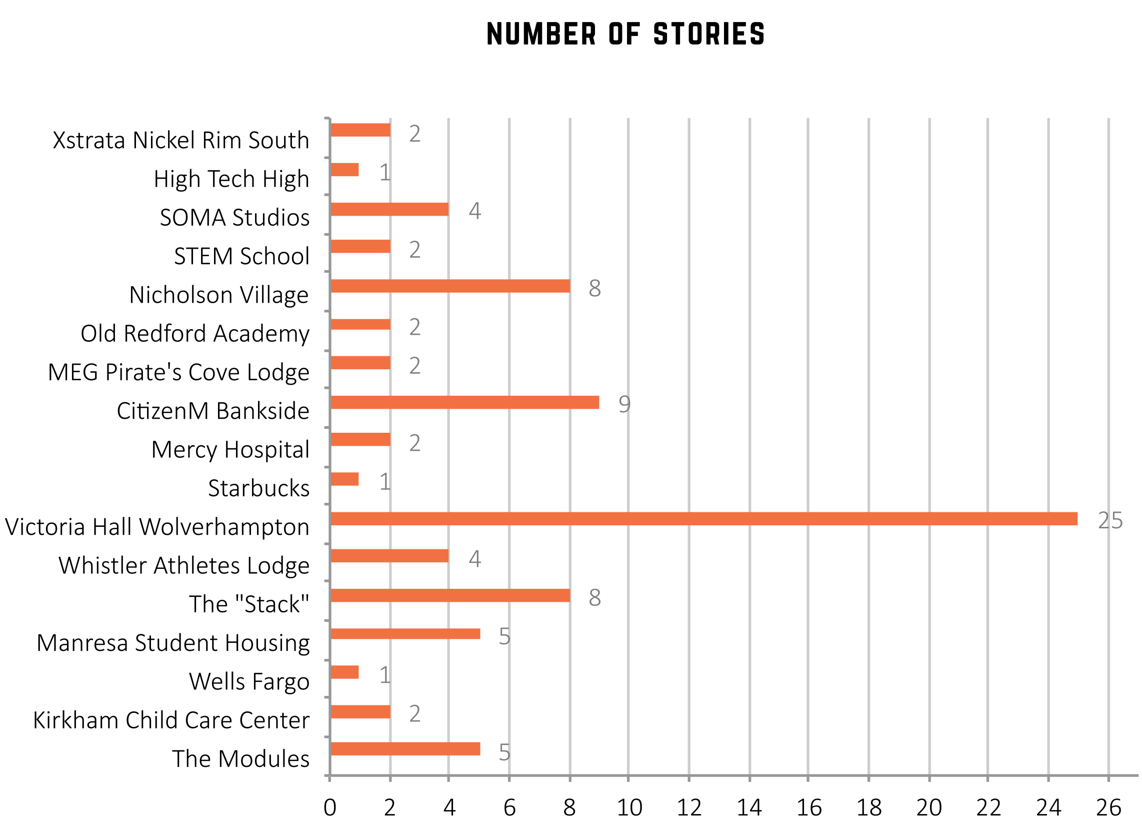

Figure 3
Stories included in this data set are not limited to stories in modular construction.

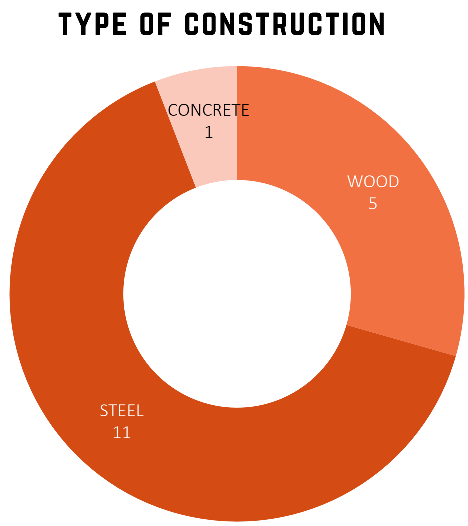

Figure 4
The type of structural material used in the volumetric construction of the module.

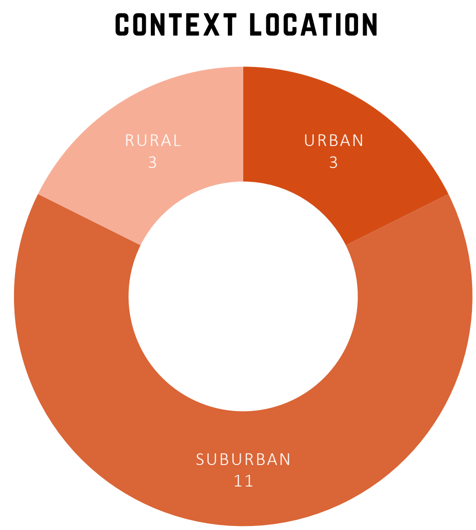

Figure 5
The density of the surrounding context.

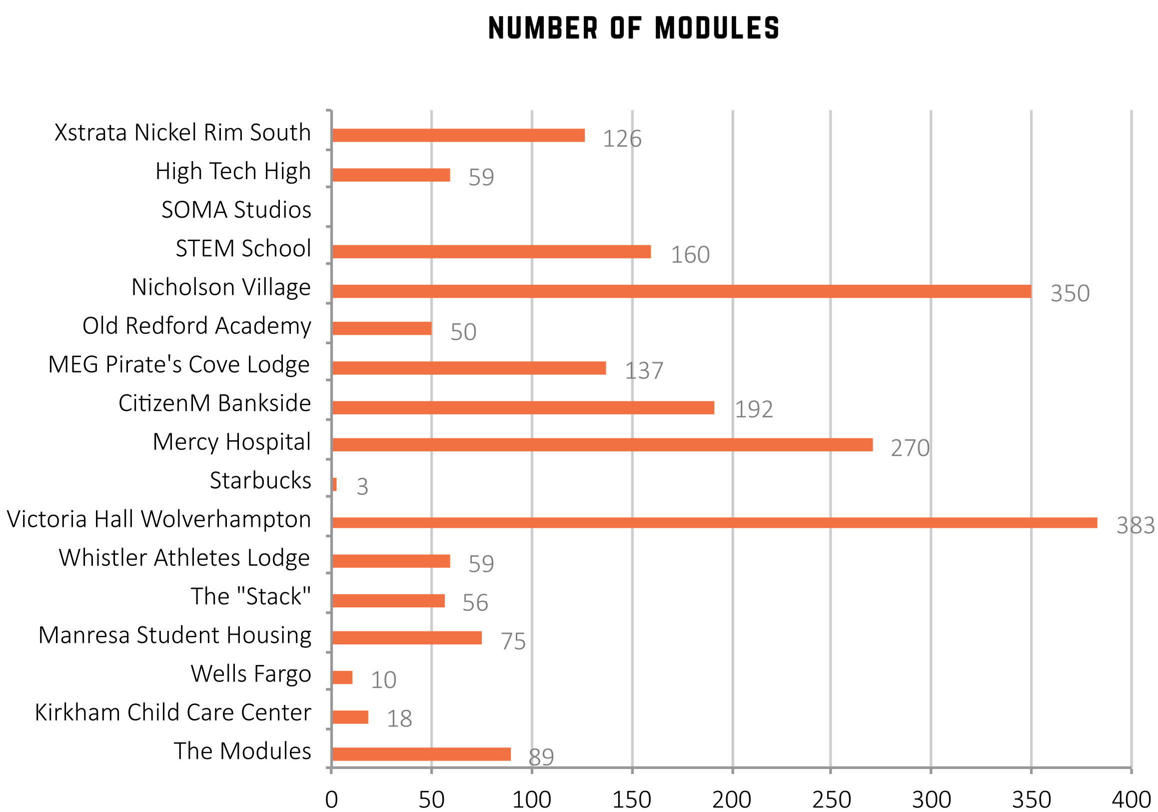

Figure 6
The number of modules included in the project.

DISTANCE FROM FACTORY

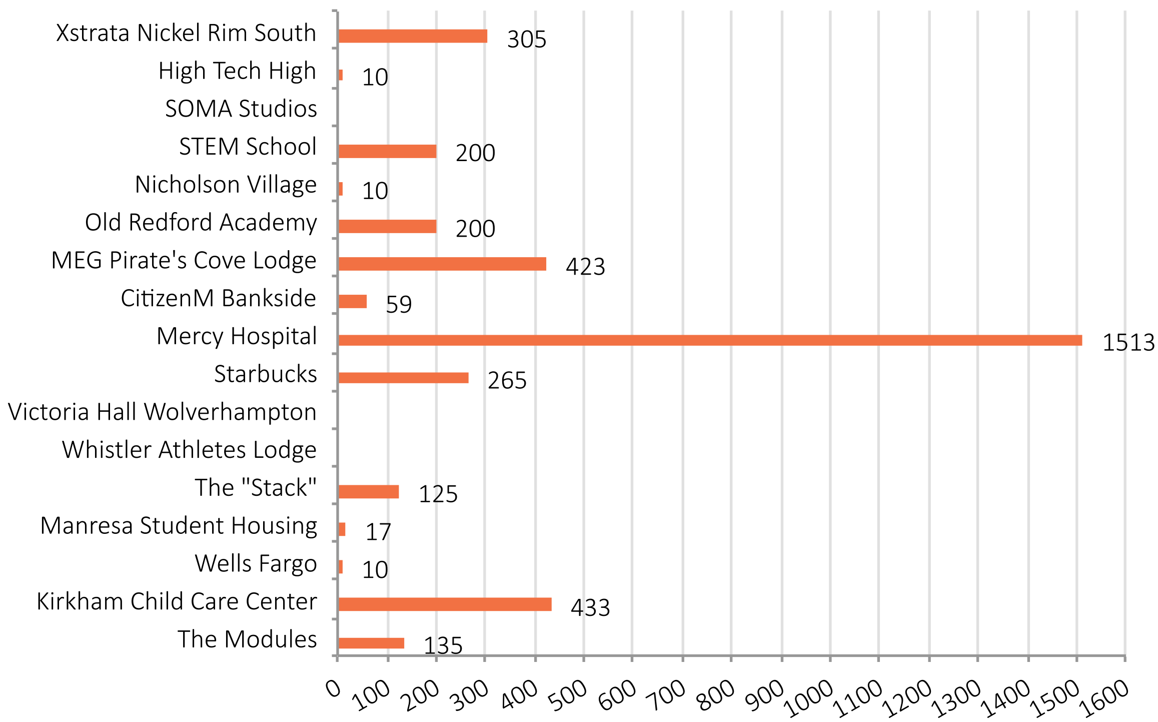

Figure 7
The distance in miles from factory to project location.

PERCENT COMPLETE IN FACTORY

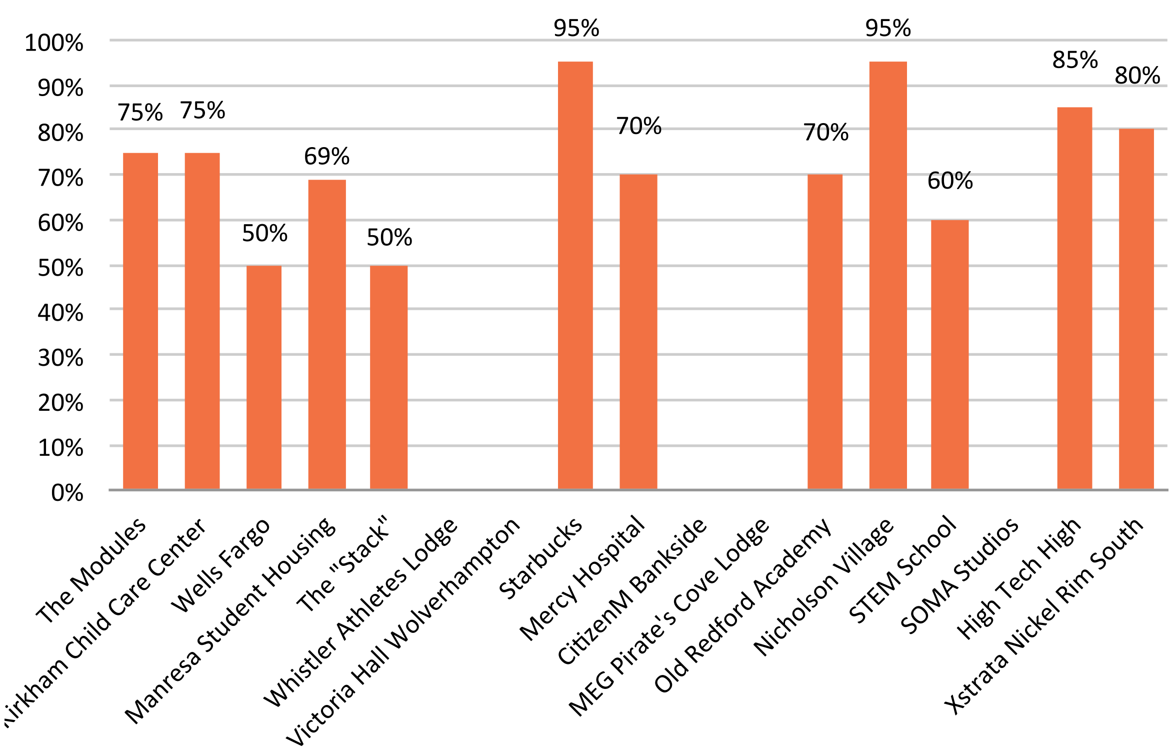

Figure 8
The level of completion from the factory.

COST

Questions regarding cost:

What was the vertical construction cost?

What was the design cost?

What was the modular contract?

Public perception of the cost of modular construction suggests that it is less expensive compared to traditional methods of construction. The cases from this study demonstrate an average of 16% cost savings compared to traditional construction. See *Figure 19*. However, further analysis in these case studies has proven that the cost is not necessarily always less. In fact, the cost sometimes comes at a premium.

The most important item to note in this cost analysis, however, is that permanent modular construction is conducive to a greater control of the cost compared to its traditional on-site methods of construction. This is attributed to the inherent ability to reduce the number of change orders in any given PMC project. In almost every case study interview that was conducted, the construction cost was said to have been better controlled. One can predict the cost of the building with more accuracy using PMC compared to conventional construction from predesign through post-occupancy.

