Modular Construction

Recently, the National Institute of Standards and Technology (NIST) requested that the National Research Council (NRC), to provide advice for advancing the competitiveness and productivity of the U.S. construction industry. The committee identified five breakthroughs to improve the efficiency and productivity of the construction industry:

1. Widespread deployment and use of interoperable technology applications, Building Information Modeling (BIM)
2. Improved job-site efficiency
3. Greater use of prefabrication, preassembly, modularization, and off-site fabrication techniques.
4. Innovative, widespread use of demonstration installations
5. Effective performance measurement to drive efficiency and support innovation.

Manufacturing building components off-site provides for more controlled conditions and allows for improved quality and precision in the fabrication of the component. Prefabrication and related techniques allow for the following:

• More controlled conditions for weather, quality control, improved supervision of labor, easier access to tools, and fewer material deliveries.

• Fewer job-site environmental impacts because of reductions in material waste, air and water pollution, dust and noise, and overall energy costs.

• Compressed project schedules

• Fewer conflicts in work crew scheduling and better sequencing of crafts persons.

• Reduced requirements for on-site materials storage, and fewer losses of materials.

• Increased workers safety.
Definition of Modular Construction:

A resource efficient, off-site delivery method to construct code-compliant buildings in a quality-controlled setting. A report from the AIA states: The life expectancy of modular construction is the same as conventional, but modular construction is more ecofriendly than conventional construction. They spend significantly less on site time, and finally modular construction allow a building to be more readily deconstructed and moved to another location.

Advantages of Modular Construction:

Less Materials Waste – Pre-fabrication makes it possible to optimize construction material purchases and usage while minimizing on-site waste and offering a higher quality product to the buyer. Bulk materials are delivered to the manufacturing facility where they are stored in a protected environment safe from theft and exposure to the environmental conditions of a job site.

Less Material Exposure to Inclement Weather – Many of the indoor air quality issues identified in new construction result from high moisture levels in the framing materials. Because the modular structure is substantially completed in a factory-controlled setting using dry materials, the potential for high levels of moisture being trapped in the new construction is eliminated.

Less Site Disturbance – The modular structure is constructed off-site simultaneous to foundation and other site work, thereby reducing the time and impact on the surrounding site environment, as well as reducing the number of vehicles and equipment needed at the site.

Safer Construction – Modular construction is a safer alternative. Conventional construction workers regularly work in less than ideal conditions dealing with temperature extremes, rain, wind, or any combination of natural conditions. This, by its very nature, is a much more challenging environment to work safely in. Additionally, the potential for injury including falls, the most common work site risk, is much higher. In a factory controlled setting, each worker is typically assigned to a work station supplied with all the appropriate equipment needed to provide the safest work environment possible. Off-site construction also eliminates the hazards associated with materials, equipment and an incomplete construction processes typical of construction sites that can attract curious and unwelcome “visitors”.

Flexibility – When the needs change, modular buildings can be disassembled and the modules relocated or refurbished for new use, reducing the demand for raw materials and minimizing the amount of energy expended to create a building to meet the new need. In essence, the entire building can be recycled in some cases.

Adaptability – Modular buildings are frequently designed to quickly add or remove one or more “modules,” minimizing disruptions to adjacent buildings and surroundings.
**Built to Code With Shorter Build Times** – with modular construction its easier to get a facility built to the same local codes with construction quality as good as or better than a comparable site built building in much less time.

**Implementation of BIM in Modular Construction:**

The extensive demand of pre project planning and coordination among members of cross-interdisciplinary professionals have significantly impeded the application of Modular Construction, with the recent development of Building Information Modeling these challenges could be overcome. The coordination and fabrication of the Mechanical, Electrical and Plumbing (MEP) systems in modular construction has always being one of the most challenging tasks encountered in the delivery process of modular constructions. The MEP coordination and fabrication process involves defining the locations for components of building systems, in where are often congested spaces, to avoid interferences.

