5 IN 5 MODULAR GROWTH INITATIVE RESEARCH ROADMAP RECOMMENDATIONS











5 IN 5 MODULAR GROWTH INITIATIVE Research Roadmap Recommendations

Ryan E. Smith, University of Utah Ivan Rupnik, Northeastern University

© Copyright 2018 Modular Building Institute



Acknowledgements: The authors would like to thank the Modular Building Institute staff, board and members for their participation and sponsorship of this work. Also, thanks goes to the research staff Kambaja Tarr and Carissa Pollock, students at the University of Utah for their work during this project. Finally, our appreciation goes out to all of the individuals and companies that participated in the study including the survey, factory tours across the globe and webinars and workshops.

CONTENTS

BACKGROUND	4
PHASE 'A' – SWOT WORKSHOP & NORTH AMERICAN SURVEY	5 - 8
PHASE 'B' – INTERNATIONAL LESSONS LEARNED	9 - 16
PHASE 'C' –ROADMAP/RECOMMENDATIONS & TACTICS WORKSHOP	17 - 26
NEXT STEPS	27 - 31
APPENDIX 'A' – SWOT ANALYSIS	32 - 33
APPENDIX 'B' – NORTH AMERICAN SURVEY DATA	34 - 37
APPENDIX 'C' – INTERNATIONAL CASE STUDIES	38 - 51

PROJECT SCHEDULE

The following is an overview of the schedule of activities conducted during this research work:

January 2017	Project Kick-off
March 2017	MBI membership SWOT workshop at WOM 2017, Tucson, AZ
April 2017	MBI Board Live Presentation in New Orleans, LA
May 2017 – October 2017	North American Survey
May 2017	International Visit – Sweden
June 2017	International Visit – Poland
September 2017	MBI Board Live Presentation in Vancouver, BC
October 2017	International Visit – UK
December 2017	International Visits – Japan and Australia
February 2018	MBI Board Webinar Presentation
March 2018	MBI Board Live Presentation and Tactics Workshop at WOM 2018 in Hollywood, FL
May 2018	Final report issued

BACKGROUND

The permanent modular construction, industry is in a process of transformation on a global scale. If managed directly, this transformation can certainly lead to a growth of "5 in 5" or 5 percent of the construction market in five years. This initiative started in 2015 was an effort to increase demand across the commercial modular sector. The modular industry has already seen growth from 2.37% of the construction expenditure in 2014 to 3.17 percent in 2017. Considering the current demand for multi-family housing and hospitality, this number will likely continue to climb. This report includes not only the research of how to strategically grow the industry, but also lessons on how to manage growth.

The 5 in 5 Growth Initiative: research roadmap recommendations, underpins this effort in order to determine a strategic path forward of how to increase the uptake of permanent modular construction in North America. The scope of this work included three concurrent phases:

- Phase 'A' surveyed the North American traditional construction sector to determine the perceived and actual barriers and challenges associated with utilizing modular construction. This phase also included a SWOT workshop held at World of Modular in 2017 with MBI members.
- Phase 'B' included literature review and live visits with key stakeholders and case study companies internationally to document lessons learned that may be implemented in the North American context.
- Phase 'C' was to create a roadmap with the MBI membership that identifies strategies and tactics to realize greater market growth. This was accomplished through continuous presentations and feedback from the board and members throughout the project, including a tactics workshop held at World of Modular 2018 with MBI members.

This report covers the research results, roadmap and recommendations from this process. The report outlines the strategies and tactics recommended by the research team in close collaboration with the MBI board during live board meetings and webinars and at workshops held during World of Modular 2017 and 2018. However, the report does not aim to prioritize the strategies or tactics, nor does it go into specifics on the particular actions that should be taken by MBI. This has been left to the organization to determine and carry out.

PHASE 'A' – SWOT WORKSHOP & NORTH AMERICAN SURVEY

In order to develop a survey for North American construction professionals, the research team held a workshop at the World of Modular 2017 conference wherein a SWOT analysis was conducted over a three-hour afternoon session. The results of the SWOT analysis demonstrate common themes and aided to identify the topics that would be questioned in the North American survey.

The SWOT analysis uncovered the MBI membership's perceptions concerning the modular industry's strengths, weaknesses, opportunities and threats. The results are included in Appendix 'A'.



Figure 1. SWOT workshop at WOM, March 2017.

The general areas of questioning for the survey were identified during the workshop at the WOM 2017 in Tucson, Arizona. Furthermore, at the spring 2017 MBI Board meeting in New Orleans, members responded to the draft of the survey before it was disseminated online in May of 2017 via SurveyMonkey. The survey was distributed to the University of Utah ITAC database to more than 23,000 architects, engineers, contractors, and building officials in North America. Seven-hundred ninety-three persons responded. A summary of the results is included below with the full results included in Appendix 'B'.

The majority of respondents were architects with contractors and owners making up the balance.

Architecture and engineering respondents to have worked on one to three projects in the last year that utilized modular with the majority being 1000-5000 SF single-family and multifamily, while contractor respondents have worked on four to five projects that utilized PMC with an average of 50000-10,000 SF in commercial construction, multi-family and single-family housing.

A. The first area of questioning was about **barriers** in uptaking of modular construction for experienced AECO professionals that have utilized permanent modular construction in one or more projects.

Barriers to modular uptake (in order of frequency):

Architects/Engineers response -

- 1. Owner perception and education
- 2. Historical stigma
- 3. Regulatory code officials, inspectors
- 4. Design restrictive / aesthetics limitations
- 5. Transportation logistics
- 6. Designer's knowledge of modular
- 7. Early engagement of modular manufacturer

Contractors' response -

- 1. Owner perception and education
- 2. Historical stigma
- 3. Designer's knowledge of modular
- 4. Regulatory code officials, inspectors
- 5. Transportation logistics
- 6. Traditional contracts (tie with seven and eight)
- 7. Early engagement of modular manufacturer
- 8. Cost estimating and budget

Owners' response -

- 1. Historical stigma
- 2. Owner perception and education
- 3. Transportation logistics
- 4. Traditional contracts
- 5. Designer's knowledge of modular
- 6. Project finance
- 7. Early engagement of modular manufacturer

Code Official / Inspector response -

- 1. Design restrictive / aesthetic limitations
- 2. Owner perception and education
- 3. Regulatory code officials, inspectors

Barriers to modular uptake qualitative experiences (all groups in no particular order):

- Bad quality, exterior envelope issues, dirty factories
- Cost has been higher on bids
- Pre-qualified builders who are approved to 'fly' the building
- 65% of construction budget in one supplier, loss of GC contract scope for self-perform
- Lack of understanding of procedures by contractors
- Modular builder and GC blame game and scope gaps

The following reasons were given for AECO professionals that have not yet utilized PMC on a project (in no particular order):

- Owner does not request it
- Lack of knowledge among project stakeholders
- Owner is not in favor
- Program / scope of building not amenable
- Designers did not specify it

A related question to barriers was that of identifying the key limitations to growth (no particular order):

- Lack of competence, capacity and capability in current modular builders, lack of competition (number of builders)
- Transportation often prices the project out of modular range, so moving to multi-trade in large commercial projects
- Lack of knowledge among owners, designers and general contractors about how to locate qualified modular builders and how to effectively engaged in the modular delivery process
- AEC industry unwilling to adapt process to unique of modular delivery due to lack of incentive
- AHJ road blocks to alternative construction methods deter project teams to use modular
- Financing road blocks for developers for early draws on capital
- Lack of marketing from the modular industry to the AEC industry
- Lack of industry standards for designers and builders
- Lack of flexibility within manufacturing process
- Contractual scope definitions unclear and not standardized
- Modular not suited for addition or renovation work
- B. The second area of questioning was to determine the **advantages** of modular construction.

Advantages to modular construction (in order of frequency):

Architects / Engineers response -

- 1. Schedule reduction
- 2. Cost control
- 3. Quality assurance
- 4. Waste reduction
- 5. Weather avoidance
- 6. Predictable process
- 7. Labor shortage solution
- 8. Productivity gains

Contractors' response -

- 1. Schedule reduction
- 2. Quality assurance
- 3. Predictable process
- 4. Labor shortage solution

- 5. Worker safety increased
- 6. Productivity gains
- 7. Waste reduction
- 8. Cost control

Owners' response -

- 1. Schedule reduction
- 2. Predictable process
- 3. Labor shortage solution
- 4. Quality assurance
- 5. Cost control
- 6. Waste reduction
- 7. Productivity gains
- 8. Weather avoidance

In addition to the responses from those surveyed, there were a number of comments from proponents who indicated that there is no problem to modular growth. In short, they indicated that all signs from the hospitality, IT and housing markets point to modular construction and they have had very positive experiences with the delivery system.

INTERNATIONAL LESSONS LEARNED

This phase was to understand what is occurring in commercial modular construction internationally in order to determine the lessons that are applicable to the North American context. This phase uncovered the business climate, markets, key players, government initiatives, regulatory climate, financing schemes, and other parameters that have made modular more or less successful using case studies of key modular companies in these countries. These drivers are key to understand in order that MBI might know where to focus their efforts for greatest impact.

The research team traveled to Sweden, Japan, Poland, UK, and Australia to understand the current state and learning that can be applied to the North American commercial modular industry. General lessons learned will be reviewed and then learning from each geographical location summarized. A full review of each country is included in Appendix 'C'.

General Lessons Learned:

Lesson 1: We need to understand our context to capitalize on it.

All offsite systems, especially volumetric modular, are local. Each country had specific market, regulatory and material logics and the success of the companies surveyed clearly optimized around those characteristics.

Lesson 2: We need to be knowledgeable of other countries approaches to business and technology of modular.

Despite of a deep focus on the local challenges and opportunities, each successful company also benefited from a comparative approach and impressive knowledge of approaches from other countries.

Lesson 3: Quick return on investment should not be expected of modular builders or their investors.

Volumetric modular requires long term planning and investment for financial success. Most companies had been producing offsite systems for 15 years or more. They also indicated that 5-7 years of learning was required to turn a profit.

Lesson 4: Capacity and capability allow for upscaling during construction demand economic seasons.

Volumetric modular is currently expanding in these contexts reaching post-WWII numbers because of the lack of available labor and workforce to meet construction demand. These modular builders are responding to this need in a diversity of markets including healthcare, affordable and market rate housing, and hospitality. In order to do this, modular builders in these contexts reinvest in their employees through upskilling training and education. These builders are looking for continuous improvement by implementing lean across the company culture and operations.

Lesson 5: Data is key for improvement and investment.

Volumetric modular data gathering, analysis and publication is an integral tool in convincing owners, designers, builders and end users of the benefits of modular. It is also a tool to garner further lending from banks and investment from government and the private sector into modular factories.

Lesson 6: A unified approach to advocacy and education has a compounding affect.

Volumetric modular in other countries is part of a larger offsite ecology of companies, universities, and trade associations that work together to advocate on behalf of increasing productivity, reduce schedule, and increase quality. This has led to more government incentives and education/outreach for and in behalf of offsite construction broadly and modular in specific.

Each country visited is included below with lessons learned for the North American context:

<u>SWEDEN</u> – Volumetric Modular as sustainable building

Sweden's growing modular industry appeared relatively recently, as compared to the United States and Japan. Lindbacks is currently the industry leader, having produced more than 10,000 housing units since 1994. Lindbacks, along with its two-other volumetric modular competitors, grew out of the large Swedish single-family home industry, but now focus almost entirely on affordable as well as market rate multi-unit housing. Like the US, Sweden's volumetric modular construction is governed by a conventional building code.



Figure 2. Lindbacks factory in Lulea, Sweden produces light wood frame modules for multi-family housing.

- Common to all three major volumetric modular companies in Sweden is the marketing strategy of closely aligning modular construction with **sustainable or green building**. This strategy is showing immediate benefits in terms of consumer response but is also seen as a long-term strategy that anticipates stricter green building regulations.
- Lacking a trade association like MBI, Swedish modular companies have closely aligned with the local **timber industry** and its **trade association**, the Timber Building Association around common interests. In Sweden, along with the rest of continental Europe, timber construction is still not common in multi-unit housing construction, so the two industries see a common interest in expanding into multi-unit housing.
- In Sweden, volumetric modular has adopted many of the fabrication techniques common to that countries panelized construction industry. **Panelization**, a part of all of light wood frame construction, has in turn assisted these companies in the application of **automation and mechanization**.
- The use of **higher grade lumber** by the modular industry in Sweden has also played a key factor in allowing for greater degrees of **automation**.
- Lindbacks has been able to deliver **nine-story volumetric modular light-wood frame** construction (comparable to the tallest steel volumetric modular project in North America, My

Micro/Carmel Place), competing with modes of multi-unit housing construction in Sweden, where reinforced concrete frame construction still dominates.

