CONFERENACE REPORT 2017

STATE-OF-THE-ART OF MODULAR CONSTRUCTION

Advancing the cutting edge of modular design and construction

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Rinker School of Construction Management
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ACKNOWLEDGEMENTS

The authors of this report would like to thank the companies, individuals, and students who participated in this conference event. Without their willingness to participate we would have not been able to gather the data to report the state-of-the-art of modular construction. Our special thanks go to professors and graduate students that helped to organize the event, worked during the event, and provided insightful information for this report.

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Dear Reader,

Off-site, modular construction strategies are gaining market share at an accelerating pace, providing owners with lower cost, faster options for delivering new facilities. The “State-of-the-Art of Modular Construction Symposium” was designed to provide you with a snapshot of the cutting edge of modular building design, component manufacturing, and construction techniques and to help stimulate a dialogue among the stakeholders to the modular process. At the Symposium you could meet owners who envision modular as a solution to the increasing costs of construction and construction managers looking to modular to help address the very serious problem of a rapidly shrinking pool of craftsmen. You also had the opportunity to discuss cutting edge design and manufacturing approaches, plus technologies such as 3D printing that can truly transform modular construction to dramatically increase its speed, precision, and quality. As an academic, I could uncover research questions that, when successfully addressed, will provide the information, materials, and manufacturing technologies needed to further improve the modular construction techniques and management processes. Additionally, this meeting was an opportunity to form new relationships among the modular industry, owners, and academia.

We are very happy for all the participation in this noteworthy event and look forward to continuing our discussions after the Symposium.

Charles J. Kibert, Ph.D., P.E.

Director of the Powell Center for Construction and Environment
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Preface

Why modular construction?

Modular construction shifts a significant fraction of construction from on-site activities to the manufacturing of major components in factory settings. It has the potential to significantly increase the speed of construction while lowering costs. Collateral benefits include a possible tenfold improvement in safety, higher precision, and lower waste generation rates.

One additional force driving the movement to modular construction is the rapidly shrinking population of skilled construction craftsmen, which is necessitating a shift to modular techniques that have the potential for application of automation, 3-D printing, and other advanced technologies.

Who attended?

The target audience for the Symposium included owners investing in modular strategies, construction management companies, architects, engineers, building component manufacturers, and subcontractors engaged in multi-trade prefabrication. The meeting focused on large multi-family, commercial, and institutional modular buildings.

Purpose and Goals

• Determining the best design practices employed by architecture and engineering companies to account for the unique characteristics of modular construction.
• Identifying the best construction practices being used by construction companies and the impacts of these practices on the cost and labor issues associated with contemporary on-site construction. These include coordination of activities with the design community and the factories manufacturing the modules.
• Articulating the best manufacturing and logistics practices for producing building modules in factories and transporting them to the site for field assembly.
• Describing the role of multi-trade prefabrication as a major component of a successful modular construction strategy.
• Identifying the information, automation, manufacturing, and construction technologies that are and will affect the progress of modular strategies.
• Determining the major research gaps that exist and that can be addressed by a collaboration of industry, academia, and the public sector.
The Modular Construction Industry

The Modular Building Institute (MBI) defines modular construction or Permanent Modular Construction (PMC) as the process of design and fabrication of at least 60 - 80% off-site under controlled factory conditions followed by the transportation of all the large volumetric units to the site for assembly. Modular buildings are constructed and designed using the same materials and following the same building codes and standards as conventionally built facilities. Buildings are built using “self-sustained modules” that, when attached together on-site, reflect the identical design intent and specifications of the most sophisticated site-built facilities – without compromise. Currently, modular construction is mostly used for housing, high-rise multi-family buildings, and commercial buildings.

Some advantages of applying modular construction include:

► **PRICE:** The cost of the design and construction of a complex building using modular strategies is generally lower than that of traditional methods. According to MBI, modular construction can save 30-50% in the construction schedule and ultimately save on costs. While costs are likely competitive to an on-site construction process, the time savings accrued from the simultaneous scheduling of off-site and on-site work enables clients to turn profits quicker and save money spent on employee displacement.

► **TIME:** Design, construction, and installation of the block-modular building are several times faster than site-built versions (See figure 1). For example, a modular building with an area of 10,000 - 20,000 square meters can be delivered in 4 - 5 months after signing a supply contract. Some parts of the mechanical system, lighting, outlets, transformers, sanitary equipment, and even furniture can be installed at the factory.

► **WASTE:** Significantly lower construction waste at the building site compared to conventional construction techniques.

PMC generally has four stages: design approval by the end user and building officials, assembly of module components in a controlled environment, transportation of modules to the final destination, and erection of modular units to form a finished building.

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**SITE-BUILT CONSTRUCTION SCHEDULE**

<table>
<thead>
<tr>
<th>design engineering</th>
<th>permits and approvals</th>
<th>site development &amp; foundations</th>
<th>building construction</th>
<th>site restoration</th>
</tr>
</thead>
</table>

**MODULAR CONSTRUCTION SCHEDULE**

<table>
<thead>
<tr>
<th>design engineering</th>
<th>permits and approvals</th>
<th>site development &amp; foundations</th>
<th>install &amp; site restoration</th>
<th>TIME SAVINGS</th>
</tr>
</thead>
</table>

*Figure 1 – Comparison of a project schedule by using conventional and modular construction. Source: Modular Building Institute*
The MBI has identified six major markets for PMC in the US. The overall total market of PMC, in terms of the value of new construction, slightly decreased from 2.94% in 2014 to 2.72% in 2015.

Table 1 - Industry analysis: 2016 annual reports. Source: Modular Building Institute, 2016

<table>
<thead>
<tr>
<th>Market</th>
<th>% Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational</td>
<td>4.11%</td>
</tr>
<tr>
<td>Office/Administrative</td>
<td>3.25%</td>
</tr>
<tr>
<td>Healthcare</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Retail</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Commercial/Housing</td>
<td>2.88%</td>
</tr>
<tr>
<td>Institutional and Assembly</td>
<td>7.22%</td>
</tr>
</tbody>
</table>

Table 2 - Industry analysis: 2016 annual reports. Source: Modular Building Institute, 2016

