Off-site construction offers project stakeholders a number of benefits. Benefits include accelerated construction schedules, which result from developing the project site while concurrently constructing the building off-site in a controlled environment without downtime, and increased construction quality by virtue of factory operations. Budget, change orders, scheduling, on-site activity, health and safety can all be controlled using off-site methods, providing an inherently greener and more sustainable process. Off-site construction can avoid waste upstream through more efficient processes. Reduced on-site activity means minimal disturbance and pollution in the area, and less travel to and from remote sites helps reduce greenhouse gas emissions. Another advantage of off-site construction is that materials are kept dry and secure under a factory roof. In addition, with less on-site activity, less time spent on-site, cleaner sites, no exposed materials, fewer pollutants, less disturbance and less vehicular traffic, the site is more secure and safe.

Despite these benefits, some barriers hinder the widespread use of off-site construction. Barriers include the traditional nature of the design and construction culture; the reliance on customary procurement practices; anxiety around transportation logistics (i.e. handling and distance from factory to site); and the lack of knowledge/education concerning off-site methods among project stakeholders. The National Institute of Building Sciences (Institute) Off-Site Construction Council (OSCC) offers steps for success, shown below, to help overcome these barriers and outline the process for deployment of an effective off-site construction project. These steps focus primarily on projects using permanent modular construction (PMC), but many of the principles are the same for other off-site construction technologies.

Selecting Off-Site Construction

Off-site construction is ideal for many market applications, and can be most beneficial where there is limited staging area for storing construction materials on-site; the building site is remote; building assembly is in severe weather conditions; time to market is crucial; speed is needed in erecting the building; and when there is a general desire for better safety on-site and reduced disturbance to business and community. See “Off-Site and Modular Construction Explained” for a more detailed examination of when off-site construction should be used.

1. Conduct pre-construction research

Pre-construction with off-site delivery begins by researching the industry for capability and capacity of the PMC factory and identifying the factory locations that are in proximity to the job site to minimize transportation costs. Pre-construction procurement strategies are no different than with a conventional construction project, in that the contractor may issue a formal request for prequalification to develop a shortlist of providers.

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1Based on a webinar hosted by the Modular Building Institute and the National Institute of Building Sciences Off-Site Construction Council, “Getting the Most Out of Off-Site Construction (Parts 1 and 2).” See http://www.nibs.org/page/oscc_webinars to access the webinar.

2Permanent modular construction (PMC) is building with volumes or blocks of space. This method can be 65 to 95% complete in a factory. With PMC, 90% of the pre-construction time is spent in the design of modules and submittals. Coordination and approvals take place before building fabrication in a controlled environment. Modules are inspected by the quality assurance (QA)/quality control (QC) manager and the authority having jurisdiction (AHJ) before being shipped to the job site.

2. Establish a collaborative team approach

To achieve project success, the project stakeholders should use collaborative thinking and integrated design coordination. The team must have a commitment to the concept and design, and understand the dynamics of off-site construction. Although the owner/architect vision does not change, PMC requires delivery changes such as structural design, greater levels of collaboration among stakeholders, scheduling and sequencing adaptations, and different roles and responsibilities based on scope definitions. Effective communication, coordination and cooperation throughout the project process is mandatory.

In PMC delivery, the design team has a modular concept early in schematic design. The modular manufacturer will take co-ownership of structural building design and design assist for the architects. The coordination of all disciplines must be intentional. A contractual agreement between a modular company and the owner through which the modular company provides design ensures that the project meets the requirements of modular construction best practices. During this process, the modular builder works with the design team to identify and resolve potential design efficiency issues and plans to meet the owner’s accelerated schedule. The modular builder may also aid in developing a high level of design specifications and/or aid in writing non-proprietary bid documents for modular competitive procurement.

3. The importance of the module

PMC has design rules. Although modular layouts may begin with conventional concepts, such concepts can be refined for more efficient layouts by the modular builder and design team. For example, the team must mind the location where two modules meet (mateline) in order to avoid doors or windows being located at the joint. Transportation regulations dictate the unit dimensions, which may vary from region to region. Although greater heights may be achieved with modular, this often means it is at the expense of the overall length of the module (approximately 54’ depending on available transport equipment). Minimizing the number of modules reduces the amount of on-site installation work needed. Module size and layout dictate foundation design.

Figure 1: A modular key plan takes conventional concepts and translates them into a modular design that can be achieved logically and efficiently without sacrificing the owner or architect’s original vision. (Image courtesy of NRB)
4. **Timing is everything**

With PMC, the phasing or sequencing of the project changes from design throughout construction. Project schedules should establish a reasonable but finite time for final design, coordination, review and approvals. In PMC, decisions must be made earlier and the modular footprint needs to be frozen in order for turnaround times related to approvals to be shortened. Changes to the scope during construction should be avoided through effective communication among stakeholders. Compared with traditional construction, PMC projects have statistically fewer change orders, which makes the design/construction process go smoother and faster. PMC scheduling is also more predictable. Design approvals, phasing and sequencing are crucial to achieving an accelerated schedule. The modular builder will often produce an overall schedule of how all the tasks are integrated, ensuring that building construction and site development are timed concurrently.