- To varying degrees, all three volumetric **modular companies engage in design and development** as well as fabrication. They are **vertically aligned** and have streamlined supply chains with suppliers.
- New partnerships and knowledge exchanges are being forged with Sweden's leading tech companies, with engineers from **Volvo** involved in Lindbacks new plant.
- The success of Lindbacks, as well as their competitors, has been directly related to long term planning.

JAPAN – Volumetric Modular as high-quality building

Japan's volumetric modular industry is nearly as old as America's, with Sekisui Heim, the top player, starting production in the early 1970s. Currently dominated by Sekisui Heim, the largest volumetric modular company in the world, with more than 10,000 housing units produced, the Japanese industry has achieved an impressive level of market penetration. Japan is a renew culture stemming from the Shinto tradition of rebuilding temples as a religious act. Therefore, modular meets this demand for new, fast delivery of housing. Like Sweden, the predominant offsite system is panelized construction. Both volumetric modular and panelized companies utilize light gauge steel components although some light wood frame construction is also used.





Figure 3. Sekisui Heim factories (8 in total) produce light wood frame and light gauge steel modules for single-family and multi-family housing on the same product platform.

- Japanese volumetric modular, like the manufactured housing industry in the United States (HUD Code), is supported from a system of "**permissions**" where their products are inspected by trained professionals according to specifications specific to the industry, even to the company, and not simply to a general building code. This is likely the single most important factor in the industries success.
- Like many offsite construction systems, including volumetric modular, Japanese companies initially touted their systems speed and affordability. Since the late 1970s, the **focus shifted to the superior quality of the product** (on average, volumetric modular is 8 percent more expensive than conventional construction.
- While highly automated in comparison to American facilities, Japanese volumetric modular fabrication facilities nevertheless showed a highly pragmatic application of mechanization and automation. For example, a light wood frame volumetric modular fabricator found that a robot arm was most effective in automating painting, while in light gauge steel volumetric modular fabrication, a similar robot arm was used primarily for welding frames or chassis. Both wood and steel systems utilized an automated track system for moving modules throughout the facility. In both cases,

mechanization and automation was paralleled and complimented by a highly skilled workforce. Since the early 1990s, Japanese companies have maintained a similar degree of automation

- Japanese companies provide a **universal product and sales platform** for multi-unit and singlefamily housing.
- Investment in **proprietary software** and the use of **architects as sales people** has allowed Japanese companies to offer a high degree of customization and client satisfaction while maintaining a highly standardized and predictable fabrication and delivery system.
- Japanese volumetric modular companies **closely collaborate with other offsite construction** companies through the Japan Prefabricated Construction Suppliers and Manufacturers Association (JPA). More recently, a new association, Sumstock, is evaluating the quality of offsite construction versus conventional construction for the potential of remodeling and reuse of the modular building stock.
- Since 2004, Japanese volumetric modular companies have **pioneered the reuse and recycling** of volumetric modular construction.
- Japan modular industry is dominated by Seki Sui Heim, a subsidiary of Seki Sui Chemical, the largest chemical company is East Asia. The parent company has **bailed out the modular company** on multiple occasions since the 1970's.

POLAND – Volumetric Modular as an export

A relative new comer to the global volumetric modular industry, the three key players in Poland all benefit from that countries steel industry as well as its furniture industry. All three companies are currently focused on Western European and North American markets.

- Polish volumetric modular companies have developed the logistics necessary for a commercially viable export business. Polcom Modular has shipped complete hotel modules to Holland, the UK, and, most recently, to New York City. DMD has shipped modules to southern Germany.
- Polish modular provides a unique case study of the **expansion of furniture manufacturers into the modular industry**, with Polcom and DMD both part of a larger furniture conglomerate.
- The focus and export and the relationship with furniture companies has created a unique manufacturing process: modular companies order standard steel volumetric modules from third-party steel mills, used for the primary structure, while using flat-packed MDF partitioned, made by their parent furniture companies, for partitions and other interior surfaces.
- CitizenM, Polcom Modular's partner, is the first hotel chain to develop a brand specifically tied to volumetric modular. Since starting the company in 2005, Citizen M has delivered volumetric modular hotels in Paris, Amsterdam, London and, most recently, in New York City. Citizen M

Bowery, their most recent projects, provides an elegant hybrid volumetric modular solution that utilizes a site cast concrete core and a three-story concrete lobby with 17 floors of volumetric modular construction.



Figure 4. DMD Modular in Poland produces hot rolled steel modules for hospitality projects in the U.S. and Europe.

<u>UNITED KINGDOM</u> – Volumetric Modular as government strategy

It is estimated that offsite construction constitutes 7 percent of the total construction output equating to £1.5 billion per annum. It is unclear how much of that is modular construction, however, modular construction has a long history in Britain stemming from colonial migration. Also, being part of Europe, modular construction in the UK leverages techniques from Sweden and Germany/Austria that have a longer modern history with the technologies. The UK has also adopted techniques from Japan in its hot rolled steel modular program. The UK tends to be geographically specific, with light wood frame Swedish techniques and automated equipment being used in Scotland and northern England and light gauge steel and hot rolled steel more common in the midlands and London. Like North America, the modular industry is regulated by the same codes as conventional construction. Offsite and modular construction is being used for primarily for low-rise multifamily row housing, 2-4 plex, and flats, but is also used for dormitories, schools and hospitality buildings.



Figure 5. CCG OSM factory in Scotland produces light wood frame panel for a myriad of building types.

- The UK government has put forward **numerous reports to industry from 1994** forward calling out the inefficiencies and lack of innovation (**productivity**). These reports set targets for the construction industry including lower initial and lifecycle costs, faster delivery, lower emissions, and the symptoms of such, dysfunction in training, and workforce recruitment. During this time, the reports have pointed to offsite manufacture as one solution to overcome such challenges.
- Offsite construction is seen as a **solution to the skills gap** in the construction sector that is currently being filled with low skill immigrant labor. The government and construction industry are selling offsite and modular as an upskilling, tech-based industry in order to **attract talent** that is currently going into business and IT as the next generation of construction workforce.
- Low-carbon targets in particular have driven the uptake of modular construction in wood and claims that reduction of waste in steel modular will aid in reduction of carbon emissions. This is linked to Europe's goal to lower carbon emissions.
- Offsite construction and modular in particular has been paired with **targets for advanced BIM** modeling and increases in construction automation. The UK has been slower than the US on BIM uptake, but offsite manufacturers have been quicker to take up BIM and market its benefits.
- UK BuildOffsite (a client, supply, professional services and academic membership organization which promotes and support offsite) have implemented an **independent verification program** of

products and buildings for fitness to support long term loans insuring consistent performance over a **determined durability of 60 years** in association with Lloyds Register, BLP Insurance and the Royal Institute of Chartered Surveyors.

There is significant investment occurring in offsite in the UK. In modular these are new players and new products include: £12M in CCG OSM light wood frame closed panel construction in Glasgow that grew out of a medium-sized site built construction company; £55M L&G (pension company) Modular Homes that is building the largest modular factory in the world, on par with the new Lindbacks factory in Sweden, but producing cross laminated timber panels and assembling modules in the factory for pension condo sales in Leeds; and £104M Laing O'Rourke Modular Concrete in Sheffield that is a subsidiary of Laing O'Rourke construction company, one of the largest in the world. Lloyds Bank's latest housing report claimed that 6 percent of British investment firms are investing in modular housing.

AUSTRALIA – Volumetric Modular as new market entrant

Although prefabrication in Australia has been alive since the Manning Cottage was delivered from the UK during the colonial period, and early research from the Australian government on the potentials of offsite construction, Australian modular construction has only emerged in the last decade. Currently there are an estimated 74 (2013) modular manufacturers in Australia of 169 total offsite manufactures. It is difficult to determine the overall contribution of modular to the construction industry in Australia, but in housing, offsite as a whole is estimated at 5 percent with modular being the dominant method. This is in comparison to 3-4 percent in the U.S., 12-15 percent in Japan with panelized and modular being about equal and 50-90 percent in Sweden with panelization being the wide majority of that market. Following population distributions, the majority of modular manufacturers in Australia are located on the east coast of Australia with the strongest stronghold in the metropolitan region of Melbourne, Victoria.

- Although there are two scales of volumetric modular occurring: steel and concrete modular for midto high-rise in centers and light wood frame and light gauge steel modules for urban and suburban housing development, the **modular companies are more diversified**, offering many different offsite solutions and material modular solutions for a myriad of building types – there is less concentration and specialization.
- Manufacturers are innovating by developing hybrid product solutions for modular and onsite work in order to modular to compete in the traditional construction sector more effectively from a cost, time and quality stand point.
- **Federal and state funding programs** for research and development including industry and universities to meet the need for an ailing manufacturing workforce and lack of productivity in construction.
- The Modular Construction Codes Board from Melbourne in collaboration with PrefabAUS and the companies it represents, the Victoria (state) government and Monash University established a code, or guideline, for the implementation of permanent modular construction in specific. The guide emphasizes the potential hybrid approaches to offsite and onsite work, working to sell

modular not as a holistic solution, but part of a project delivery process. Its emphasis is on **quality** control and improved safety.

- Melbourne School of Engineering has led a charge nationally to grow the Australian offsite industry as a whole from 5 percent to **15 percent by 2025**, contributing to 20,000 new jobs and \$30B Australian Dollar growth.
- **Vertically integrated companies** that utilize modular are emerging in Australia as they have Japan, Sweden and now the U.S. The leader is Lend Lease that is using CLT.
- PrefabAUS, its members and the universities are actively advocating for modular construction. One leader in this education and outreach effort is a 3rd party that produces **Built Offsite magazine** for the construction sector and general public.



Figure 6. Hickory Group delivers modules for One9 – a nine level condo project in Melbourne built assembled from 36 boxes in five days.

ROADMAP & RECOMMENDATIONS

Starting in 2015, the decision to strategically grow the market to 5 percent of construction expenditure in five years by the MBI Board is currently in its third year. The modular industry in North America has already seen significant growth in the past three years from 2.37 percent of the construction expenditure in 2014 to 3.177 percent in 2017. Highlights of this growth include:

MARKETS

Post-recession growth (2009 – present) in *multi-family* (five or more units) has surpassed pre-recession growth. This is occurring because of repressed up demand from the downturn, the passage of baby boomers into senior years, and rising preference of millennials for residing in urban cores. Over the long-term, demand for multi-unit housing can be expected to moderate as a result of the projected aging of the population and as interest rates rise, developers will be more conservative in their multi-unit speculations.

Although multi-family market rate housing is seeing a slowing in recent months, there continues to be a dearth of affordable housing, especially in urban centers of San Francisco, Chicago, New York and Philadelphia. The mayors of San Francisco, New York, and Philadelphia have all indicated that modular is a solution to the affordable housing problem in their cities. Factory OS in Vallejo, California was recently established in order to provide a modular solution to the affordable housing crisis in the bay area. The factory follows a recent trend of venture capital investment from the IT industry in Silicon Valley to try and reinvent the housing industry.

There has been anywhere from \$1M to \$1B in the case of Katerra located in Phoenix that has been invested into newly formed multi-family PMC companies. These companies include: Katerra, Factory OS, Blueprint robotics, Full Stack Modular, Prescient, Stack Modular, ManufactOn, Blockable and Plant Prefab. These companies are located primarily on the west and east coasts.

In addition to the housing industry, modular is finding traction in the *hospitality* sector. Marriott Hotels announced that 15% of its 2018 new builds will be modular construction. PMC is seen as a solution to deliver low rise wood light frame product. Champion Commercial and Guerdon Enterprises are two modular builders servicing this industry. Citizen M Hotels have moved into the US market from Europe. The new high-rise in New York City is assembled from hot rolled steel frame modules shipped from Polcom in Poland. Citizen M is continuing their efforts to build across the US using this supply chain.