<table>
<thead>
<tr>
<th>Region</th>
<th>Revenue ($)</th>
<th>% change 2015 - 2016</th>
<th>Strongest Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>United States</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>18.9 Billion</td>
<td>5.3</td>
<td>Healthcare, education, and multi-family</td>
</tr>
<tr>
<td>Mid-Atlantic</td>
<td>13.2 Billion</td>
<td>31%</td>
<td>Retail, office, education, and governmental</td>
</tr>
<tr>
<td>Southeast</td>
<td>21.8 Billion</td>
<td>21</td>
<td>Healthcare, hotels, and multifamily</td>
</tr>
<tr>
<td>South Central</td>
<td>30.4 Billion</td>
<td>- 3%</td>
<td>retail, multifamily, hotel, and education</td>
</tr>
<tr>
<td>Central</td>
<td>15.8 Billion</td>
<td>18%</td>
<td>retail, multifamily, healthcare, and education</td>
</tr>
<tr>
<td>Western</td>
<td>21.8 Billion</td>
<td>29%</td>
<td>retail, multifamily, and education</td>
</tr>
<tr>
<td>Northwest</td>
<td>8.2 Billion</td>
<td>- 17%</td>
<td>Education, multifamily, and healthcare</td>
</tr>
<tr>
<td>North Central</td>
<td>6.4 Billion</td>
<td>- 25%</td>
<td>energy sector</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Canada</td>
<td>11.4 Billion</td>
<td>- 9%</td>
<td>workforce housing supplied to oil and gas companies</td>
</tr>
<tr>
<td>Eastern Canada</td>
<td>15.1 Billion</td>
<td>16%</td>
<td>retail, general office, multifamily, healthcare, and education</td>
</tr>
</tbody>
</table>
Modular construction marketing often claims that it provides better, faster, and cheaper solutions. As off-site construction continues to grow in volume and impact, metrics for evaluating its effectiveness are critical to the success of the modular sector and the advancement of the construction industry in general. This presentation reported a research conducted over a decade of measuring, quantifying and qualifying, modular construction and modular business operations.

**Definitions**

There are two types of modular construction:
1) Relocatable buildings which includes HUD homes, classrooms, construction trailers, and mobile homes;
2) Permanent Modular Construction (PMC), which evolved out of the first category.

There are three peculiarities that distinguish construction from other production industries:

1) the place where you manufacture the product is different every time;
2) the program, the shape, and the design of the product is different every single time;
3) the available labor fluctuates constantly.

“It is hard to become efficient in a production industry when people cannot control these peculiarities of construction.”

**Business strategies**

Literature reviews, online surveys, and interviews were performed to gather financial information of the industry. Publicly held and privately held modular companies were compared in US versus UK, as the UK is more advanced in this particular area. The results and data were mapped together on the Strengths, Weaknesses, Opportunities, and Threats (SWOT) matrix (next page). It was concluded that the internal strength of modular building companies includes: diverse investment in product, marketing, unique selling point, quality experience, and flexibility. Among weaknesses, there is a lack of innovation, resistance to changes, poor management (especially in family owned companies), and failure to understand and respond to the market quickly. The opportunities include increasing demand for off-site conducive building types, increasing average salaries and employment, and less opposition from builder for using off-site method.

However, there are several threats including building codes that continue to restrict the use of

**Continued...**
modular construction, local jurisdictions that do not completely understand the construction process, negative perception of public and industry, low demand for modular buildings, and the conservative construction culture.

**STRENGTHS**
- Diverse Investments and Products
- Marketing
- Unique Selling Point
- Quality, Experience, and Flexibility are signs of success

**WEAKNESSES**
- Lack of innovation
- Resistance to Change
- Poor Management
- Failure to understand the market

**OPPORTUNITIES**
- Demand for off-site conducive building types
- Avg. Salaries & Employment increasing
- Builders are less opposed to using off-site methods.

**THREATS**
- Codes
- Public and Industry Perception (σigma)
- Little to no demand
- Construction Culture

The 5 in 5 initiative

The MBI is trying to increase the share of the modular industry to 5% of the total construction industry in five years. Currently, modular construction holds around 3.5% of the construction market share. Several methods can be used for reaching this goal:

- **Stream 1: Investing in research.** Currently, some countries such as North America, Scandinavian countries, Japan, Scotland, Germany and Austria, are using modular construction more frequently than others. Some interviews with key stakeholders in specific countries are being conducted for research purposes.
- **Stream 2: Promoting modular construction.** MBI is already encouraging architects, general contractors, engineers, and owners in North America. Several workshops will also occur in the following years.
- **Stream 3: Establishing a roadmap including the generation of a SWOT-analysis.**

**Contextual situation that has led to the proliferation of modular method**

There are three main factors that contribute to the adoption of modular construction: the higher costs of land in specific places, increasing costs for labor, and adverse weather conditions. These factors together can result in a preference of prefabrication over the traditional on-site construction method. However, there are some barriers that hinder the development of modular construction, such as the low sophistication of the modular building industry compared to conventional industry, current design/build standards, and the lack of knowledge about modular construction.

Also, General Contractors often blame quality standards and the lack of knowledge about how to properly integrate modular into the project delivery system. The modular industry itself also faces issues related to technology integration, unqualified labor, cash flows processes, and the low diversity of products in manufacturing plants.

**Projects to overcome barriers**

1) The **Online Market Place** was created in collaboration with the University of Montreal, Autodesk, and MarterBuild to build a system with relevant information about specifications and the material properties of prefabricated objects.

2) The **Built Environment Exchange** was created as a collaboration of international universities to obtain as much information as possible about the off-site construction industry. It allows international students to work during the summer in a foreign off-site construction company and perform research. The information and results are then shared at the end of the semester.
Platform for Life is a tool for creating a generative housing systems technology. It refers to a completely integrated system that includes design systems, design thinking, software engineering, fabrication of ideas, material science, to name a few. Platform for Life aims to create forms of housing and urban development that are livable, sustainable, and affordable at the same time. The system should be adaptable and flexible to co-evolve with the needs of society, and be regenerative both in terms of thinking about the environmental changes and also in terms of the value of an investment.

About 15 years ago, the world experienced an increasing urban housing crisis with inadequate and unaffordable housing solutions. Along with the unprecedented process of urbanization, such as global warming, rapid changes in society, a lack of innovation, and risk averseness.

Nowadays, the world is facing environmental challenges that have never been faced before. Cultural identity, the way how people live and work, ideas and forms of collaboration, individualization, and increasing consumption are also important considerations. The question now is how do we design building systems for a future that nobody really understand? One option is to shift construction industry from low-rise or extremely high-rise buildings to mid-rise mixed communities.

A survey of how people imagine their community showed that they want it to be:

- Livable
- Green
- With public spaces
- Pedestrian-friendly
- Ultimately connected to the fabric of the city.

Generally, fulfillment of people’s needs for sustainable, green, livable housing and infrastructure means additional costs that make housing unaffordable. However, there should be something that can be baked into the DNA of the system from the very beginning to make this possible. Market-driven development of ideas based on politics, quick profits, low-quality construction, short-term thinking must be replaced with a holistic thinking that allows people to create long-term values, and increases quality, affordability, and sustainability.

In 1967, Moshe Safdie, a 25 year-old architect designed the Habitat 67 - a truly unique and remarkable project of residential housing in Montreal, Canada where all units had outdoor spaces and community areas that enabled neighbors to socialize. The project used prefabricated concrete modules and is considered a remarkable project because it was feasible to execute, was affordable, and sustainable.
Vacant sites in major cities usually tend to be smaller, have inherent risks for new construction, and do not necessarily have a significant return on investment. GLUCK+ has been working with urban infill projects in Manhattan, New York and showing the potentials for modular buildings in this circumstances.