Three primary reasons contributing to the challenges of MEP fabrication in modular construction:

First, the process is highly fragmented between design and construction firms. Second, the level of technology used in different coordination scenarios has historically varied significantly between engineers and construction contractors. Third, historically the process did not provide a model for use by specialty contractors plan prefabrication.

With BIM technology an accurate virtual model of a building is constructed with precise geometry and relevant data needed to support the procurement, fabrication, on-site installation activities. The implementation of BIM systems in modular construction normally involves in the following process:

- **Visualization:** ability to create a 3D presentation of building modules geometry, location, space, contained systems in relation to each other

- **Modeling:** ability to generate a 3D rendering tool to present the final product and finishes to owners, designers and constructors

- **Code reviews:** allows for building officials and fire officials could use the 3D models with related data for code compliance reviews

- **Fabrication/ shop drawings:** facilitates for the generation of detailed shop drawings could be easily produced once the BIM model is completed
- **Communication**: facilitates simultaneously creation of construction documents, product imagery, rapid prototypes, exterior envelope, interior finishing, and MEP fixtures of building modules. Through this single information platform, BIM promote collaborations among the design team, consultant, constructors and the clients.

- **Cost estimating**: provides for cost estimating, material quantifications, and pricing to be automatically generated and modified while changes are applied for each building module.

- **Construction sequences**: provides a complete construction schedule for material ordering, fabrication, delivery and onsite installation of each building systems. With the integration of 3D rendering, 4 D (3D model + scheduling information) could be easily generated during the project design and construction phase.

- **Conflict, interference and collision detection**: ability to determine building system interferences which can be visually presented. For instance, an air distribution duct for the HVAC system physically interfering with a concrete beam. There are many locations in buildings that repeatedly cause coordination problems. These include building corridors, points of entry and exit, openings in shear walls. The need for MEP coordination grows out of the lack of detailed design provided for fabrication and installation of building systems, and exists regard-less of the project delivery process used.

**Modular Construction in Nuclear Power Plants:**

A major problem during the construction of many large nuclear plants is low morale of the labor force associated with low worker productivity and low construction quality. Studies at large nuclear projects have identified six factors which influence their productivity: low material availability, low tool availability, high rework rates, needless interference with other crews, overcrowded work areas and time consuming inspection delays. Reducing the amount of on-site labor with factory produced power plant modules is one avenue for increasing productivity and quality. In order to implement modular fabrication effectively both the design and construction phases of a project must be addressed. Thus consistent methods must be developed for: design of the plant for modular construction, efficient construction of the designed modules, simplified installation of modules within the power plant and evaluation of the economic performance of modular methods.
Crane utilization & Modular Constructions:

The most significant niches for modular buildings are school facilities, campus/dormitory living, and affordable housing, airport roofs (NASA spacecraft building), and health care units. Assembling the entire fleet of modules rely on optimization of the crane position to ensure minimal configuration changes for the selected crane. Based on one case study in literature, over 90 modular units were delivered to Muhlenberg college in Pennsylvania for the assembly of five new dormitory building. Assembling the whole modules was done in a record time of 10 days by optimizing of crane position.

Effective Method of estimating wall fabrication productivity rate:

A thesis with the title of: “Improving the efficiency, productivity and cost-effectiveness of modular design and construction processes” is done by Calvin van Mulligen in the University of Alberta. This thesis has provided a methodology to incorporate building information modeling (BIM), lean construction and simulation modeling into a cohesive package in the context of modular manufacturing. That methodology provides an effective method of estimating wall fabrication and erection probabilistic productivity rates. A time study is conducted on 5 modules to determine the production durations and labor requirement of the wall fabrication and wall erection stations. Then the data is analyzed and the probabilistic productivity is determined for each tasks based on the wall type, number of windows and number of doors and columns.
References:

- “Improving Construction efficiency & productivity with Modular Construction”, by Modular Building Institute

- Christopher W.Lapp , Michael W.Golay,1997, “ Modular Design and Construction techniques for nuclear power plants”, nuclear engineering and design