The *southeast* US has historically not had PMC manufacturers because of lack of demand. However recent announcements were made of branch factories opening for existing modular companies in Knoxville, TN (Done Group), and Alabama (Z Modular). Furthermore, Deluxe in Pennsylvania has new owners that plan to reopen that factory, and Best Gen Modular are slated to open in April in South Dakota. There are also a few that have asked to remain anonymous but indicate a plan to open factories in the next year in the southeast.

Data centers are another growing building type that is leveraging PMC for new builds. This particular market does not seem to be slowing and less susceptible to market fluctuations. It is challenging to get information about this market because of proprietary information.

ROADMAP

The construction cultures of the UK, Sweden and Japan had a period of 10 to 15 years to mature their modular markets and build capacity within the modular industry. Given the current success in PMC and growing markets of housing, hospitality and data centers, there is great momentum. However, to continue this momentum, it is recommended by the research team to set a new goal of 10 percent of the construction market by 2025.

GROW 10% / 2025

There are 4 areas of strategies recommended by the research team in order to grow the modular market to 10% by 2025. The strategies include:

DATA

what is measured can be claimed, what is measured is improved

PARTNERS

strategic alliances extend reach and educate constituents

STANDARDS

competitiveness fosters innovation

3C

foster builder competence, capacity, and capability to deliver

The diagram below describes each strategy and its relationship to adjacent strategies. This section then outlines specific tactical actions that can be taken by the MBI members in order to realize 10% by 2025. It is suggested that the MBI Board and its members prioritize these strategies and tactics with specific actions moving forward.



Figure 7. Roadmap for 5 in 5 initiative suggests moving to 10% by 2025 through a 4-prong strategy: data, partners, standards and 3C.

RECOMMENDATIONS

STRATEGY 1 – DATA

"what is measured can be claimed, what is measured is improved"

Tactic 1A: Collect **internal data** to the PMC industry via MBI in order to claim construction performance and improve upon performance.

This recommendation is to leverage the MBI Awards of Distinction program for data gathering on PMC performance. Specifically, when members submit their award entry, additional data fields need to be filled out for the purpose of building a long-term dataset for analysis. The data will be used to update the membership and claim findings to media outlets regularly. These criteria would also provide the award jury with a more consistent set of parameters with which to assess the quality of the submission. Furthermore, this data can serve as the basis for case study examples to be used in professional practice and by students in education.

Tactic 1B: Work with **external** partners in the construction sector to collect data about how PMC is performing compared to traditional construction.

Partner with organizations who run surveys and studies on construction performance (cost, schedule, value, quality, change orders, etc.) and incentivize them to include a demographic marker for permanent modular construction so that data can be sorted accordingly. Organizations might include (Dodge, RS Means, ENR, BD&C, CSI, AIA, AGC, NIBS, FMI, McGraw Hill, etc.) Engage 3rd party in setting up the process and/or analyzing the data annually for the annual report and dissemination partners.

Use the data from the internal and external modes and present to potential capital investment audiences. This includes but is not limited to hospitality sector, IT industry, and the federal housing association HUD. Furthermore, the data will aid in understanding what among the 3Cs has greatest priority in the industry.

S1 \rightarrow S2 Relationship = leverage relationships with partners for external data and to disseminate internal data in order to raise capital from investment companies and government.

STRATEGY 2 – PARTNERS

"strategic alliances extend reach and educate constituents"

Tactic 2A: Integrate **light wood frame** modular builders.

Strategically position MBI to be knowledge and advocacy center for light wood frame commercial, especially multi-family. From the survey and international responses, the division between residential and commercial is not as definitive as MBI versus MHBA. Furthermore, wood multi-family modular is the fastest growing market, and many factories span between residential and commercial projects types. In this way, these organizations can work collectively to accomplish the other recommendations in this summary. The

key is to bring multi-family low rise wood modular builders into the MBI organization to strengthen numbers and solidify the industry knowledge.

Tactic 2B: Foster federal, state, and municipal government reports.

In mature modular markets (Japan, UK and Sweden) there is a recognition of PMC at the highest levels of government. In these markets, the relationship overseen by HUD between government and the manufactured housing industry is often cited as a model. Furthermore, in these mature markets, there are annual reports that illustrate the modular contribution to overall construction and argue for various performance metrics by virtue of modular (i.e. productivity, labor shortage, carbon, etc.) These are government sponsored and government entity reports that build upon one another each year. They have linked modular to environmental policy and economic development and competitiveness for the host country.

This recommendation is for MBI to work with other partner organizations in this summary to target government to write industry reports that tackle issues broadly in the construction sector and demonstrate modular as a solution among many (i.e. NRC report in 2009). This might come by virtue of NIBS OSCC, or a specific government agency partnership. The prime example is of the US GSA adoption and announcement of BIM format for schematic design submittals which in a few years pushed all architecture firms to adopt BIM. It was later illustrated that this was backed by Autodesk looking to sell its newly acquired software Revit, but the technology benefited the government and industry, so it was difficult to argue with at that point.

Tactic 2C: Partner with municipalities that are sympathetic to modular.

This recommendation is for MBI to partner with states, municipalities and other governments that have spoken well of modular construction to form an alliance of governors, mayors and the like committed to this progressive form of construction as a strategy to meet carbon goals, increase jobs, etc. This may begin with publicly sympathetic cities such as New York City (Bloomberg), Philadelphia (Go Mod), and San Francisco (Lee). These cities see modular as a solution to affordable housing. Affordable housing may also be the topic by which the government leaders get behind modular construction. In international contexts, certain government municipalities have adopted modular as a solution for realizing low carbon and housing affordability. The municipal scale offers opportunities to develop models for larger scale initiatives. MBI may consider awarding these mayors for their advocacy for PMC and ask for their participation on an owners group to target owner education and awareness.

Tactic 2D: Forge partnerships with trade and sector organizations for targeted market growth.

MBI can partner with trade associations that are looking for more innovative ways to represent their companies. For example, in Japan there is a deep relationship between modular builders and the wood and steel building industry associations for more than half a century, directly contributing to that markets development. In Sweden, the Wood Building Council is effectively the same as the industrial building association. Specific partnerships with trade associations of complimentary interest can facilitate greater exposure and advocacy efforts.

Also, MBI can advocate on behalf of modular to owners' meetings as was done with Marriott Hotels some years ago. This can be done with Google, Amazon, and Facebook. By sending unaffiliated expert

representatives to meet with these companies rather than one modular company can aid in educating and offering free information. This builds confidence in the modular industry and can help to grow the entire modular sector. This may be, for example, with the healthcare facility managers, affordable housing association, retailers' development association, etc. This may result in an owners' advisory council to MBI.

S2 \rightarrow S3 Relationship = standards consensus process requires partnerships with AEC, key markets, and trade associations

STRATEGY 3 - STANDARDS

"competitiveness fosters innovation"

Tactic 3A: Lead in developing a consensus process for **product standards** regarding different modular materials.

Initial research findings have suggested that a streamlined specification and permitting process is what sets apart those markets where volumetric modular is most successful (Sweden, Japan) from the rest of the global market. In light of that finding, it would be worthwhile to host a consensus process to develop detail and specification guidelines for permanent modular construction in light gauge steel, light wood frame, and hot rolled steel construction oriented at designers: architects and engineers and modular builders. MBI via the National Institute of Building Sciences Offsite Construction Council is partnering with the AIA, CSI, and Avitru, the publisher of the AIA master specification system in order to develop guidelines for PMC specification.

It is recommended that MBI capitalize on the opportunity that housing and hospitality presents to lead a consensus process with their light wood frame members to establish a detail and specification guideline for the industry. This will allow competitive bidding in public procurement projects and place modular on equal footing with other building systems.

Tactic 3B: Lead in developing a consensus process for **procurement and procedure standards** regarding different modular materials.

Similar to the last recommendation, MBI hosts a consensus process to develop a procurement guide oriented at general contractors and modular builders. This process should engage members of the AGC who represent general contractors. Specifically, a procurement guide would help project teams to navigate through insurance, bonding, lending, permitting, inspection, etc. that differ slightly from traditional construction. Furthermore, it would address supply chain, scope delineation, cost estimating, and other aspects deemed necessary from the consensus process. The procurement guide would build upon and address in an integrated fashion the AIA Contract Documents and AGC Consensus Documents, which constitute the wide majority of contractual procurement arrangements in the traditional construction sector.

Tactic 3C: Continue to **define the offsite industry** through forming clear definitions and their relationship to modular.

Clear definitions of terms, processes and standards need to be developed and widely distributed and discussed in the industry. This is a consensus process that is key in order to mature the permanent modular sector. International examples demonstrate that this was an early activity in other countries and a

common vocabulary is widely used today. This is important for both recommendation S1 in order to establish standards and a guide for implementation. Currently, general contractors using multi-trade prefabrication. A language is developing on a general contractor company specific basis (i.e. Balfour Beatty, PCL, Whiting-Turner, etc.). However, when these same contractors engage the modular industry, there is a language barrier. The consensus terms and processes recommendation need to include both modular builders and GCs in order to effectively define for traditional construction integration.

S3 \rightarrow S4 Relationship = standards foster the overall capability of modular builders

STRATEGY 4 - 3C COMPETENCE, CAPACITY, CAPABLIITY

"foster builder competence, capacity and capability to deliver"

Tactic 4A: Foster **competence** among modular manufacturer members and for the industry at large to increase its reputation and quality assurance.

This recommendation is to bring the best of modular manufacturing companies from around the globe to the US to workshop with MBI members. This is envisioned as an invitation only MBI workshop to strategically move the modular industry forward. The workshop might focus on business, product and process platforms. This would allow executives and factory managers to interact with the modular company consultants (i.e. Seki Sui Heim from Japan and Lindbacks from Sweden). This might be a workshop at WOM or just before or after the primary WOM event.

Furthermore, factory workers need investment from their companies into continuous improvement training for upskilling. This will provide a stronger base for the modular sector and allow future leadership in the sector to ensure that it thrives. This may result in an executive training program, a university program specific to this purpose or a certification program from MBI offered at WOM. Related to standards, a lean platform that can be implemented in factories needs to be codified as to raise the competence and quality of all builders, especially new players, to a particular level and grow the reputation of the industry.

Tactic 4B: Develop a plan for fostering capital and financing for members that would like to **increase capacity** to meet demand.

MBI members need to determine a way to upscale to meet the current demand outlined in the market section of this report. There is interest from the hospitality, affordable housing, and IT sector in investing in the industry, but these sectors do not see the modular industry able to meet the demand of their needs. In this way, all tides rise as the membership bands together to develop a capacity strategy to respond to growing interest.

Tactic 4C: Create ways that the membership can increases its **capability** by responding to the volatility in the market and demand.

As competence and capacity increase, the capability of the industry as a whole will rise. Construction in general is negatively viewed by new recruits and recent graduates. The modular industry has an opportunity to embrace technology and communicate its approach to construction as a high tech, sophisticated and more knowledge economy-based solution to construction. This will attract more talent and capability within the industry. Therefore, the MBI membership needs to embrace BIM, appropriate

automation and standards as a way of talking and operating with greater professionalism. A greater mix of varied experience and educational backgrounds should be included in the modular sector to aid in this transformation to capability (i.e. architects in modular companies, computer science in modular companies, business graduates, etc.)

S4 \rightarrow S1 Relationship = data focuses 3C development in strategic areas and specific needs of the market.

TACTICS WORKSHOP

The roadmap and recommendations were presented in a workshop held at World of Modular 2018 in Hollywood Florida. Approximately 30 to 40 attendees participated in a tactics workshop whereby they responded to the results of the research by separating into three tables representing three of the four strategies in the roadmap: Partners, Standards, and 3C. Strategy 1 – Data was not reviewed by a particular table. Each strategy table was charged with reviewing the tactics proposed in the recommendations and either being more specific on actions or developing their own tactics to be implemented by MBI. Below is a list of the tactics listed by strategy developed by the WOM participants.



Figure 8. Tactics workshop at WOM 2018.

STRATEGY 2 – PARTNERS

"strategic alliances extend reach and educate constituents"

The table identified the partner groups to get an accounting of potential outreach from MBI, noting that in all of these constituents, MBI members are the key stakeholder at the center of this conversation.