The Stack Project has been developed as a testing model of modular technology for infill housing. The building aims to integrate modern buildings that can speak to the context of old fabric/architecture. The Stack building also expresses the modular unit by a constant movement of pushing and pulling boxes. The building used on-site construction methods for the commercial podium and off-site modules for the housing units. The modules are non-combustible and made of steel, metal deck, and metal studs. An innovative aspect of the project refers to the lack of relationship between the modules and the apartment layout, meaning that apartments plans can cut across one or more modules. The sandwich floor-ceiling was around 20-22 inches thick due to the self-contained structure of each module. When compared to concrete cast buildings (usually 8 inches) it represents an important factor for high-rise buildings, especially where the urban zoning limit building height. From a developer perspective, losing one floor due to a height restriction can potentially turn a project unfeasible. Site logistics is another important factor for modular high-rise buildings. Crane allocation and transportation restrictions should be investigated in advance.

The Lady Liberty School is a K-1 to K-8 school built in the suburb of New York. Modular construction was used mainly because of budget and time restrictions. Traditional schools in NY cost around $600/sf, but in this case, only $225/sf was available. Therefore, traditional methods of construction would not be feasible. A cost analysis study of different modular construction methods indicated costs of:

- $290/sf for non-combustible modules
- $275/sf combustible construction module with wood
- $235/sf hybrid construction with wood and steel
- $225/sf hybrid + precast foundation

The New Liberty School was built with a precast concrete foundation, precast concrete foundation walls, precast foundation slab and piers, modular units made of wood. The project took 9 months to finish, in which 3.5 months were used only to zip-up the modules, including joints and mechanical connections.

Lessons learned

- Double walls between modules take more room from a developer perspective but are perfect for acoustic.
- Designing and estimating several design options was essential for both projects.
- Working with the manufacturer during the design helped to conceptualize the modules. Several pieces could also be manufactured in the plant to improve the installation of the modules.
The ISA, Interface Studio Architects LLC, company specializes in robust urban multi-family housing, offices, installations and experiments (e.g. utilizing shipping containers to create small offices).

Modular construction allows architects to control the process, obtain building permits, and oversee the whole construction process. However, close collaboration with contractors is also extremely important to assist in decision-making process.

The economic and market demand is constantly changing every year. Each city finds a way to better adapt with those changes. Moreover, there is a dynamic situation in every place. There is a type of contextually to the way the city works and to the way it can receive modular construction. Also, the housing market does not always keep up the pace with construction costs. In other words, market values do not compensate construction costs driven by union labors. These conditions should be taken into account when choosing the construction method for a future project.

The are several affordable housing projects in Philadelphia funded and subsidized by the State of Pennsylvania. Some of designs aim to lower the cost of affordable housing, allowing more investments in green technology. To fulfill the expectations of a modern life, with gardens and bigger spaces, some projects interlock site plans that manage surface parking spaces, yards, and buildings.

These projects aim to create buildings that could be modularized to reduce construction costs. Thus, some basic information costs control of modularity are embraced into the fundamental design. Diagramming process, where one could see a model of a building, rotate modules, add or remove attributes, play with design forms, numbers of doors or windows, are used for optimizing costs of the manufacturing process.

The main reasons why some of these projects are not built with modular techniques are because of the complexity of contractual process between owners, general contractors, and subcontractors, and the overhead costs for storing modules and installing cranes.

“System Thinking: Integrating Modular Construction within a Broader Design Language

Brian Phillips

“There is an unspoken relationship between economy and construction methods. There will be no demand for modular structures when the economy remains stable. The demand for modular buildings increases as soon as construction costs dramatically raise. Architects can be real proponents for encouraging modular construction. However, it is essential that they anticipate modularity and respect the efficiency of this method at the beginning of the design phase.”
Improving the construction industry and doubling its quality is an achievable goal for manufacturers, architects, and contractors. Improving the energy performance and standard requirements, shortening the time from design to delivery stages of the building, and reducing the consumption of raw resources play a vital role in the construction industry.

“Let’s think about a washing machine as an example of the challenges of modular construction. It washes and dries clothes, it is compact and fits everywhere, and it is inexpensive. If one can provide all the necessary resources needed for the washing machine to operate, like energy, water, some room, it turns into a masterpiece. However, a washing machine is not a modular building. The construction industry is now trying to fit this construction technology everywhere without any specific framework: no regulatory framework, no design framework, and no contractual basis to understand how to use it.”

**Design Manufacture Construct (DMC)**

The DMC framework was created to guide building design so that construction industry will leverage manufacturing productivity. The elements of DMC framework includes:

- **Complexity**: Modularity is vastly more complex. For a future enhancement, DMC should find an appropriate complexity for modular construction.
- **Quality**: DMC aims to remove the barriers of quality by training its labor force and increasing repeatable processes. A DMC condition that allows finding quality given the existing situation should be created.
- **Speed**: The speed of the entire project should be accelerated. If it is possible to shorten the overall cycle of the project, then there can be a potential revenue source for other projects.

Chris Giattina
In an example project in Las Vegas, the application of modular construction method allowed the project to remove 25% of the complex tasks (including machinery and workforce) from the job site to a controlled factory environment. The manufacturing environment of off-site production structured those tasks in an organized fashion. We should not consider this 25% reduction as the most important part of the prefabricated construction process. However, the interesting aspects is that the remaining 75% of the tasks can be highly optimized around the 25% of modular components.

Healthcare projects constitute other practical example of the implementation of the DMC method. Healthcare facilities are required to be built faster, under higher quality, and less cost. In this case, DMC method allowed determining the standard modules for each department such as standard departments, standard patient rooms, standard exam rooms, and standard surgery. This variation was later converted into eight modular building types. Software then translated the information to a platform to leverage technology. The manufacturing process starts when raw materials, regulatory and manufacturing constraints, standards, and configurable parts are placed together.

Results of the modular experience
- Designers and contractors understand standard parts.
- It was found that increasing standardization is essential for improving the model.

“You have to learn how to make a small uncomplicated box before you make a small complicated one. Then, once you learn all of those components, you can keep adding to it.”
The construction industry is a key industry for boosting regional and global economies. Every year, about $10 trillion is spent globally on construction such as buildings, infrastructure, and industrial installations. All of this is equivalent to 13% of world GDP. Moreover, construction industry employs over 7% of the globe workforce and plays an important role in meeting the global urbanization demand. At the same time, the construction industry is the largest consumer of raw materials, is responsible for 50% of energy consumption, and emits around 40% of greenhouse gases. In addition to these impacts, the industry has a long record of poor productivity, over regulation, fragmented contracts, inadequate design and built incorporation, poor on-site execution, lack of technology integration, to name a few.

High-rise buildings have always required more time. For construction, prefabrication techniques for these buildings usually refer to specific elements and structures. However, a rapidly urbanizing world dictates a different rhythm. The Broad Group’s Sustainable Building (BSB) method is an innovative principle that rethinks high-rise buildings. It considers integrating the development and implementing new technologies and materials, such as tubular stainless steel sandwich panels, superior structure, and streamlined production.

