NEW HORIZONS
A Chance to Grow FOUNDATION An HVAC and Sheet Metal Industry Initiative™

vision
future

OFF-SITE CONSTRUCTION, MODULARIZATION, AND SHEET METAL PREFABRICATION: TRENDS, CURRENT PRACTICE, AND RECOMMENDATIONS

2015

Prepared By:

Jonathan W. Elliott, Ph.D.
Kevin Grosskopf, Ph.D.

EXECUTIVE SUMMARY

Reports produced by government and non-governmental agencies (NIST, MBI, FMI, NIBS, etc.) suggest significant cost, scheduling, safety, and environmental benefits result from off-site preassembly, prefabrication, and modularization of construction components. The vast majority of HVAC contractors surveyed reported project-level schedule reductions (78%), increased quality (72%), and overall cost-effectiveness (63%) as actual benefits realized from off-site construction[1]. FMI's[2] study of over 1000 electrical and mechanical contractors indicated that 93% of those surveyed forecast savings of over 15% on labor alone due to prefabrication/preassembly. Under the premise of this paper, New Horizons Foundation (NHF) researchers completed an in-depth review of literature to provide an aggregated overview of factors that influence off-site construction and its impact within the HVAC and sheet metal specialty.

As part of this study, NHF researchers in partnership with the National Institute of Building Science (NIBS) Off-Site Construction Council (OSCC) surveyed nearly 300 industry professionals on current trends in off-site construction with an emphasis on mechanical prefabrication, and compared this data to two comprehensive and industry-recognized surveys conducted by McGraw Hill Construction (MHC) and FMI. Finally, NHF acquired preliminary case study data from key industry members to provide an informed list of recommendations, lessons learned, and essential project criteria for successful implementation of preassembly and prefabrication techniques. This paper represents a foundational first phase in NHF modularization research. Further study will include comprehensive HVAC and sheet metal preassembly case studies and continued progress towards the establishment of a best practices guide for an industry trending towards modularization.

SCOPE OF WORK

This paper reviewed the most recent (2011-2014) literature and studies that explore the use of off-site techniques within the construction industry. Herein, industry-wide off-site construction data are distilled to the highest plausible degree to isolate HVAC and sheet metal-specific prefabrication trends and factors that contribute to project-level and Mechanical. Electrical, and Plumbing (MEP) contractor success. A major task was the review of the most recent, comprehensive, and industry recognized studies on off-site, prefabricated construction[3,4]. As part of this study the NHF researchers, in partnership with the NIBS OSCC, administered a survey to collect original data from various project stakeholders including HVAC and sheet metal contractors. Finally, based on the literature and existing study review, as well as the data produced via the NIBS survey, NHF researchers completed three interviews with sheet metal contractors implementing preassembly, prefabrication, and modularization techniques on commercial construction projects. Industry interviews were used as preliminary case-studies to identify lessons learned and pitfalls to avoid when approaching projects the maximize off-site construction techniques. This report focused on off-site construction from the perspective of prefabrication, and installation of preassembled building components within "traditional" site-built construction project delivery methods or systems (*see page 18 for detailed methodology*).

INDUSTRY SURVEYS

The review of literature (*see page 18-20 for detailed summary*) revealed several studies that have investigated the use of modularization techniques in the construction industry. This paper focuses on the two most significant recent prefabrication and modularization studies that were deemed worthy of detailed explanation due to the size and comprehensiveness of the participant samples.

The results of the studies conducted by MHC[3] and FMI[4], respectively, were reviewed, analyzed, and compared to the data collected by the NFH researchers in collaboration with NIBS. The following sections isolate appropriate data from the MHC and FMI surveys for comparison with the current NIBS data in an aggregated overview.

Table 1: Overview of Existing Studies						
Study 1:						
Author: MHC (2011)						
Title: Prefabrication and Modularization: Increasing Productivity in the Construction Industry						
Survey Respondent Summary: 809 Total Participants						
Participant Breakout:	101	Architects	190	Engineers	518	Contractors
Contractors Breakout (518):	79	Gen. Contractors	55	Con. Managers	119	Mech. Contractors
	141	Elec. Contractors	59	Fabricators	65	Design Build/ Other
Study 2:						
Author: FMI (2013)						
Title: Prefabrication and Modularization in Construction						
Survey Respondent Summary: Over 1000* Total Participants						
Participant Breakout:	100%	Contractors				
Contractor Breakout:	39%	Gen. Contractors	28%	Con. Managers	14%	Concrete Contractors
	7%	Mech. Contractors	3%	Elec. Contractors	8%	Other Contractors
**exact numbers of participants over 1000 was not reported by FMI, therefore, percentages were reported*						

NHF researchers in partnership with NIBS administered a survey in 2014 (*Appendix C*) intended to address the current implementation of off-site construction techniques (including prefabrication and modularization) and their impact on the construction industry as a whole. The NIBS survey was completed by 298 general contractor and construction managers, architects, engineers, and trade contractors.

For the purpose of this report the 74 trade contractor responses were isolated for analysis. Of the 74 trade contractor responses, 46 were members of the Sheet Metal and Air Conditioning National Association (SMACNA). Data from these 46 respondents were segregated to help better understand Sheet Metal/HVAC contractor experiences with the off-site construction techniques.

FACTORS DRIVING OFF-SITE CONSTRUCTION

Project owners recognize the benefits of prefabrication such as "reduced cost of off-site labor combined with the increased productivity of the fabrication shop"[3]. According to the NIBS survey, 22% of respondents reported that the client specifically requested prefabrication to be utilized on their project. Further, 84% of contractors, 90% of engineers, and 72% of architects surveyed reported that their construction projects utilize prefabrication or modularization techniques. "For mechanical and electrical contractors, the largest factor driving demand for prefabrication is to improve productivity. This is ultimately the focal point for other factors driving demand, such as improving the construction schedule, bidding competitively, and finding a way to make up for a shortage of skilled labor on the jobsite.[4]"

Table 2: Factors Driving Prefabrication Tends in Construction:

Source: MHC (2011)

	518 Contractors		***101 Architects***		***190 Engineers***	
Driver Reported:	**# of responses**	**%**	**# of responses**	**%**	**# of responses**	**%**
Improved Productivity	477	92%	69	68%	133	70%
Competitive Advantage	440	85%	53	52%	114	60%
Greater ROI	368	71%	40	40%	81.7	43%
Owner/Client Demand	161	31%	35	35%	96.9	51%

ADVANTAGES OF OFF-SITE

The most frequently touted advantages of off-site construction are reported in the literature as follows:

1. Improved project schedule/productivity
2. Reduced cost/budget advantages
3. Improved site safety
4. Reduced environmental impact (e.g. waste reduction).

The result of the surveys[3,4] support this claim from the perspective of all contractors and designers. The following table illustrates the advantages in schedule and cost reduction due to off-site construction techniques.