In conventional construction delivery, change-orders cause significant cost increases. In a recent study conducted in Montgomery County, Maryland, the Office of Leglislative Oversight studied 17 county government building projects that reached substantial completion in 2009-2013. The study found an 8% overall increase in contract costs due to change orders. (OLO, 2014)

Many of the responses to this topic concluded that the reason why modular construction cost is so well controlled is because the design must be flushed out before module production. See the Qualitative Analysis section of this report on page 24-26. The reason for choosing off-site construction methods is not in cost efficiency, but in precision of the construction and its ability to control and predict the cost of the building. See Industry Survey section for more benefits in using off-site construction methods on pages 29-32 of this report.

The cost premium parameters reported by stakholders include:

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

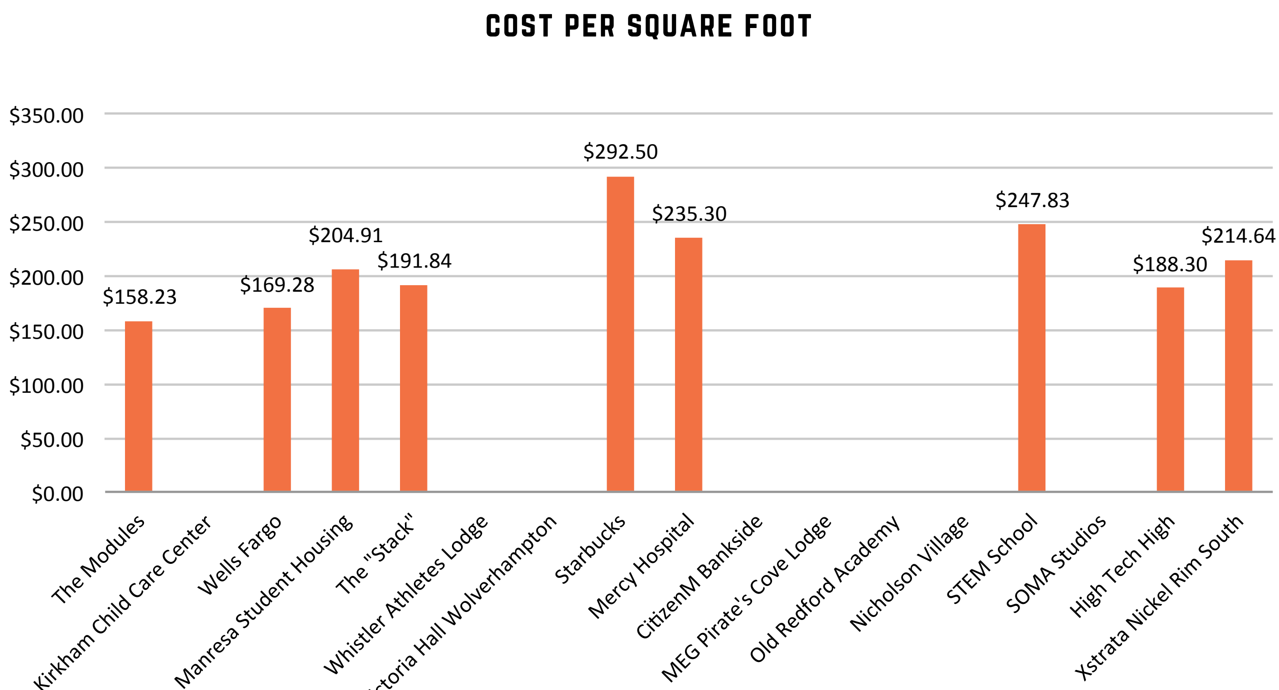

Figure 9
The vertical construction cost per square foot of the PMC building case studies.

SCHEDULE

The reduction of time in the production of buildings that use permanent modular construction is one of, if not, the biggest incentive that this method of construction has to offer. It is also one of the largest claims that the industry has and the majority motivation as to why permanent modular was used in these projects. The following questions involve schedule:

What was the project duration?

What was the design duration?

What was the construction duration?

How much time were the modules in the factory?

How long did it take to erect the modules?

Among the cases, the schedule was reduced by an average of 45%. An average of 9.29 months for PMC cases and 16.86 months for conventional construction. See *Figure 18*. Because modules are built in a factory, the site-work and foundations can be constructed simultaneously. This reduces the lag time that a traditional on-site built building has where site-work, foundations and building construction occur consecutively. The time saved using

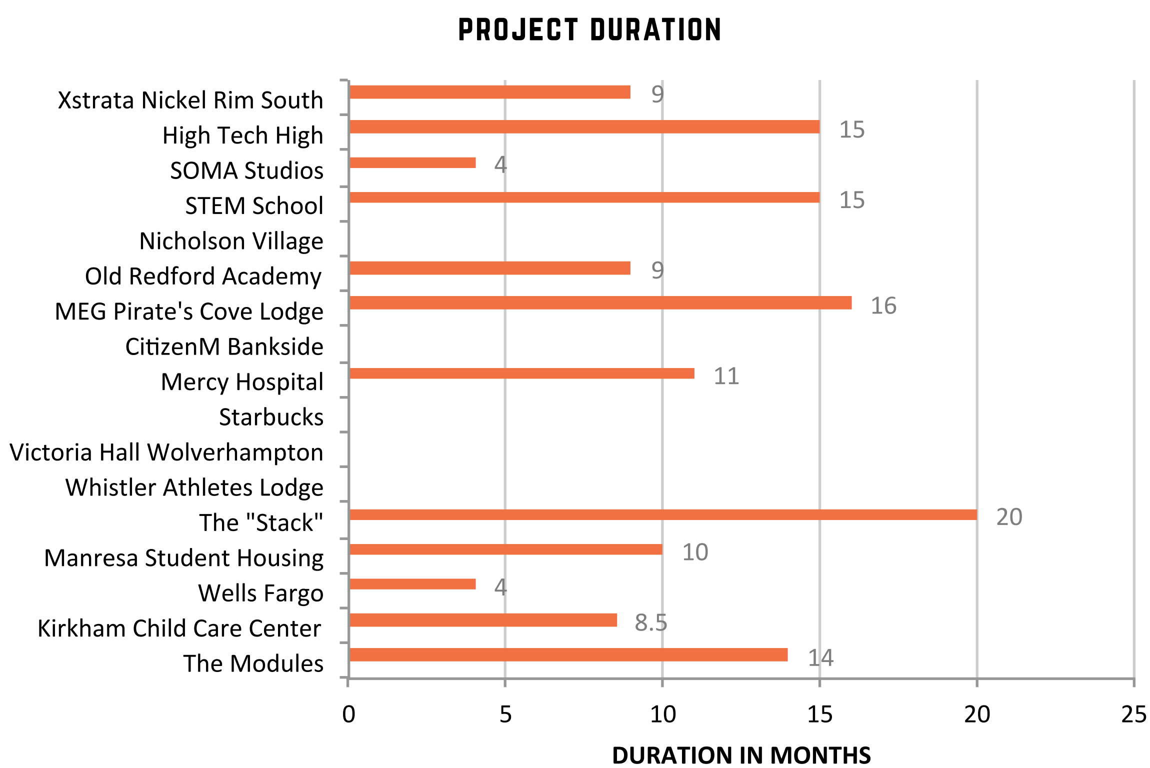

Figure 10
The total project time in months.

PMC opens a whole window of opportunity for cost savings. This is substantiated in a Return on Investment study found on pages 32-33 of this report.

In the Office of Legislative Oversight study on the Change Orders in County Government Construction Projects, change orders increased the 17 case studies construction time by 30.3%. In two of the 17 case studies, change orders more than doubled the construction time. (OLO, 2014)

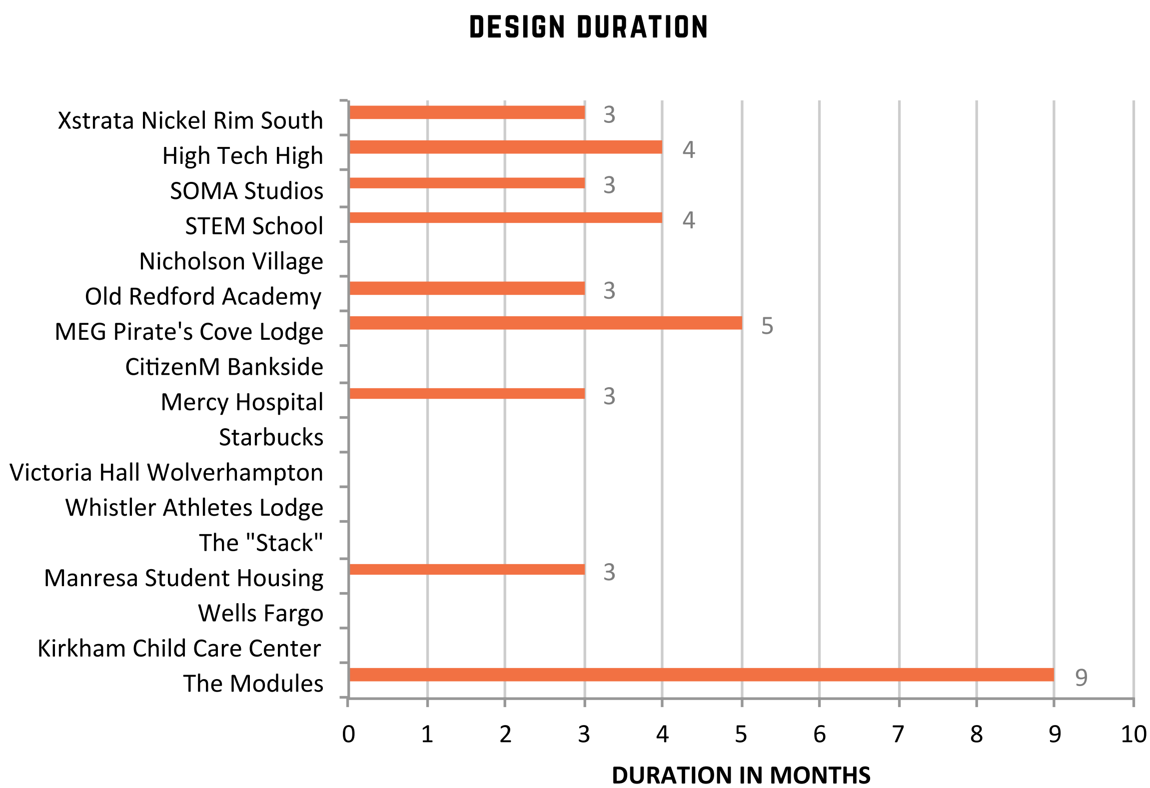

Figure 11
The peoject design time in months.

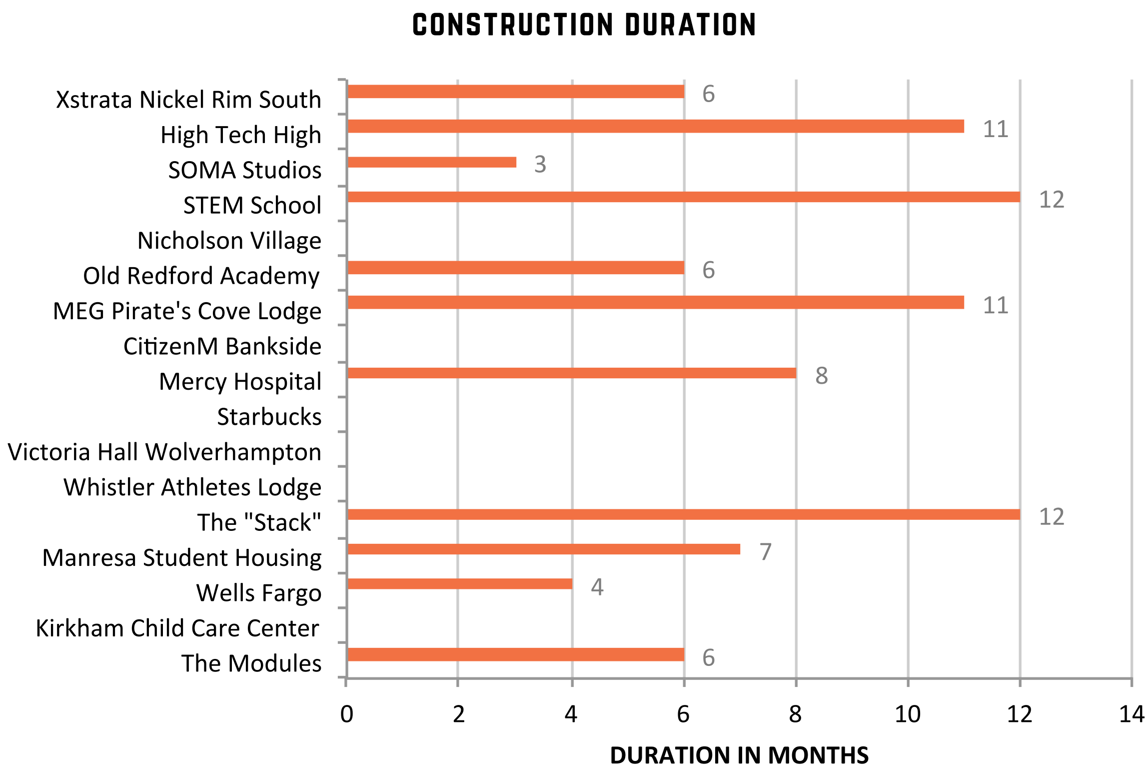

Figure 12
The project build time in months.