The BSB approach has changed the construction process from an extensive to a more simplified sustainable production line. BSB buildings are 90% factory-made. Some benefits are:

- **Faster**: BSB are tubular stainless steel sandwich panels used for columns, beams, and floor slabs. They are 90% factory-made. With BSB technique, the speed of construction increases. For instance, a 57-storey building in China was completed in 19 days at a speed of three stores per day. By contrast, traditional high-rise buildings require 2-10 days per store for pouring and allowing concrete to cure. Moreover, BSB panels can be accommodated into 40 feet containers, which facilitate transportation to the site. Overall, the efficiency of production, installation, and logistics of BSB method is 6-10 times higher than conventional methods.

- **Cheaper**: Shifting construction work into the factory enables construction cost-savings due to factory cost controls, the ability to eliminate construction material waste, and the ability to control on-site idle time. Off-site production also reduces transportation and logistics costs. Overall, prefabricated building can costs 20-40% less than a conventional building.

- **Better**: Innovative anti-corrosion technology is being used in structures. Prefabrication can also overcome the lack of a qualified workforce by using standardized, quality-controlled manufacturing processes.
Overview of Modular Building Structure

Roland Brown

Design and structural constraints of prefabrication

• **Architectural programming:** The goal is to develop designs that are cost-effective and meet particular customer needs. Thus, the availability of architects for instant collaboration is essential.

• **Code and building safety requirements:** The International Building Code and ASCE 7-10 have established structural requirements for commercial modular buildings. However, there is no special “modular building code”. The non-combustible characteristics of a building can arise as a potential structural problem and should be addressed in the early design stage.

• **Manufacturing limitations:** Module height and size is a major limiting factor for modular construction companies. In some cases, crane capacity is another factor that can limit designers and construction teams. Additionally, off-site assemblies should be light enough so that cranes can lift them.

• **Shipping limitations:** Some modules may require special equipment to move them to the construction site.

• **Design loads, gravity, wind and seismic activities:** Although some approaches can be costly, current methods can overcome these constrains.

• **Budget:** The budget varies according to the location.

Considerations about the modular structural systems

• **Floor systems**

  The biggest challenge in using steel framing, steel pans, and poured off-site concrete floors is cracking. A professional should identify the points of inflection within the frame and design for corrections. For steel framing with cement board decking floor systems, a one-inch concrete board covered with one inch of high-strength gypcrete can be used. Another option is a concrete slab on grade or floorless modules.

• **Lateral systems**

  Lateral systems are essential for resisting wind and seismic forces. The roof is used as a horizontal diaphragm. The force from the roof is resisted by shear walls, diagonal bracing, or moment frames that are connected to the roof boundary members. The modular approach requires segmenting the roof diaphragm, which should be structurally re-connected after the modules are placed on the foundation. Vertical lateral options used in modular construction are:

  1. Shear walls: The building walls can be used as shear walls. They can be sheathed with a variety of materials.
  2. Diagonal bracing: Can be made with flat, hot form straps, or flat cold straps.
  3. Moment frames: Rectangular structures that have sufficient strength and connections to work as a steel frame.
The MEP rack modularization
The design prefabrication process for MEP racks consists of four major phases:
1. The engineering design process and modeling in Revit aiming to find the optimal design solution
2. The identification of every single element that will be installed in the rack
3. The organization of elements and the formulation of systems in the rack
4. The fabrication drawings with specific software.

As soon as racks are assembled, they are tested in the shop and prepared to be transported. Each rack module receives a tag with a number which corresponds to their specific assembly location in the system.

Lessons Learned
The inclusion of local inspectors early in the design phase minimizes problems at the commissioning stage. Also, time savings were only significant after some racks were completed.

“One of the things we need to think about is that the individuals working, at least in the commercial sector, have been used to a certain rhythm and meter on the site. So, when we incorporate larger components and modules, the rhythm and meter change completely. We often expect the superintendent to be the orchestrator and conductor, but most of the time we just got cacophony in the field. To avoid that, we need to be more involved in the process.”

Applications of Offsite Construction and MEP Systems Modularization
Kevin Labrecque

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Earlier design decisions</td>
</tr>
<tr>
<td>• Reduced work at height</td>
<td>• Teams familiar with stick built are used to a certain flow of key decision timing, with parallel construction off-site, decisions timing changes</td>
</tr>
<tr>
<td>• Individual working in ergonomic strike zone</td>
<td>• May result in overdesign</td>
</tr>
<tr>
<td>• Reduced number of operations on-site</td>
<td>• Commitment for modeling building component early</td>
</tr>
<tr>
<td>• Reduced open flame jobs on-site</td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>Project Team “Buy-In”</td>
</tr>
<tr>
<td>• Work performed in a controlled environment</td>
<td>• Failure to stick to a plan that allows installation of modularized components</td>
</tr>
<tr>
<td>• Inspection and testing processes incorporated into standard work</td>
<td>• Schedule created through off-site approach can be lost to traditional practices on-site</td>
</tr>
<tr>
<td>Schedule</td>
<td>Supply chain management</td>
</tr>
<tr>
<td>• Shortened overall project durations,</td>
<td>• Hiccups in supply ripple through “Just in time” systems</td>
</tr>
<tr>
<td>• Modules are produced in parallel with on-site operations</td>
<td>• Application of lean manufacturing practices in the fabrication facility</td>
</tr>
<tr>
<td>• Risks of on-site coordination are minimized</td>
<td>• Extra support for shipping may need to be considered</td>
</tr>
<tr>
<td>Wastes Minimized</td>
<td>Opportunities to standardize shipping and packaging</td>
</tr>
<tr>
<td>• Materials waste reduced significantly</td>
<td>• Cash flow considerations</td>
</tr>
<tr>
<td>• Wastes of time and motion associated with site construction eliminated</td>
<td></td>
</tr>
</tbody>
</table>

“Some of the things that are a fundamental assumption about our industry, from the stick-built perspective, are in place because of momentum and not because they make sense.”
The significant needs of housing and infrastructure are outstripping the ability of construction industry to meet the demand. The construction industry has also not been able to eliminate cost overruns and late deliveries, the most common problems in the industry. Additionally, the construction industry is considered one of the least digitized industries.

The 7 levers for improvement in the construction industry

1. Reshaping regulation and increasing transparency
2. Rewriting the contractual framework
3. Rethinking the design and engineering process and increasing standardization
4. Improving procurement and supply-chain management
5. Improving on-site execution
6. Infusing digital technology, new materials, and advanced automation into the process
7. Reskilling the workforce

Off-site volumetric construction has emerged as an alternative for developers of residential buildings, hotels, and dormitories. The major advantages are the controlled environment, the increased speed of construction that attend to market expectations, predictability regarding costs and time, and the ability to apply continuous improvement principles to drive ongoing cost and schedule improvements.