Contractors and HVAC trade responses ranked off-site construction advantage in the same order[1]. Interestingly, sustainable goals were ranked quite low as an advantage of prefabrication (only 11% by HVAC contractors). However, a reduction in site waste was identified as an advantage by 72% of the contractors surveyed[3]. This result could be interpreted as an indication that site waste reduction is associated more with cost savings than it is with environmental sustainability.

Table 3. Advantages of Prefabrication: Contractor and Designers		
Source: MHC (2011)		
Schedule	**# of responses**	**%**
Duration Reduced Due to PreFab	534	66%
4 weeks or more	283	35%
3 weeks	81	10%
2 weeks	113	14%
1 week	57	7%
Schedule Neutral	227	28%
Duration Increased Due to PreFab	49	6%
Cost Reduction	**# of responses**	**%**
Cost Reduced Due to PreFab	526	65%
1-5% Reduction	194	24%
6-10% Reduction	154	19%
11-20% Reduction	138	17%
Over 20% Reduction	40	5%
Cost Neutral	218	27%
Cost Increased Due to PreFab	65	8%
Safety	**# of responses**	**%**
Safety Neutral	453	56%
More Safe Due to PreFab	275	34%
Less Safe Due to PreFab	81	10%
Material Use/Waste Reduction	**# of responses**	**%**
Site Waste Reduced	582	72%
More than 5% Site Waste Reduction	356	44%
Less Material Used	65	8%

PREFABRICATION BY SECTOR

The top 5 building sectors using modularization are as follows (percentages represent the portion of building in the sector that utilized modulation/prefabricated components)[3]:

1. Healthcare (49%)
2. Higher Education (42%)
3. Manufacturing Facilities (42%)
4. Low-Rise Offices (40%)
5. Public Works (40%)

While the building sector names and definitions may vary slightly between the reports, the survey produced similar results. Interestingly the HVAC contractor-specific responses indicated that prefabrication was equally common in the "commercial", "industrial", and "healthcare" building sectors[3]. This result could be due to the fact that sheet metal and piping fabrication may be similarly utilized in the aforementioned sectors, whereas other prefabricated components (such as curtain wall assemblies) may be more prevalent in the "commercial" than in the "industrial" building sector when viewed from the perspective of a general contractor, architect, or engineer. That is, since the surveys[3,4] included over 1100 general contractor and designer responses, the use of prefabricated components in "commercial" construction appears higher due to the vast array of prefabricated components (aside from mechanical systems) that are currently utilized in commercial buildings.

Table 4: Utilization of Prefabrication by Building Sector				
Source: NIBS (2014)				
	All 298 Responses		***46 HVAC Contractors***	
Building Sector	**# of responses**	**%**	**# of responses**	**%**
Commercial	158	53%	30	65%
Industrial	146	49%	30	65%
Healthcare	125	42%	30	65%
Higher Education	104	35%	15	33%
Housing (Multi-Family)	69	23%	8	17%

PREFABRICATION BY COMPONENTS

Survey results indicated that prefabrication was utilized most often in MEP systems across all contractor and designer responses[3]. Nearly 2/3 (62%) of all contractors surveyed reported utilizing prefabricated components within the MEP trade specialty.

Table 5: Utilization of Prefabricated Components						
Source: MHC (2011)						
	518 Contractors		***101 Architects***		***190 Engineers***	
Component Category	**# of responses**	**%**	**# of responses**	**%**	**# of responses**	**%**
Mech., Elec., Plumbing	321	62%	69	68%	133	70%
Exterior Wall Systems	202	39%	53	52%	114	60%
Interior Wall Systems	161	31%	40	40%	81.7	43%
Superstructure Elements	155	30%	35	35%	96.9	51%

Further segregating the results shed light on where specialty and trade contractors are utilizing prefabricated components. HVAC contractor responses indicated the highest utilization of prefabrication techniques in "MEP risers, racks, etc.", which included single and multi-trade collaboration, as well as equipment skids[1]. Service pods and headwall assemblies were reported less frequently, a trend mirrored in contractor responses[3].

Table 6: HVAC Specific Prefabrication Utilization

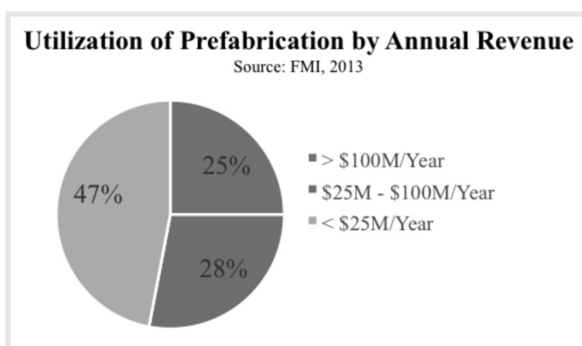
Source: NIBS (2014)

	298 Responses		*46 HVAC Contractors*	
Component Category/Subcategory	**# of responses**	**%**	**# of responses**	**%**
Mech., Elec., Plumbing				
MEP Risers, Rack, Etc.	119	40%	38	83%
Equipment Skids	89	30%	20	43%
Headwall Assemblies	42	14%	11	24%
Service Pods	27	9%	9	20%
Exterior Wall Systems				
Curtain Wall Assemblies	86	29%	2	4%
Exterior Wall Assemblies	80	27%	2	4%
Interior Wall Systems				
Interior Walls/Soffit Panels	42	14%	4	9%
Superstructure Elements				
Precast Concrete Structure	134	45%	6	13%
Steel Assemblies	125	42%	12	26%

PREFABRICATION BY ANNUAL REVENUE

Respondents (contractors and designers combined) who reported annual revenues under $25M were more involved in prefabrication processes than those who reported larger annual revenues[4]. While this initially may appear counterintuitive, it is plausible that contractors reporting smaller revenues may be trade contractors, such as those in the MEP and sheet metal specialty, who are utilizing prefabrication techniques on a regular basis.

Figure 1: MEP Contractor Cost Savings Resultant of Prefabrication



To further investigate this finding, the data was segregated by annual revenue and analyzed. Of the 46 mechanical trade contractors who responded, 34 provided annual revenue information. An annual revenue benchmark of $50 million was selected to divide the responses into two similarly sized groups. This allowed investigation of the differences in prefabrication and modularization component between contractors who report more or less than $50M in annual revenue. The results indicate that companies with larger revenues reported a higher frequency of prefabrication of headwall assemblies, equipment skids, and modular service pods[1].

Table 7: HVAC Specific Prefabrication Utilization by Annual Revenue				
Source: NIBS (2014)				
	20 HVAC Contractors < $50M		***14 HVAC Contractors > $50M***	
Component Category/ Subcategory	**# of responses**	**%**	**# of responses**	**%**
Mech., Elec., Plumbing				
MEP Risers, Rack, Etc.	18	90%	12	86%
Equipment Skids	7	35%	10	71%
Headwall Assemblies	4	20%	6	43%
Service Pods	2	10%	6	43%

REALIZED BENEFITS OF OFF-SITE

Respondents reported the actual benefits realized from off-site construction on the most successful project that utilized prefabrication/modularization. It was noted that the top 5 expected advantages and actual benefits of prefabrication and modularization were identical.