Partner Group 1 – Design Community

- American Institute of Architects
- Construction Specifications Institute

- Design Build Institute of America
- Structural Insulated Panel Association
- American Institute of Steel Construction

Partner Group 2 – Construction Organizations

- Associated General Contractors of America
- Occupational Safety and Health Administration
- Authorities Having Jurisdiction
- Mechanical Contractors Association of America

Partner Group 3 – Modular Builders

- MBI members
- Modular Home Builders Association
- National Association of Home Builders Building Systems Council
- State Agencies and Regulatory Organizations
- Vendors to modular builders

Partner Group 4 – Market Specific Owners

- Building Managers and Owners Association
- Hotel Associations
- Relators Associations

The table determined that the goal of partnering is primarily to overcome the negative perception of permanent modular construction. The table determined that tactics in order to do this include:

- Creating coalitions to address specific barriers to modular construction.
- Develop MBI advisory groups or councils that consist of MBI members and the partner groups identified in the list above for the purpose of education and outreach.
- One of the advisory groups should be focused on best practices in addressing the challenge of unions and modular construction.

STRATEGY 3 - STANDARDS

"competitiveness fosters innovation"

The table identified the key tactics that MBI should be addressing to realize additional standardization in the industry.

- Codes and bureaucratic standards to streamline the regulation process for PMC
- Make the roadmap developed in the 5 in 5 research publicly available to be transparent and demonstrate the need for standards
- Create a nationally accepted approval process similar to Japan and Housing and Urban Development code for but PMC
- Foster a flexible database of guides, best practices, details, specifications etc. for public consumption

- Work with key municipalities and states that are sympathetic to modular to offer incentives to owners and projects that utilize PMC
- Create industry standards for design and procurement
- Create contract standards for development with PMC
- Create BIM standards for PMC
- Continue to share best practice case studies

STRATEGY 4 – 3C COMPETENCE, CAPACITY, CAPABLIITY

"foster builder competence, capacity and capability to deliver"

This table identified the different types of competence, capacity, and capability required to meet the current demand for modular construction. These include:

Competence:

- Create awareness and education for Designers and architects Owners and developers General Contractors
- Formulate standardized quality certifications for modular builders and general contractors that set
 modules

Capacity:

- Create partnerships and alliances to increase financing schemes for modular projects for owners and developers
- Stress the improvement of quality to lending institutions
- Partner with third-party suppliers and modular builders to meet demand of large projects

Capability:

- Demonstrate to partners how to lower risk with modular through a controlled setting of the factory
- Encourage modular members to embrace risk
- Partner with government for research and development incentives for companies to innovate and increase capability in order to improve construction quality and productivity

NEXT STEPS

During the time of this research project from January 2017 to March 2018 the central question of the 5 in 5 initiative has shifted from one of increasing demand for the modular sector to one of increasing supply, sustainably. Managing growth and decline is one of the greatest challenges that the modular industry has had to face over its history. Unfortunately, the same factors that have led to the drop in construction productivity overall in the US and led companies like Marriott to modular are also the same factors that make scaling up to meet demand so risky. As the *Economist* so succinctly explained last year, the shocking plunge of productivity in the American construction industry to half of pre-1970 levels have been caused by increased volatility in demand, leading builders to curb capital-intensive investment, "with workers replacing machinery." A general deskilling of management and workforce has paralleled this decrease of mechanization, or what the magazine called "unlearning by doing".

Increasing capacity and capability is risky enough for conventional builders, who demand less capitalintensive investment; it is even more risky for modular manufacturers, with the fixed costs of a plant and a trained workforce. The *Economists'* insightful analysis, drawing heavily on research from McKinsey Global Institute, did not discuss a more recent factor that throws a wrench in the conventional construction industries race to the bottom of productivity and that is the increasing labor shortage. The construction industry seeks productivity and believes an answer lies with modular. Innovation is needed in order to be more productive as a modular industry. Over the course of last 70 years in many sectors, innovation has been integral to productivity. Disruptive, sustaining and radical innovation to answer the construction sector's stagnation in productivity and demand for growth may come from a myriad of business models including existing modular company upscaling and upskilling, general contractors moving into the modular manufacturing realm through self-performing or multi-trade prefabrication near to site, or new start-ups looking to vertically integrate the supply chain of project delivery in a radical fashion. For the purpose of this report the focus is on existing modular companies and new entrants.

3C MODULAR COMPANIES

Despite the risk, established modular companies are transforming in response to market shifts and finding success. The majority however are light wood frame modular home builders shifting to commercial construction. Simplex Homes, a Scranton, PA based modular builder, founded in 1971 by the Fricchione family, has been shifting from a focus on residential to multi-unit construction over the last decade. Even before this shift, simplex gained national attention as the modular builder of the first Dwell Magazine house, designed by Res 4 Architecture, a New York based architectural practice which has since focused almost entirely on bringing modular construction into the high-end residential market across the country. Simplex gradual transformation from a residential to a commercial modular company (multi-unit is 40 percent of their business now, planned to be 50 percent soon) has been supported by a number of key strategies, from founding a dedicated "multi-family" division, to acquiring key personnel from the commercial modular building industry (John Baker, formerly of Deluxe Building System), to entering into a research project with the construction management faculty from Lehigh University to study their entire production process, to adopting Revit in their engineering department. In tandem with their shift to multi-unit housing and with the positive press from dwell, Simplex has also shifted their residential work to a higher end of the market, a trend similar to those observed in companies like Sekisui Heim. Simplex has also benefited from strong support from the state of Pennsylvania and the city of Philadelphia in the form of reports touting the benefits of modular construction. Most recently, simplex has also been involved in the post Superstorm Sandy "build it back" program in New York and New Jersey, demonstrating the potential for modular construction in disaster relief situations.

NEW START-UP INNOVATION

In the past 18 months there are numerous entrants into the offsite sector that are looking to innovate in construction. An article in CB Insights from August 2017 lists 14 companies that are various stages of venture capital funding ranging from \$120,000 to \$1 billion USD. Some of these companies were in existence and have had recent reinvestment from outside due to the renewed interest in modular and multifamily such as Project Frog, while the majority are completely new to the market including Stackable, Blokable, Full Stack Modular, Factory OS and Katerra. While Project Frog, Stackable, and Full Stack Modular represents a traditional modular start-up that seeks to supply an improved product to the building industry, Factory OS and Katerra are different in that they claim end to end delivery.

Katerra, a Phoenix based company with \$865 million in funding and \$1.3 billion in business, is developing a vertically integrated project delivery company comparable to Lindbacks and Sekisui Heim. In fact, the majority of funding is coming from Japan-based Soft Bank's investment fund while much of the equipment being used in their Phoenix factory has come from Sweden's Randek. The Wolf Company, a real-estate private equity firm, initiated the formation of Katerra as a response to the current housing shortage and labor shortage across the country, as well as the persistently low level of the productivity of conventional construction. Katerra is currently using panelized light wood frame construction out its Phoenix, Arizona factory, with plans for the implementation of CLT panels from their Spokane, Washington factory. While Katerra is currently not manufacturing volumetric modules, their equipment, supplied by Randek, is nearly identical to that used by Swedish companies like Lindbacks. This company initially focused on panelized systems before adopting volumetric modular.



Figure 9. Software system being refined by Katerra that links design to manufacturing.



Figure 10. Katerra panel line in Phoenix.

Factory OS, the bay area's first commercial volumetric modular company, is completing work on its plant at the Mare Island Naval Facility, in Valleio (formerly used by Bu Homes). Like the Brooklyn Navy Yards in New York City, where Capsys was located and Full Stack Modular is now stationed, Mare Island demonstrates the potentials that former industrial sites and municipal initiatives to retain manufacturing jobs in cities provide for the modular industry (like Mayor Bloomberg in NYC, Bay area modular has enjoyed the support of Mayor Ed Lee). The housing developer behind Factory OS was first introduced to modular through work with Zeta Modular, in Sacramento (2009-2016); it was because of that experience, as well as Zeta's bankruptcy in 2016, which led to the formation of Factory OS. Like Katerra, Factory OS demonstrates a recent trend where developers are owning offsite construction as a response to recent changes in the housing market. Like Lindback's, Factory OS has cultivated a relationship with higher education through Carol Galante, the I. Donald Terner Distinguished Professor in Affordable Housing and Urban Policy at UC Berkeley and the former Federal Housing Commissioner at the U.S. Department of Housing and Urban Development (HUD) (Reference. Carol will run Factory OS's Innovation Lab, housed on the premises of the Vallejo plant. Factory OS has also directly addressed offsite construction's relation to unionized labor through a collaboration with the Northern California Carpenters Regional Council. Factory OS plans to begin production in May 2018, fulfilling an order for Google's company housing. The new facility will have 24 to 28 stations. Average volumetric modular size will be 12' in width and 50/60' in lengths. Production volume is planned at four modules per day.



Figure 11. Factory OS light wood frame modular for multi-family housing.

Both Factory OS and Katerra were launched as development companies, and while the method of delivery (panels for Katerra, modules for Factory OS) are important to the business model, they are one of many strategies (building performance, financing, software, etc.) to try disrupt the construction industry. The notion is that if one company can take the margin out of all of the steps of building delivery that currently exist in construction and integrate in order to create more value, that is disruption because 1) it is a low-end entrant by providing a good enough and maybe even better product and service than traditional competitors, and 2) it is also a new-market disruptor by creating an unprecedented development and delivery model that the U.S. The idea of a vertically integrated offsite construction company is not necessarily new. Lindbacks in Sweden and Sekisui Heim in Japan have similar business model of end to end delivery as developers and builders. For these companies, product and service innovation lead to a potential process overhaul of the construction industry. The difference with Katerra in particular is aggressively and ambitiously acquiring significant talent from the full supply chain – architects, building engineers, software engineers, researchers, interior designers, construction managers, manufacturing engineers, etc. This is quintessential radical innovation.

INTERNATIONAL LESSONS ON MANAGING GROWTH

Factory OS and Katerra represent a new model for panelized and modular enterprise in North America, a vertically integrated company that develops, designs and builds. Whether these new start-ups will be able

to respond to the current demand remains to be seen, however Lindbacks and Sekisui Heim have been managing volatility for the past 4 decades under this business model.

Lindbacks entered the modular industry from upstream, in supply chain terms. Lindbacks began as a wood products company before moving to panelized platform frame construction in 1960. The company focused on single family and some multi-unit for nearly three decades before scaling up, in capacity and capability, to volumetric modular, starting in 1994. By that time, the company had also sold off its wood products business, focusing instead on developing long term relationships with other suppliers. Their volumetric modular was operating at a loss until 2000 and did become stable and profitable until 2004, by which time they also moved entirely away from panelized. Four years later, they managed the increased capacity and decreased demand of the economic downturn by focusing on affordable housing and student housing, with municipal and educational clients actually preferring to invest during a downturn. They also used the downturn to expand into development. Profits increased again in 2010, with demand beginning to exceed capacity by 2014. Since that year, they began planning a new plant, double the size of their existing one, with that facility opening earlier this year. After 2010, affordable housing dropped down to 20 percent, their own developments between 10 and 2 percent with the remainder being work for other developers. Throughout the process, investments in mechanization have been gradual, with much of the machinery used in 1994 coming from their panelized business and slowly being replaced over time. It is likely that both panelized and volumetric product was being produced in their facility. The new plant includes comparable levels of mechanization and automation with the most significant technological changes occurring in the rolling floor for the modules.

More recent investment has been riskier for Lindbacks as it moves to modular from panelized and invests in mechanization. This is to serve a single market, multi-family housing. Sekisui Heim, however, is offering both single-family housing and multi-family housing based on the same product platform. Initially, Japanese modular companies competed in the market as a low cost, fast schedule option. However, over time the industry has changed its product and marketing toward quality. Modular is now the preferred construction method for mid- to high-quality at a premium. The modular companies in Japan have catered to the end user with informational campuses near their factories to demonstrate the added value of modular for safety shelter in disasters, and the ability to renew their home interiors throughout its lifecycle. Modular has now become part of the circular economy in Japan, meeting the needs of customers for newness in their dwellings. Whereas modular in the US continue to compete as a supply business, these companies have integrated modular into the business platform meeting the needs of the direct customer in end to end delivery, maintenance and ownership. This long term real estate holdings in working as both developer and landlord allow for Lindbacks and Sekisui Heim to weather economic depressions.

The research team recommends that MBI members consider diversifying their portfolio by having real estate holdings, not unlike the relocatable fleets. But as the market shifts to PMC, other types of investment may be necessary. Joint ventures with general contractors, IT industry, municipalities, and especially developers are emerging to make the investment in PMC from existing factories less risky.