At Full Stack, a project starts with the modular assessment, initial layout with custom scripts, and estimation of costs for the building. The project proceeds with a detailed design, implementation documents, procurement and process engineering, production of the modules, and the final stacking and mateline.

Guidelines and principles for designing, manufacturing, and assembling

- Minimize variation and avoid mirroring plans
- Minimize the number of components
- Freeze design to enable modular production
- Align vertical risers to corridor or closet walls
- Standardize parts and materials
- Create modular assemblies
- Use consistent chassis sizes to reduce costs and variations
- Simplify manufacturing operations
- Maximize modular efficiency by delivering mods with a higher level of finishes completed
- Separate structural braced frame to be considered for buildings over 18 stories
- No risers on wall partitions
- Install access panels to valve locations
Golden Construction was a General Contractor company that was transformed into a Design/Build Modular Construction company because of the recent financial crisis and the collapse of the housing market. The company initially partnered with BLOX company for some projects that included the use of modular units and pods. From those projects, they realized the potential for using modular construction, the durability of the construction method, and the importance of controlling design and subcontractors.

How to use modular to rescuing a project

The Fairhaven project was one of the first steps in the process of implementing modular construction. It was a 10-year project with major budget issues, financed with non-rated bonds, and significant problems with the original GC. The owner needed a contractor who could show transparency, work collaboratively, and deliver the project with speed because of the high costs of financing. The modular construction model was integrated in the project by using the following objectives:

• **Controlling design and building plans:** Trusting and committing to modularization from the beginning, removing the burden from the design team and making subcontractor part of the solution, getting the design team to create rules for building the bathroom, making the design reflect how to build the project, and showing modularization on the plans.

• **Leading the subcontractors:** Co-creating estimates and validating assumptions with weekly meetings, building visual models, showing the real product in factory.

• **Pairing modular:** Pairing modular components by using wall panels that accelerate the creation of the structure; electrical and HVAC pre-assembly that accelerate rough-in; and bathroom pods that speed finish work.

• **Ownership:** Creating the conditions for modular to work.

Restructuring a company

The construction industry is extremely fragmented. The more fragmentation across the industry, companies and projects, the more coordination is needed. Macrganization aims to reduce the fragmentation and optimize processes and projects. In the process of restructuring the company, the major transformations happened in (1) People, (2) Process and (3) Tools. The most challenging part was explaining the changes and concepts.

The grounds for dismissal

• Not being aligned
• Not being in learning mode
• Lack of ownership
• Not being expert at the tools
• Lack of results
Current manufacturing practices for generating prefabricated elements to the residential sector are not efficient, demand significant physical effort, and still rely heavily on traditional methods. Improving manufacturing modular practices requires the promotion of pre-assembly elements, encouragement of standardization, and stimulation of innovative construction processes.

“As the modular construction seems to be moving rapidly towards a volumetric approach, Lean concept can be applied to improve work processes and productivity standards in construction industry and projects. The application of Lean concept can play a vital role in eliminating waste in production and optimizing complex construction operations.”

The 7 types of waste in Lean theory arise from motion, waiting, transportation, inventory, defects, over-processing, and overproduction. For example, the process of assembling a floor made of rim boards has not changed in the last 45 years. But yet, it takes workers around 45 minutes to complete a 5-10 minute task. The reason is that it takes more time due to unnecessary movements and talks during the process. Money and time can be saved even without any technology only by moving the task from one location to another or settling the object in a different way. Therefore, it is essential to reduce the volume of unnecessary moves on the factory as time spent reflects in additional costs.

Increasing efficiency in the factory requires an analysis of the production process in different stages and the design of better manufacturing methods with the use of automated systems. 3D modelling and animation methods can be used to avoid potentially costly on-site errors. By using lean manufacturing strategies, a new manufacturing process is proposed for the workstations which increases productivity, reduces waste, time, and human resource.

Methods for reducing inefficiency of the process

- Using pre-drilling and subassemblies
- Multi-panels: Production of one wall at a time used to be a norm. However, a novelty of the modular method is to assemble parts of the walls

Continued...
altogether to turn them into one wall. In this case, the number of elements for walls can decrease from approximately 50 pieces to 6-14 ready-to-install walls.

- **Automation:** Prefabrication originally used manual methods for assembling building elements off-site, such as measurements and hammers. However, construction automation should be used for equipment selection and on-site utilization.

The optimized prefabrication method allows building a small houses in 6 hours or larger homes in 2 days. Most improvements can be done at no additional cost.

**What can be done to optimize the modular method?**

**Research hypothesis:** A Production Line Breakdown Structure (PBS) integrated Value Stream Mapping (VSM) analysis with the consideration of Lean manufacturing concept will help to promote a reliable, predictable, efficient, and innovated manufacturing construction process from a conventional construction dominated manufacturing practice.

**Research objectives:**
- Designing the PBS for modular off-site construction manufacturing to assist the production line analysis, diagnose and problem-solving.
- Integrating the PBS with lean manufacturing and adjusted VSM to create a framework for performance assessment.
- Implementing the framework through commonly used four steps improvement process.

One of the main questions for the assembly process is when to assemble each component. One should first consider all levels of modular manufacturing process to identify the time for each activity. Level 1 refers to overall production line; Level 2 refers to production line zones; Level 3 to building components; Level 4 refers to work station flow and activity performance; and Level 5 to Activity Motion analysis.

After looking into the levels and having basic predictions about the timeframe for each of the elements, one should apply the lean concept, which refers to considering current practices. Then the future state and finally the likelihood that the future state would be an improvement of the current practice are considered. Most of the current design and drafting software has not been designed for modular construction. However, some of these can be used for modular design with add-on attributes. This software allows producing a 3D model of a building including electrical connections, mechanical connections, and structure connections. BIM aims to reduce manual labor, improve quality, to be cost effective, to save time, to allow higher accuracy, and to improve safety.

The Light Gauge Steel Automated Framing is a machine that frames light gauge steel wall panels. As an example, the concept of splitting the building into the elements and a multi wall system were applied to a multi-story building. Al Hussein is developing a machine that automates the production of light gauge steel frames which adjusts the table width, activates electromagnetic squares, and places tracks and studs manually. Panels members are assembled together manually before the machine automates the hard connections. This machine also uses snap-on soft connections: studs and tracks punched with screw dimples at specific locations are produced using Roll-former machines.
3D printing is a subject undergoing intense study lately. The application in the construction industry has also been an increasing trend. 3D printing is an option for building elements or components that cannot be manufactured with the traditional building techniques, with the available labor, and construction materials. The technology is still in its infancy, therefore not many applied examples can be seen worldwide.

“Although 3D printing seems to revolutionize the industry, it is believed that it will not take over everything. Instead, it will revolutionize separate elements that usually are expensive to manufacture with traditional techniques, such as complex shapes or components that are typically difficult to handle in normal manufacturing processes.”