Table 8. Expected Benefits Realized from Off-Site Construction				
Source: NIBS (2014)				
	298 Contractors		***46 HVAC Contractors***	
Advantage	**# of responses**	**%**	**# of responses**	**%**
Schedule Advantage	218	73%	37	80%
Quality	179	60%	31	67%
Cost-Effectiveness	164	55%	30	65%
Site Operations	122	41%	23	50%
Safety	101	34%	22	48%
Weather Concerns	98	33%	13	28%
Sustainability Goals (e.g. LEED)	36	12%	5	11%

Table 9: Actual Benefits Realized from Off-Site Construction				
Source: NIBS, 2014				
	298 Contractors		**46 HVAC Contractors**	
Benefits Realized	**# of responses**	**%**	**# of responses**	**%**
Schedule advantage	209	70%	36	78%
Quality	179	60%	33	72%
Cost-effectiveness	146	49%	29	63%
Site Operations	119	40%	20	43%
Safety	104	35%	26	57%
Client Satisfaction	110	37%	26	57%

Table 10: Actual Benefits Realized by HVAC Contractor Annual Revenue				
Source: NIBS, 2014				
	20 HVAC < $50M		***14 HVAC > $50M***	
Benefits Realized	**# of responses**	**%**	**# of responses**	**%**
Schedule advantage	19	95%	11	79%
Quality	16	80%	10	71%
Cost-effectiveness	16	80%	9	64%
Safety	10	50%	9	64%
Client Satisfaction	11	55%	9	64%
Site Operations	8	40%	5	36%

LABOR RELATED COST SAVINGS

The skilled labor shortage in the construction industry is well-documented[5], yet the demand for shorter construction schedules and reduced construction budgets remains a constant pressure for contractors to remain competitive. One avenue to reducing the cost of construction is to reduce the cost on labor itself. Survey results indicated that 96% on MEP contractors reported labor cost saving in 2012 due to prefabrication. It was noted that 67% of MEP contractors reported shop prefabrication labor was less expensive than field labor, and 27% report shop and field labor were of equal cost. Since prefabrication presumably increases shop labor while reducing field labor, one could predict an overall cost saving resulting from a change in shop and field labor composition. Finally, as prefabrication continues to become more prevalent in the construction industry as a whole, MEP contractors predict an increased utilization of shop labor and a reduction in field labor between 2012 and 2019[4].

Figure 2: MEP Savings Resultant of Prefabrication

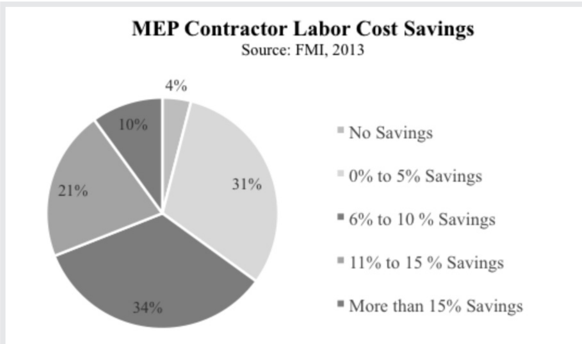
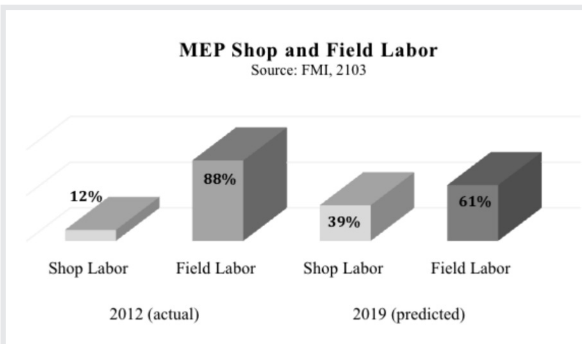


Figure 3: Labor Cost Composition



OFF-SITE CONSIDERATION: DECISION FACTOR

The top 5 reasons that non-users of modularization or prefabrication give for choosing not to incorporate off-site construction techniques on their projects are as follows[3]:

1. Architect did not design prefabricated/ modular into the project.
2. Project type was not applicable.
3. Not familiar with the process.
4. Owner does not want prefabricated/ modular elements.
5. Availability of a local prefab shop.

Similarly, the top 5 reasons that "users of modularization or prefabrication" (e.g. those that incorporate off-site techniques on some projects) give for choosing not to use prefabrication on a given project as follows:

1. Architect did not design prefabricated/ modular into the project.
2. Project type was not applicable.
3. Owner does not want prefabricated/ modular elements.
4. Availability of a local prefab shop.
5. Availability of a trained workforce.

Barriers, and the degree to which the barriers impede implementation of off-site construction techniques, were ranked on a 4-point scale (0 = not a barrier to 4 = a significant barrier)[1]. The mean scores for each item were used to rank the identified barrier. All project stakeholders and the HVAC and sheet metal trade contractors surveyed indicated that the "design and construction culture" was the greatest barrier. This result could be interpreted as in alignment with the MHC (2011 report) which identified "architect did not design prefabricated/modular into the project" as the number one reason for not implementing prefabricated components on a project.

Table 11: Barrier to Incorporating Off-Site Construction				
Source: NIBS, 2014				
Ranking based on mean score (0 = not a barrier to 4 = significant barrier)				
		298 Respondents		***46 HVAC Contractors***
Rank	**Barrier**	**Mean Score**	**Barrier**	**Mean Score**
1	Design + Construction Culture	2.78	Design + Construction Culture	2.76
2	Distance from factory to site	2.53	Program of the Building	2.60
3	Transportation	2.46	Transportation	2.51
4	Program of the Building	2.46	Industry Knowledge	2.44
5	Industry Knowledge	2.44	Distance from factory to site	2.31

When the data were segregated by annual revenue, differences were observed in HVAC contractor responses. While 'design and construction culture' remain the number one barrier for HVAC contractors with annual revenues under $50M, the 'program of the building' was the most important for HVAC contractors with annual revenues over $50M[1]. One could speculate that HVAC contractors with higher annual revenues may be involved in larger, perhaps more collaborative, projects in which they provide preconstruction services which impact early design, presumably making prefabrication easier. However, 'design and construction culture' remains the number two barrier for HVAC contractors with higher annual revenues.