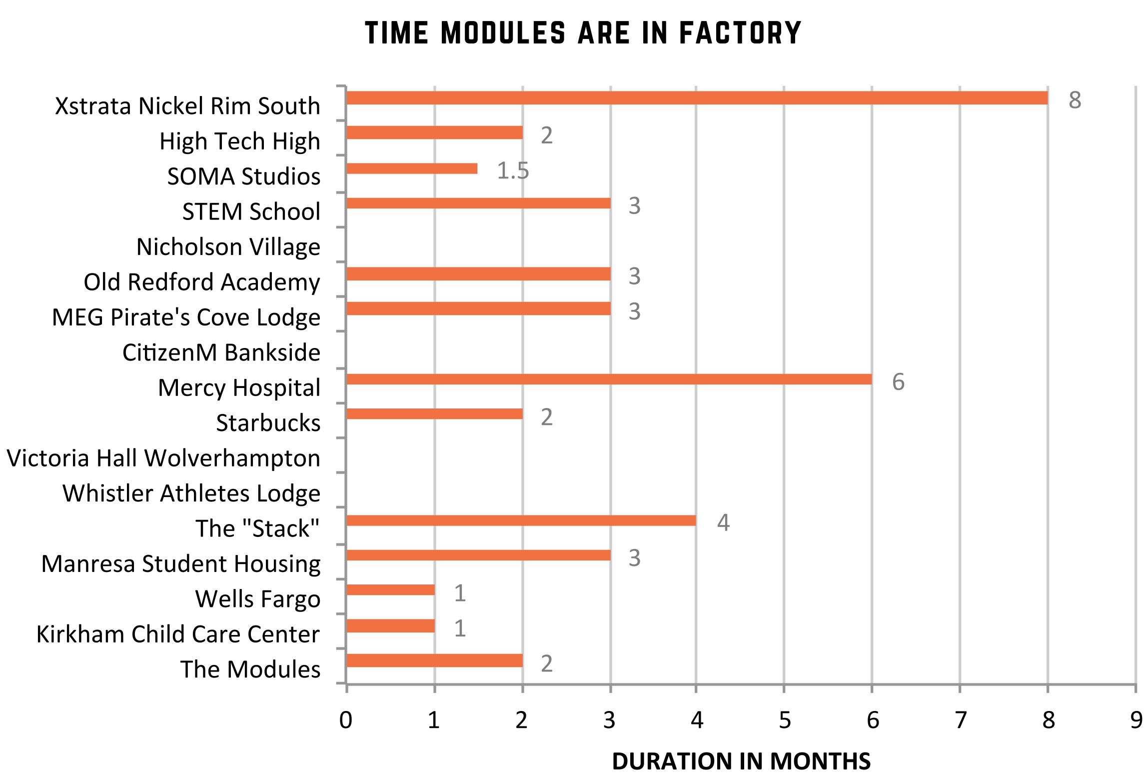

Figure 13
The factory production time of the modules in months.

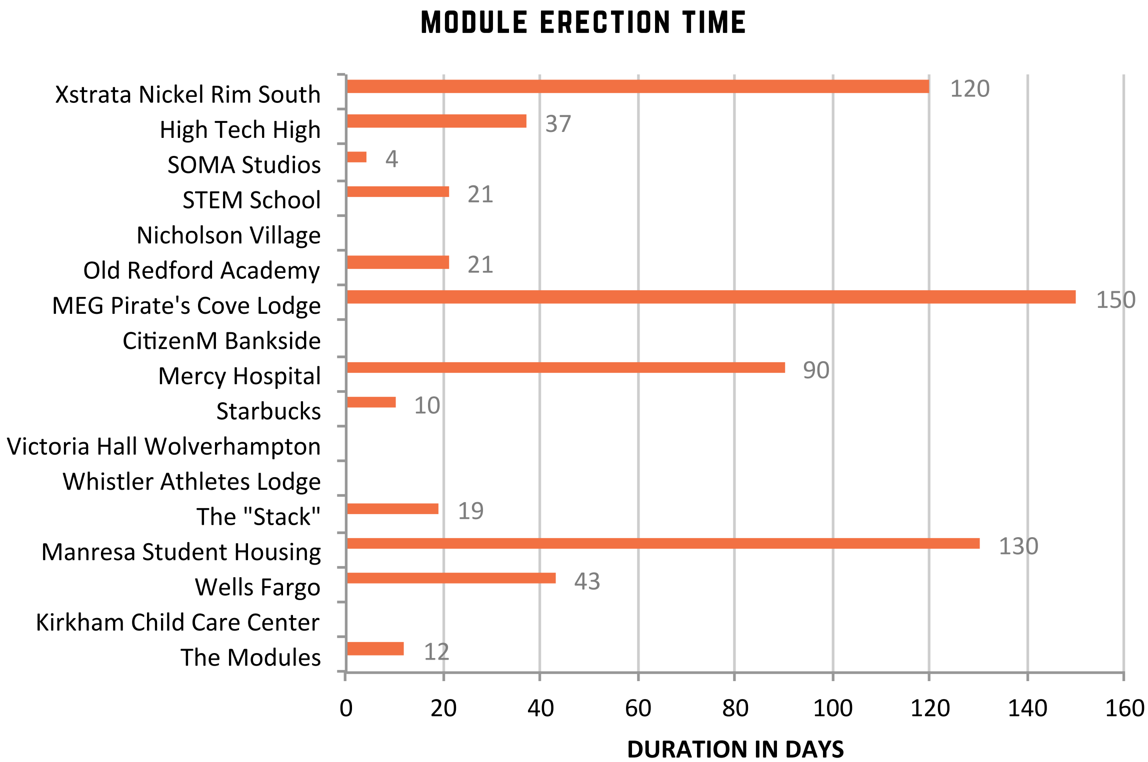

Figure 14
The time in days for the erection of the modules.

QUALITY AND SAFETY

This topic includes questions of quality and safety. These topics present overlaps that reinforce the cost and schedule findings:

How many change orders were in the project?

How many reported safety incidents were there?

How many labor hours were there?

The previous two sections have shown that the factory controlled conditions of PMC contribute to projects that have a faster delivery with better cost control. It may also be the case that PMC leads to working conditions that are safer for workers and surrounding neighborhoods. The answers to the above questions might give us a clearer picture to the reality of these claims in these 17 projects.

Across the 11 case studies that provided an answer to these questions, the number of change orders is averaged to be 5.4 per project. The change order responses are broken into categories by quantity. See *Figure 15*. The interesting finding in this question is the fact that the number of change orders that are in the 11 or more category are at a substantial amount, both at 15. The median of this data set is only 3. This indicates that the two cases with 15 change orders has skewed the average change order per project metric much higher.

CHANGE ORDERS

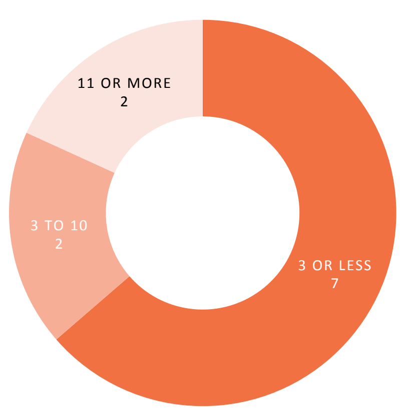

Figure 15
The number of change orders.

REPORTED SAFETY INCIDENTS

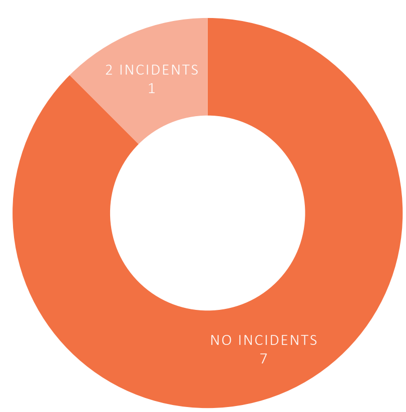

Figure 16
The number of reported safety incidencts on the project.

According to the 8 cases in this report that provided an answer on safety, there was only one project that had reported incidents. All other cases did not have any safety incidents. See *Figure 16*. With the quantity of given information, no claim can be made that is statistically significant concerning safety.

Only one project was able to supply labor-hours productivity data, and this project was not located in North America. It is uncertain why the North American construction industry does such a poor job of tracking per project productivity. Answering this is an important area for further investigation, as it will be necessary to evaluate the relative productivity gains that may be possible with PMC methods.

QUALITATIVE

The following qualitative questions were asked to get a better understanding of how permanent modular construction performs against conventional construction methods. This information is intended to give some understanding of how permanent modular can be improved.

Why was Permanent Modular Chosen?

What digital software was used?

Were there any permitting/code issues?

What would you do differently next time?

What were the greatest successes of the project?

WHY WAS PERMANENT MODULAR CHOSEN?

Generally, there is a struggle to turn over construction projects on time and on budget. Based on these cases collected, these survey results show that the use of permanent modular construction can mitigate cost and schedule challenges. The most frequent response to this question was a motivation to reduce the construction schedule. LeRoy Stevens from Stevens Architects explains why he prefers permanent modular, "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% when compared with traditional construction. See *Figure 19*.

WHAT DIGITAL SOFTWARE WAS USED?

The primary software used by all the manufacturers, architects, and contractors are 2D drawings programs such as AutoCAD. Suprisingly, few are using BIM software. No matter what software is being used, it is always used in conjunction with AutoCAD. See *Figure 17*.

SOFTWARE

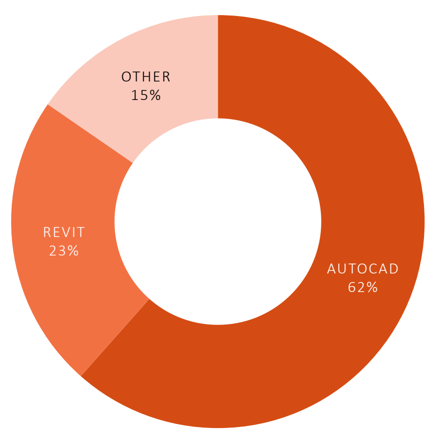

Figure 17
The design software used .

WERE THERE ANY PERMITTING/CODE ISSUES?

Of the six cases providing answers to this question, three answered that permitting and code issues delayed the project. Permitting and code officials aren't familiar 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, MO. Because the factory was located in California, 1500 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 often times 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.

WHAT WOULD YOU DO DIFFERENTLY NEXT TIME?

There was only one response that answered "nothing" to this question. The rest were some variant of "more collaboration at the beginning of the project." 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. A Design-Bid-Build Contract, while still possible to achieve this level of collaboration, is very difficult and not as inherently collaborative as its Design-Build or Integrated Project Delivery counterparts. There is a question in the NIBS OSCC Industry Survey that addresses this topic and aims to provide a clearer definition as to when this collaboration should occur for the greatest benefit. See *Industry Survey* on Pages 28-31.

Survey respondents agree that during, the Design Concept Phase, the time needed to research modular construction should be increased. "There needed to be more time to research/design for better quality of the project", states Leon Stevens. Referring back to the previous answers to this question, the need to have a near complete design with little anticipation of change orders is crucial to the success of the project. This not only requires the need for all major trades to be involved early, but there is also a need for the design and research time to be increased to design for manufacture and assembly. The cost and schedule implications of late design stage or early construction phase changes can have negative impacts on performance.

The infancy of permanent modular construction compared to traditional site building makes for many prototype projects, in which the architect, contractor and manfuacturer are expierencing their first modular build. Because of this, it is likely that the number of permanent modular 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 makes 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 an Integrated Project Delivery.

WHAT WERE THE GREATEST SUCCESSES?

The most successful performance of permanent modular buildings is its ability to be completed with reduction in schedule. Every survey respondent names meeting the substantial completion deadline as a success. The use of PMC, according to these case study interviews, shows that a loss of quality compared to conventional construction does not exist. All interviewees were impressed with the substantial quality of the PMC buildings.

COMPARATIVE ANALYSIS

In result of the comparison method included in this report, the following is a summary of the analysis in cost and schedule metrics.

Substantial information to conduct a schedule comparison analysis was provided for 7 case studies. For a cost comparison, there were 8 case appropriate for comparison.

An average of an 16% reduction in cost is proved by using PMC rather than conventional methods of construction. See *Figure 18*

The results shown in *Figure 19* display an average schedule reduction by 45%, with a high of 60%, and a low of 25% schedule savings.

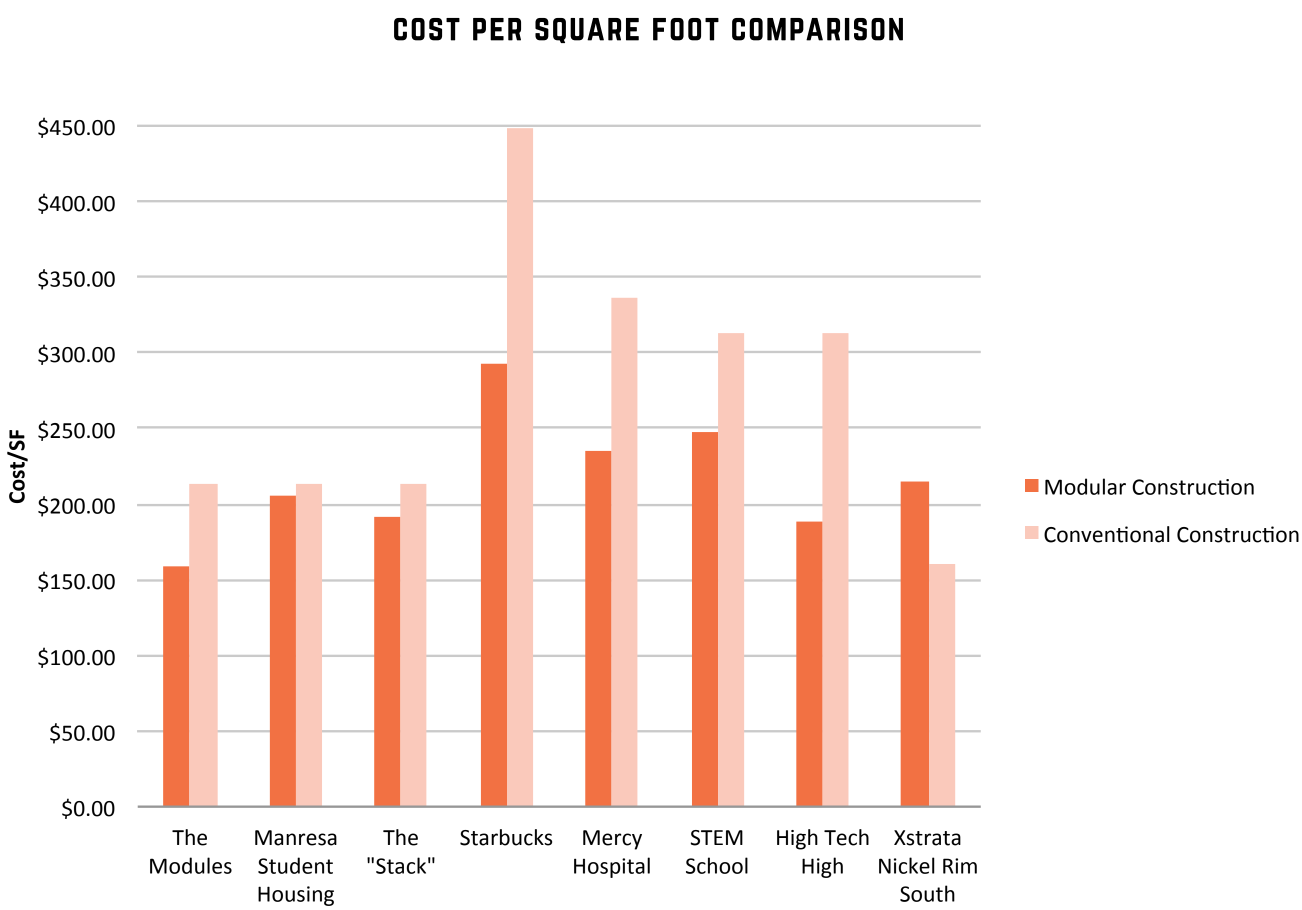

Figure 18
Cost per square-foot comparison analysed by Cumming Corp.