5. **Create a clearly defined scope of work**

The specification determines what products, system and assemblies are used on a building project. The scope of work defines who does what to execute the project according to the specification (and also incorporates a responsibility matrix). The scope of work ensures a cooperative and coordinated effort by all. It defines and demarcates off-site versus on-site elements to mitigate scope gaps, overlaps and double handling. The project team may choose to create a clear, detailed checklist to help account for all project-related elements. This also can take the form of an agreement between project stakeholders.

Unlike some traditionally built projects, in PMC each project must be tailored to suit the team’s agreed approach, roles and responsibilities. Three different approaches may be used, which will result in varying scope delineations: 1) the modular builder may be a subcontractor, turning the complete modules over to the general contractor (GC) at the site to finish; 2) the modular builder may be a subcontractor that self-performs installation only; or 3) in some instances, the modular builder may also be the GC performing all aspects of the project.
6. Understand project delivery methods

**Design-Bid-Build – Low Cost**

This is the most widely recognized construction method. It relies upon a known cost of construction and competitive bidding. The evaluation of such bids is simply lowest cost. It relies upon clear scope definitions. Design-Bid-Build has the disadvantage of being a linear sequential schedule, with hand-offs from one party to the next. This often results in poor communication between the design and construction team. This method of delivery is only suggested for PMC when the project is designed to be built off-site.

**Design-Bid-Build – Value Based**

(cost is not the driver)

This delivery method allows other factors, such as sustainability, schedule, experience, value add and quality, to weigh into the evaluation. Although it is value-based, it still has the disadvantage of any Design-Bid-Build—longer schedules and poor communication. If PMC can offer the value sought after in the project, then it is a potentially positive solution.

**Project Delivery CM or EPCM**

There are a variety of types of construction manager (CM) or engineering procurement and construction management (EPCM) methods including: 1) advisor during design document or construction; 2) manager/agent, where the owner contracts directly with trades; and 3) constructor at risk where the CM assumes the GC role at contracted cost. The CM provides benefits in design assistance/advice to the owner, including the ability to call for bids sequentially, which potentially can result in fast track scheduling, cost input and value engineering during the design phase, and monitoring of costs and schedules throughout the duration of construction. The disadvantages are that construction can commence before all costs are known, so there are often additional costs to contract for the CM third-party consultant, and it places the owner in the constructor role. CM delivery is only modular friendly if the project is developed using an off-site construction methodology.

**Design Build**

The advantage of design-build (DB) contracting for the owner is the single point of responsibility. In this delivery method, the architect is contracted by the design builder and the contractor is engaged before completion of design. It is more suitable for a fast track process and provides immediate feedback during design and construction phases. Since the design builder plays an integral role in design, real costing can be established early on in the design process, which allows adjustments to be made during design to assure budget compliance. DB requires team collaboration through all phases of delivery. Some challenges in utilizing DB include the responsibility of design approvals shifting to the design builder; the reduced role of the architect as leader of the design team; costs may be declared before final designs are completed; and there is a higher level of trust required by the owner for the DB team. DB may be appropriate in PMC if modular is included in the design phase as part of the DB team.

7. **Modular certification and labeling**

Unlike conventional construction, 31 states have a preemptive state-wide program that involves the submittal, review and approval of building drawings in PMC. Local authorities having jurisdiction (AHJs) must accept the state program’s findings, including all plans, reviews and inspections of the modular building at the plant. Also, the AHJ reviews and inspects all site improvements and site-constructed scopes not included in the modular scope. Accredited third-party agencies inspect buildings at the manufacturing plant for code compliance. Once design is approved, construction phase and manufacturing process inspections are required.

8. **Coordinate with CM or GC for local permitting**

With PMC, project teams need to determine what permits are necessary (local and state) to ensure the responsibility matrix reflects the roles and the schedule reflects the timing, including the plan review period, process to field comments and revisions, compliance with zoning ordinances, permit fees, impact fees, tap fees, necessary inspections and how/when to call for them.

9. **Site mobilization considerations and coordination**

Due simply to the size of the completed three-dimensional (3D) modules, the staging area and mobilization requirements for modular construction differ from that of conventional construction. Establish or coordinate areas for project offices and parking; dumpsters and sanitary facilities; raw materials/spoil storage; module staging area; module access routes to and from the crane; crane access; and module pre-lift prep areas.