Table 12: Barrier to Incorporating Off-Site Construction by HVAC Contractor Annual Revenue				
Source: NIBS, 2014				
Ranking based on mean score (0 = not a barrier"; to 4 = "significant barrier,)				
		20 HVAC < $50M		***14 HVAC > $50M***
Rank	**Barrier**	**Mean Score**	**Barrier**	**Mean Score**
1	Design + Construction Culture	2.71	Program of the Building	3.10
2	Industry Knowledge	2.57	Design + Construction Culture	2.90
3	Program of the Building	2.29	Cost vs. Value	2.70
4	Transportation	2.21	Supply Chain + Procurement	2.60
5	Site Operations	2.14	Transportation	2.50

The top four characteristics that influenced the decision to use off-site techniques were reported by contractors, architects, and engineers as follows:

1. Job site accessibility
2. The number on building stories
3. The type of building exterior
4. The layout on the building

Building characteristics 2, 3, and 4 above are all related to the "program of the building" which HVAC contractors identified as the number two barrier to implementation behind "design and construction culture"[1].

For the purpose of this report, "*traditional*" prefabrication is intended to describe a project scenario where and HVAC contractor creatively applies off-site prefabrication techniques within an existing project design to increase their own productivity, reduce cost, etc.

For the purpose of this report, "*advanced*" prefabrication is intended to describe a scenario where the HVAC contractor provides early design phase input to modify the project's design to make it conducive to off-site modular techniques to increase the overall project productivity, reduce cost, reduce project duration, etc.

HVAC CONTRACTOR INTERVIEWS

Three mechanical trade contractors were interviewed to gain their perspectives and shed light on practical considerations, lessons learned, and pitfalls to avoid when considering off-site fabrication on a given project. All three contractors regularly utilize "*traditional*" prefabrication of sheet metal assemblies that incorporate sheet metal and piping in-house and often involve additional non-self-performed trades such as electrical. Some of the contractors interviewed regularly complete "*advanced*" multi-trade MEP rack systems that contain three or more stacked MEP trades as well as drywall and/or other systems in a modular component. According to the contractors interviewed, multi-trade rack MEP corridor systems required a great deal of early-on coordination with the design team. Whereas, traditional prefabrication and component preassembly can more easily be adapted or incorporated within a design-bid-building project design and delivery system.

COMMON PROJECT CONSIDERATIONS

All contractors interviewed indicated that prefabrication and off-site techniques are considered and used on almost all projects, but clearly, larger prefabricated systems may not be the best or most advantageous approach for a sheet metal contractor on every job site. As with any construction method or technique, the contractors interviewed view prefabrication as a "tool in the toolbox", meaning that if it provides a financial advantage or competitive edge over other bidders then it should be considered. If prefabrication is not an avenue to achieve a financial advantage, then it's simply not the right "tool for the job" (that is, the project is not suitable for off-site fabrication).

All contractors interviewed agreed that, while off-site, prefabricated, and modular sheet metal components are incorporated in (almost) every project to some degree, the level of implementation and size of prefabrication assemblies is what needs to be closely evaluated on every project to determine if prefabrication makes sense. The following quote from one the contractors helps to further explain this topic:

> *"Sheet metal contractors by nature have to prefabricate their work, whether they choose to invest in a fabrication facility or just purchase fabricated duct from a facility…as opposed to a piping/plumbing contractor who has the choice of prefabricating or field building. If a sheet metal contractor chooses to pursue heavy fabrication projects, they will more than likely invest in a fabrication facility because it allows them to have greater flexibility with scheduling their work and in the long run it is more economical (caution should be noted here because there is an entirely separate discussion related to the investment and payback analysis of a fabrication facility)."*

Since each project presents a unique set of characteristics and variables beyond simply the repeatability of HVAC assemblies, the contractor interview identified myriad factors that should be considered when making the decision to pursue off-site fabrication.

Design Parameters

1. Identification of repeatable components and/or repeating layouts such as building cores, assemblies, or entire floors.
2. Designs with vertically stacked mechanical systems: riser, plenums, hot water/cold water supply (if applicable), electrical supply, etc., that facilitate consolidated connection points.
3. Structural MEP supporting rack system design and approval by engineers of record.

Logistics (location and transportation)

1. Distance from the shop, routes from shop to site, the moving and positioning of assemblies within the building, minimized site storage, and size restrictions when transporting assemblies (height and width restriction).
2. Identification of transportation bottle necks and pinch points that limit preassembled component/module sizes; e.g. freight elevators, corridors, and corners
3. The risk of just-in-time delivery,shop or off-site assembly storage in the case of overall project delays.

> *"The contractor must avoid loading up a project with modularized / fabricated duct all at once because they will end up spending a lot of money handling the duct multiple times to keep it out of the way of other trades. With a heavy fabrication / modularization component, the project schedule must incorporate fabrication activities into it so that the fabrication can be managed properly."*

Human Factors

1. The General Contractor's (and even a specific project superintendent's) willingness to help coordinate delivery schedules so that the benefits of off-site construction techniques can be realized.
2. Design team willingness to collaborate, especially in early design phase.
3. Owner/Clients understanding of prefabricated components and perception of quality.

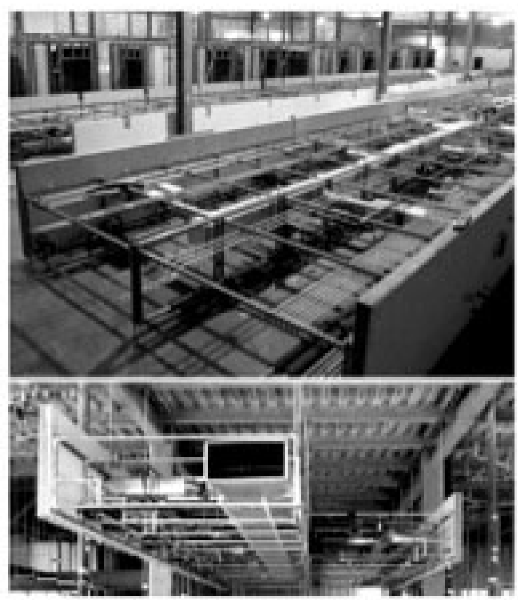
"TRADITIONAL" PREFABRICATION EXAMPLE

The following pictures illustrate a VAV system assembly that was replicated 84 times on the same project (42 VAV is each directional configuration attached to a main trunk line). The assembly includes a 12 foot flex duct and the appropriate electrical leads (installed

in the shop by the electrical contractor) for the fan box in one assembly. In this instance, several VAV assemblies were loaded on custom racks within a Conex container, transported to the site, rolled to the lifting location and zipped into their final location on site. Field connections included flex duct to diffuser, spiral connection to trunk loop, and electrical tie-in (by others). The contractor reported that shop labor hours substantially exceeded field labor hour on this project (allowing a labor reduction factor to be used) and the installation was duration reduced, affording the contractors a competitive advantage.

ADVANCED PREFABRICATION EXAMPLE

The following set of pictures represent the multi-trade MEP rack shop fabrication, lifting, and placing example for a multi-story medical facility. An example of a typical patient wing hospital corridor[6] (16 foot wide by 140 foot long) with a large variety, complexity and quantity on MEP and fire protection systems installed above the corridor's acoustical ceiling tile. An integrated multi-trade MEP racking approach was to shop fabricate corridor sections of the MEP system (perhaps 8 feet wide by 20 feet long) with flexible connections at the junction between each integration MEP rack. This system was enclosed on each side by a smoke-tight fire rated partition. For final install, the integration MEP racks are hung and field-built fire-rated corridor partitions are erected, defining the corridor and patient rooms.