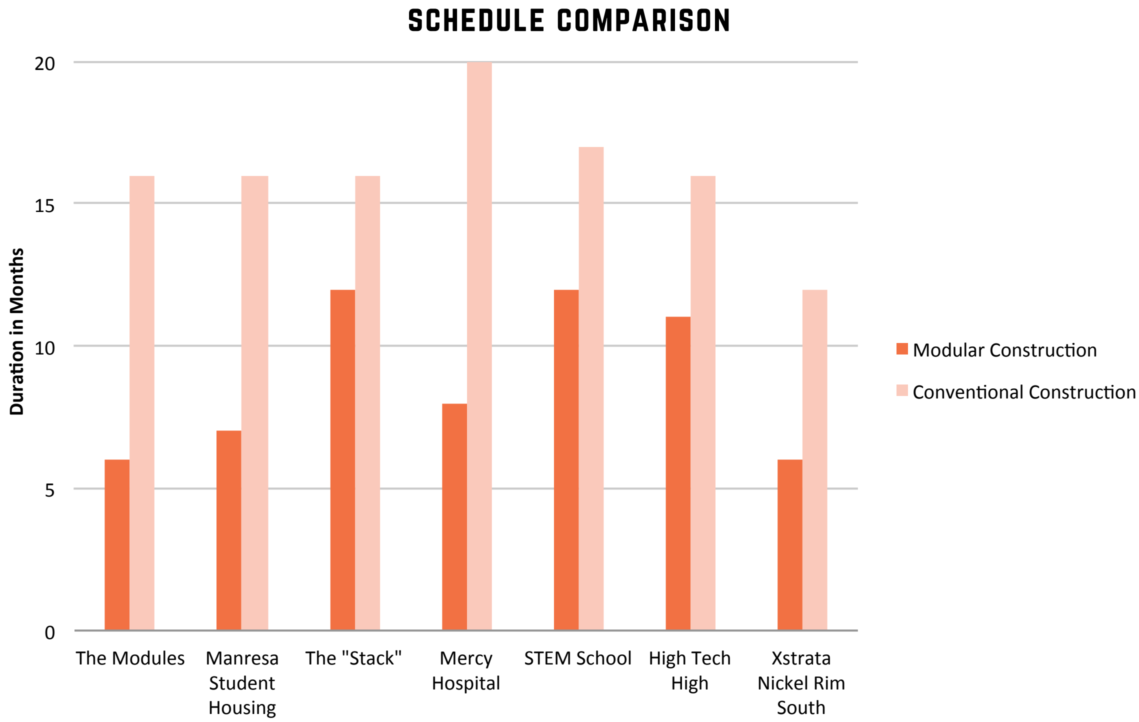

Figure 19
Schedule comparison in months analysed by Cumming Corp.

INDUSTRY SURVEY

The survey revealed that 93% of respondents indicated utilizing off-site fabricated components to some degree and 83% identified that they will utilize off-site more or the same in the next 12 months. This suggests that off-site construction and delivery has reached a critical mass of adoption across the commercial building sector.

53 of the 312 total respondents, or 17%, indicated they had implemented PMC on a project in the past.

The survey indicates where off-site is most often utilized. Responses show that 57% are using off-site for commercial construction, 51% for industrial, 45% for healthcare, 37% for education, 24% for multi-family, and 23% for hospitality. The respondent pool was geographically diverse across the U.S.

The survey results delineate perceived and realized benefits of PMC to project performance. The primary benefit identified by the survey is reduced overall project schedule and construction phase duration. Other realized benefits noted from the survey include the quality of the product and cost effectiveness. PMC has historically not been a lowest cost solution for project delivery; however, respondents are indicating that it is a cost-effective solution. Comments from respondents suggest that the life-cycle benefits of off-site techniques include schedule reductions resulting in overall cost benefits and reduced defects as a result of an increase in quality. The survey evidenced an increase in project stakeholder collaboration when employing off-site methods. According to 78% of respondents, off-site construction requires moderately higher or significantly higher levels of stakeholder engagement. A more integrated approach to delivery increases quality and reduce changes late in the construction stage. The benefits of a tighter schedule and the reported increases in collaboration in this survey confirm previous evaluations by McGraw-Hill. (McGraw Hill, 2009)

The survey reveals that when project teams make the decision to go to modular later than the schematic design phase, it is likely to have a negative impact on project schedule and cost. This suggests the importance of involving PMC manufacturers early in the project delivery process through design assist contracts and early technical definition of the design parameters.

The survey also reveals the barriers and challenges to realizing PMC. According to the respondents, one of the most significant barriers is transportation, and more specifically the distance of the factory to the site. The building program was also identified as being a major challenge. Not all project types, long-span structures for example, are equally well-suited to leveraging the advantages of factory finished elements. Each project has unique requirements that must be met through an appropriate technical solution. Industry knowledge was identified as a barrier to the uptake of modular construction. Survey respondents indicated that unions might hinder off-site utilization with factory non-union labor. This has been an actual deterrent in projects on the east coast. (*The Stack* and *Modules* projects)

The survey points to potential issues that a lack of supply chain integration can present for PMC projects. The modular manufacturing industry is maturing and will require time to more effectively integrate with site-built work. In addition, contractors are learning how to manage PMC and other off-site products for assembly on-site. Interestingly, respondents stated that the most significant barrier to off-site and PMC is design and construction culture. Comments indicate that late design changes, lack of collaboration and an adversarial climate for project delivery leads to difficulties in realizing the benefits of off-site construction.

www.nibs.org/oscc

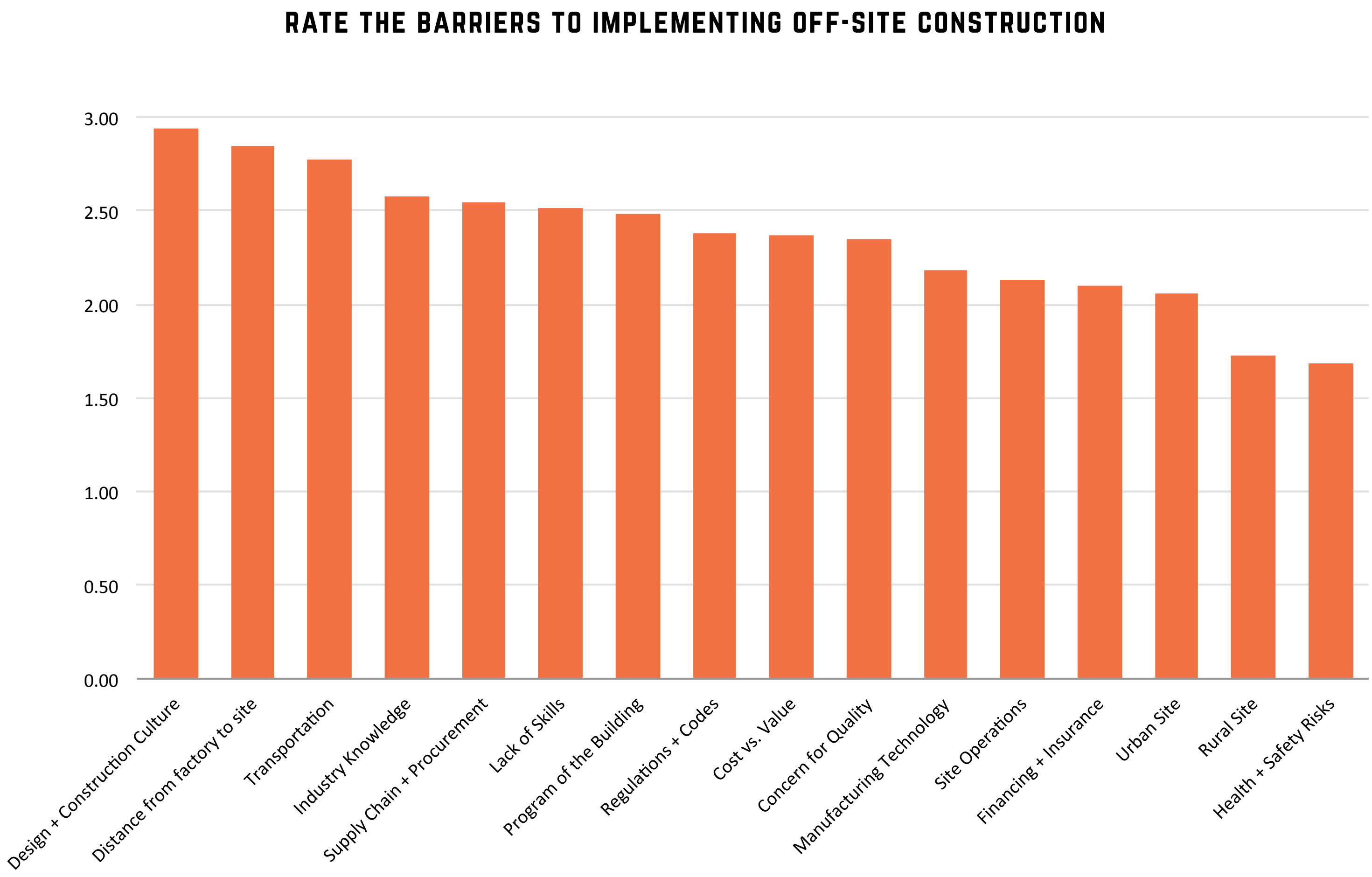

Figure 20

The barriers of integrating off-site technologies in projects by a weighted average of 4 responses that range from none, small, moderate, to significant.

FOR THE CONSIDERED PROJECT, WHEN DID YOU COLLABORATE WITH THE CONTRACTOR PERFORMING THE OFF-SITE WORK AND BASED ON YOUR EXPERIENCE, WHEN DO YOU RECOMMEND ENGAGING THE OFF-SITE CONTRACTOR?

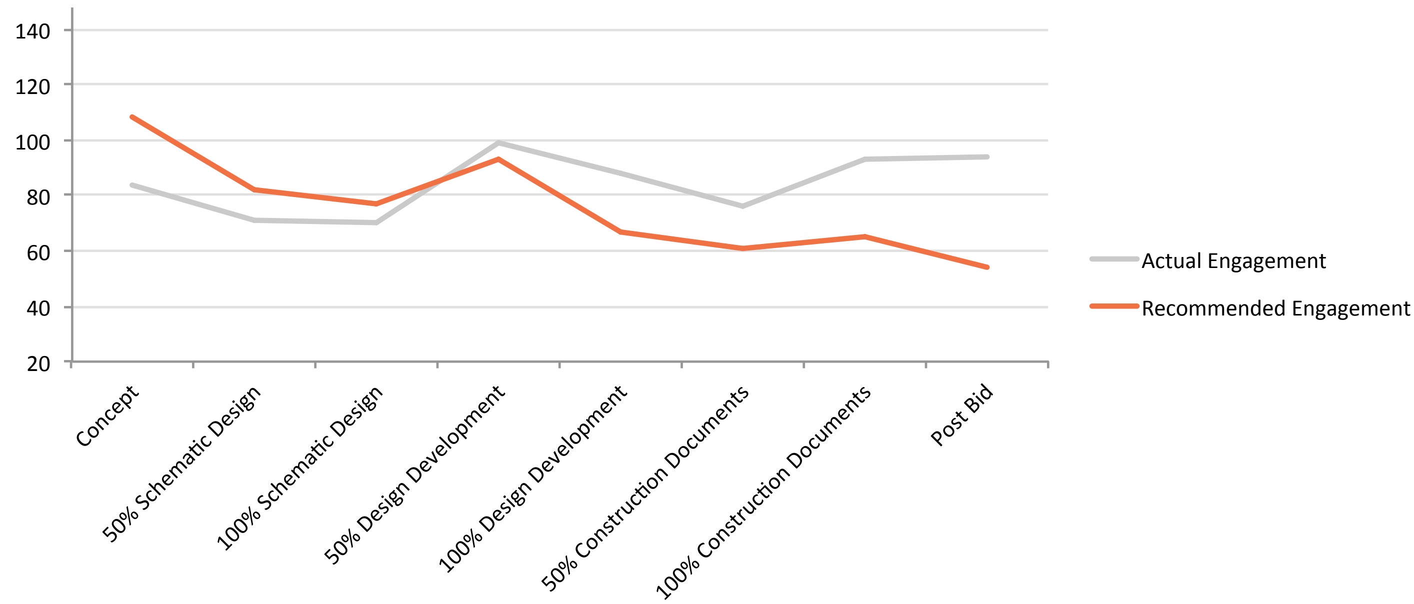

Figure 21
The responses included in this question are based on the number of respondents.

FOR THIS PROJECT, WHAT WERE THE ACTUAL BENEFITS REALIZED BY USING OFF-SITE CONSTRUCTION?

