DISRUPTIVE DEVELOPMENT: MODULAR MANUFACTURING IN MULTIFAMILY HOUSING

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Disruptive Development: Modular Manufacturing in Multifamily Housing

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Since the 1830s balloon frame construction has dominated the development industry in the United States without competition. Recently, off-site manufacturing has changed the way developers; architects and contractors think about building housing. Modular construction is primed to disrupt the way we produce housing on a large scale in a cost effective and time sensitive manner. This report quantifies the benefits of off-site construction, discusses the challenges, and presents next steps for the widespread adoption of this disruptive technology for the development of multifamily housing in the Bay Area.

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Introduction

Modular construction, a process by which units are built and inspected off site in a manufacturing facility, while foundation, podium and infrastructure is built on site, is a method that has the potential to increase housing production by accelerating construction time and reducing construction costs. Anecdotal claims suggest that modular construction can save between 10-20% on hard costs and reduce construction time by 30-50%. While modular construction is not a new method, it has yet to be adopted on a broad scale in the multifamily market. This report will shed light on the benefits and challenges of using modular construction in multifamily housing.

Long entitlement and approval timelines, coupled with rising construction and labor costs, have created a uniquely difficult development environment in the San Francisco Bay Area. The particular challenges facing developers in the region have forced a wide variety of industry members to consider alternative means and methods for housing construction. As such, this paper will focus on the Bay Area and use completed and planned modular development projects as well as three modular manufacturers who have successfully completed multifamily projects in the region as case studies. The report will consider the benefits and challenges of modular manufacturing from each stakeholder's point of view and will discuss the implications of modular construction for site selection, design, construction, financing, and policy. Using these case studies, this report will conclude with next steps for broader use of modular construction focusing

on challenges that can be addressed immediately and those that require longer-term investigation and policy changes. Although this report focuses on the Bay Area, the questions, solutions, and analysis have applications to other regions where rising demand for housing is generating a need for creative development solutions.

The Housing Shortage in the Bay Area

The current housing crisis in the San Francisco Bay Area can in part be explained by insufficient housing supply. The Association of Bay Area Governments (ABAG) produces a Regional Housing Needs Allocation (RHNA), which is a state-mandated process that identifies the total housing need for the San Francisco Bay Area for an eight-year period (from 2007-2014 in the previous cycle, and 2014-2022 in the next cycle).[1] Using population growth and household formation rates, the RHNA for 2007-2014 projected a regional need of 214,500 new housing units. However, between 2007 and 20014 the region as a whole, including Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma Counties, permitted only 57% the units needed to meet projected population growth.[2]

County	Total		
	RHNA	Permits Issued	Percent RHNA Met
Alameda	44,937	19,615	44%
Contra Costa	27,072	16,800	62%

[1] Final Regional Housing Need Allocation Adopted. (n.d.). Retrieved May 11, 2016, from http://abag.ca.gov/planning/housingneeds/

[2]http://reports.abag.ca.gov/sotr/2015/section4-housing-goals-progress.php#section4_3http://www.bizjournals.com/sanfrancisco/blog/real-estate/2015/04/bay-area-housing-supply-cities.html

Marin	4,882	1,543	32%
Napa	3,705	1,434	39%
San Francisco	31,193	20,103	64%
San Mateo	15,738	8,169	52%
Santa Clara	60,338	44,823	74%
Solano	12,985	4,972	38%
Sonoma	13,650	5,639	41%
Total	**214,500**	**123,098**	**57%**

Table 1: Bay Area Progress in Meeting 2007-2014 Regional Housing Need Allocation[3]

In its Regional Housing Needs Plan the Association of Bay Area Governments (ABAG) states that the Bay Area must plan for 187,990 new housing units between 2014-2022 to meet the regions based on population projections carried out by the California Department of Finance.[4] However, developers in the Bay Area cities face unique circumstances that challenge their ability to build enough housing to meet regional demand.[5] Restrictive zoning, community opposition, impact fees, and potential litigation, are only a few of the factors that have made the Bay Area an increasingly difficult environment for real estate development.

Challenges to Meeting Demand

The combination of rising development cost and long development schedule stand out as key challenges to housing development in the Bay Area.