MacDonald-Miller
FACILITY SOLUTIONS


MacDonald-Miller
FACILITY SOLUTIONS

BUSINESS-LEVEL CONSIDERATIONS

Beyond project-specific factors, preliminary case study interviews revealed that, while prefabricated components are common-place on most projects, the business-level decisions regarding ROI on a fabrication shop should be considered carefully. One of the mechanical contractor interviews identified that "caution should be noted [when considering projects maximizing off-site construction techniques] because there is an entirely separate discussion related to the investment and payback analysis of a fabrication facility". Tracking project-level efficiency clearly requires a different set of parameters then tracking the efficiency and effectiveness of owning a prefabrication facility. Only 55% of Mechanical and Electrical contractors indicated that they completed Return on Investment (ROI) calculation prior to making capital investment in prefabrication assets and over one quarter have never analyzed the efficiency of their prefabrication efforts.

OTHER LESSONS LEARNED

> *"The more work one can fabricate off site, the more successful the project will be in terms of manpower, schedule and risk. If you can fabricate work in a safe, controlled shop where all tools and equipment necessary to build the work is available, you reduce the number of people needed to install the work in the field. This allows field installation activities to be completed in shorter time frames."*

> *"The margins created by [advanced] modularization are very slim, and mistakes in the field quickly eat up any financial or schedule advantages gained through early coordination with the design team to incorporate modular components."*

INDUSTRY-INFORMED RECOMMENDATIONS

An experienced shop fabrication manager is critical

A strong shop fabrication manager, who knows how to build duct and knows how work is installed in the field, is essential. There is a lot of fabrication that works in theory, you must have a fabrication manager who knows what can actually be made with the equipment on hand.

The mechanical contractor must understand and communicate the seismic requirements

Working with the project structural engineering team as early as possible is critical, this collaboration provides engineers the opportunity to perform actual calculations instead of using generic live and dead load factors.

Understand the end-user requirements as early as possible during design

Design multi-trade racks so that stacked MEP trades are accessible for the end user (clearances of VAV, access panels, maintenance, etc.) during facilities and building operation post construction.

Understand and plan transportation and logistics

A thorough, well-planned and properly executed module delivery and site logistics plan is critical to success. The over-handling of assemblies and modules in transportation and field installation overshadows, eliminates, and nullifies any benefit realized from modularization. That is, any cost saved in the shop is quickly spent on unplanned material handling in the field.

Communicate with the Authorities Having Jurisdiction (Inspectors)

Completing inspections and required testing can be problematic: you must coordinate with inspectors for material or systems that are hidden in stacked MEP racks, (e.g. connections, pipe fittings, insulation, etc.)

If possible, establish an inspection and testing protocol with the authorities having jurisdiction that can be performed in the shop/ before assemblies leave the fabrication facility:

1. Duct leakage, pressurize piping, testing individual assemblies and recording the result for/with inspectors at the shop.
2. Complete air test on as much piping as possible BEFORE module leaves the assembly area.
3. Pre-test any medical gas piping before it gets buried within other trades.
4. Establish a company quality control protocol for reducing leaks/inspection failures during shop fabrication and modular assembly.

<u>Example:</u> A process for the multi-trade rack off-site mechanical inspections taking place on a project in Seattle, Washington:

1. Establish a multi-trade rack numbering and identification systems (rack tag) for each job.
2. Fully assemble the ductwork and mechanical equipment (VAV boxes or Fan Coil Units) into their final position on the multi-trade rack.
3. Cap all but 1 inlet and outlet on the system in preparation for the pressurization testing.
4. Complete a pressurized leakage test on the multi-trade rack system.
5. Document by photographing the test gage adjacent to the multi-trade rack tag so that the inspector has a reference in the field on which multi-trade rack was tested. For each rack provide a Pass/No Pass confirmation.
   - If the multi-trade rack fails the leakage test, document that the system failed, identify the steps taken to fix the problem, and retest that specific rack again either onsite, or if time allowed, at the shop. This should show the inspector that we were willing to identify failures, identify the procedures to fix them, and document that they were fixed prior to being hung in the air and buried.
6. Combine all testing documentation in a package to follow each delivery of multi-trade racks to the jobsite for review as needed by the Inspector in the field.

Finally, in advanced prefabrication, an overarching recommendation for a contractor approaching multi-trade MEP racks is to identify the repeatable components and work with the design team and Owner to design these systems into the project as soon as possible. The greatest strategic advantages, and the most project margin, can be gained in the most congested multi-trade areas. One of the contractors interviewed believes that multi-trade racks are not cost-effective for the end user unless more than three trades can be included on a rack. While some of the trades may be performed by the same contractors (sheet metal and piping for example), the largest gains are seen when subcontractors (including drywall, and finishes if possible) are working together on a single coordinated MEP rack system.

CONCLUSIONS AND FURTHER RESEARCH

This report represents a foundational first phase in NHF off-site construction and sheet metal modularization research. Under the premise of this initial project, the NHF researchers worked in close collaboration with NIBS to survey nearly 300 construction project stakeholders to quantitatively assess the current trend and use of off-site construction techniques within the HVAC and sheet metal specialty. The original data collected via the NIBS survey[1] was compared to the two most prominent construction industry prefabrication and modularization studies (FMI[2] and MHC[3]). In addition, three preliminary case study interviews were conducted to gain input from mechanical contractors on lessons learned and pitfalls to avoid when participating in projects that maximize off-site construction techniques.

Report findings generally confirm those of FMI[2] and MHC[3] while furthering the understanding of the impact of an industry trending toward off-site construction techniques for HVAC and sheet metal trade contractors. All stakeholders surveyed reported that the most common instance of off-site construction was in MEP systems; among HVAC contractors, prefabricated MEP risers and equipment skids were more heavily utilized than were headwall assemblies and volumetric service pods (such as restrooms). Of all contractors, those with smaller annual revenues (< $25M, presumably a heavier concentration of specialty trades) utilize prefabrication and off-site construction techniques more regularly than those with larger annual revenues ($25M-$100). The most frequently reported benefits to the implementation of off-site construction techniques were: 1) schedule reductions, 2) increased quality, and 3) reduced cost.

As with many technological advances in the construction industry, the preliminary case study interviews revealed that maintaining high levels of communication and coordination with all project stakeholders (designers, owner, facility manager, authorities having jurisdiction, etc.) is paramount for realizing the benefits of off-site prefabrication and modular construction. While it appears that most mechanical contractors participate at some level in component prefabrication and preassembly (e.g., the "traditional" off-site construction techniques described in this paper), fewer contractors participate in "advanced" prefabrication processes that involve a large number of trade contractors collaboration.