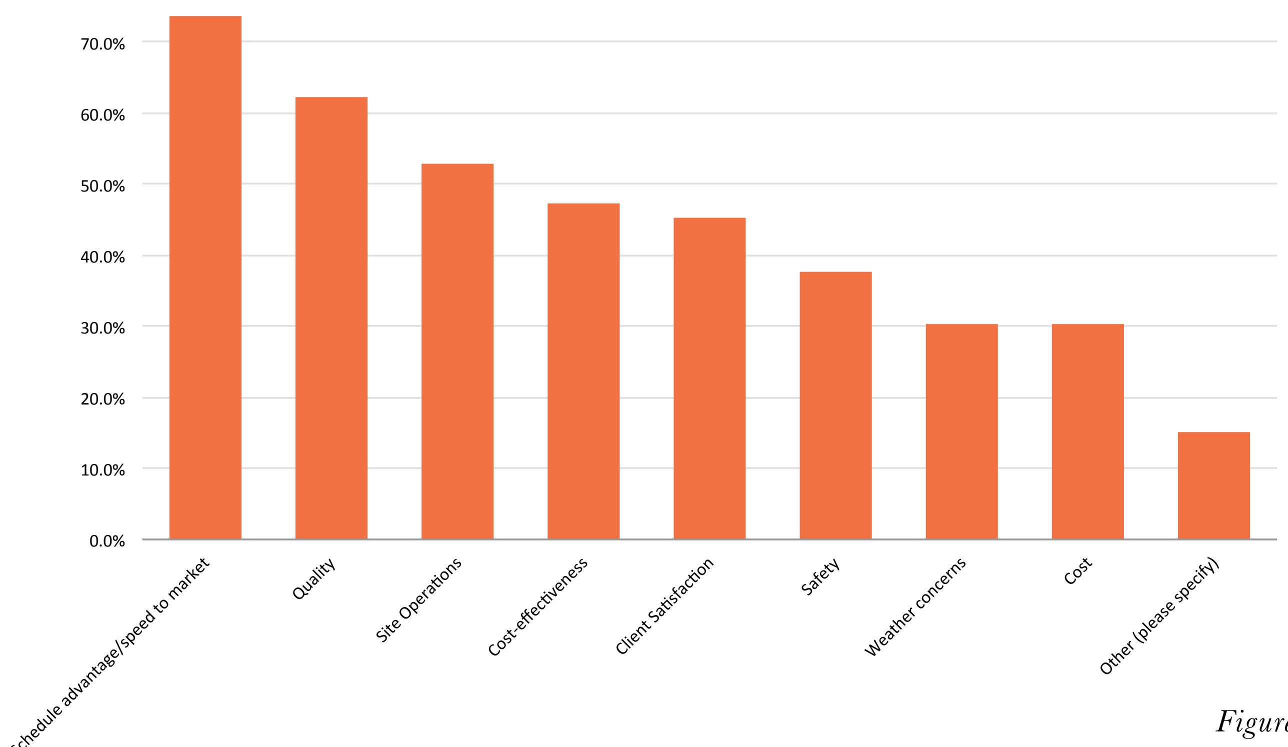

Figure 22
The percentage of all who responded to this question

IN THE NEXT 12 MONTHS, HOW OFTEN DO YOU ANTICIPATE USING MODULAR CONSTRUCTION?

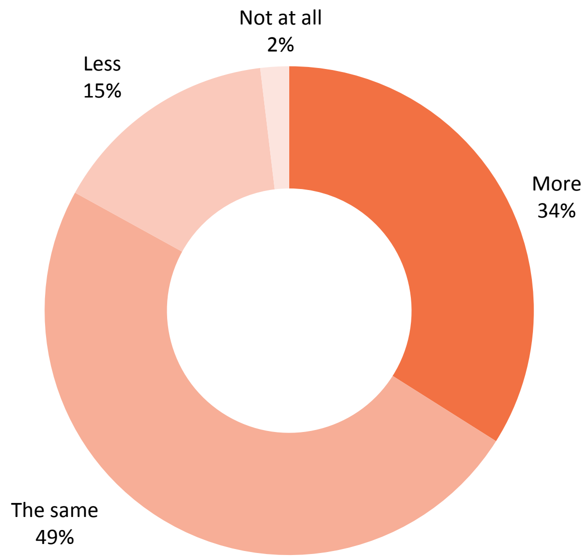

Figure 23

This question aims to anticipate the growth of modular construction.

RETURN ON INVESTMENT STUDY

SUMMARY

The pro-forma comparisons show two areas where there is an opportunity to save in cost using permanent modular construction. These areas include the cost of the construction loan and the money generated during the time saved. This clearly shows that, though treated individually in the survey results, cost-savings and profitability are tied directly to schedule in most cases.

In the retail space case study at a 25% schedule reduction, $5,187 was saved in construction interest, and $29,333 generated in rental income producing an Effective Gross Income of $34,520. At 50% schedule reduction, $10,350 was saved in construction loan interest, and $58,666 generated in rental income for an Effective Gross Income of $69,017. See *Figure 24.*

The office space pro-forma shows a construction interest savings of $52,214 and a generated rental income of $292,333 for an Effective Gross Income of $345,547 at 25% schedule reduction. At 50% schedule reduction, the Effective Gross Income shows $518,147. See *Figure 25.*

In the charter school case study, $29,821 was saved in construction interest with a 25% schedule reduction. $134,029 was generated in rental income for an Effective Gross Income of $163,851. There would be a construction interest savings of $74,244 with a 50% schedule reduction. A generated rental income of $335,074 for an Effective Gross Income of $409,318. See *Figure 26.*

All three case study pro-formas show an average of $5.81 per square foot in total cost reduction at 25% schedule savings. At 50% schedule reduction, the average cost per square foot savings shows $10.93. At a 25% schedule reduction, the retail, office, and charter school show a cost per square foot savings of $4.32, $8.64, and $4.48 respectively. At 50%, $8.63, $12.95, and $11.20 is saved in the same order.

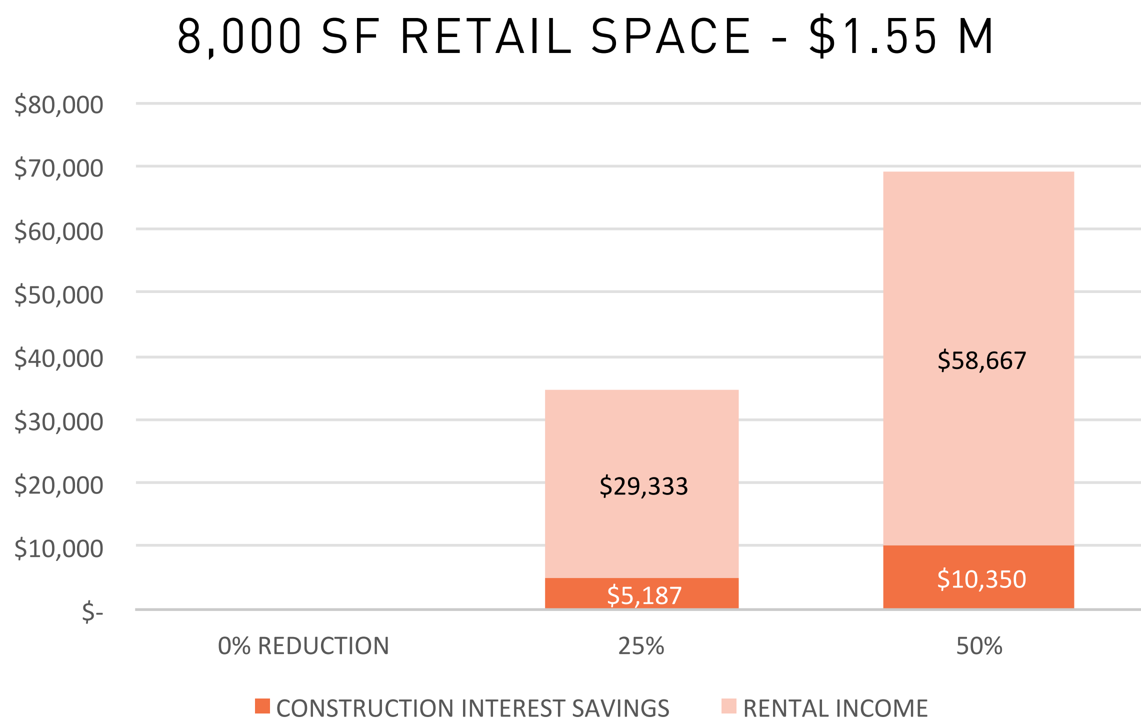

Figure 24

Pro-Formas include a cost reduction in terms of a 25% and 50% faster build time. The lease rate information assumes a 100% building occupancy to reflect the possible savings.

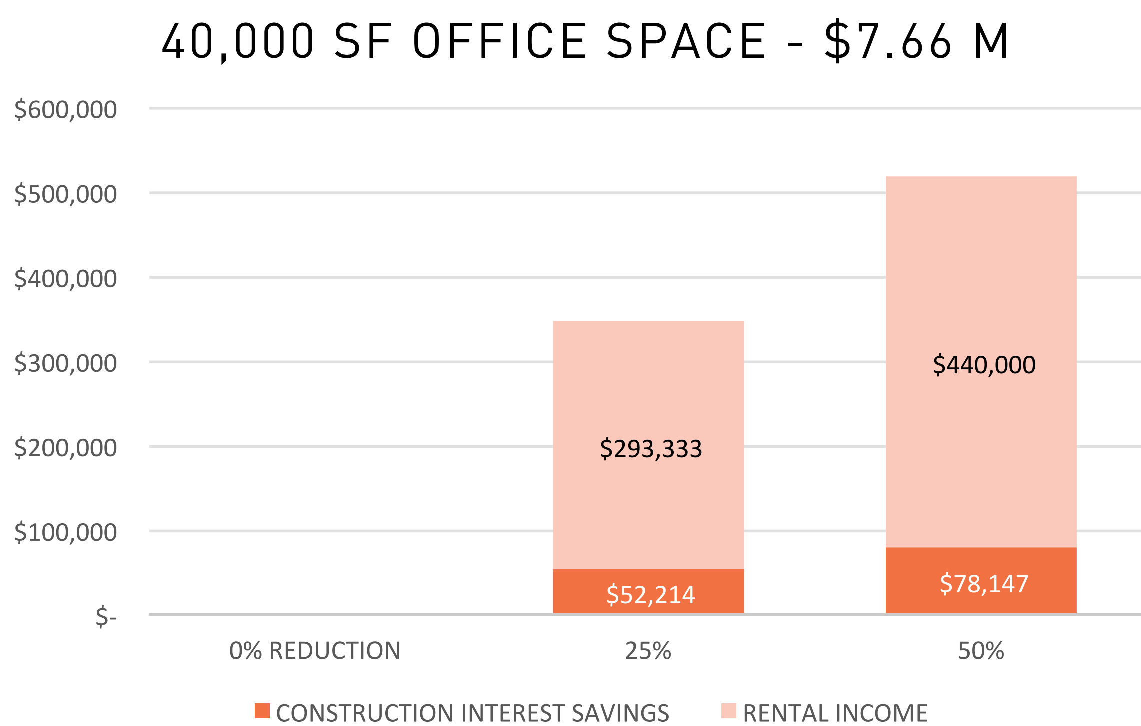

Figure 25

Pro-Formas include a cost reduction in terms of a 25% and 50% faster build time. The lease rate information assumes a 100% building occupancy to reflect the possible savings.

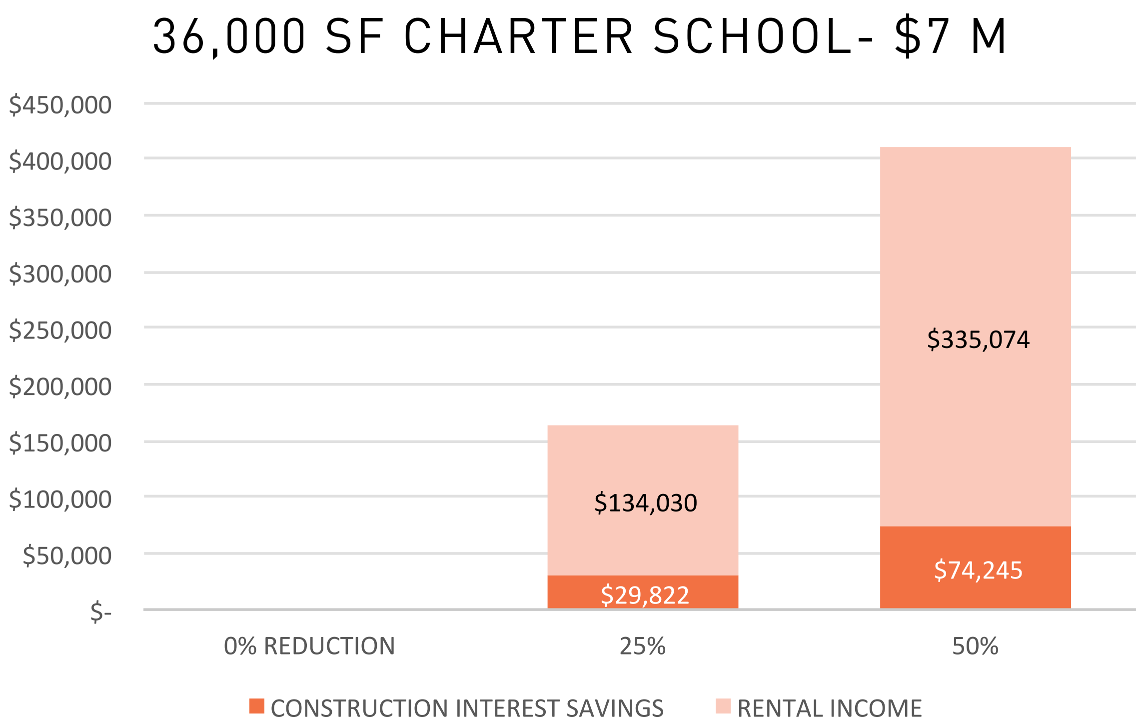

Figure 26

Pro-Formas include a cost reduction in terms of a 25% and 50% faster build time. The lease rate information assumes a 100% building occupancy to reflect the possible savings.

CONCLUSION

SUMMARY

The results from this study indicate:

Quantitative Analysis

Cost	16% Savings
Schedule	45% Savings
Quality	5.4 Average Change Orders
Safety	0.25 Average Safety Incidents

Qualitative Analysis

Why Chosen	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.
Successes	Permitting and transportation schedule overruns

Survey Analysis

Benefits	Schedule reduction during construction phase Quality of product Cost Effectiveness
Barriers	Design and construction culture Transportation costs and logistics Distance of factory to site Industry knowledge Labor unions

Collaboration	Increased collaboration between stakeholders through project lifecycle Decision to go PMC at schematic phase or later has negative impact
Decision Makers	CM/GC first, AE second and owners last

Return on Investment

25% Schedule Reduction	$5.81/SF Average
50% Schedule Reduction	$10.93/SF Average

MODULAR OUTLOOK

Modular construction is on the rise. Since the economic downturn of 2008, the demand of construction and the skilled labor supply for that construction followed suit. Yet, the skilled labor supply has increased at a lesser rate and has shown to level off, while the damand is still increasing. This presents a gap where modular construction can take advantage due to its lower labor requirements. See *Figure 27*.