APPENDIX 'A' – SWOT ANALYSIS

<u>STRENGTHS</u>	WEAKNESSES
 Safety Reuse Reduced on-site activity Year round construction Sustainability & reuse Quality of products Systematic approach Deconstructability Disruptive industry Lack of standardization Enthusiastic experience State regulatory agencies Positive picture to finance Consistent quality Accelerated schedules Predictable delivery model Controlled assembly process Evolution will eventually come Lack of international competition Price protection (contract) Ability to bring in sub-contractors and them not being foreign to the subject Measure the performance now and what it can do in the future Sooner or later it will be the most used method of construction 	 Transportation regulations being different in every jurisdiction Lack of investments Lack of better data with the industry Industry knowledge Less capabilities Process and Skilled labor shortage Focus on manufactured process not whole building Lack of investments in ourselves and innovation Fear of change Spending too much time protecting the fleet Diversity of product quality Focusing on 3% instead of working together to get to 5% Protecting fleet instead of focusing on the market share Finger Pointing instead of looking at it as group work Perception of industry Too many stakeholders/layers of profit Financially weak Biased manufacturer infrastructure Cost in some regions Lack of automation Pricing and market particularly to GCs Wood heavy Inability to transport our products to other countries Educating stake holders and training the workforce Mentorship and workforce pipeline Aesthetic excellence Not enough companies Unbiased input, openness and ability to change and grow with the help of external sources

OPPORTUNTIES

- Advanced technology
- Fragmentation
- No preconception
- New application to new market
- Affordable Housing demand
- Multi generational occupancy
- 97% of market as opportunity
- Could we grow the market with what we have or will we need more GCs to get to 5%?
- Modular as a new technology; a new way to build
- Looking back and leaning from the past
- Healthcare
- Educate and take care of misconceptions
- Policy related to affordable housing
- Local suppliers save on transportation cost
- Funding:
- Solidarity to compose a proposal to bigger companies
- Working with schools to get students interested
- Solar Decathlon
- Sustainable and green/passive opportunity
- Vastness of market opportunity
- To address worker shortage
- Fragmentation of industry
- No preconceptions
- New application into current market
- Workforce availability

<u>THREATS</u>

- Cost
- Wages
- Union
- Education
- Banks
- Sub-trades
- Architects
- Strategic failure
- Lack of standardization
- Opportunities can be threats
- Transportation regulations
- Failure of industry to educate
- Stigma (not understanding what it is)
- Procurement process
- Codes and compliance (Changing)
- Construction Mafia
- GCs seeing the Industry as a threat
- Worker shortage
- Obstacles not talked about
- AIA contract not written for the modular industry, and IBC as well.
- Focusing on educating GCs rather than customers first

APPENDIX 'B' – NORTH AMERICAN SURVEY DATA

These results include a summary of all of the questions and respondents' answers. For a break down by discipline, or an analysis of the data in other formats, contact the research team directly.

Q1 - Has your organization or company worked on permanent modular construction (PMC) projects before?

ANSWER CHOICES -	RESPONSES	•
✓ Yes (1)	44.82%	355
✓ No (2)	55.30%	438
TOTAL		792

Q2 – How many of your company's projects have implemented permanent modular construction (PMC) in some part in the last year?

ANSWER CHOICES	▼ RESPONSES	
✓ 0 (1)	33.45%	96
▼ 1 (2)	21.25%	61
▼ 2-3 (3)	23.34%	67
▼ 4-5 (4)	8.36%	24
 ▼ 5-10 (5) 	2.79%	8
▼ 10+ (6)	10.80%	31
TOTAL		287

Q3 – What is the average square footage size of the PMC projects your company has worked on in the past year?

ANSWER CHOICES	RESPONSES	•
▼ 1000 - 5000 SF (1)	38.03%	89
▼ 5000 - 10,000 SF (2)	14.96%	35
✓ 10,000 - 25,000 SF (3)	11.97%	28
▼ 25,000 - 50,000 SF (4)	8.55%	20
▼ 50,000 - 100,000 SF (5)	11.54%	27
▼ 100,000 - 200,000 SF (6)	5.13%	12
▼ 200,000 SF + (7)	9.83%	23
TOTAL		234

Q4 – What building type has your company worked on that utilizes PMC in some form?

ANSWER CHOICES	▼ RESPONSES	•
 Single family residential (1) 	36.23%	96
 Multi-family housing (2) 	38.49%	102
 Commercial (3) 	24.15%	64
- Education (4)	21.89%	58
 Healthcare (5) 	21.89%	58
 Industrial (6) 	13.96%	37
 Hospitality (7) 	15.85%	42
▼ Retail (8)	6.79%	18
✓ Data Centers (9)	4.15%	11
Total Respondents: 265		

Q5 - In your experience, select the top three barriers to utilizing permanent modular construction (click three below in no particular order)

AN	ISWER CHOICES	•	RESPONSES	•
•	Historical stigma (1)		30.28%	86
•	Traditional contract structures (2)		17.61%	50
•	Regulatory agencies, code officials and building inspectors (3)		28.52%	81
•	Project finance (4)		7.39%	21
•	Insurance bonding (5)		1.76%	5
•	Owner perception and education (6)		32.04%	91
•	BIM integration (7)		3.17%	9
•	Transportation logistics (8)		24.65%	70
•	Program of the building not amenable (9)		12.68%	36
•	Design restrictive/ aesthetics (10)		25.00%	71
•	Designer's knowledge of modular (11)		20.77%	59
-	Lack of standards in process and product (12)		9.51%	27
•	Early engagement of modular manufacturer (13)		17.61%	50
•	Cost estimating and budget (14)		11.97%	34
•	Scheduling and sequencing (15)		9.15%	26
•	Bidding and procurement (16)		7.75%	22
•	Market competition (17)		12.68%	36
•	Quality control / assurance (18)		11.27%	32
•	Other (please specify) (19) Respon	ises	15.14%	43
То	tal Respondents: 284			

Q6 - In your experience please select the top three advantages to utilizing permanent modular construction (click three below in no particular order)

AM	ANSWER CHOICES -			•
•	Schedule reduction (1)		68.55%	194
•	Cost control (2)		35.69%	101
•	Productivity gains (3)		18.02%	51
•	Increasing profit margins (4)		4.24%	12
•	Competitive advantage (5)		7.77%	22
•	Worker safety increased (6)		10.25%	29
•	Waste reduction and sustainability benefits (7)		31.45%	89
•	Quality assurance (8)		36.75%	104
•	Labor and skills shortage stop gap (9)		19.08%	54
•	Reduction in change orders (10)		9.19%	26
•	Weather avoidance (11)		32.16%	91
•	Predictability of process (12)		32.86%	93
•	Other (please specify) (13) Response	5	5.30%	15
То	tal Respondents: 283			

Q7 - In summary, permanent modular construction is estimated to be 2.5-3% of the North American construction market. Please explain your opinion about what pain points restrict modular construction from growing to 5-10% of the market:

Results were entered as text. For a full listing contact the research team.

Q8 - Rate the following barriers to your company engaging and realizing PMC (from least to most significant barrier): This question is for those that selected 'No' for question Q1.

	-	LEAST SIGNIFICANT (1)	MODERATELY SIGNIFICANT (2)	MOST SIGNIFICANT (3) 🔹	TOTAL 👻
•	Regulatory challenges	36.76% 118	47.66% 153	15.58% 50	321
•	Lack of knowledge among project stakeholders	13.08% 42	42.06% 135	44.86% 144	321
•	Project finance difficulties	47.98% 154	41.12% 132	10.90% 35	321
•	Insurance bonding barriers	55.45% 178	36.45% 117	8.10% 26	321
•	Owner does not request it	20.87% 67	24.30% 78	54.83% 176	321
•	Owner is not in favor	22.12% 71	34.89% 112	42.99% 138	321
•	Transportation logistical challenges	42.68% 137	43.61% 140	13.71% 44	321
•	Program/scope of the building not amenable	22.43% 72	35.20% 113	42.37% 136	321
٠	Designers do not specify it	28.35% 91	35.20% 113	36.45% 117	321
•	Not cost effective	40.50% 130	38.94% 125	20.56% 66	321
•	Construction sequencing challenges	54.21% 174	35.51% 114	10.28% 33	321
•	Bidding and procurement challenges	33.33% 107	42.06% 135	24.61% 79	321

APPENDIX 'C' – INTERNATIONAL CASE STUDIES

The countries and companies were chosen according to questions raised by MBI and its membership. It is important to note that in terms of overall scale of industry, the United States is by far the largest volumetric modular industry in the world. In terms of market penetration, Japan is currently comparable to that of the United States, while the United Kingdom, Sweden, and Poland have a significantly smaller market percentage. This can partially be explained by the relative newness of the industries in those countries, for while modular has existed in Japan since 1971, significant investment in the modular industry in the UK, Sweden and Poland began in the mid-1990s.

During factory visits, the questions asked of the companies included:

- What are the key factors supporting the growth of volumetric modular in a particular country?
- Who are the key players?
- What are the biggest strengths of the industry? What are the most significant threats? (Are these strengths and threats aligned with those of the MBI SWOT analysis?)
- Is the scope of the market national or international?

<u>JAPAN</u>

Japan's volumetric modular industry is nearly as old as America's, with Sekisui Heim, the top player, starting production in the early 1970s. Currently dominated by Sekisui Heim, the largest volumetric modular company in the world, with 10,000+ housing units produced, the Japanese industry has achieved an impressive level of market penetration. Like Sweden, the predominant offsite system is panelized construction. Both volumetric modular and panelized companies utilize light gauge steel components although some light wood frame construction is also used.

The factors that have contributed to the appearance, growth and primary characteristics of the volumetric modular industry in Japan are as follows:

1955 – The growth of the light gauge steel industry in Japan during the Korean War directly influenced that countries industrial development in general (car industry) and the volumetric modular industry in particular.

1955-1968 – During this period, the Japanese government supported the application of offsite systems being developed in Europe for low-cost mid-rise multi-unit housing. These systems were found inadequate, and the Ministry of International Trade and Industry (MITI) sought to encourage a higher degree of industrialization of the construction industry through a concerted 10 year program, starting in 1962. They offered low interest loans encouraging higher degrees of industrialization and the use of noncombustible materials. In 1970, the program was evaluated. The Ministries expected a 15 percent share of the market but found a 7 percent share of the market (offsite reached 15 percent in the eighties, at which time this government program no longer existed). Two companies, Daiwa and Sekisui Chemical both began developing light-gauge steel systems, focusing on single-family and low-rise multi-unit housing. Daiwa House's panel system and Sekisui House's kit-of-parts systems are the largest offsite systems in Japan

today, with each company producing 40,000 housing units, or 5 percent of the market each. In 1964, the Ministry of International Trade and Industry (MITI) established the Japan Prefabricated Construction Suppliers and Manufactures Association, the closest equivalent to MBI in Japan. All major offsite construction companies are members.

1967-1971 – In 1970 MITI encouraged companies to consider a higher degree of offsite production, automation and mechanization, referencing an influential article by Prof. Yoshitika Utida titled "The Housing Industry", that predicted that the housing industry would replace the car industry in terms of economic significance for Japan, and a doctorate by Prof. Katsuhiko Ohno, that advocated the use of volumetric modular construction, or unit construction. HUD's Operation Breakthrough program was also used as a justification for government initiatives supporting volumetric modular in Japan. Five companies already active in the offsite construction field chose to develop volumetric modular systems around 1970. A major global recession decimated the Japanese housing market in 1974, bankrupting many of these companies and also leading to a loss of interest amongst the public sector in further subsidy programs to increase mechanization and automation in construction. While three companies survived this initial recession, Sekisui Heim, a subsidiary of Sekisui Chemical (which also owns significant stock in Sekisui House, a panelized system) became the dominant player in the industry.

1971-1994 – Sekisui Chemical hired Prof. Katsuhiko Ohno as a consultant in order to develop their initial volumetric modular system. By 1975, after four years of trial and error, their first plant was open in Nara, near Kyoto. The initial system consisted of light gauge steel for single-family and low-rise multi-unit housing (see appendix). After 1976, lightweight autoclaved ceramic panels became the standard cladding material for Sekisui Heim and many of its competitors. In 1977, the company established a nationwide sales system. The basic module structure was set in 1980. During the 1980s, the system was further adapted in response to more stringent seismic codes. In addition to the light gauge steel system, a second system, Two U, was introduced, which utilized light wood frame construction. By 1994, the company had optimized its product platform and manufacturing process, focusing much of its efforts since that time in marketing and sales.