As the market slowly shifts toward off-site construction, this paper presents an industry-informed list of lessons learned and associated recommendations for mechanical contractors as they approach projects that maximize MEP system modularization. Many of the recommendations within this report address fostering and facilitating a team atmosphere where all project stakeholders communicate openly to incorporate off-site construction techniques efficiently and effectively to achieve project goals. As the foundational, first phase of NHF research in HVAC and sheet metal-specific off-site construction, the aim of this study was to provide the groundwork for continued investigation and in-depth sheet metal modularization and off-site construction case studies. In depth, data rich, project-specific case study data would allow the researchers and NHF to develop a sheet metal contractor's how-to-guide for approaching and successfully executing construction projects that maximize the use of off-site construction techniques.
A more comprehensive and nuanced understanding of the lessons learned and off-site construction pitfalls to avoid through in-depth off-site construction case studies would constitute a significant step toward addressing NHF's ultimate question: "How does a sheet metal contractor make off-site construction work for their company?

SUPPLEMENTAL MATERIALS

Expanded Scope

This paper focused on the most recent (2011-2014) literature and studies exploring the use of off-site techniques within the construction industry. Herein, the overall trends in off-site construction are distilled to address those that pertained specifically to HVAC and sheet metal trade contractors. In order to achieve this goal, the literature review progressed from broad topics in general contracting (and the views of owners, designers and general contractors) to mechanical, electrical, and plumbing (MEP) specific trends, and finally removes electrical contractors data to the highest plausible degree to isolate HVAC and sheet metal-specific prefabrication trends and factors that contribute to project and business success.

A major task included within the scope was review of the most recent, comprehensive, and industry recognized studies on off-site, prefabricated construction[3,4] that investigate the trend towards off-site construction practices within the construction industry as a whole. This review produced an aggregated overview of the use and impact of modularization on the construction industry from multiple stakeholder perspectives including, but not limited to, project owners, designers, general contractors, and trades contractors including the mechanical and sheet metal specialty.

Next, the NHF researchers in partnership with the NIBS OSCC Off-Site Construction Council, administered a survey to collect original data from various project stakeholders including HVAC and sheet metal contractors. The responses from HVAC and sheet metal specialty contractors were isolated, aggregated, and analyzed. The results of the data analysis and the alignment of NIBS survey findings with previous studies are presented.

Finally, based on the literature and existing study review, as well as the data produced via the NIBS survey administration, NHF researchers completed three interviews with sheet metal contractors implementing preassembly, prefabrication and modularization techniques on commercial construction projects. The HVAC and sheet metal contractor interviews were completed to shed light on some lessons learned and pitfalls to avoid when approaching and executing construction projects that maximize, or intend to maximize, the implementation of off-site construction techniques. Two of the HVAC contractors interviewed are currently implementing off-site construction techniques (prefabrication and preassembly) within their mechanical and sheet metal shop with the incorporation of a few additional trades (in-house piping and third party electrical, etc.). The other contractor has experience working on projects that incorporate large scale coordinated multi-trade MEP racks and stand-alone non-structural service pods.

Background and Literature Review Summary

Since previous works have investigated, and discussed at length, the recent history of the prefabrication, preassembly, and modularization in the construction industry[7], this paper explores the use of off-site techniques within the construction industry reported between 2011 and 2014. Off-site construction has several forms and facets that are often cobbled together and/or used interchangeably with “modular construction”. Further, the term “modular construction”, in and of itself, is wrought with misconceptions, stereotypes, stigma, and confusion regarding its quality, definition and scope[3]. For the purpose of this report, off-site construction is broadly defined by the National Institute of Building

Science[7] as the "process of planning, designing, fabricating, transporting, and assembling building elements for rapid site assembly to a greater degree of finish than in traditional piecemeal on-site construction." Within the off-site construction arena, true modular buildings contain the most complete building sections or components and require the least amount of finishing when delivered and installed on site.

Upon hearing "modular" many people envision a pre-manufactured home and, while manufactured housing does represent a fairly well-developed sector of the modular construction industry, there are distinct differences between commercial and single-family residential modular construction. Pre-manufactured homes are often considered temporary or relocatable housing, and are built to U.S. Department of Housing and Urban Development (HUD) standards while permanent residential (and most commercial) modular buildings generally adhere to the national building codes[8].

Commercial modular buildings are generally divided into two major categories: permanent modular construction (PMC) and Relocatable Buildings (RB). RBs are intended for a shorter service life and can be moved to a new location at the end of the use period. Common commercial RB examples are temporary classrooms, laboratories, and communication centers. Fully implemented PMC sits at the opposite end of the commercial modular spectrum, in that PMC replaces traditional site-built construction project delivery. PMC buildings are intended to have the same feel, be of equal (or higher) quality, and possess the same service-life as comparable site-constructed permanent structures. Generally both commercial PMC and RB are designed and built to adhere to the International Building Code (IBC), a state-adopted adaptation thereof, or code systems modeled after IBC.

However, from an industry market perspective, it should be noted that, the total value of true "turnkey commercial PMC" (lodging, multifamily, office, commercial, healthcare, education and religious combined) comprised only 1.3% ($3 of $231 Billion) of the construction in this market segment in 2013[8].

A distinctly important, yet subtle, difference in off-site construction is that "PMC refers to three-dimensional (or volumetric) building modules that are prefabricated off-site and transported to the site to make up portions of, or the entire building, rather than prefabricated mechanical systems or wall assemblies"[8]. This report does not exclude PMC, rather it focuses on off-site construction from the perspective of prefabrication and installation of preassembled building components within "traditional" site-built construction project delivery methods or systems. For example, the inclusion of non-structure (3D, volumetric) building modules, such as restroom service pods, mechanical rooms as well as 2-dimentional (Planar) wall panels, head walls, and other assemblies that are implemented in a traditional site-built superstructure[3].

Construction component pre-fabrication and preassembly are certainly not new concepts and one could argue that "modular" systems and components are currently utilized in our industry at fairly high frequency. For example, precast cladding system, structural insulated panels (SIP), pre-hung doors, roof-top air handling units, etc., are components that meet the definition of preassembled or pre-manufactured off-site construction components that are implemented or installed on nearly all traditional site-building construction projects. However, as pre-assembled construction components become larger, more complex, inclusive of multiple specialty trades, requiring greater levels of design and construction coordination, the distinct line between manufacturing and construction is blurred.

Comparison of the premanufactured or modular construction to automobile production is common[8]. However, in most cases it is not a parallel comparison. One must consider the differences and variability which exists between most once-off building designs and the repetitious production of thousands of the supposedly identical automobiles. This is not to say that some of the lessons learned and techniques employed in manufacturing processes cannot be applied to premanufacturing in construction, but rather that these advantages need to be considered in light of each building and specialty trade's unique set of requirements and characteristics. Much like the creation of an automobile prototype, which presumably become more efficient over time as a company gains experience in prototype design and fabrication, off-site construction processes can become more efficient as experience is gained in prefabrication and preassembly. However, each construction project, even if the building is replicated from a previous design, represents its own set of unique variables due to site constraints, quality of work performed by others, structural building component tolerances, etc.