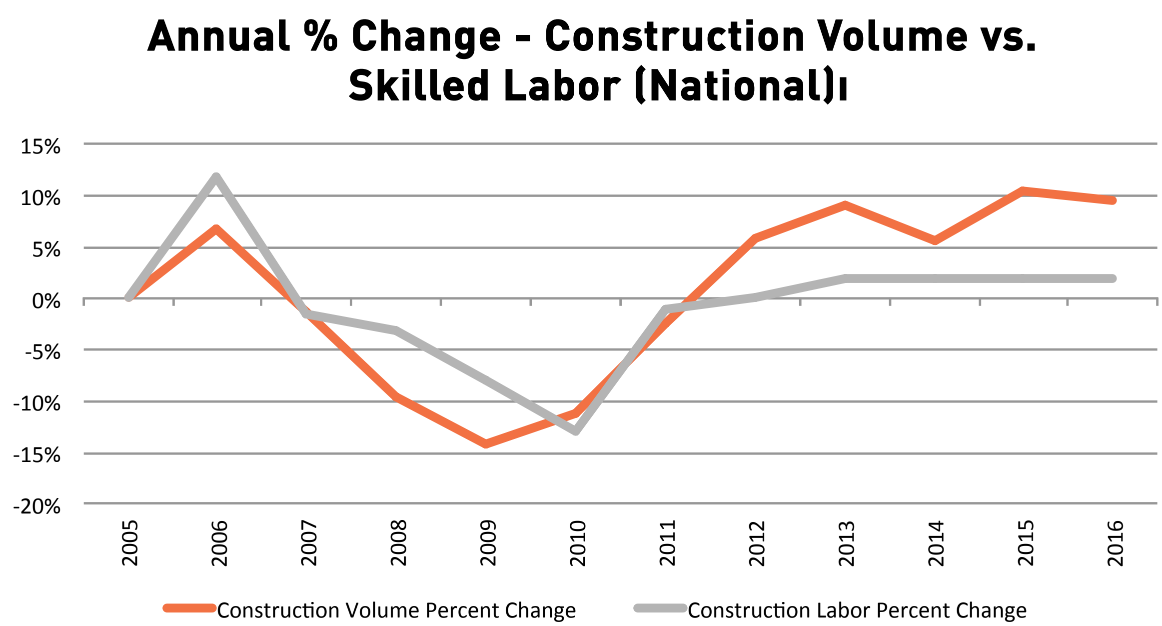

Figure 27
Construction volume vs skilled labor and its forecast showing a gap.

ALTERNATIVE METHODS

This studyis limited by sample size, lack 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 permanent modular 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 lifecycle benefits of off-site modular. This section discusses next steps in this research to demonstrate the performance of permanent modular construction. Suggestions for methods to conduct this future research are included herein.

The study took PMC projects and gathered quantitative and qualitative data for each case through literature sources and questionnaires of project stakeholders. This was followed by qualitative interviews of the architect, contractor and modular manufacturer. The data collected was compared to benchmark case studies by Cumming Corp., a cost estimation consultant. The benchmark projects were traditional site built projects completed in the last 10 years. Although cost data was normalized so the location factor was similar, it was challenging to find projects that were comparable enough to permanent modular construction cases to draw feasible claims that demonstrate the performance of modular.

Identifying a traditional site built project of similar size in overall square footage, height and number of stories, with similar specification is difficult. Peer review of this study suggests that future research use two suggested comparative methods to determine cost performance. See *Table 6.1.*

TABLE 7 - ALTERNATIVE METHODS

Two other methods were developed to compare PMC projects to conventional.

Method A	1. Locate a built project whose type is appropriate for permanent modular construction. 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 permanent modular 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 permanent modular construction including multifamily housing, office complex, corporate retailer, or a hotel chain that is building the same brand in two different cities (i.e. Starbucks or Fairfield Inn by Marriott) 2. Convince the building owners to build one in traditional stick built construction and the other in permanent modular construction. 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 owner, architect and contractor on each project to gather qualitative data. 5. Compare the site built to PMC project across the construction performance parameters and determine what contextual qualitative factors from the interviews lead to successfully PMC delivery.

METRIC STANDARDS

In addition to discovering alterative methods that may be more effective in determining performance of PMC, the study has also determined key metrics that should be followed in collecting data. This study collected quantitative data and comparative data based on the standards below. In future studies, the PMC research effort should continue to refer to sources that establish standards for quantitative data in construction including:

- ASTM
- ISO
- NIST

These standards suggest informational categories of: cost, schedule, incidents of injury, defects, and change orders, that we collected in this report. One data area that was not adequately collected in the 17 PMC case studies evaluated was labor hours. It rendered this metric area not comparable. This metric alone could allow traditional stick built work to be compared to PMC work. However, the traditional site built sector does not seemingly collect this data well either. In order for the construction sector to progress and track productivity effectively, labor hours need to be documented.

In addition to labor hours to measure productivity, the following metrics will aid in evaluating lifecycle benefits of construction. These include:

- Operational energy performance
- Construction energy and carbon performance
- Waste factors in construction
- Schedule per square foot
- Labor per square foot
- Incidents per square foot
- Change orders per square foot
- Defects per square foot

RESEARCH NEEDS ASSESSMENT

The process collecting data and interviewing stakeholders in the PMC industry has made the need to collect additional data and perform additional research clear. The survey used in this report should be updated and sent out annually to determine the current state of PMC in the market and perceptions of benefits and barriers. Further, the survey reported in this study demonstrates the need for an implementation guide in off-site construction broadly to aid construction professionals in realizing off-site delivery. Additional research is needed in the specific categories listed below. This list has been codified in partnership with the NIBS OSCC and Oregon BEST and occurs in no particular order.

TABLE 8 - RESEARCH NEEDS

The following is a list of research needs for Permanent Modular Construction

Labor	• Labor Skills • Labor Impacts • Health and Safety
Supply Chain	• Integration • Standardization
Market Assessment	• Benefits and Drivers • Perceptions • Levels of Use • When and where to use off-site
Regulatory Accomodation	• Performance based specifications
Transportation Logistics	• Cost Analysis • Technology Development • Regulatory
Design Constraints	• Impact

Performance Evaluation	• Intrinsic: Fire, Structure, Hygrothermal, etc. • Extrinsic: Cost, Schedule, Worker Safety, Quality, Enviornmentatl Impact (Life Cycle Analysis, Air Quality, Worker Safety, Maintenance, etc.)
Implementation	• Next Step in a Company • Best practices case studies • Educational tool development for different audiences
R&D New Product	• Product Development Model • Standardization across sectors • Commercialization and IP Evaluation
BIM and Fabrication	• Interoperability and IFC compliance design to fabrication • BIM Standards for Off-site Sectors
Efficiencies	• LEAN Construction
Factory Efficiencies	• LEAN Manufacturing • Cost estimating for manufacturers • Contract negotiating for manufacturers

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ASTM E2691 Standard Practice for Job Productivity Measurement

ASTM E631 Terminology of Building Constructions

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APPENDIX A
CASE STUDIES

The following case studies are developed based on the information gathered through questionnaires, interviews, and literature. Missing data left out of the following cases represents data not able to be procured through these methods. Cost information is the adjusted cost to the Washington DC locale in Q1 of 2014. The cost data is also a reflection of the vertical construction cost only; all site improvement, land aquisition, and utility improvements, etc. are not included. Traditional construction comparisons were provided by Cumming Corp.

Of the 17 original case studies, 8 projects had enough information for a comparative analysis.

XSTRATA NICKEL RIM SOUTH
ONTARIO, CAN

Architect: Allen and Sherriff Architects
Modular Builder: NRB Inc.
Contractor: NRB Inc.

ABOUT

The inherent ability of Permanent Modular Construction to reduce a building's schedule led to the success of this project. Modular Construction also lends itself easily to the achievement of a greener building. A LEED Gold project in a remote area such as this would have been much harder to complete if it were not for PMC.

GENERAL

OFFICE, INDUSTRIAL BUILDING TYPE

2008 YEAR COMPLETED

59,200 SQUARE FEET

126 STEEL MODULES

2 STORIES TALL

COST

$559K DESIGN COST

$12.7M CONSTRUCTION COST

SCHEDULE

9 MONTHS FROM START TO FINISH

6 MONTHS UNDER CONSTRUCTION

3 MONTHS FOR DESIGN

6-8 MONTHS IN FACTORY

4 MONTHS TO ERECT

$214.64 PER S.F.

34% LESS COST EFFECTIVE

305 MILES FROM FACTORY TO SITE

25% FASTER CONSTRUCTION

REFERENCES

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Greene, Troy. MMM Group

Images: NRB Inc.

	XSTRATA PROJECT	COMPARED PROJECT
CONSTRUCTION DURATION	6 MONTHS	12 MONTHS
STORIES AND CONSTRUCTION TYPE	2 STORIES STEEL	2 STORIES STEEL
SQUARE FOOTAGE	59,200	46,000
COST	$12.7M	$7.36M
COST/SF	$214.64	$159.97

THE MODULES
PHILADELPHIA, PA

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

ABOUT

The Modules project is a great example of how Permanent Modular 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 only constructed in 6 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

$3.6 M 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 S.F.

25.8% MORE COST EFFECTIVE

135 MILES FROM FACTORY TO SITE

63% FASTER CONSTRUCTION

LESSONS LEARNED

Permanent Modular 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, the importance of up front collaboration between the contractor, architect, and modular manufacturer would have avoided the issues of on-site 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 modular construction gives rise to the importance of starting the permitting and code approval process early.

Images: is-architects.com/the-modules

- Work with coding officials early
- Collaboration and communication will greatly improve the stitching process
- Improvements in factory construction knowledge to site construction knowledge

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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

MANRESA STUDENT HOUSING
MANRESA, SPAIN

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

ABOUT

High Quality is an inherent attribute of off-site construction. Manresa Student Housing boasts this trait while showing a schedule reduction of 56% and slightly less expensive. Permanent Modular Construction 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 S.F.

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 building.

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	44,240	55,000
COST	$9 M	$11.7M
COST/SF	$204.91	$213.33

THE STACK APARTMENTS
NEW YORK, NY

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 Apartments.

GENERAL

HOUSING BUILDING TYPE

2013 YEAR COMPLETED

38,000 SQUARE FEET

8 STORIES TALL

COST

$5.4M MODULAR CONTRACT

$7.3M CONST. COST

SCHEDULE

20 MONTHS FROM START TO FINISH

12 MONTHS UNDER CONSTRUCTION

4 MONTHS IN FACTORY

19 DAYS TO ERECT

$191.84 PER S.F.

10% MORE COST EFFECTIVE

125 MILES FROM FACTORY TO SITE

25% FASTER CONSTRUCTION

LESSONS LEARNED

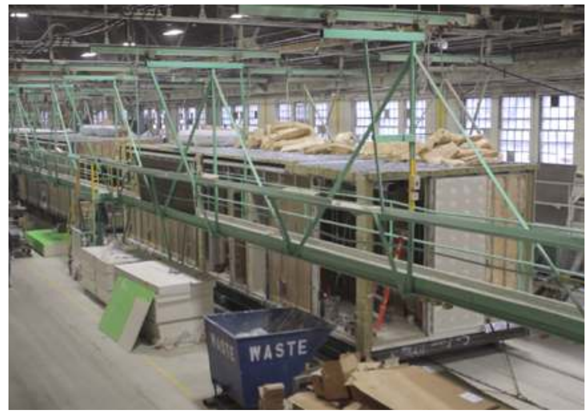
The difficulty in constructing a building with such an accelerated schedule is the collaboration between trades for permits and deadlines. In this building's case, a simple fault in insurance renewal led to a delay in schedule. "In the future, there will be more involvement in the drawing, fabrication and stitching processes."

- Ignoring small details can delay schedule greatly
- Thorough knowledge from fabrication to on-site stitching is crucial

REFERENCES

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

Erb, John. Deluxe Building Systems.



Images: Gluck+ and Amy Barkow

	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	$7.3 M	$11.7 M
COST/SF	$191.84	$213.33

STARBUCKS
MARYSVILLE, WA

Architect: RHL Design Group

Modular Builder: Blazer Industries

Contractor: Jackson Dean Construction

ABOUT

Starbucks conducted a small build program with a few modular stores. They found great success in achieving a look that is not tied to the modular construction method and had a full building in a very short time.

GENERAL

RETAIL BUILDING TYPE

2007 YEAR COMPLETED

1,763 SQUARE FEET

1 STORIES TALL

COST

$502K MODULAR CONTRACT

SCHEDULE

2 MONTHS IN FACTORY

10 DAYS TO ERECT

$284.74 PER S.F.

35% MORE COST EFFECTIVE

265 MILES FROM FACTORY TO SITE

16% FASTER CONSTRUCTION

LESSONS LEARNED

This project was constructed at very high quality and on a rapid build schedule. The success of this project was due to the benefits that a controlled factory environment can offer. Factory built modules generate less waste, the cost is controlled, and the safety risk is significantly reduced.

REFERENCES

Girard, David. Blazer Industries. Interview with Talbot Rice on 5.21.14

Images: Blazer Industries

	STARBUCKS	COMPARED PROJECT
CONSTRUCTION DURATION	2.5 MONTHS	3 MONTHS
STORIES AND CONSTRUCTION TYPE	1 STORY STEEL	1 STORY STEEL
SQUARE FOOTAGE	1,763	1,475
COST	$516K	$662K
COST/SF	$292.50	$448.85

MERCY HOSPITAL
JOPLIN, MO

Aspen Street Architects
Walden Structures
McCarthy Building Co.

ABOUT

The Mercy Hospital was a disaster relief project after a tornado in Missouri. The need for fast construction was imperative yet at the same time, a hospital of this caliber could not afford to lose quality. This building was one of the first of its kind and shows remarkable timesavings without quality loss.

GENERAL

HOSPITAL BUILDING TYPE

2012 YEAR COMPLETED

150,000 SQUARE FEET

270 STEEL MODULES

2 STORIES TALL

COST

$43.5M CONSTRUCTION COST

$1.8M DESIGN COST

SCHEDULE

11 MONTHS FROM START TO FINISH

8 MONTHS UNDER CONSTRUCTION

4 MONTHS FOR DESIGN

6 MONTHS IN FACTORY

2-3 MONTHS TO ERECT

$235.3 PER S.F.