1994-2016 – Sekisui Heim, as well as two other companies producing volumetric modular, Misawa Homes and Tokyo House, experienced steady growth through much of this period. With Japans economic stagnation and shrinking population, these companies have had to develop new economic strategies. One of the key strategies has been the formation of Sumstock, an association of offsite manufacturers which successfully lobbied for a higher valuation of manufactured housing value as compared to conventional construction. Since 2004, Sekisui Heim, in partnership with its parent company, Sekisui Chemical, has integrated PV panels and other green technologies into their volumetric modular system. At that time, Sekisui Heim, as well as Toyota House, began offering refurbishment services to their customers as well as buying back existing structures in order to recycle modules. Sekisui is referring to this new strategy as the "Cyclical Business Model for Housing and Living Environment Businesses." A continued shortage of skilled labor in Japan is leading Sekisui Heim to consider increases in automation and mechanization.

Sekisui Heim Company profile:

Sekisui Heim is a subsidiary of the Sekisui Chemical Company. In 2016, the company delivered 13,620 housing units (see appendix). 80 percent of those units were light gauge steel, 20 percent light wood frame. 90 percent of those units were single-family, 10 percent low-rise multi-unit. Since 1977, the company has had a national sales platform, and since around 1990, they have operated a network of eight factories throughout Japan as well as a single factory, which produces lightweight autoclaved ceramic panels.

Sekisui Heim is a fully vertically integrated company, with each of the eight regions serviced in Japan being further broken down into a sales, production, construction and after-sales, servicing and remodeling company. In 2016, net sales were 494 billion yen (4 billion dollars). The company employed 10,419 people.

Sekisui Heim light gauge steel system:

Sekisui Heim's basic volumetric module is fabricated entirely out of light gauge steel. They use 100 to 120 mm square steel tube for posts, 200 mm square steel tube for the beams and 150 mm non-flexible square steel tube for the floor beam. The joint between post and beam is spot welded, with a 3-5 ton strength. This connection fulfills Japanese seismic code requirements. The fabrication of the box frame structure is one of the most automated aspects of the manufacturing process, with robot arms, adapted from the car industry utilized in the process. Module lengths range from 1.8 to 5.4 meters (nine standard lengths), widths from 1.3 to 2.5 meters, and heights 2.4 to 2.6 meters. Modules are designed to be assembled into two- or three-story assemblies. The system allows for four modules to be assembled into a column-free space, as well as for double height spaces. Remaining partitions are light wood frame. Lightweight autoclaved ceramic panels are applied in the factory, providing a high degree of exterior finish. Rubber weather stripping, similar to products used in the car industry, provides a joint between panels assembles in the factory as well as the joints finished on site. Units are 80 percent completed in the factory. On average, two workers complete a typical house in 20 days on site, with another two weeks on average for foundation work before delivery. Standard houses are 130 square meters and consist of 12 to 13 modules. Multi-unit structures range from two to 12 apartments. Identical modules are used for single-family and multi-unit structures.

Tokyo Heim – Sekisui Heim light gauge steel system facility:

The Tokyo Heim facility is the largest of Sekisui Heim's eight facilities, with 94,000 square meters of production areas (see appendix). The factory serves a 100 km radius or one day trip. Materials for a particular project are purchased two weeks prior to the date of delivery, with the modules typically produced two days before shipment date. The factory is influenced by studies of the car industry undertaken by Sekisui Heim in the 1970's. The production flow has been in place without significant changes for the past 20 years. Maximum factory production is 157 modules, with average production being 123 modules. Ten houses a day are produced on average. Task time is three minutes. There are 100 factory stations, on average one every six meters. All of the equipment is made and serviced by a local company in the Tokyo region, with all steel coming from Nisshin steel.

Sekisui 2 U System (Light wood frame):

The Kanto Factory in Kasama City is the only facility dedicated to this wood system, with four other facilities producing wood and light gauge steel systems. The main production facility is 35 by 260 meters, operating on two floors. The top floor fabricates modules while the bottom floor applies finishes and interior components such as stairs, cabinetry and other equipment (see Appendix). The Kanto facility produces 700 houses a year, on average. It employs 114 people. Eighty percent of the lumber used comes from Canada, with the remainder coming from Northern Europe. Maximum factory production per month is 1500 modules, with 800 being average. Average daily production is 36 volumes. Module widths are 2.5 meters with lengths ranging from 2.7 to 5.4 meters. The most popular house type is 150 square meters and consists of 14 modules.

Sales/Marketing:

Direct sales to the consumer or the property manager has been a part of the Sekisui Heim business model from the outset. Customers are currently presented with about a dozen basic house types in steel and eight in wood. Proprietary software allows sales people to provide a detailed price estimate as well as to allow for significant variation to the basic house types. In addition to sales offices throughout Japan, each factory is equipped with a sales facility. For example, 30,000 people visited the Tokyo Heim factory last year. These sales facilities include full-scale mockups of the modules performance in hot and cold weather as well as in earthquakes and typhoons. On average, the design of a project takes one to three months, depending on the client. During that process, a customer makes a 10 percent deposit, at which point production starts. Currently, 88 percent of sales are to the middle end of the market (20-40 million ven (around \$350.000); 6.4 percent are to the higher end of the market (+\$350,000) and 5.3 percent to the lower end of the market. The wood system is generally cheaper than the steel system and also offers significantly less customization. On average, Sekisui Heim's houses are 8 percent more expensive than similar conventionally built houses, but are seen as a higher guality product that retains value. In the future, Sekisui Heim plans to shift its market mix, hoping to expand the low-end of the market share to 41 percent of overall sales, while maintaining the high-end of the market. They hope to expand the low-end of the market share by expanding their real estate development wing, essentially constructing mini-subdivisions. They hope to retain their middle class clients through the addition of green technologies while maintaining the same price point. They also expect growth in an expanding range of refurbishment services.

Code / Permitting:

In Japan, the Ministry of Construction regulates housing construction in dialogue with a series of building system specific associations. Prefabricated construction has its own association, the Japan Prefabricated Construction Suppliers and Manufactures Association, as does light wood frame or 2X4 construction, heavy timber construction, etc. The Japan Prefabricated Construction Suppliers and Manufactures Association has played a significant role in the formation of this structure. In addition, each company submits their particular system to ministries building center for assessment and approval by a group of experts. Sekisui Heim submits revisions to its permissions three times a year on average. These permissions stream line the permitting process since inspectors are now inspecting volumetric modular buildings according to their own pre-approved specifications and not only to a general building code. Inspections occur primarily in the factory. This system of permissions is to single most important factor in the success of Japan's offsite construction industry, including volumetric modular.

Export:

In the 1960's, the Japanese government saw offsite construction, including volumetric modular, as a potential export industry, but companies have not been entirely successful in achieving this goal. In 2009, Seksiui Heim developed a joint venture with SCG Building Materials Co., Ltd. to establish a volumetric modular manufacturing facility outside of Bangkok, Thailand. Sekisui Heim also decided to use this opportunity to further automate and mechanize its established production line around the same basic volumetric modular product. In Thailand, Sekisui Heim's product is targeted towards a high-end consumer as opposed to the middle and upper middle end consumer in Japan. The success of this venture is still not entirely clear, nearly a decade later. It is clear that is not yet a profitable part of the company's business. Also, the higher end market seems to expect a higher degree of customization than Sekisui Heim has been accustomed to in the Japanese market. Nevertheless, this is a unique example of an established volumetric modular company attempting to expand into a new market.

Japan – Lessons Learned:

- Japanese volumetric modular, like the manufactured housing industry in the United States (HUD Code), is supported from a system of "permissions" where their products are inspected by trained professionals according to specifications specific to the industry, even to the company, and not simply to a general building code. This is likely the single most important factor in the industries success.
- Like many offsite construction systems, including volumetric modular, Japanese companies initially touted their systems speed and affordability. Since the late 1970s, the focus shifted to the superior quality of the product (on average, volumetric modular is 8 percent more expensive than conventional construction
- While highly automated in comparison to American facilities, Japanese volumetric modular fabrication facilities nevertheless showed a highly pragmatic application of mechanization and automation. For example, a light wood frame volumetric modular fabricator found that a robot arm was most effective in automating painting, while in light gauge steel volumetric modular fabrication, a similar robot arm was used primarily for welding frames or chassis. Both wood and steel systems utilized an automated track system for moving modules throughout the facility. In both cases, mechanization and automation was paralleled and complimented by a highly skilled work force. Since the early 1990s, Japanese companies have maintained a similar degree of automation
- Japanese companies provide a universal product and sales platform for multi-unit and single-family housing
- Investment in proprietary software and the use of architects as sales people has allowed Japanese companies to offer a high degree of customization and client satisfaction while maintaining a highly standardized and predictable fabrication and delivery system
- Japanese volumetric modular companies closely collaborate with other offsite construction companies through the Japan Prefabricated Construction Suppliers and Manufacturers Association (JPA). More recently, a new association, Sumstock, whose charge was to more accurately valuate the quality of offsite construction as opposed to conventional construction
- Since 2004, Japanese volumetric modular companies have pioneered the reuse and recycling of volumetric modular construction.

Experts interviewed:

Prof. Shuichi Matsumura, Department of Architecture, Graduate School of Engineering Mr. Utsumi, Sales, Sekisui Heim Mr. Shimazu, Sumstock / Japan Prefabricated Construction Suppliers and Manufactures Association Mrs. Rika Nagatomo

Mr. Toshiya Namura, Director of Tokyo Heim, former Director of Thailand Plant

Mr. Takemasa Kobayashi, Business Planning, Sekisui Heim

Literature Survey:

Comparatively speaking, the Japanese volumetric modular industry is the single most studied industry in the world. The authority on the subject is Prof. Shuichi Matsumura, who has published extensively on the subject in Japanese and English. A number of British scholars have also investigated the industry. The topic has been studied through the lens of various disciplines, including architecture, production engineering and business management. One of the areas where more research is clearly needed is the regulatory framework that supports the industry.

Bibliography:

Berg, Nate. (2017)"Prefab Homes: what the U.S Can Learn from Japan." Curbed. Hall, Robert W. (2008) "Tokyo Sekisui." Vol. 24, no 2.

Barlow James and Ozaki Ritsuko. (2005) "<u>Building mass customised housing through innovation in the</u> production system: lessons from Japan", Environment and Planning A, 37, (1), 9-20.

Johnson, W. (2007) "Lessons from Japan: A Comparative Study of the Market Drivers for Prefabrication in Japanese and UK Private Housing Development. Unpublished MSc Dissertation". University College London.

Smith Ryan E., (2009) "History of Prefabrication: A Cultural Survey", Center for Integrated Design and Construction, University of Utah.

Smith Ryan, Quale J (Eds) (2017) "Offsite Architecture: Constructing the Future". Routledge Taylor & Francis.

<u>SWEDEN</u>

Sweden's growing modular industry appeared relatively recently, as compared to the United States and Japan. Lindbacks is currently the industry leader, having produced more than 10,000 housing units since 1994. Lindbacks, along with its two other volumetric modular competitors, grew out of the large Swedish single-family home industry, but now focus almost entirely on affordable as well as market rate multi-unit housing. Like the US, Sweden's volumetric modular construction falls under that countries general building code.

Growth of the volumetric modular industry in Sweden:

The factors that have contributed to the appearance, growth and primary characteristics of the volumetric modular industry in Sweden are as follows:

1964-1974: Like the US and Japan, Sweden's modular industry's roots can be traced to the postwar housing crisis. As HUD noted in 1968, "(t)he only major divergence from the general trend toward continued expansion of industrialized building is perhaps to be found in Sweden ... the only highly developed Western European country that has not provided special assistance to industrialized housing systems." Sweden, like the US and Japan, had a relatively late start in developing a national strategy for introducing industrialized building. In 1964, the Swedish government began the Million Homes Program with the goal of building 100,000 housing units by 1974. During these intense years (constructing housing for one-sixth of the population), the house-building industry transformed from being led by smaller, local master builders to the formation of large, professional contractors. One third of the housing constructed was single family, one third mid-rise (really low-rise) and one-third high rise (really mid-rise). Like many

other postwar housing programs of this period, the program was hit by the energy crisis combined with a rapid decline in population growth in the mid-1970s. The housing was also perceived as low quality, creating stigmas associated with industrialized building that would persist for decades to come. Nevertheless, representatives of the contemporary modular industry have stated that, through this program, methods were tested and regulations defined that have form the foundation of the industries success today.