For contractors working in sheet metal modularization, identification of off-site techniques that are independent of, or mitigated by, project variability will likely lead to value gained at the company's bottom line. Simply stated, off-site construction techniques that are applicable to a commercial construction project regardless of its geographic location, the design team, or owner, etc. will be applicable to a sheet metal fabricator's practices on all projects. However, it is the identification of project-specific factors that *should* be considered when deciding if off-site techniques make sense for a given project. Optimization of a company's fabrication capabilities and processes that can be applied to all projects should be considered low-hanging fruit, and it is the techniques that provide project-specific competitive advantages and increase job-specific productivity and/or profitability that pose the greatest challenges (and potential opportunities) for a sheet metal contractor.

The marketing of modular construction advantages coupled with a documented lack of skilled construction labor[5] and constant pressure to increase productivity, shorten project duration, lower costs, and reduce environmental impact, has brought this topic to the forefront of the construction industry. Questions exist regarding a small to medium sized contractor's ability to invest the upfront implementation costs of prefabrication and preassembly equipment in order to stay competitive. That is, HVAC and sheet metal contractors with large annual revenue (>$100M[4]) may have more financial resources than a smaller contractor,which justifies capital investments in preassembly and premanufacturing (facilities, equipment, training, materials) with longer returns on investment (ROIs). However, regardless of a company's current level of implementation, pre-fabrication and preassembly represents a burgeoning area of opportunity for progressive specialty trades contractors. Existing challenges, such as the labor shortage, the proliferation of new technologies, and an overall increase in competitiveness in the current construction market had led to research studies attempting to gauge the current level of utilization of off-site construction techniques as well as identify its advantages and the existing barriers to implementation.

ACKNOWLEDGEMENTS

The NHF researchers would like to thank the following organizations for their participation and partnership in the research and providing valuable data and insights:

National Institute of Building Science:
Off-Site Construction Council
(http://www.nibs.org/?page=oscc)

U.S. Engineering
(http://www.usengineering.com/)

Trautman and Shreve
(http://www.trautman-shreve.com/)

Macdonald Miller
(http://macmiller.com/)

And all the individual SMACNA members who completed the NIBS online survey

APPENDIX A: DEFINITION OF TERMS

Due to the variation in the complexity and level of implementation of modular construction systems, as well as differing definitions and terms used to describe its scope, an initial step in the research process was to define the different facets of off-site construction and classify/assess their impact on HVAC and sheet metal contractors.

Off-Site Construction: The process of planning, designing, fabricating, transporting and assembling building elements for rapid site assembly to a greater degree of finish than in traditional piecemeal on-site construction.[7]

Permanent Modular Construction (PMC): 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.[8]

Relocatable Buildings (RB): A partially or completely assembled building that complies with applicable codes and state regulations, and is constructed in a building manufacturing facility using a modular construction process. Relocatable modular buildings are designed to be reused or repurposed multiple times and transported to different sites.[7]

Pods: Nonstructural modular units, such as toilets and bathrooms that are supported directly on the floors of a building.[9]

Planar Construction: Two-dimensional panels, used mainly for walls, that can be prefinished with the insulation and boarding attached before delivery to the site.[8]

Prefabrication: A manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of a final installation.[10] These prefabricated components often only involve the work of a single craft.[11]

Preassembly: The process by which various materials, prefabricated components, and/or equipment are joined together at a remote location for subsequent installation as a unit.[9] Preassembly is generally considered to be a combination of prefabrication and modularization. It may use fabricated components made off-site and then assembled near the site. These units can then be installed at the site, similar to modules.[10]

Modularization: The preconstruction of a complete system away from the job site that is then transported to the site. The modules are large in size and possibly may need to be broken down into several smaller pieces for transport. Usually more than one trade is involved in the assembly of a module.[10]

APPENDIX B: ENDNOTES

[1] National Institute for Building Science. Off-Site Construction Council. http://www.nibs.org/?page=oscc

[2] FMI Corporation. (2012). Modularization and prefabrication - Role Development and Evolution. http://www.fminet.com/media/pdf/article/ModularizationandPrefab_Trends2012.pdf

[3] McGraw Hill Construction. (2011). Prefabrication and modularization: Increasing productivity in the construction industry. http://construction.com/market_research/FreeReport/PrefabSMR/

[4] FMI Corporation. (2013). Prefabrication and modularization in construction: 2013 survey results. http://www.fminet.com/media/pdf/report/PrefabricationSurvey2013.pdf

[5] National Center for Construction Education and Research. (2013). Craft workforce development 2013 and beyond: A case for greater stakeholder commitment. http://www.nccer.org/uploads/fileLibrary/Craft_WFD_2013_And_Beyond.pdf

[6] Nbbj Architects (2014). Photo and Description. Miami Valley Hospital Part 5: Integrated MEP Rack. http://www.nbbj.com/work/miami-valley-hospital-heart-and-orthopedic-center/, for additional information see https://www.youtube.com/watch?v=xP-LOsmRbrM

[7] Smith, R. (2014). National Institute of Building Science. Whole Building Design Guide. http://www.wbdg.org/resources/offsiteconstructionexplained.php

[8] Modular Building Institute. (2014). Permanent modular construction: 2014 Annual Report. http://www.modular.org/HtmlPage.aspx?name=2014_Annual_Reports_MA

[9] Lawson, M., Ogden, R., & Goodier, C. (2014). Design in Modular Construction. CRC Press. Boca Raton, Florida

[10] Tatum, C. B., Vanegas, J. A., and Williams, J. M. (1987). Constructability Improvement Using Prefabrication, Preassembly, and Modularization, Construction Industry Institute, The University of Texas at Austin.

[11] Haas, et al. (2000). Prefabrication And Preassembly Trends And Effects On The Construction Workforce. http://www.caee.utexas.edu/org/ccis/a_ccis_report_14.pdf

APPENDIX C: NATIONAL INSTITUTE OF BUILDING SCIENCE: OFF-SITE CONSTRUCTION COUNCIL SURVEY

National Institute of BUILDING SCIENCES
An Authoritative Source of Innovative Solutions for the Built Environment

Off-Site Construction Industry Survey

The purpose of this survey is to identify the opportunities and challenges associated with the use of off-site construction processes and technologies and how the National Institute of Building Sciences can foster the utilization of off-site construction to support high-performance buildings. This survey is anonymous. Your answers will be included in the aggregate only. There is an option to leave contact information at the end of the questions to allow follow-up, but this is voluntary.