10. **Material procurement**

Once final design and submittals are approved, materials are ordered to suit the production schedule. Long lead time items may require early submission and pre-approvals. For sequencing, determine what is plant installed and what is field installed. Materials should be received and safely stored in a dry, secure environment until needed in the plant.

11. **Prepare to ship**

A detailed packing list of all ship loose materials that go to the site for finishing or site installation is created. Ship loose materials are labeled and may include components for site finishing, unique finish materials, fixtures or casework that cannot be preinstalled. In PMC, material delivery sequencing is considered, and may be packed and shipped in modules or transported separately.

12. **Transportation and logistics**

Transportation regulations vary greatly from region to region and state to state. Therefore, the module size and location of the shipment origin must be considered at the design phase. The size of the staging area on-site will dictate how many modules can be staged simultaneously, and the frequency that modules must be shipped. Important factors to consider when planning for the arrival of modules include potential overhead and immovable obstructions, such as urban infrastructure and trees, ensuring adequate turning radii and a clear crane zone area. The scope document should determine who is responsible for handling modules from completion in the factory to final finishing on-site.
13. Establishing the site

PMC does not differ from traditional construction in establishing the site, including grading and drainage, soil conditioning as required by geotech studies, and extension of utilities from point to connection to the building, including domestic and fire safety water, sanitary and storm sewers, gas and electricity.

14. Foundations for modular construction

Foundation design is dictated by geotechnical investigation and local trade practices. The depth of a foundation is dictated by geotech and by climate. The layout of the foundation, the footprint, is dictated by the modular key plans. Modular buildings with floor assemblies may require a crawlspace that will vary in depth depending on the required under-floor access. Modular buildings without floor assemblies normally require a reinforced slab. As with traditional construction, the International Building Code is used to determine the type of construction. PMC may be hot rolled steel, light gauge steel, precast, mass timber or light wood framed.

15. Module to foundation attachments (different options)

There are different options for PMC attachments to foundations on-site, just as there are for traditional construction. There are no unique foundation conditions with modular, however.

16. Establishing finish floor height

The height of PMC projects above finished grade depend on different conditions, including soils, foundation type and desire or lack thereof to excavate. Considerations on how to proceed with the options rely upon establishing the desired degree of plant versus site finish, drainage, ventilation and related costs or savings. Often modular buildings are 30’ above finish grade (AFG), with stairs and accessibility ramps. But PMC buildings may have excavated crawl spaces for grade level entries. Floorless PMC buildings adopt a slab on grade.

17. Crane set installation

Modular construction requires a crane to set large heavy boxes. There are two primary methods for craning modules: spreader bar with belt strap slings around the belly of the modular box or pick points on the corners of the module. In either case, the lifting strategy needs to be accounted for in the structural design up front and must be engineered to provide a safe and level lift.

With PMC, adequate manpower is needed to maximize crane efficiency and ensure safety. Lift and place days must be planned minute by minute. There needs to be clear access between staging areas and crane lift points. A cost-effective strategy is to maximize the crane reach, thereby minimizing moves. Once modules are placed, they are welded or bolted together and then welded, bolted or strapped to the foundation.
18. Immediately after the building set, building envelope must be addressed

Once the modules are set and secured to one another and the foundation, infill sheathing is installed at all matelines to create a lateral resisting diaphragm. In these areas, sheathing is held back for the purpose of module to module attachment. Also, the gap sheathing will maintain continuity of the exterior façade and exterior cladding. Weather-in of the building envelope (secondary water plane and air barrier) is crucial to ensure the investment of the module is maintained. Therefore, the install team and finishers quickly seam the roof, create or complete secondary water planes, install exterior wall cladding where required (may be all or just over matelines as designed), and install commercial store front at mateline if needed by design. In addition to exterior stitching, interior infill finishes are added at matelines.

19. Other considerations

The level of finish applied between the plant and site depends upon the geographical region or building type. A higher degree of finish is more prevalent in the Northeast, Mid-Atlantic and West Coast. Items to be considered are final finishes for walls, floors and ceilings, as well as casework and other architectural items. Greater emphasis on more scope completion at the factory can depend on several factors, including higher local labor rates, requirements to keep on-site activity to a minimum and the remoteness of the location. Site finish-out elements that occur simultaneously with building finish-out include drives and parking, area lighting, entrance canopies, landscaping, signage, plumbing, sprinklers and low voltage systems tests.

20. Commissioning and contract close out

This stage of delivery is not necessarily different than on-site building. The requirements will vary with each contract based on specifications and scope of work. In PMC, warranties can differ based on scope and responsibility in the original contract.

By understanding these key processes in the utilization of off-site construction, architects, engineers, contractors, code officials and building owners should become more comfortable. Manufacturers of off-site construction components can help design teams and contractors walk through these steps and deliver the benefits off-site construction can provide.