1974-1994 – During this period, industrialized building, particularly panelized light wood frame construction, became the norm, with as much as 80 percent of single-family housing and 30 percent of low-rise multi-unit being constructed with this system. Nevertheless, the vast majority of multi-unit housing was constructed using concrete and/or masonry construction.

Lindbacks

1994-2005 – Lindbacks began as a family-owned lumber business in 1924, expanding to single family and low-rise multi-unit panelized light wood frame housing construction during the mid-1960s, in direct response to the Million Homes Program. By 1994, Lindbacks began developing a volumetric modular system specifically for low- and mid-rise multi-unit housing (up to nine stories). The system became commercially viable by 2000 and fully compatible with and optimized Swedish building code by 2004.

2004-2016 – Between 1994 and 2010, Lindbacks delivered 10,000 housing units from their single facility in the north of Sweden. In 2017, Lindbacks began construction of a new plant, near their existing facility in the north of Sweden. That plant, the largest in the European Union, began production in January 2018.

Derome

1960-2019 – A new volumetric modular company, Derome was also founded as a family-run lumber business in 1946. In 1960, they began producing panelized single-family houses, also benefiting from the Million Homes Program. By 2003, Derome began delivering multi-unit housing with their Derome Hus line. They are currently in the process of rolling out a volumetric modular system, their Derome Plus House, which will begin production in 2019. Like Lindbacks, they have adapted their existing automated production systems from panelized to volumetric modular construction. Both companies have benefited from a full-suite of fabrication equipment provided by Randek, a Swedish company specializing in tools for the offsite construction industry.

Randek

1960-2019 – Founded in 1940, Randek focused entirely on developing tools for the offsite industry during the Million Homes Program. The company introduced significant automation in 1980, fully incorporating CAD CAM technology by 1985. Between 1950 and 1980, Randek's tools were used to produce 300,000 housing units, primarily in Sweden. Since, 1980, the company has expanded to the international market, with their equipment being used in 40 countries, including New Zealand, Australia, U.S. and Canada. The company claims to currently have equipment being used for one million housing starts, across the globe. In 2016, Katerra equipped their new facility in Phoenix with Randek tools and equipment (see North American report). In their new plant, Lindbacks is using a combination of equipment from Randek and Weinmann, their main European competitor, based in Germany. Despite of developing a range of highly automated tools, Randek still offers equipment ranging, starting with relatively low degrees of automation, and they encourage their customers to gradually increase the degree of automation.

Lindbacks System:

Lindbacks was initially focused on panelized single-family construction and is now entirely focused on permanent volumetric modular multi-unit projects. It utilizes light wood frame construction. Currently, maximum module sizes, dictated by their current plant, are maxed out at 8.7 meters (28 feet) in length, with a maximum finished floor to finished ceiling height of 2.5 meters (eight feet). Modules range from to two to 8.7 meters in length, two to 4.15 meters in width, and 2.8 to three meters in height. Double layer gypsum board is used throughout. Lindbacks has constructed seven-stories of light wood frame volumetric modular, with plans for projects as high as nine-stories.

Lindbacks Company info:

The company is currently engaged in 15 to 20 projects. In 10 to 20 percent of projects, Lindbacks acts as the developer, 20 percent are municipal projects, with the remainder are market rate projects for other developers. The company operates through design-build contracts. Customers make their first payment when the first module is set on site (90 percent of cost). Their design department has, including 12 draftsmen, four structural engineers, six project managers and other contributors. The head of the design department is Helena Lidelow. A typical project takes five months to design and five to six months to fabricate and complete on site. Three percent of annual profits is dedicated to research, conducted in collaboration with Lulea University, where Helena Lidelow is a professor. The economic down turn in 2008 led Lindbacks to expand their focus to affordable housing, student housing as well as to pursue more of their own development projects. The downturn also gave them more time to experiment with the size and scope of projects.

Lindbacks – Current Plant, Pitea, Sweden

The plant has been operating since 1994. Between 1994 and 2010, approximately 10,000 dwelling units or around 23,000 volumetric modules (2.3 modules per unit on average) were produced at the plant.

The plant is 900 km (500 miles) from their main market, the greater Stockholm region. Three to four of total cost is transport. At peak capacity, seventy trucks per week are delivering modules, with two modules per truck. A typical delivery includes three trucks plus one car, as per Swedish transit regulations. Modules are stored a maximum of two weeks before being shipped to the site.

The plant operates according to lean management principles (see Appendix). Currently, the plant size is 24,000 m2. The plant operates on two shifts but as planning to move to a single shift. On average, 63 volumes are produced per week, eight per shift. Ninety-five people work on a typical shift. The factory has 37 stations.

Lindbacks utilizes automated equipment from Randek and, more recently, from Weinmann for the production of their floor and wall panels, with an average production time of 15 minutes for a typical 3x8 meter wall or 4x8 meter floor panel. Module production is manual. After completion of the basic module, modules are moved through the facility on a track system. Lumber arrives precut from Martinsons (this high degree of standardization and precision is possible due to the standardization achieved in the 1960s through the Million Houses Program). Martinsons replaced Lindbacks own lumber mill, which the company sold in the 1990s.

Lindbacks - New Plant, Lulea, Sweden

Two factors have led Lindbacks to develop a new plant, an increase volume of production and the desire to further automate their production process, without stopping production in their current plant. The plant, which opened in January 2018, is double the size and production capacity of the current plant (48,000 m2 / 16 volumetric modules per shift). Lindbacks has invested six million dollars into the new plant. With increased automation, double the production will be achieved with 50 percent more employees (150 instead of 95). The site also affords opportunities for rail and maritime transport. The plant will have 51 stations (as opposed to the current 37). The plant director, Henrik Haupman, was brought in from Volvo. Haupman plans to start with a production time of 55 minutes per module and gradually work up to 30 minutes per module. He hopes to also entirely remove forklifts from the plant, due to diesel exhaust problems, accidents, and general life safety issues. Over time, the existing facility will be adapted to operate to the same parameters as the new plant, resulting in what Lindbacks refers to as a "twin factory" concept. The company is moving away from specialists to multi-skilled operators who will skilled in every aspect of the process. When asked what was different about the volumetric modular industry, as opposed to the car industry, Haupman commented that there seems to be more of a focus on and opportunity for innovation.

Lindbacks: Code / Permitting / Union Labor

Lindbacks is a member of the Sveriges Träbyggnadskansli or Swedish Timber Council. There is no specialized offsite or volumetric modular association in Sweden. The Swedish Timber Council has advocated for timber construction in Sweden, where, until recently, timber construction was relegated to single-family housing. Lindbacks worked for over a decade to ensure that their volumetric modular system complied with Swedish building code, overcoming a general bias against multi-story timber construction. Lindbacks was originally affiliated with the Swedish construction union, but moved to wood product manufacturers union. In the new plant, Lindbacks has focused on hiring skilled industrial workers instead of those coming from the building trades. Lindbacks, along with other members of the timber industry, anticipate that new European Union regulations will further increase their competitiveness over masonry, concrete and steel construction, which still dominate multi-story construction in Sweden.

Derome company profile

A relative new comer to volumetric modular construction in Sweden, Derome, located near the Gothenburg metropolitan area prides itself on a range of services "from the forest to the finished house". They have retained their lumber business and plant continue producing single-family panelized housing as they expand into multi-unit volumetric modular construction.

Company subdivision:

Derome Skog – source raw lumber – 800,000 m3 of wood sourced annually – network of 3,000 forest owners

Derome Timber – sawing capacity – 450,000 m3 a year

Derome Biofuel – heats the equivalent of 120,000 homes a year – opened a pellet factory in Kinnared, 60,000 tons of pellets a year

Derome Byggvaror- building products and logistics

Derome Trateknik - roof trusses (focused on German market)

Varberghuses - custom homes

A-hus – panelized single-family, Sweden

A-hus professional – complete panelized houses for international market

Derome Hus – panelized multi-unit Derome Plus Hus – volumetric multi-unit Derime Mark & Bostad – development

The company currently employs 1750 people. 90 percent of current production is panelized single-family housing (1300 units per year), 10 percent panelized multi-unit (four to seven stories, 20 structures a year, on average, since 2003). They see volumetric modular as a key part of their strategy to shift to 50 percent multi-unit by 2025. In anticipation of stricter European Union regulations, Derome is developing a fossil fuel free transportation fleet and passive house standards. They currently have projects planned through 2040. Thirty-five design all yearly production, with some external architects also engaged. Derome develops some of its own projects, such as Goingegarden, with 500 units of single family, terraced housing (townhomes) and low-rise multi-unit.

Derome, new volumetric modular plant:

The Derome PlusHus line will be produced in a new facility, near Gothenburg. They see the growth of volumetric modular in Sweden being driven by a lack of qualified contractors and skilled-labor. The new plant will produce up to 600 units (around 1200 to 1500 modules) a year. Structures will vary from two- to four-stories in height. While panelized construction will target the mid- and high-end market, volumetric modular will target middle class consumers in urban centers. They anticipate that the same low to mid-rise multi-unit housing project that currently takes nine months to construct will take them 10 weeks, using their volumetric modular system. The system and plant have been in planning since 2014 and will open in 2019. Like Lindbacks, Derome is planning to install a mix of Randek and Weinmann machinery in their new plant.

Sweden: Lessons learned

- The volumetric modular industry in Sweden is closely aligns modular construction with sustainable or green building. This strategy is showing immediate benefits in terms of consumer response but is also seen as a long-term strategy that anticipates stricter green building regulations.
- Swedish provides one of the most ecologically efficient manufacturing ecologies, with volumetric modular companies utilizing that countries local timber supply
- Lacking a trade association like MBI, Swedish modular companies have closely aligned with the local timber industry and its trade association, the Timber Building Association around common interests. In Sweden, along with the rest of continental Europe, timber construction is still not common in multi-unit housing construction, so the two industries see a common interest in expanding into multi-unit housing
- In Sweden, volumetric modular has adopted many of the fabrication techniques and equipment common to that countries panelized construction industry (see Randek.com).
- The use of higher grade lumber by the modular industry in Sweden has also played a key factor in allowing for greater degrees of automation
- Swedish companies deliver up to seven-story volumetric modular light wood frame construction.

- To varying degrees, all three volumetric modular companies engage in design and development as well as fabrication.
- New partnerships and knowledge exchanges are being forged with Sweden's leading tech companies, with engineers from Volvo involved in Lindbacks new plant
- The success of Lindbacks, as well as their competitors, has been directly related to long term planning

Swedish Experts Interviewed:

Susanne Rudenstam, Managing Director, Swedish Wood Building Council Dan Wilded, Product Manager, Martinsons (Lindbacks lumber supplier) herese Kreisel, Architect, Spatial Planning and Community Development, Skelfea Municipality Helena Lidelow, Director, Design Department, Lindbacks Henrik Haupman, Plant Director, Lindbacks Derome Staff Randek Staff

<u>UK</u>

It is estimated that offsite construction constitutes 7 percent of the total construction output equating to £1.5 billion per annum. It is unclear how much of that is modular construction, however, modular construction has a long history in Britain stemming from colonial migration. Also, being part of Europe, modular construction in the UK leverages techniques from Sweden and Germany/Austria that have a longer modern history with the technologies. The UK has also adopted techniques from Japan in its hot rolled steel modular program. The UK tends to be geographically specific, with light wood frame Swedish techniques and automated equipment being used in Scotland and northern England and light gauge steel and hot rolled steel more common in the Midlands and London. Like North America, the modular industry is regulated by the same codes as conventional construction.

- The UK government has put forward numerous reports to industry from 1994 forward calling out the inefficiencies and lack of innovation (productivity). These reports set targets for the construction industry including lower initial and lifecycle costs, faster delivery, lower emissions, and the symptoms of such, dysfunction in training, and workforce recruitment. During this time, the reports have pointed to offsite manufacture as one solution to overcome such challenges.

- Offsite construction is seen as a solution to the skills gap in the construction sector that is currently being filled with low skill immigrant labor. The government and construction industry are selling offsite and modular as an upskilling, tech based industry in order to attract talent that is currently going into business and IT as the next generation of construction workforce.