[3] http://reports.abag.ca.gov/sotr/2015/img/Table_4-1_original.pdf
[4] http://www.abag.ca.gov/planning/housingneeds/pdfs/2014-22_RHNA_Plan.pdf
[5] Although one can argue with the methodology of the RHNA, for the purposes of this report the RHNA is considered an accurate method for determining population growth and housing demands.

Development Cost

Construction costs have increased nearly 25% in the last two years, including the cost of land, materials, fees, and code compliance.[6] Today, the cost of building a single unit in San Francisco is upwards of $700,000 including land costs.[7] While material prices remain relatively fixed because they are linked to a global commodities index, California's building codes and energy efficiency standards often require more expensive materials and labor. For example, the state's Title 24 legislation requires builders to use expensive high quality windows, insulation, and heating and cooling systems to reach specified energy efficiency goals.[8]

More importantly, the cost of labor has skyrocketed in the region. Construction labor is roughly 20% more expensive in California than the rest of the country.[9] This is due to a shortage of construction labor, government mandated project labor agreements (PLA), and an up-market creating more demand than there are construction workers. This gives general contracts pricing leverage power and a chance to recoup drained profit margins during the downturn. The construction industry was hit particularly hard by the financial crisis with some industry reports estimating that 1.5 million jobs were lost.[10] Though it has been nearly a decade since the Great Recession, the construction industry

[6] ULI Berkeley Multifamily Housing Panel
[7] Is Prefab Pretty Fab? (2016). Retrieved May 11, 2016, from http://www.spur.org/publications/urbanist-article/2016-01-19/prefab-pretty-fab
[8] http://lao.ca.gov/reports/2015/finance/housing-costs/housing-costs.pdf
[9] http://lao.ca.gov/reports/2015/finance/housing-costs/housing-costs.pdf
[10]http://www.constructiondive.com/news/construction-labor-shortage-update-dont-overlook-the-long-game/410781/

has not recovered the loss of workers and construction employment in California has decreased by 28% since its 2007 peak.[11] The general decrease in number of construction workers in the Bay Area, coupled with project labor agreements requiring construction be performed by expensive union labor, has caused the price of development to skyrocket to unsustainable and untenable levels.

Development Time

The average construction schedule of a conventionally built project is 16.86 months[12], not including the time it takes for planning approval and entitlements. In San Francisco, it takes an average of six months from the time of submitting a preliminary development application just to have a city planner assigned to your project. Projects entitlements can take as much as a decade to secure and even after a project has been approved, it is vulnerable to CEQA litigation and challenges by initiatives or referenda.

Rising costs of construction, land, and labor, combined with the acute need for housing to meet the demands of population growth, have forced policymakers and developers alike to explore alternative construction methods. The need for more housing has reached such a critical point that there is motivation to figure out a solution. Modular

[11]http://www.theatlantic.com/business/archive/2015/02/where-have-all-the-construction-workers-gone/385417/

[12] Smith, R. E., & Rice, T. (2015, April). Off-Site Studies - Permanent Modular Construction - Process Practice Performance [Editorial]. *Modular Building Institute*. Retrieved May 11, 2016, from http://www.modular.org/HtmlPage.aspx?name=foundation_offsite_PMC_report, 28.

construction may be the answer to several of the key barriers inhibiting housing development today.

Definitions and History of Modular Construction

The term modular construction is often used interchangeably to describe a wide variety of products and construction processes. To clarify what is meant by "modular construction" in this report, it is important to provide definitions and make distinctions:

Stick/Site Built refers to conventional wood frame construction methods. Homes are constructed from pieces of wood, concrete or steel that are delivered to a site, cut or measured on site, and then assembled.

Panelized homes are constructed out of wall panels that are manufactured in a factory. Panelized systems may include plumbing, electrical wiring, and insulation - closed-panel systems - while open panel systems only include framing and exterior sheathing. Panels are shipped from the factory to the site and assembled by use of a crane that sets the individual panels onto a foundation.

Manufactured/Mobile homes, like modular homes, are composed of boxes built in a factory. Though manufactured and modular homes share many attributes, the primary

difference is their portability and regulatory compliance. Manufactured homes comply with certain HUD regulations ensuring easy and safe transportation.

Modular Construction is a process by which individual components or modules are built off-site in a factory and then transported and assembled on site by use of a frame that sets the modules on a foundation and stacks them on top of one another. Modular units are permanent and subject to stricter state and local building codes.