30% MORE COST EFFECTIVE

1513 MILES FROM FACTORY TO SITE

60% FASTER CONSTRUCTION

LESSONS LEARNED

To provide such a high quality building in such a short amount of time is no easy task. The success of the project was certainly attributed to the collaboration of the Architect and Modular Manufacturer from the beginning and the dedication all trades had for the project. The building did run through some difficulties, however. Due to the fact that these entire buildings are modular, the critical decisions of materials and components present a high risk to the modular manufacturer as all the liability will fall on them. Unlike traditional buildings with many different companies providing different services to the building, most of the modular buildings are by the modular manufactuer. In this building's case, a wrong decision in flooring led to many legal difficulties and eventually the expiration of a company. Transportation from California to Missouri presented a few issues as it had delayed schedule a couple times. If it is any recommendation to reduce schedule, it would be to make sure the factory was relatively close by.

Images: McCarthy Building Co.

REFERENCES

Hitchcock, Bryan. Aspen Street Architects. Interview with Talbot Rice on 6.3.14

Meuschke, Stephen. McCarthy Building Co. Interview with Talbot Rice on 6.3.14

http://www.aspenstreetarchitects.com/modular-health-alliance/

	MERCY HOSPITAL	COMPARED PROJECT
CONSTRUCTION DURATION	8 MONTHS	20 MONTHS
STORIES AND CONSTRUCTION TYPE	2 STORY STEEL	3-4 STORY STEEL
SQUARE FOOTAGE	150,000	190,000
COST	$35.3M	$63.85M
COST/SF	$235.3	$336.06

HIGH TECH HIGH
SAN DIEGO, CA

Architect: Studio E Architects
Modular Builder: William Scotsman
Contractor: BYCOR
Structural Engineer: R & S Tavares Associates

ABOUT

The school is situated on an eight acre site in southeastern Chula Vista overlooking the Otay River Valley and Mexico to the south. The design of the school reflects the charter school's emphasis on three fundamental values – transparency, community and sustainability. The school is a combination of modular and site built construction. (Arch Daily)

GENERAL

EDUCATION BUILDING TYPE

2009 YEAR COMPLETED

61,445 SQUARE FEET

59 STEEL MODULES

1 STORIES TALL

COST

$7.9M CONSTRUCTION COST

$4M MODULAR CONTRACT

SCHEDULE

15 MONTHS FROM START TO FINISH

11 MONTHS UNDER CONSTRUCTION

4 MONTHS FOR DESIGN

2 MONTHS IN FACTORY

37 DAYS TO ERECT

$188.30 PER S.F.

40% MORE COST EFFECTIVE

10 MILES FROM FACTORY TO SITE

31% FASTER CONSTRUCTION

REFERENCES

Naslund, Eric. Studio E Architects. Interview with Talbot Rice on 6.17.14

Hudson, Valerie. BYCOR. Interview with Talbot Rice 6.11.14

http://www.archdaily.com/130879/high-tech-high-chula-vista-studio-e-architects/

Images: Studio E Architects, Jim Brady Architectural Photography, Christopher Gerber

	HIGH TECH HIGH	COMPARED PROJECT
CONSTRUCTION DURATION	11 MONTHS	17 MONTHS
STORIES AND CONSTRUCTION TYPE	1 STORY STEEL	4 STORIES STEEL
SQUARE FOOTAGE	61,445	73,000
COST	$11.57M	$22.8M
COST/SF	$188.30	$312.27

STEM SCHOOL
LAKE WASHINGTON, WA

Architect: Integrus Architecture
Modular Builder: M Space
Contractor: Absher Construction

ABOUT

The STEM school provides an efficient design for students and educators and represents the broad capabilities and limitless design opportunities when integrating permanent modular construction and traditional construction. (MSpace)

GENERAL

EDUCATION BUILDING TYPE

2010 YEAR COMPLETED

63,000 SQUARE FEET

160 STEEL + WOOD MODULES

2 STORIES TALL

COST

$15.6M CONST. COST

$10.2M MODULAR CONTRACT

SCHEDULE

15 MONTHS FROM START TO FINISH

12 MONTHS UNDER CONSTRUCTION

4 MONTHS FOR DESIGN

3 MONTHS IN FACTORY

3 WEEKS TO ERECT

$247.83 PER S.F.

21% MORE COST EFFECTIVE

200 MILES FROM FACTORY TO SITE

29% FASTER CONSTRUCTION

LESSONS LEARNED

Even though this project was a Design-Bid-Build, there was great collaboration between the trades. Several issues, such as structural alignment, point to the need for a design-build process in the future.

Images: Absher Construction

REFERENCES

Tiegs, Jeff. Absher Construction. Interview with Talbot Rice on 6.20.14

http://www.mspaceholdings.com/project/lake-washington-school-district

	STEM SCHOOL	COMPARED PROJECT
CONSTRUCTION DURATION	12 MONTHS	17 MONTHS
STORIES AND CONSTRUCTION TYPE	2 STORY STEEL	4 STORIES STEEL
SQUARE FOOTAGE	63,000	73,000
COST	$15.6 M	$22.8 M
COST/SF	$247.83	$312.27

APPENDIX B
COMPARATIVE ANALYSIS

INTRODUCTION

DESCRIPTION

This analysis compares multiple modular construction projects to a baseline control project reflecting a traditional construction approach. Analysis of total labor and material costs, total labor hours, and total design and construction schedules have been analyzed to understand the advantages of modular vs. traditional construction methods.

SOURCES USED

The following sources have been used in the course of the study:

- ITAC Research Team providing 10 different modular based projects (US and International)
- Davis Bacon Wage Rates
- RS Means Geographical Indices
- RS Means Standard Hourly Rates for the Construction Industry
- Cumming Corporation Internal Econ/Market Report

METHODOLOGY

The comparative analysis uses information provided by the research team for 10 modular projects that included raw cost and schedule data. Benchmark traditional projects were identified in the Cumming Corp. database. The modular and traditional build cases data was normalized for compariative function. The research team determined that 7 case studies were appropriate for reporting. In doing so, the following variables have been accounted for:

Timeline

All costs take to “current dollars” / Q1 2014 by using the following escalation %s:

2008	-	0.00%
2009	-	0.00%
2010	-	1.50%
2011	-	2.50%
2012	-	3.00%
2013	-	3.50%
2014	-	3.50%

Location

All costs have been modified to reflect current market conditions, labor rates, and taxes of the Washington DC construction market

Site Location

All costs have been modified from either Rural or City Center site locations to “Urban”. This adjusts cost and schedule variables for access, laydown, parking, working hour restrictions, etc. to a level play field.

Currency

All costs have been modified to reflect US $.

Quantities

All costs have been reflected over imperial measures ($/SF)

Delivery

All costs have been reflected over imperial measures ($/SF)

BASIS FOR UNIT COSTS

Unit costs are based on current bid prices in the Washington DC area. Subcontractor overhead and profit is included in each line item unit cost. This overhead and profit covers each subcontractor’s cost for labor, materials and equipment, sales taxes, field overhead, home office overhead, and profit. The general contractor's overhead and profit is shown separately.

ITEMS EXCLUDED FROM THE ANALYSIS

- Hazardous material abatement
- Utility infrastructure improvements/upsizing
- Professional design and consulting fees
- General building permit
- Testing and inspection fees
- Land acquisition costs

ITEMS AFFECTING THE COST ESTIMATE

- Items that may change the estimated construction cost include, but are not limited to:
- Modifications to the scope of work included in this estimate
- Unforeseen sub-surface conditions
- Restrictive technical specifications or excessive contract conditions
- Any specified item of equipment, material, or product that cannot be obtained from 3 sources
- Any other non-competitive bid situations
- Bids delayed beyond the projected schedule

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 4)

Project No: 14-00061.00
Date: 09/16/14

Comparison Summary (Permanent Modular)

		Traditional Construction - Confidential Benchmarks						Permanent Modular Samples									
Ref	Description	Student Res.	Hospital	Classroom	Shop	Office (HR)	Office (LR)	Xstrata (Office)	The Modules (Student Res.)	Manresa (Student Res.)	Inwood (Apartments)	Starbucks (Retail)	Mercy Hosp. (Healthcare)	Chula Vista HT (Classroom)	STEM School (Classroom)	Kirkham (CCC)	Wells Fargo (Retail / Bank)
1.	SF-age	55,000 SF	190,000 SF	73,000 SF	1,475 SF	154,960 SF	46,000 SF	59,200 SF	80,000 SF	44,239 SF	38,000 SF	1,763 SF	150,000 SF	61,445 SF	63,000 SF	9,000 SF	5,000 SF
2.	Stories	5	3	3	1	10	2	2.5	4	5	8	1	2	1	2	2	1
3.	Total Cost (USD $)	$11,733,182	$63,850,577	$22,795,894	$662,048	$37,010,974	$7,358,759	$12,706,580	$12,658,140	$9,065,187	$7,289,848	$515,686	$35,295,347	$11,569,837	$15,613,510	$900,543	$846,396
4.	Total Cost / SF	$213.33	$336.06	$312.27	$448.85	$238.84	$159.97	$214.64	$158.23	$204.91	$191.84	$292.50	$235.30	$188.30	$247.83	$100.06	$169.28
5.	Indirect Cost / SF (USD $)	$27.83	$43.83	$40.73	$68.47	$31.15	$20.87	$28.00	$20.64	$26.73	$25.02	$38.15	$30.69	$24.56	$32.33	$13.05	$22.08
6.	Material Cost / SF (USD $)	$83.48	$131.50	$122.19	$171.17	$93.46	$62.60	$85.86	$74.47	$90.87	$100.47	$123.60	$114.23	$88.45	$112.79	$49.81	$66.82
7.	Labor Cost / SF (USD $)	$102.03	$160.72	$149.35	$209.21	$114.23	$76.51	$100.78	$63.12	$87.31	$66.35	$130.75	$90.38	$75.28	$102.72	$37.19	$80.38
8.	Total Labor Hours	97,208	432,816	188,862	4,374	306,633	60,967	78,391	80,072	66,112	40,888	3,859	214,083	73,420	101,595	5,194	6,523
9.	Labor Hours / SF	1.77	2.28	2.59	2.97	1.98	1.33	1.32	1.00	1.49	1.08	2.19	1.43	1.19	1.61	0.58	1.30
10.	Construction in place / month *	$733,324	$3,192,529	$1,340,935	$220,683	$2,056,165	$613,230	$1,058,882	$1,406,460	$1,295,027	$607,487	$257,843	$4,411,918	$1,051,803	$1,301,126	$120,072	$211,599
11.	Mod vs Traditional Labour Hours / SF Comparison							1.98	1.77	1.77	1.77	2.97	2.28	2.59	2.59	TBD	2.97

Key Comparative Considerations:

# of Stories:	Affects structure size & type, wind loads, floor:skin ratios, glazed : non glazed surfaces, heat gain.
SF-age:	Affects building efficiences, grossing factors, economies of scale, opportunities for repetition.
Local Market Conditions:	The above assume typical bid conditions but each project would be open to key variables depending on time of bid, project size, labor availability, bid instructions, perceived risk, competing workload.

Limitations - Project Variables Not Yet "Levelled"

Project Size	The traditional construction benchmarks are representative of similar project "types" to the modular samples. Variances in overall SF-age, height, and configuration can affect economies of scale, building component relationships (eg - skin:floor ratio), wind loads, seismic considerations, project access, and labor productivity.
SF-age Program	The traditional construction benchmarks are representative of similar project "types" to the modular samples. Variances in program "make up" do exist such as comparing a retail sample with a retail : bank modular project.
Delivery Method	Each sample project will utilize variations on delivery method (design-bid-build, CM@Risk, negotiated, design-build). Each delivery model affects initial and final construction costs differently.
Bid Timing	We have not differentiated the above samples for any seasonal bidding trends. Q4 bids typically fall into the "optimum bid cycle" which can yield 3 - 5% in savings, spring and summer bids can trend the opposite.

* Assumes an equal spread of construction in place per month.

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 4)

Project No: 14-00061.00
Date: 09/16/14

Permanent Modular Summary / Comparison - Xstrata Nickel Rim South

		Xstrata Nickel Rim South Quantative Analysis				Baseline "Traditional" Comparison - Office (Low Rise) Quantative Analysis			
#	Description	Info	Unit	Total	Total / SF	Info	Unit	Total	Total / SF
1a	**Base Information**								
	Type	Office				Office Low Rise			
	Construction	2.5 Story / Steel				2 Story			
	Location	Otario, Canada				Washington DC			
	Timeline	Q1 / 2008				Q1 / 2014			
	Construction Schedule	12 Months				12 Months			
	GSF		59,200 SF				46,000 SF		
	Base Cost			**$12,717,500**	**$214.82**			**$7,358,759**	**$159.97**
	Adjusted Cost (see o/leaf)			**$12,706,580**	**$214.64**			**$7,358,759**	**$159.97**
1b	**Comparison**								
	Total Costs								
	Sitework			$6,353,290	$107.32			$323,617	$7.04
	Shell / Core			$5,082,632	$85.86			$3,257,244	$70.81
	Interior Fit Out			$1,270,658	$21.46			$3,777,898	$82.13
	GC Indirect Costs			incl above	incl above			incl above	incl above
				$12,706,580	**$214.64**			**$7,358,759**	**$159.97**
	Direct Cost Only								
	Labor / Equipment			$4,525,237	$76.44			$3,519,407	$76.51
	Materials (+ taxes)			$6,523,962	$110.20			$2,879,514	$62.60
	Labor Hours / Hours per SF			78,391	1.32			60,967	1.33
	Schedule - Design			4 Months	-			5 Months	-
	Schedule - Construction			9 Months	-			12 Months	-

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 3)

Project No: 14-00061.00
Date: 09/16/14

Permanent Modular Summary / Comparison - The Modules

#	Description	The Modules Quantative Analysis				Baseline "Traditional" Comparison - Residence Quantative Analysis			
		Info	Unit	Total	Total / SF	Info	Unit	Total	Total / SF
1a	**Base Information**								
	Type	Student Residence				Student Residence			
	Construction	5 Story / Wood				4 Story / Wood			
	Location	Philadelphia, PA				Washington DC			
	Timeline	Q2 / 2010				Q1 / 2014			
	Construction Schedule	9 Months				16 Months			
	GSF		80,000 SF				55,000 SF		
	Base Cost			**$11,000,000**	**$137.50**			**$11,733,182**	**$213.33**
	Adjusted Cost (see o/leaf)			**$12,658,140**	**$158.23**			**$11,733,182**	**$213.33**
1b	**Comparison**								
	Total Costs								
	Sitework			$1,265,814	$15.82			$1,183,744	$21.52
	Shell / Core			$6,329,070	$79.11			$5,356,392	$97.39
	Interior Fit Out			$5,063,256	$63.29			$5,193,046	$94.42
	GC Indirect Costs			incl above	incl above			incl above	incl above
				$12,658,140	**$158.23**			**$11,733,182**	**$213.33**
	Direct Cost Only								
	Labor / Equipment			$4,622,309	$57.78			$5,611,522	$102.03
	Materials (+ taxes)			$6,384,769	$79.81			$4,591,245	$83.48
	Labor Hours / Hours per SF			80,072	1.00			97,208	1.77
	Schedule - Design			2 Months	-			7 Months	-
	Schedule - Construction			9 Months	-			12 Months	-