- Low carbon targets in particular have driven the uptake of modular construction in wood and claims that reduction of waste in steel modular will aid in reduction of carbon emissions. This is linked to Europe's goal to lower carbon emissions.

- Offsite construction and modular in particular has been paired with targets for advanced BIM modeling and increases in construction automation. The UK has been slower than the US on BIM uptake, but offsite manufacturers have been quicker to take up BIM and market its benefits.

- UK BuildOffsite (a client, supply, professional services and academic membership organization which promotes and support offsite) have implemented an independent verification program of products and buildings for fitness to support long-term loans insuring consistent performance over a determined durability of 60 years in association with Lloyds Register, BLP Insurance and the Royal Institute of Chartered Surveyors.

- There is significant investment occurring in offsite in the UK. In modular these are new players and new products include: £12M in CCG OSM light wood frame closed panel construction in Glasgow that grew out of a medium-sized site-built construction company; £55M L&G Modular Homes, a subsidiary of a pension company, that is building the largest modular factory in the world, on par with the new Lindbacks factory in Sweden, but producing cross laminated timber panels and assembling modules in the factory for pension condo sales in Leeds; and £104M Laing O'Rourke Modular Concrete in Sheffield that is a subsidiary of Laing O'Rourke construction company, one of the largest in the world.

Experts Interviewed: Robert Hairstans, Edinburgh Napier University Callum Murray, CCG OSM Stewart Milne Timber Systems FutureForm

POLAND

A relative new comer to the global volumetric modular industry, the three key players in Poland all benefit from that countries steel industry as well as its furniture industry. All three companies are currently focused on Western European and North American markets. Polcom Modular has recently delivered a hotel to New York City, with its main competitor, DMD Modular planning a second hotel in the Big Apple.

Growth of the volumetric modular industry in Poland:

1994 -2018 A relative new comer to the volumetric modular industry, companies began to develop systems in the mid-1990s. Two established furniture manufactures, Polcom and Black Red White, were part of that countries mature industry (IKEA has been producing furniture in Poland since the seventies). As Poland opened to the global market, both companies moved into the hospitality industry, and it seems logical that after fitting out the interiors of many hotels, both companies now focus on hospitality in their modular divisions.

Polcom Modular (a subsidiary of Polcom):

The Polcom Group was founded in 1997 in Topole, Poland, with offices in Cheshire, UK, New York and Dubai. Polcom has developed a long-term relationship with the CitizenM, a Netherlands-based hotel chain, founded in 2005. Since 2008, the company has constructed hotels in Amsterdam, Glasgow, London, Paris, and, most recently New York. Most of their hotels use permanent volumetric modular construction (the Times Square CitizenM does not), and many have been fabricated by Polcom Modular, including Citizen M

Bowery. Polcom's tallest building to date, CitizenM Bowery has a 15-story modular component (14 modules per floor for a total of 210 modules, fabricated in northern Poland and shipped to the United States). The modules are approximately eight feet in length, with two 150 square foot hotel rooms and a corridor contained within many of the modules (a few of the modules adjoin a site caste concrete core and are shorter).

DMD Modular (a subsidiary of Meble Black Red White)

DMD Modular is one of 26 subsidiaries of Meble Black Red White, a Polish furniture company. Until recently, Meble Black Red White supplied wall partition to DMD Modular. DMD's initial system followed the basic dimensions and fabrication principles of a shipping container but has since moved away from this approach. The initial module width was 2.4 meters (similar to Polcom), with a module width of three meters standard in their current work (3.2 meters is the maximum width from transport in Poland). Module lengths average six to eight meters, with 14 to 15 meter widths used in some projects. The module height is three to 3.6 meters. DMD has used Pfeiderer wood products but is shifting to Fermacell gypsum fiberboard for fire seperation. The Tracks company, another Black Red White company, makes all of the MDF wall panels. used in DMD's modules. They arrive flat packed to the facility where they are directly installed into the steel chassis. The steel chassis is fabricated by one of a number of steel mills near Krakow, to DMD's specifications. Steel modules take two months to fabricate, with 1.5 months needed for the remaining interior finishes and site work, on average. Steel in Polan is 2.5 euros a kilogram, significantly cheaper than in other parts of the European Union. For this reason, the DMD facility is essentially an assembly plant. DMD benefits from an abundance of suppliers and skilled industrial labor in their immediate vicinity in Krakow (they also commented that Polcom's location, in the north of Poland, is problematic due to access to labor). DMD works closely with a number of subcontractors and specialists, in order to keep their permanent staff small, with a total 15 employees, seven of whom are architects. Fabrication staff is hired on a project-by-project basis and ramp up to as many as 150 employees (for two large projects).

Like Polcom, DMD is focused primarily on markets outside of Poland. A recent project included the production of low-rise multi-unit structure for the suburbs of Munich. Typical units were 70 m2 in area and cost 1100 to 1500 euros per square meter. Current production levels are about 1000 m2 per month (1200 per year), with plans for expanding up to 4000 m² per year. Hospitality is seen as the primary area for future growth, along with multi-unit. DMD is seeing a growth in modular construction in Poland, as established companies look to expand into the industry.

Poland Lessons Learned:

- Polish volumetric modular companies have developed the logistics necessary for a commercially viable export business. Polcom Modular has shipped complete hotel modules to Holland, the UK and, most recently, to New York City. DMD has shipped modules to southern Germany.
- Polish modular provides a unique case study of the expansion of furniture manufacturers into the modular industry, with Polcom and DMD both part of a larger furniture conglomerate.
- The focus and export and the relationship with furniture companies has created a unique manufacturing process: modular companies order standard steel volumetric modules from third-party steel mills, used for the primary structure, while using flat-packed MDF partitioned, made by their parent furniture companies, for partitions and other interior surfaces.

 CitizenM, Polcom Modular's partner, is the first hotel chain to develop a brand specifically tied to volumetric modular. Since starting the company in 2005, Citizen M has delivered volumetric modular hotels in Paris, Amsterdam, London and, most recently, in New York City. CitizenM Bowery, their most recent projects, provides an elegant hybrid volumetric modular solution that utilizes a site-cast concrete core and a three-story concrete lobby with seventeen floors of volumetric modular construction.

Experts Interviewed Marek Szpakiewicz, DMD Modular Ewelina Anna Woźniak Szpakiewicz, DMD Modular

<u>AUSTRALIA</u>

Although prefabrication in Australia has been alive since the Manning Cottage was delivered from the UK during the colonial period, and early research from the Australian government on the potentials of offsite construction, Australian modular construction has only emerged in the last decade. Currently there are an estimated 74 (2013) modular manufacturers in Australia of 169 total offsite manufactures. It is difficult to determine the overall contribution of modular to the construction industry in Australia, but in housing, offsite as a whole is estimated at five percent with modular being the dominant method. This is in comparison to three to four percent in the U.S., 12 to 15 percent in Japan with panelized and modular being about equal and 50 to 90 percent in Sweden with panelization being the wide majority of that market. Following population distributions, the majority of modular manufacturers in Australia are located on the east coast of Australia with the strongest stronghold in the metropolitan region of Melbourne, Victoria. There are two scales of volumetric modular occurring in Australia that follows the pattern in North America: steel and concrete modular for mid- to high-rise in the urban center of Melbourne and now Sydney and light wood frame and light gauge steel modules for urban and suburban housing development. However, unlike North America, modular companies are more diversified, offering many different offsite solutions and material modular solutions for a myriad of building types – there is less concentration and specialization.

One company in particular that has excelled in the steel and concrete volumetric modular space is Hickory Group. Using continuous innovation, Hickory has delivered hybrid mid- and high-rise projects in Melbourne that are the envy of the modular world up to 65 levels in their most recent 568 Collins Street. On-site assembly times are record breaking with: nine levels in five days, and the modular fabrication in the factory has pioneered first a monocoque chassis that was abandoned in favor of a three or four sided open box for stacking to limit the floor-to-floor heights. The company has focused on construction performance, delivering just what traditional site-built offers but through a modular solution.

The drivers for volumetric modular in Australia are twofold: 1) over the past six years there has been significant federal and state political support for encouraging factories in any sector to save the depleting manufacturing workforce from leaving due to automobile production moving out of the country; and 2) similar to North America, productivity challenges in construction have moved the industry to look for more efficient ways to achieve cost and schedule control as well as quality and sustainability improvements. This has resulted in both federal and state funding schemes to support industry and universities working together to realize construction productivity and job growth goals via offsite and modular in particular.

Under the Labor Party, the Manufacturing Excellence (META) was established to foster new offsite factory growth for job creation. This was replaced by the Advanced Manufacturing Growth Center, an advocacy group at the Federal level that has recently issued grants for business development. This is both focused on supporting large construction companies to increase productivity and small/medium construction and manufacturing companies to increase their scope, scale, and delivery capabilities.

PrefabAUS emerged in Australia as a catch all offsite construction trade association in order to advocate, share knowledge and respond to the drivers for offsite construction and modular in Australia. PrefabAUS partners with housing associations and organizations to align their efforts for lobbying and guide development. Australia PMC must follow the same regulations that traditional site-built construction complies with. And, like the U.S., codes have historically been not sympathetic to volumetric modular or other factory-built methods. However, in the past few years, a group called the Modular Construction Codes Board from Melbourne in collaboration with PrefabAUS and the companies it represents, the Victoria (state) government and Monash University established a code, or guideline, for the implementation of permanent modular construction in specific. The Victoria Modular Code of Construction Handbook released in May of 2017 for public comment does not focus on the uniqueness of modular in particular but emphasizes the potential hybrid approaches to offsite and onsite work, working to sell modular not as a holistic solution, but part of a project delivery process. Its emphasis is on quality control and improved safety. A new edition will be released in 2018. Also, Melbourne School of Engineering has led a charge to grow the Australian offsite industry as a whole from five to 15 percent by 2025, contributing to 20,000 new jobs and \$30B Australian Dollar growth.

In addition to single-family and multi-family housing, affordable housing is lacking in urban centers. Municipalities are looking for way to meet their housing crisis and modular has been targeted as a potential solution. Also, due to a current school space shortage, there is much interest in leveraging modular for faster build cycles. Similar to trends in the Japan, Sweden and now the U.S. with companies such as Katera, Australia is seeing its share of emerging integrated supply chain develop, design, build companies. Lend Lease is vertically integrated delivering end to end multi-family mid-rise housing. However, it is using mass wood CLT for its builds procured from central Europe originally and now investing in a CLT manufacturing start-up. This and similar company developments in Australia have much university involvement for research support. Although CLT saw early signs of imports of offsite product, modular construction in Australia has not been impacted by the threat of Chinese or other Asian import industry as has been recently experienced in the U.S. from Poland and China.

Recent research by Dale Steinhardt from Queensland University of Technology, demonstrates that the challenges and perceptions of owners, developers, architects, contractors as well as the general public is very similar in Australia as it is in North America. However, in the last couple of years, there is a concentrated effort across the offsite sector for education and outreach. For example, the Built Offsite magazine and website was established that is produced by a third-party and marketed by PrefabAUS. Having published over a dozen issues, the literature is well received by the construction industry as a whole and increasing the discussions outside of the offsite and modular construction sector. It mirrors a similar magazine that emerged in the UK titled "Offsite".

Experts:

Matthew Aitchison, University of Sydney Damien Crough, (formerly with Hickory, now Chairman of PrefabAUS) George Argyrou, Hickory Group Warren McGregor, PrefabAUS Director

Bibliography:

Steinhardt, Dale A. Manley, Karen Miller, Wendy. (2013) Profiling the nature and context of the Australian prefabricated housing industry. Queensland University of Technology. <u>https://eprints.gut.edu.au/81176/1/nature-and-context-australian-prefabricated-housing.pdf</u>

Steinhardt, D. & Manley, A. Exploring the beliefs of Australian prefabricated house builders. Construction Economics and Building, 16(2), 27-41. <u>file:///Users/ryansmith/Desktop/4741-21897-1-PB.pdf</u>

Steinhardt, D. & Manley, A. Adoption of prefabricated housing-the role of country context. Sustainable Cities and Society Volume 22, April 2016, Pages 126–135.

http://builtoffsite.com.au/issue-04/modular-construction-code-board-handbook/

5 IN 5 MODULAR GROWTH INITIATIVE Research Roadmap Recommendations

© Copyright 2018 Modular Building Institute