Major worldwide groups working with mega-scale additive manufacturing

- Contour Crafting LLC (Berok Khoshnevis)
- 3D Print Canal House (DUS Architects)
- D-Shape (Monolite UK Ltd)
- World’s Advanced Saving Project (WASP)
- Digital Construction Platform (MIT)
- Institute for Advanced Architecture of Catalonia (IAAC)
- Freeform Project (Loughborough Univ.)
- Backyard Castle (Andrey Rudenko)
- Branch Technology
- Winsun
- ORNL
- NASA
- ERDC

The Branch technology

The U.S. Army is currently researching additional construction options that have the capability to print custom-designed expeditionary structure on-demand, in the field using locally available materials. Current 3D printing techniques are using vertical and horizontal reinforcing because there is a major gap in research as far as reinforcing strategies for 3D printing buildings.
Getting the most from off-site construction: strategies, implementation guidelines and best practices

Laurie Roberts

Overcoming barriers and challenges of off-site construction will require a significant effort for changing the design and construction culture and perception. Providing education is fundamental at the grassroots levels of academics, owners and developers, architects and design professional, and construction managers/contractors.

Pre-construction Strategies

• Researching the industry and performing due diligence.
• Collaborative approach and integrated design process: This strategy involves a commitment to the concept, knowledge sharing, and understanding of the dynamics of the buildings, communication, coordination, and cooperation among several stakeholders involved in the project. Because of the differences in traditional methods, design coordination becomes a critical discovery factor before construction begins.
• Recognizing the importance of the module: Modular plans start with a conventional concept from where a module key plan will be elaborated. Changes in the project might include shifting doors and windows to keep them out of modules splits lines. Transportation regulations dictate modules sizes and they can vary greatly between geographical regions. The number of modules will also affect the on-site work and impact the foundation design. Site access should be planned beforehand and includes considerations about overhead obstructions, immovable objects, adequate turning radius, crane area and position.
• Phasing or sequencing of the project change from design through construction: The project schedules should establish a reasonable time for final design, coordination, review, and approvals. Decisions must be made earlier to avoid changes during fabrication, which are costly.
• Developing a detailed and defined scope of work: Specifications should determine the products, systems, and assemblies. A scope of work to define the coordination of the project and demarcation of roles and responsibilities should be made earlier. There are no standardized scope of work, but three different approaches can be used: (1) modular builder as a subcontractor turning the completed modules over the GC at site to install and finish, (2) modular builder as a sub-contractor self-performing building installation only and all other site development by GC. (3) modular builder as GC performing all aspects of the project.

Continued...
Procurement methods

- **Design-bid-build**
  
  **Advantages:** widely recognized, low cost and known costs, easy evaluation for owners.

  **Disadvantages:** linear and longer process, reduced communication between design and construction, prescriptive approach does not allow innovative alternatives.

  **Application for modular projects:** must be designed around modular methodology initially.

- **Design-build**
  
  **Advantages:** one contractor and one point of responsibility, more collaboration and fast track.

  **Disadvantages:** architect role may be reduced, declared costs may change during the design process, more trust required by owner.

  **Application for modular projects:** contractor should be engaged at design level.

- **Integrated Project Delivery**
  
  **Advantages:** easily collaboration and alignment of stakeholders. Committee approach to decision making shared interests and objectives throughout the project, shared risks and rewards, and transparent.

  **Disadvantages:** relatively new concepts and not fully understood, can require new IT sharing platforms, required higher level of trust between stakeholders.

  **Application for modular projects:** highly recommended project delivery method.

Contracts and payments

Typical AIA construction contract documents do not make provisions for payment for materials prior to delivery to the construction site. However, the modular building could be as much as 90% complete prior to delivery. If arrangements cannot be made, lack of progress based on a schedule of values for construction places a financial burden on the modular builder. Many modular companies cannot or will not take on a large project on this basis. Validation of work completed at the plant to a defined monthly draw based on the schedule of values can be done by the owner or its representative.

“Modular plans start with a conventional concept from where a module key plan will be elaborated.”
Project execution strategies

- **Site mobilization**: Transportation plan with routes, timing, security, staging area should be planned accordingly, as well as a layout lift plan for cranes.

- **Module production**: Includes planning and mobilization, establishing of a scope of work, modular design, building specifications, and construction drawings.

- **Coordinate with GC for local permitting**: Determine what permits are necessary to ensure responsibility matrix scopes of work and time allotted.

- **Material procurement**: Once final design and submittals are approved, materials are ordered to suit the production schedule. Long lead time items require early submission and pre-approvals. Materials should be received, identified, and verified.

- **Prepare to ship**: Prepare a detailed packing list for all materials to be shipped to the site. Loose materials must be received, accounted, and protected. Oversize loads may require specialized routing due to overhead obstructions or restricted times for moving or receiving modules.

- **Foundation attachment**: Foundations should be designed for downloads, lateral resistance, and uplift. Attachment of building sections to the foundation and adjacent sections may be mechanical or structural welded.

- **Module floor elevation**: Modules can be placed in three different ways:
  1. On top of the conventional built lower level
  2. Placed on a concrete podium, or
  3. Erected on grade level foundation.

- **Crane set installation**: Lift system and pick points are engineered for specific building sections. Develop a lifting schedule, lift safety plan, and establish the maximum/minimum radius reach.

- **Site completion**: Complete structural connections between sections, exterior cladding between sections, interior partitions with respective finishes, connections of electrical, plumbing, HVAC, feeders between main distribution panel and sub panels, domestic water and sewer lines, and low voltage systems.

- **Commissioning and contract close-out**: Requirements will vary with each contract based on specifications and scope of work but may include certified test and balancing reports, performance testing against owner’s project requirements, operating and maintenance manuals, warranty documents, and as-built drawings.
Panel Discussion: Methods, Processes, and Technologies

What are the challenges associated with modular construction, its value added to construction and the real estate market? Why does modular construction not constitute a greater percentage of the entire construction market?

“This is a complex question that involves the business aspect. I think it was already proven that with provided resources, some processes can be done in a factory. However, the competition is a negative component. Today, our industry has this cancerous attitude that the cheaper is better. Moreover, there are a handful of companies that successfully work with major projects, but fail when taking over complicated projects that require advanced knowledge. It is a fact that, when you disappoint a customer, you can lose them for ten or fifteen years. Additionally, there is the problem of “feeding the monster”. Companies are trying to reach some level of production and trying to keep their staff employed. But they very often fail because of inexperience.”

Roland Brown

“When we visited different plants throughout North America, we found few things that surprised us. Firstly, we were wondering what is the point of weather protected facilities that does not have a systematic process other than getting you out of the weather and maybe having better quality control. Secondly, we noted how completely analog these shops all were. Basically, there were cutting things, people were pulling wires, slapping on drywall, and shipping components out. It seemed so disconnected from any other industry we were looking at that are all fully technological. Major breakthroughs have advanced these industries and changed the product completely. Currently, we all are wondering where is that sort of change, the synthesis of things, the integration, the collaborative conversation, the manufacturing mindset for modular construction, instead of the cheaper and faster philosophy.”