1. I have incorporated the following off-site elements in one or more projects in the last 12 months. (check all that apply)

- ☐ Precast concrete structure
- ☐ Cross laminated timber structure
- ☐ Prefabricated exterior wall assemblies
- ☐ Curtainwall assemblies
- ☐ Permanent building modules (i.e. volumetric construction)
- ☐ Prefabricated interior wall or soffit panels
- ☐ Service pods (bathrooms, utility rooms, etc.)
- ☐ HVAC, Plumbing and Electrical racks, risers and other assemblies (single trade or multi-trade)
- ☐ Headwall assemblies
- ☐ Equipment skids
- ☐ Steel Assemblies
- ☐ None

Other (please specify)

2. Rate the barriers to implementing off-site construction?

	No Barrier	Small Barrier	Moderate Barrier	Significant Barrier
Industry Knowledge	○	○	○	○
Cost vs. Value	○	○	○	○
Design + Construction Culture	○	○	○	○
Program of the Building	○	○	○	○
Lack of Skills	○	○	○	○
Concern for Quality	○	○	○	○
Supply Chain + Procurement	○	○	○	○
Regulations + Codes	○	○	○	○
Site Operations	○	○	○	○
Health + Safety Risks	○	○	○	○
Transportation	○	○	○	○
Financing + Insurance	○	○	○	○
Manufacturing Technology	○	○	○	○
Urban Site	○	○	○	○
Rural Site	○	○	○	○
Distance from factory to site	○	○	○	○

Other (please specify)

3. Considering the most successful project that utilized off-site construction, what was the distance from the factory to the site?

4. During project planning phase for this project, who was responsible for the decision to use off-site? (select all that apply)

- ☐ Client Request
- ☐ Architect Specified
- ☐ Engineer specified
- ☐ Construction Manager or GC requested or required
- ☐ Other (please specify)

5. Considering your most successful experience with off-site construction, what were the pre-construction expected benefits of using off-site? (select all that apply)

- ☐ Schedule advantage/speed to market
- ☐ Quality
- ☐ Cost-effectiveness
- ☐ Weather concerns
- ☐ Cost
- ☐ Safety
- ☐ Sustainability goals (such as LEED)
- ☐ Site operations
- ☐ Schedule
- ☐ Other

6. For this project, what were the actual benefits realized by using off-site construction? (select all that apply)

- ☐ Schedule advantage/speed to market
- ☐ Quality
- ☐ Cost-effectiveness
- ☐ Weather concerns
- ☐ Cost
- ☐ Safety
- ☐ Site Operations
- ☐ Client Satisfaction
- ☐ Other (please specify)

7. 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 offsite contractor?

	Project Engagement	Recommended Engagement
Concept	☐	☐
50% Schematic Design	☐	☐
100% Schematic Design	☐	☐
50% Design Development	☐	☐
100% Design Development	☐	☐
50% Construction Documents	☐	☐
100% Construction Documents	☐	☐
Post Bid	☐	☐

8. What level of stakeholder collaboration is required to implement off-site construction in comparison to traditional construction methods?

- ○ Significantly higher level of collaboration
- ○ Moderately higher level of collaboration
- ○ Similar level of collaboration
- ○ Lower level of collaboration

Please explain

9. In the next 12 months, how often do you anticipate using off-site construction?

- ○ More
- ○ The same
- ○ Less
- ○ Not at all

Why is this?

10. What types of support could the National Institute of Building Sciences Off-Site Construction Council offer that would benefit your company's utilization of off-site construction? (select all that apply)

☐ Case Studies

☐ Industry Data (Construction Performance)

☐ Design Standards, Details, Specifications

☐ Glossary

☐ Networking

☐ Academic/Research Partnerships

☐ Other

11. What aspects of off-site design and construction information and data are you interested in? (select all that apply)

☐ Design, Engineering, Specification

☐ Lean Manufacturing

☐ Automation (CNC and CAD/CAM)

☐ Emerging materials, products and systems

☐ Transportation logistics

☐ Installation logistics

☐ Regulatory/Codes

☐ Sustainability, LCA

☐ Project management and project delivery

☐ Maintenance and durability

☐ Accelerated construction and schedule methods

☐ High-rise off-site construction

☐ Labor skills/training

☐ Residential construction

☐ Commercial construction

☐ Other

12. The company I represent primarily provides the following services. (check all that apply)

- ☐ Construction Manager/GC
- ☐ Architecture
- ☐ Engineering
- ☐ Owner/Developer
- ☐ Trade Contractor
- ☐ Please specify the company type (i.e. HVAC contractor)

13. What is your company's annual revenue?

14. The project types where my company has utilized off-site construction include: (check all that apply)

- ☐ Healthcare
- ☐ Hospitality
- ☐ Housing - single family
- ☐ Housing - multi-family
- ☐ Education
- ☐ Commercial
- ☐ Industrial
- ☐ Data Center/Mission Critical
- ☐ Other

15. In which state(s) was/were the project(s) that utilized off-site construction located?

16. Which organizations does your company belong to? (select all that apply)

- ☐ Air Conditioning Contractors of America (ACCA)
- ☐ American Concrete Institute (ACI)
- ☐ American Institute of Architects (AIA)
- ☐ American Institute of Constructors (AIC)
- ☐ American Institute of Constructors (AIC)
- ☐ American Institute of Steel Construction (AISC)
- ☐ American Society of Civil Engineers (ASCE)
- ☐ American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
- ☐ American Society of Professional Estimators (ASPE)
- ☐ American Wood Council (AWC)
- ☐ Associated Buildings and Contractors Inc. (ABC)
- ☐ Association of Wall and Ceiling Industries (AWCI)
- ☐ Building Owners and Managers Association (BOMA)
- ☐ Building Trades Association (BTA)
- ☐ Construction Industry Institute (CII)
- ☐ Construction Management Association of America (CMMA)
- ☐ Construction Owners Association of America (COAA)
- ☐ Construction Specifications Institute (CSI)
- ☐ Construction Users' Roundtable (CURT)
- ☐ Design Build Institute of America (DBIA)
- ☐ International Code Council (ICC)
- ☐ International Facility Management Association (IFMA)
- ☐ Lean Construction Institute (LCI)
- ☐ Mechanical Contractors Association of America (MCAA)
- ☐ Modular Building Institute (MBI)
- ☐ National Association of Home Builders (NAHB)
- ☐ National Electrical Contractors Association (NECA)
- ☐ National Fire Protection Association (NFPA)
- ☐ National Institute of Building Sciences (NIBS)
- ☐ Precast Concrete Institute (PCI)
- ☐ Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)
- ☐ The Associated General Contractors of America (AGC)
- ☐ U.S. Green Building Council (USGBC)

Other (please specify)

17. If you would like a follow-up concerning The Institute's Off-site Construction Council activity, please identify yourself with name and email address in the box below (voluntary).

The National Institute of Building Sciences, Off-Site Construction Council will be conducting periodic surveys to support the AEC industry in implementing off-site construction. We invite you to join the National Institute of Building Sciences Off-Site Construction Council and participate in this discussion. It is open to professionals from across the building industry. Visit The Institute's website and register as a member at: http://www.nibs.org.

Done