Modular construction is not a new concept. The first documented prefabricated home was the Manning Portable Cottage built in the 1830's by a carpenter in London. Manning wanted to construct a home for his son who was immigrating to Australia but didn't know what materials and supplies his son would find there so he built the house in pieces so that it could be stored and shipped and then assembled upon arrival. In the United States, prefabricated construction began with the balloon-frame method created by Chicago builder Augustine Taylor. This particular method allowed walls to be built off site and then transported on-site so that a building could be erected more quickly. Sears Roebuck and Co. home introduced perhaps the most well-known and successful prefab in 1908. The order-by-mail house was delivered in pieces and then assembled on-site. At the time, these houses cost less than two-thirds of a conventionally built home.

Between 1908 and 1940 Sears Roebuck and Co. sold over 500,000 catalogue homes.[13] The United States experienced a severe shortage of housing supply following the end of the World War II when soldiers returning to the United States wanted to buy a home. The demand for homes was greater than the conventional construction industry could handle and soon builders were looking for solutions to increase efficiency and lower the cost of home construction. The single-family modular manufacturing industry experienced a boon in this market and at one point there were over 70 active modular manufacturers, ultimately leading to the construction of roughly 200,000 prefabricated homes.[14]

In Postwar Europe, prefabricated housing was used to address the loss of over 25% of housing stock in companies such as Germany due to bombings. The Nissen Hut as it was known in the UK or the Quonset Hut in the US – a prefabricated steel structure made from corrugated steel - was used extensively across the world for domestic, military and institutional uses. Although it had many flaws, such as its cylindrical design which made it difficult to place rectangular furniture in, they were economical in their use of

[13] Prefab: From Utilitarian Home To Design Icon. (n.d.). Retrieved May 11, 2016, from http://www.npr.org/templates/story/story.php?storyId=94119708
[14] A Brief History of Prefab. (n.d.). Retrieved May 11, 2016, from http://www.architectureweek.com/2012/1003/design_1-1.html

materials and were portable and quickly erected.[15] In Britain over 155,623 prefabricated homes were produced after the Second World War.[16]

Architects have long seen prefabricated construction as a way to deliver "smart design to the masses". Inspired by the Industrial Revolution, which proved the efficiency of assembly line manufacturing, architects like Walter Gropius, Buckminster Fuller and Frank Lloyd Wright envisioned the technology of mass production being applied to manufacturing homes. Fuller, for example, designed the Dymaxion House in 1927, which, although never built, was to be shipped in pieces and then assembled on site.[17]

Countries around the world have utilized prefabricated methods in construction for decades – particularly in Finland and Japan where it makes up 20% of the housing market.[18] Companies like Muji in Japan, BoKlock in Scandanavia, and also companies in Poland and England, have been providing prefabricated housing in large quantities for years. In Sweden, a country with only 9 million inhabitants, 14,000 units of prefabricated housing are sold a year and 84% of detached homes use prefabricated

[15] A Brief History of Prefab. (n.d.). Retrieved May 11, 2016, from http://www.architectureweek.com/2012/1003/design_1-1.html
[16] http://www.bbc.co.uk/ahistoryoftheworld/objects/iyZiTEbQRVerIZnwYg5q1g
[17] A Brief History of Prefab. (n.d.). Retrieved May 11, 2016, from http://www.architectureweek.com/2012/1003/design_1-1.html
[18] Prefab: From Utilitarian Home To Design Icon. (n.d.). Retrieved May 11, 2016, from http://www.npr.org/templates/story/story.php?storyId=94119708

timber elements (as compared to 5% in the US, Australia and the UK).[19] In Germany 9% of new residential building permits are for prefabricated buildings and in the Netherlands 20% of all new housing uses wood or concrete prefab materials.[20] Today, several building sectors in the United States are utilizing some form of prefabrication or modular building processes today; 49% of healthcare facilities, 42% of college buildings and dorms, and 42% of manufacturing buildings are using this technology.[21] However, multifamily residential housing is notably absent from these categories.

Though modular construction is widely used in the single-family home and hospitality industries across the world, only a handful of projects have used this technology in multifamily housing in the United States. Several of the country's multifamily modular projects exist in the San Francisco Bay Area and those, described below, serve as the primary case studies to discuss the benefits and challenges of utilizing modular construction.