Oliver Lang

“Due to the absence of a framework in modular construction companies are making their own versions of simple elements one after another. However, this repetition can be avoided if all the processes will be standardized and organized universally. Until that happens we will continue talking about design manufacturer construct as an attempt to establish that basic framework.”

Chris Giattina

“It is just very complicated and there are a lot of players in the industry. It is all about an optimization problem. I think the turn key approach to what keeps it from trickling up into all kinds of architectural pursuits meaning is the moment when you say: “I am going to deliver a building faster and cheaper on your site”, because it limits the amount of the market. Modular industry is not an approach when one thing should be replaced with another, but it should be a bridge to something that is radically different in construction methods. I think what is fascinating is the idea of including architects and design, local governments and labor, building codes and clients. Modular construction is all about optimization, which, however, it needs some more time.”

Brian Phillips
How do you see the assembly line itself evolving in different environments (off-site and on-site)?

“"For around 100 years, the industry has had automation in some form. The problem is its value in repetition. The modular building industry relies on volume and it is very difficult for manufacturing companies to make the investment. Companies have to follow peaks and valleys in construction seasons. So, how do we fill the voids? How do level-off production? There is very little volume and repetition at this point, and that will push automation in construction industry forward.”

Laurie Robert

“There are several issues. For instance, most of manufacturers in the US are fairly small. However they have reached the balance. They have enough marketing, they have enough purchasing, and they have enough engineering to support their existing production rate. When you move into automation you can quickly up ramp that.”

Charlie Walden

“I would say that I am fairly impressed by a large amount of automation. A lot of the production is already happening, such as highly efficient buildings made of modules. I would say that labor shortages in different areas could potentially contribute to the automation of some processes, because when we start adding automation whether it is robots or other sort of automation, we change the job types. If you do not have enough people who are experienced at construction or if we have an excess professionals experienced in robotics or automation, then you need to change the job types. Thus, if you can change the job type to be a higher technical field, then you can fill some of the gaps that are not currently filled in those low labor shortage areas.”

Megan Kreiger

“I see the assembly line evolving to be highly sophisticated. The other component is the progress occurring in the factory. If somebody visits a factory periodically, let’s say every six months or so, that person will be in a new factory because they learn new things and improving their processes. For example, instead of watching the processes on-site, cameras will be everywhere in the factory. Changes in the processes might be minor, but mean a lot on a timescale. The other thing is called family sustainability which means that people working in the factory can go home with almost the same physical abilities as if they were coming after working in an office. Thus, workers have time and energy to play with their kids and enjoy time with their families. Technology allows to reduce the amount of everyday stress. The RFID system is another example which allows monitoring components through the processes in the factory. For example, even when the assembly line is producing components for four different clients concurrently, the RFID gives information for each component.”

Mohammed Al-Hussein
Do you think there is an opportunity for a modular foundation or designing modular foundation system? How are you dealing with foundations in your projects?

“In Alberta, we implemented a precast system for single-family homes. They have an interesting system called crib-structure system. I’m not sure if it could fit as a modular in the future, but it is widely used as basement for single-family homes or for multi-story buildings. The best program I have seen is in Finland, where I saw a lot of precast panels for basements. In US we have the colored sandwich panels.”

Mohammed Al-Hussein

“I would consider two types. For temporary foundations, we have state codes that allow buildings to be located on temporary foundations. They still have to be restrained laterally and for uplift, but they can be steel piers, I-beams, or other structures. However, what we usually do is more about permanent construction and we almost always use permanent concrete foundations, whether that are slurry-walls, pilings, or actually piers.”

Charlie Walden

How do you see the implementation of the 3D printer technology in modular construction? Would it fit in your business model? Do you consider this technology suitable for modular construction in future?

“One easy example of implementation can be for the creation of fixtures and jigs. 3D printing seems like a fantastic solution to just print something and see if it fits, works, doesn’t work, and iterate to optimize the outcome.”

Kevin Labrecque

“I was shocked at the speed of growth for this technology. I had seen the contour crafting video some years ago and now the amount of growth is impressive within a very short period of time.”

Charlie Walden
Which terminology and definitions would you use for your field of work: off-site, modular, or industrialized construction?

“For 3D printing, we use the term on-site construction as we are printing directly where it needs to go. Off-site is just anything outside of that. But, we have not really considered the idea of having a 3D printer right next to the foundation and I think that is a great area. I think modular construction could come from 3D printing, but the 3D printing does not necessarily involve modular construction industry.”

Megan Kreiger

“It depends where you are located. If you go to China, you are not going to hear the world modular. The word industrialized construction is then a better terminology there. I think either of these definitions fit the same context and there is no specific term used by all at this moment. However, it is believed that there is a stigma around the word modular construction. Some people will have the fear of the word modular since the early generations of such buildings were not as sophisticated as what we see today. This is to the extent that some say the acceptance of modular construction is still a victim of this stigma.”

Mohammed Al-Hussein

“Off-site construction benefits the on-site operations from a safety and a congestion perspective. However, several projects set up a manufacturing units adjacent to the site. In this case, it is technically “on-site” but the goal is to benefit from taking advantage of the manufacturing approach.”

Kevin Labrecque

“I think the off-site construction is defined even by the Off-site Construction Council in Washington as anything that is built in a controlled environment away from the final assembly location and then delivered to the site location. So there are many activities that are considered off-site construction: mechanical applications, bathroom pods, roof trusses, or generally anything that is prefabricated. Modular construction tends to refer to the volumetric three-dimensional “big chunk of building” that incorporates smaller modules. The term modular has a stigma attached to it and that is probably why China does not want to hear the word modular. As an industry, the Modular Building Institute struggled about the usage of this terminology.”

Laurie Robert
Conference Survey

The “Symposium on the State-of-the-Art of Modular Construction” was designed to provide a snapshot of the cutting edge of modular building design, component manufacturing, and construction techniques and to help stimulate a dialogue among the stakeholders of the modular process. The following table shows the total registered participants and the type of registration.

<table>
<thead>
<tr>
<th>Registration Type</th>
<th>Number of registered participants</th>
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</thead>
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<tr>
<td>Speaker</td>
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</tr>
<tr>
<td>Faculty</td>
<td>17</td>
</tr>
<tr>
<td>Student</td>
<td>25</td>
</tr>
<tr>
<td>Audience</td>
<td>43</td>
</tr>
</tbody>
</table>

Questionnaires were distributed to speakers, faculty and the audience at the beginning of the first day of the event and returned throughout the event. No student has received the questionnaire. A total of 30 questionnaires were received during the two days of the event from a total of 69 distributed questionnaires. This resulted in a 43% return rate.

**Which industry category you would identify yourself?**

![Pie chart showing industry categories]

**The perception of change of off-site construction in the future.**

90% believe the off-site construction will increase in the future.
Top types of construction that currently use off-site construction.

The top 5 modular construction sectors are single-family and multi-family housing, commercial, educational, and healthcare.