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 3)

Project No: 14-00061.00
Date: 09/16/14

Permanent Modular Summary / Comparison - Manresa Student Apartments

#	Description	Manresa Student Apartments Quantative Analysis				Baseline "Traditional" Comparison - Student Housing Quantative Analysis			
		Info	Unit	Total	Total / SF	Info	Unit	Total	Total / SF
1a	**Base Information**								
	Type	Student Residence				Student Residence			
	Construction	5 Story / Modular				4 Story / Wood			
	Location	Manresa, Spain				Washington DC			
	Timeline	Q2 / 2008				Q1 / 2014			
	Construction Schedule	7 Months				16 Months			
	GSF		44,239 SF				55,000 SF		
	Base Cost			**3,640,254 €**	**€ 82.29**			**$11,733,182**	**$213.33**
	Adjusted Cost (see o/leaf)			**$9,065,187**	**$204.91**			**$11,733,182**	**$213.33**
1b	**Comparison**								
	Total Costs								
	Sitework			$906,519	$20.49			$1,183,744	$21.52
	Shell / Core			$4,532,594	$102.46			$5,356,392	$97.39
	Interior Fit Out			$3,626,075	$81.97			$5,193,046	$94.42
	GC Indirect Costs			incl above	incl above			incl above	incl above
				$9,065,187	**$204.91**			**$11,733,182**	**$213.33**
	Direct Cost Only								
	Labor / Equipment			$3,816,404	$86.27			$5,611,522	$102.03
	Materials (+ taxes)			$4,066,368	$91.92			$4,591,245	$83.48
	Labor Hours / Hours per SF			66,112	1.49			97,208	1.77
	Schedule - Design			2 Months	-			7 Months	-
	Schedule - Construction			7 Months	-			12 Months	-

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 3)

Project No: 14-00061.00
Date: 09/16/14

Permanent Modular Summary / Comparison - Inwood Apartments

#	Description	Inwood Apartments Quantative Analysis				Baseline "Traditional" Comparison - Student Housing Quantative Analysis			
		Info	Unit	Total	Total / SF	Info	Unit	Total	Total / SF
1a	**Base Information**								
	Type	Residence Apts				Student Residence			
	Construction	8 Story / Modular				4 Story / Wood			
	Location	New York, NY				Washington DC			
	Timeline	Q3 / 2012				Q1 / 2014			
	Construction Schedule	12 Months				16 Months			
	GSF		38,000 SF				55,000 SF		
	Base Cost			**$8,550,000**	**$225.00**			**$11,733,182**	**$213.33**
	Adjusted Cost (see o/leaf)			**$7,289,848**	**$191.84**			**$11,733,182**	**$213.33**
1b	**Comparison**								
	Total Costs								
	Sitework			$728,985	$19.18			$1,183,744	$21.52
	Shell / Core			$3,644,924	$95.92			$5,356,392	$97.39
	Interior Fit Out			$2,915,939	$76.74			$5,193,046	$94.42
	GC Indirect Costs			incl above	incl above			incl above	incl above
				$7,289,848	**$191.84**			**$11,733,182**	**$213.33**
	Direct Cost Only								
	Labor / Equipment			$2,360,330	$62.11			$5,611,522	$102.03
	Materials (+ taxes)			$3,978,669	$104.70			$4,591,245	$83.48
	Labor Hours / Hours per SF			40,888	1.08			97,208	1.77
	Schedule - Design			6 Months	-			7 Months	-
	Schedule - Construction			12 Months	-			12 Months	-

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 3)

Project No: 14-00061.00
Date: 09/16/14

Permanent Modular Summary / Comparison - Starbucks

		Starbucks Quantative Analysis				Baseline "Traditional" Comparison Quantative Analysis			
#	Description	Info	Unit	Total	Total / SF	Info	Unit	Total	Total / SF
1a	**Base Information**								
	Type	Retail				Retail Front			
	Construction	1 Story / Modular				1 Story			
	Location	Marysville, WA				Washington, DC			
	Timeline	Unknown				Current			
	Construction Schedule	Unknown				3 Months			
	GSF		1,763 SF				1,475 SF		
	Base Cost			**$502,016**	**$284.75**			**$662,048**	**$448.85**
	Adjusted Cost (see o/leaf)			**$515,686**	**$292.50**			**$662,048**	**$448.85**
1b	**Comparison**								
	Total Costs								
	Sitework			$51,569	$29.25			$61,676	$41.81
	Shell / Core			$257,843	$146.25			$293,046	$198.68
	Interior Fit Out			$206,274	$117.00			$307,327	$208.36
	GC Indirect Costs			incl above	incl above			N/A	N/A
				$515,686	**$292.50**			**N/A**	**N/A**
	Direct Cost Only								
	Labor / Equipment			$217,870	$123.58			$308,582	$209.21
	Materials (+ taxes)			$230,553	$130.77			$252,476	$171.17
	Labor Hours / Hours per SF			3,859	2.19			4,374	2.97
	Schedule - Design			Unknown	-			2 Months	N/A
	Schedule - Construction			Unknown	-			3 Months	N/A

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 3)

Project No: 14-00061.00
Date: 09/16/14

Permanent Modular Summary / Comparison - Mercy Hospital

#	Description	Mercy Hospital Quantative Analysis				Baseline "Traditional" Comparison Quantative Analysis			
		Info	Unit	Total	Total / SF	Info	Unit	Total	Total / SF
1a	**Base Information**								
	Type	Hospital				Hospital			
	Construction	2 Story / Modular				3 - 4			
	Location	Joplin, MO				Washington, DC			
	Timeline	Unknown				Current			
	Construction Schedule	8 Months				20 Months			
	GSF		150,000 SF				190,000 SF		
	Base Cost			**$43,500,000**	**$290.00**			**$63,850,577**	**$336.06**
	Adjusted Cost (see o/leaf)			**$35,295,347**	**$235.30**			**$63,850,577**	**$336.06**
1b	**Comparison**								
	Total Costs								
	Sitework			$3,529,535	$23.53			$2,720,297	$14.32
	Shell / Core			$17,647,674	$117.65			$28,262,497	$148.75
	Interior Fit Out			$14,118,139	$94.12			$32,867,782	$172.99
	GC Indirect Costs			incl above	incl above			incl above	incl above
				$35,295,347	**$235.30**			**$63,850,577**	**$336.06**
	Direct Cost Only								
	Labor / Equipment			$12,358,286	$82.39			$30,537,232	$160.72
	Materials (+ taxes)			$18,333,320	$122.22			$24,985,008	$131.50
	Labor Hours / Hours per SF			214,083	1.43			432,816	2.28
	Schedule - Design			6 Months	-			8 Months	-
	Schedule - Construction			8 Months	-			20 Months	-

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 3)

Project No: 14-00061.00
Date: 09/16/14

Permanent Modular Summary / Comparison - Chula Vista High Tech Classroom

#	Description	Chula Vista High Tech Classroom Quantative Analysis				Baseline "Traditional" Comparison Quantative Analysis			
		Info	Unit	Total	Total / SF	Info	Unit	Total	Total / SF
1a	**Base Information**								
	Type	Classroom				Classroom			
	Construction	1 Story / Modular				4 Story			
	Location	San Diego, CA				Washington, DC			
	Timeline	Q1 / 2008				Current			
	Construction Schedule	11 Months				17 Months			
	GSF		61,445 SF				73,000 SF		
	Base Cost			**$11,111,573**	**$180.84**			**$22,795,894**	**$312.27**
	Adjusted Cost (see o/leaf)			**$11,569,837**	**$188.30**			**$22,795,894**	**$312.27**
1b	**Comparison**								
	Total Costs								
	Sitework			$1,156,984	$18.83			$1,085,519	$14.87
	Shell / Core			$5,784,918	$94.15			$10,090,259	$138.22
	Interior Fit Out			$4,627,935	$75.32			$11,620,116	$159.18
	GC Indirect Costs			incl above	incl above			N/A	N/A
				$11,569,837	**$188.30**			**N/A**	**N/A**
	Direct Cost Only								
	Labor / Equipment			$4,238,290	$68.98			$10,902,384	$149.35
	Materials (+ taxes)			$5,822,437	$94.76			$8,920,132	$122.19
	Labor Hours / Hours per SF			73,420	1.19			188,862	2.59
	Schedule - Design			6 Months	-			7 Months	N/A
	Schedule - Construction			11 Months	-			17 Months	N/A

Permanent Modular Construction Analysis
Cost & Schedule Comparison
Various Locations, USA + International
High Level $ / SF Analysis (Rev 3)

Project No: 14-00061.00
Date: 09/16/14

Permanent Modular Summary / Comparison - STEM School

#	Description	STEM School Quantative Analysis				Baseline "Traditional" Comparison Quantative Analysis			
		Info	Unit	Total	Total / SF	Info	Unit	Total	Total / SF
1a	**Base Information**								
	Type	Classroom				Classroom			
	Construction	2 Story / Modular				4 Story			
	Location	Lake Wash., WA				Washington, DC			
	Timeline	2012				Current			
	Construction Schedule	12 Months				17 Months			
	GSF		63,000 SF				73,000 SF		
	Base Cost			**$15,700,000**	**$249.21**			**$22,795,894**	**$312.27**
	Adjusted Cost (see o/leaf)			**$15,613,510**	**$247.83**			**$22,795,894**	**$312.27**
1b	**Comparison**								
	Total Costs								
	Sitework			$1,561,351	$24.78			$1,085,519	$14.87
	Shell / Core			$7,806,755	$123.92			$10,090,259	$138.22
	Interior Fit Out			$6,245,404	$99.13			$11,620,116	$159.18
	GC Indirect Costs			incl above	incl above			N/A	N/A
				$15,613,510	**$247.83**			**N/A**	**N/A**
	Direct Cost Only								
	Labor / Equipment			$5,864,736	$93.09			$10,902,384	$149.35
	Materials (+ taxes)			$7,712,229	$122.42			$8,920,132	$122.19
	Labor Hours / Hours per SF			101,595	1.61			188,862	2.59
	Schedule - Design			4 Months	-			7 Months	N/A
	Schedule - Construction			12 Months	-			17 Months	N/A

ABOUT THE MODULAR BUILDING INSTITUTE

Founded in 1983, the Modular Building Institute (MBI) is the international non-profit trade association serving modular construction. Members are manufacturers, contractors, and dealers in two distinct segments of the industry - permanent modular construction (PMC) and relocatable buildings (RB). Associate members are companies supplying building components, services, and financing.

As the Voice of Commercial Modular Construction (TM), it is MBI's mission to expand the use of off-site construction through innovative construction practices, outreach and education to the construction community and customers, and recognition of high quality modular designs and facilities.

The MBI Educational Foundation (MBIEF) is the only organization established specifically to provide educational opportunities in the form of training and scholarships to individuals with an interest in commercial modular construction. Since 2001, the Foundation has trained over 1,000 industry professionals through its popular "Essentials of Commercial Modular Construction" educational series, begun intensive development of a modular buildings installation certificate program, awarded student scholarships and has spear-headed valuable industry research.

The MBI Canadian Foundation (MBICF) Mission: To expand opportunities, increase awareness and foster growth in the off-site construction industry, by supporting research and development, providing scholarships for students and developing partnerships and alliances with other complimentary interests. MBICF was approved by the Canada Revenue Agency in January 2011.

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ABOUT THE NATIONAL INSTITUTE OF BUILDING SCIENCES OFF-SITE CONSTRUCTION COUNCIL

The National Institute of Building Sciences is a non-profit, non-governmental organization that successfully brings together representatives of government, the professions, industry, labor and consumer interests, and regulatory agencies to focus on the identification and resolution of problems and potential problems that hamper the construction of safe, affordable structures for housing, commerce and industry throughout the United States. Authorized by the U.S. Congress, the Institute provides an authoritative source and a unique opportunity for free and candid discussion among private and public sectors within the built environment. The Institute's mission to serve the public interest is accomplished by supporting advances in building sciences and technologies for the purpose of improving the performance of our nation's buildings while reducing waste and conserving energy and resources.

The U.S. off-site design and construction industry has made significant advances in implementing processes and materials to build and deliver more sophisticated and complex facility types by virtue of system prefabrication, unitization, modularization and panelization. More and more owners are turning to off-site methods for multi-story wood construction, steel framed structures, healthcare facilities, educational structures and large-scale military projects. As an industry however, owners, architects, engineers and contractors up until now have lacked an unbiased source for evaluating the applicability and potential benefits for use of such methods, for determining where and when fabrication is appropriate, and for identifying the range of choices inherent in integrating and collaborating with fabricators.

In 2013, the National Institute of Building Sciences established the Off-Site Construction Council (OSCC) to serve as a research, education and outreach center for relevant and current information on off-site design and construction for commercial, institutional and multifamily facilities.

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ABOUT ITAC

The Integrated Technology in Architecture Center at the University of Utah's College of Architecture + Planning is an agent of change toward better buildings.

Faculty and students in the center research for buildings that are more construction efficient and energy efficient throughout their life cycle.

ITAC conducts activities with academic and industry partners, provides education in the form of teaching and workshops, and conducts outreach with university and community groups.

Expertise

- Research and development of sustainable building technologies through a holistic approach
- Off-site, modern methods of construction, and lean construction
- Optimization, energy efficiency strategies through passive design tactics
- Inquiry into digital workflow, parametric modeling, and BIM
- Study of integrated practice, collaboration and architect as leader in project delivery
- Knowledge management and transfer of innovative processes and products of construction

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PERMANENT MODULAR CONSTRUCTION
PROCESS, PRACTICE, PERFORMANCE

Ryan E. Smith and The Modular Building Institute