[19]Why Sweden beats the world hands down on prefab housing. (n.d.). Retrieved May 11, 2016, from http://www.globalconstructionreview.com/trends/why-sweden-beats-world-h8an0ds-4d2own0-6p4r2e0f8ab/

[20]Why Sweden beats the world hands down on prefab housing. (n.d.). Retrieved May 11, 2016, from http://www.globalconstructionreview.com/trends/why-sweden-beats-world-h8an0ds-4d2own0-6p4r2e0f8ab/

[21]http://www.nist.gov/el/economics/upload/Prefabrication-Modularization-in-the-Construction-Industry-SMR-2011R.pdf, p. 10

Case Studies: Modular in the Bay Area

Due to the unique characteristics of the development environment in the San Francisco Bay Area, this paper uses projects, manufacturers, and stakeholders located in or serving the Bay Area market as case studies. Modular manufacturers vary in their production capabilities, technologies, and target product markets. For the purposes of this report, only modular manufacturers with demonstrated capability in the multifamily market are discussed in depth. The appendix at the end of the paper contains additional information and resources, including information regarding multifamily modular manufacturers and projects outside of the Bay Area region.

Modular Manufacturing

ZETA Design + Build: The first modular manufacturer to produce a multifamily project in the Bay Area entered the market in 2010 as a vertically integrated developer seeking to produce housing using more sustainable building methods. In 2010, ZETA Design + Build developed its first project in the Bay Area - two net-zero-energy townhomes in Oakland.[22] ZETA's founder determined that "modular net-zero energy factory construction is the most sustainable way to build green, energy efficient housing…"[23] The two homes were built to demonstrate economical and innovative housing energy solutions and their modular construction was only a by-product of the company's desire to manufacture energy efficient housing. Through the exercise, however, ZETA found

[22] http://urbanland.uli.org/sustainability/modular-net-zero-energy-townhouses/
[23] http://urbanland.uli.org/sustainability/modular-net-zero-energy-townhouses/

that modular manufacturing dramatically reduced the construction time of a project and thus, could reduce the overall cost of a project through savings in project financing.

The success of ZETA's first project prompted other developers to take an interest in modular housing and led ZETA to partner with Patrick Kennedy of Panoramic Interests in 2013 to complete the first multifamily modular project in San Francisco at 38 Harriet Street. Following the success of 38 Harriet Street, ZETA expanded its product line to include multifamily modular housing. ZETA went on to partner with four other developers in the Bay Area and produced over 350 housing units before going out of business in the spring of 2016. Despite lack of capital and leadership issues, which ultimately led to the company's demise, ZETA's experiences in multifamily modular construction provide important insights into the benefits and challenges of utilizing a modular approach.

Nemo Building Systems: In 2014, Nemo Building Systems launched a modular manufacturing facility in Lathrop with the goal of applying lean manufacturing concepts to home construction. As a vertically integrated manufacturer of modules for its sister company Nautilus Group, Nemo does not currently produce modules for third party developers. Nautilus has five sites across the Bay Area that will use modular manufacturing to construct student housing, multifamily, and mixed-use projects.

Nautilus's first project, a 236-bed student housing project in Berkeley, will be completed in summer of 2016.

Guerdon Enterprises: A modular manufacturer based in Boise, Idaho, Lad Dawson founded Guerdon in 2001 with a vision of bringing modular manufacturing to residential and commercial construction. Guerdon began by manufacturing modular single-family homes and has since grown to produce large-scale modular projects including commercial buildings, hospitality facilities, remote work camps, and single and multifamily housing throughout the western United States. Guerdon has produced three multifamily housing projects in the Bay Area, two of which are the largest modular multifamily projects in the region containing over 300 units each.

Modular Multifamily Housing

Completed Modular Development Projects[24]

Project	38 Harriet St	The Domain	Parkside Studios	5830 Third St	Marea Alta
Date	2013	2013	2015	2016	2016
Location	San Francisco	San Jose	Sunnyvale	San Francisco	San Leandro
Developer	Panoramic Interests	Equity Residential	Charities Housing	Holliday Development	BRIDGE
Modular Manufacturer	ZETA	Guerdon	ZETA	ZETA	ZETA
Contractor	Pankow	Douglas Ross	Cahill	Cannon	Cannon
Architect	Lowney Architecture	Humphrey's & Partners	Studio E	Lowney Architecture	Ankrom Moisan
Financing	*N/a*	Northwestern Mutual Life	Silicon Valley Bank	Union Bank	Wells Fargo
Units	23	444	59	136	115
No. Modules	n/a	540		312	308
Module Cost	n/a	$46.5 million*	$3.8 million*	$10 million*	$14 million*
Project Cost	n/a	$155 million	$12.7 million	$33 million	$47 million
Construction Time	3 months	9.5 months	12.5 months[25]	8 months	TBD

[24] For the purpose of this project, this section only covers projects that have been completed in the San Francisco Bay Area as of spring 2016. Where modular cost was not available, estimates were made using a 30% of total project cost value as affirmed by interviews. Where information was not available a designation of n/a was filled in.