What decision-makers are more important for selecting off-site construction?

35% believe that the client is the most important decision-maker when selecting the construction method, followed by the architect (31%), and the contractor (26%).

How can the educational system contribute to broader use of off-site construction?

- 31%: Provide courses in off-site construction
- 29%: Provide continuing education courses on off-site construction
- 20%: Conduct research on topics related to off-site construction
- 13%: Other
Profiles

RYAN SMITH
Associate Professor of Architecture and Dean for Research in the College of Architecture + Planning, University of Utah Integrated Technology in Architecture Center. Author of Prefab Architecture (Wiley, 2010), Building Systems (Routledge, 2012), Off-site Architecture (Routledge, 2017), and Process & Product (Lunch Humphries, 2017). Founder and past chair of the National Institute of Building Sciences, Off-site Construction Council and Senior Research Fellow in the Centre for Off-site Construction.

OLIVER LANG
Principal at LWPAC, President of Intelligent City and a licensed architect in British Columbia, NRW Germany and the State of New York. Oliver has served as an advisor to the City of Vancouver and the University of British Columbia on their paths towards carbon neutrality. He is also the President of Intelligent City, a Vancouver based company engaged in the design, engineering, development, fabrication, and research for advanced mixed use urban housing as a generative integrated systems based product.

CHARLIE KAPLAN
Named in the top 10 most innovative architecture companies by Fast Company in 2014, GLUCK+ is recognized for Architect Led Design Built. Award-winning project include “The Stack” – the first prefabricated steel and concrete multi-story residential development in New York (AIA/NY/BSA 2015 Housing Honor Award); House in the Mountains (2013 AIA National Housing Award); and Cary Leeds Center for Tennis & Learning in Bronx (2012 NYC Public Design Commission Award for Excellence).

BRIAN PHILLIPS
Founding principal of Interface Studio Architects LLC, a firm that designs buildings, master plans and installations across US. ISA has won over thirty design citations, including AIA Silver Medal, AIA National Housing Award, AIA COTE Top Ten Award, and USGBC LEED for Homes Project of the Year. Brian was named an emerging voice by the Architectural League of New York in 2015 and his work has been featured in ARCHITECT, Architectural Record, DWELL, Metropolis and The Boston Globe.

CHRIS GIATTINA
Chris is an Architect, manufacturer, and CEO of Blox and GA Studio. Chris and his team developed an open source-project delivery process called Design Manufacture Construction - a design that uses manufacturing productivity to simplify construction. Unable to find a manufacturer interested in their work, he started Blox – a ground-up manufacturing company using DMC principles. Today Blox works with large healthcare systems across the country designing, manufacturing and constructing complex buildings.

SUNNY WANG
Mr. Wang is the executive manager of Broad Group. He heads up the United States operation of Broad Group and is in charge of the overall operational management in North America. The Broad USA is a market leading low carbon Technology Company with high performance that delivers proven solutions in absorption cooling and prefab high rise. The Broad USA always stands behind our customers to leverage their sustainable development goals through state of the art engineering and service support.
ROLAND BROWN
VP of Design for Ramtech Building Systems, Inc. - a design/build GC that utilizes multiple modular construction techniques for relocatable and permanent buildings. Mr. Brown is responsible for supervising the Architectural Design and the Product Engineering Group, and Quality Assurance. He also serves as Secretary of the MBI’s Board of Directors, chairman of the Government Affairs Committee, and was appointed to the Texas Industrialized Building Code Council in 2010 by Governor Rick Perry.

KEVIN LABRECQUE
Kevin has over twenty years of project management and operational leadership in the construction industry. Currently, he serves on the executive management team of Harper Building Systems, a Limbach Facility Services company, as Senior Vice President of Operational Excellence. His primary objectives consist of leading the continuous journey of Lean transformation, maintaining the company’s market-leading execution of BIM, and advancing efforts in off-site manufacturing of mechanical systems. Kevin got his bachelor in civil engineering from Rutgers University on 1996. He worked for Bovis Lend Lease from 2002 to 2009 and worked on risk engineering. He has been working at Limbach Company since 2009, where he focuses on lean management and application of BIM in CNC shop systems and fabrications.

ROGER KRULAK
Roger is the CEO of Full Stack Modular LLC. He has extensive experience on both the construction and development sides of the real estate business. In 2008, Roger spearheaded the first R&D project for Modular Construction which leads to the creation of FC Modular and subsequently the creation of a factory and business to build the tallest volumetric modular building in the world. Recipient of the Popular Mechanics Breakthrough Award 2014 for the creation of a high-rise modular process. Roger got his bachelor in management, organization, and psychology from Bobson College on 1986. He has worked for several companies since then. On early 2016 he became the CEO of Full Stack Modular LLC.

JOSH OAKLEY
Josh is responsible for the execution of Golden’s mission to “Build People and Revolutionize the Construction Process”. He is an expert in technology in the AEC industry including BIM and Virtual Construction as well as how to lead organizations through the change required to fully adopt new tools and process. With experience on both design and construction sides of the business, Josh is transitioning Golden from a traditional builder to a fully integrated Design/Manufacture/Construct company.

MOHAMED AL-HUSSEIN
Professor, Department of Civil & Environmental Engineering, Holc School of Construction Engineering at the University of Alberta. NSERC industrial research chair in the Industrialization of Building Construction. His research has proffered many contributions the industrialization of the building construction process through the development of modular and off-site construction technologies. He is researcher and consultant in Modular and Off-site Construction, Lean Manufacturing, Construction automation, Construction process optimization, and Building Information Modeling.

MEGAN KREIGER
Active in the research area of mega-scale additive manufacturing for construction. Mechanical Engineer for the U.S. Army Corps of Engineer - Engineer Research and Development Center - Construction Engineering Research Laboratory.
LAURIE ROBERT
Laurie Roberts joined NRB in 1982 as sales manager. After 10 years, in 1992, she became VP of Sales and Marketing. Having become involved in the Modular Building Institute (MBI), she joined the MBI board. She was elected president of the MBI Board of Directors in 2001. In 2005, she was awarded MBI’s Outstanding Achievement Award. Currently, she serves on the executive Board of Directors of the National Building Institute of Building Science Off-Site Construction Council. On March 21st, 2017, Laurie was inducted into the Modular Building Institute’s Hall of Fame.

CHARLIE WALDEN
Partnering with Silver Creek Industries (SCI) in 2014, Charlie Walden brought with him experience providing infrastructure, site improvements, and installation of modular buildings from his career with Walden Structures. With projects ranging from hospitality to military, to medical and to commercial markets, Charlie has broad experience dealing with all phases of modular construction including design, construction, fabrication, delivery, installation, close-out and commissioning. Now Director of Permanent Modular Construction at SCI, Charlie has helped expand they’re once educational facility focused market to larger permanent modular buildings.

Acknowledgement To Our Industry Sponsors

Acknowledgement To Our Volunteers

Alireza Adibfar
Alireza Shojaei
Andriel E. Fenner
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