[25] Parkside Studios experienced issues with water damage after a storm, which extended their construction time by 3 months. Still, despite the water damage, the project was ultimately completed in the same amount of time conventional construction would have taken.

Upcoming Modular Development Projects[26]

Project	Date	Location	Developer	Modular Manufacturer	Contractor	Architect	Units	No. Modules
Garden Village	2016	Berkeley	Nautilus	NEMO	NEMO	Nautilus	236 Beds	295
5110 Telegraph	TBD	Berkeley	Nautilus	NEMO	NEMO	Nautilus	204	520
4801 Shattuck	TBD	Oakland	Nautilus	NEMO	NEMO	Nautilus	42	95
4700 Telegraph	TBD	Oakland	Nautilus	NEMO	NEMO	Nautilus	48	120
EVIVA Midtown	2016	Sacramento	Urban Core	Guerdon	Tricorp Hearn	Devrouax Purnell/LDA	118	200
Windflower Lofts	2017	Union City	Fei Tsen	Guerdon	Cannon	David Baker	243	388
The Union	2017	Oakland	Holliday	Guerdon	Cannon	David Baker	110	60
2711 Shattuck	2017	Berkeley	Panoramic Interests	*Chinese Manufacturer	n/a	n/a	22	22

Why Use Modular Construction?

Today, the housing crisis in the Bay Area requires us to think innovatively about how to increase supply of housing at a reasonable cost. The question is how to do so at a speed, price, and scale that can correct the decades long supply-demand imbalance of housing production the Bay Area.

[26] For the purposes of this project, this section only discusses projects that are planned, under construction, or being contemplated in the San Francisco Bay Area as of spring 2016.

Interviews with developers, architects, and contractors using or contemplating the use of modular manufacturing all cite the same overarching reason for considering modular: cost containment. Modular construction can reduce development costs in three ways: fixed price contracts, shortened development time and lower labor costs.

Construction costs in the Bay Area have increased between 5-7% annually since 2013.[27] One of the main reasons developers chose modular construction is because a guaranteed maximum price is negotiated and agreed upon between the developer and the modular manufacturer up to six months before modular production actually begins. While the cost of a project using modular may not beat conventional construction in terms of ultimate construction cost, developers and contractors alike agreed that this price guarantee alone warranted utilizing modular construction. Although construction cost may not be reduced, with units built in a manufacturing facility while site work continues at the project, modular construction creates efficiencies in the production of housing that translate into a significantly shortened construction timeline.[28] The value of reducing construction time can be realized through shorten construction loan terms and the unquantifiable benefit of brining a product to market faster than when utilizing conventional stick built construction.

[27]Building costs go through the roof: The Bay Area's new affordability crisis. (2014). Retrieved May 11, 2016, from http://www.bizjournals.com/sanfrancisco/print-edition/2014/11/21/constuction-costs-rise-sf-real-estate-development.html?page=all

[28] Although these cost savings may not trickle down to the end user, lower construction costs mean more housing developments.

Benefits

Using modular construction in multifamily housing in the Bay Area has many advantages. To date, most of these benefits are only recorded anecdotally. This section will outline and quantify, where possible, the purported advantages of modular construction and compare those benefits to conventional construction when possible.

Cost Savings

Anecdotal evidence suggests that modular construction can save upwards of 20% on the cost of construction of a multi-family housing project. The most significant cost savings come from reduced reliance on expensive on-site labor. Additional cost savings are realized as a result of less overtime pay for on-site workers and reduction of on-site resources (for example, with labor off-site the cost of support facilities like portable toilets is reduced).

Additionally, cost savings come from the value of having a fixed project budget as opposed to traditional construction projects, which are known for innumerable change orders and subsequent budget increases. A study published by the Office of Legislative Oversight in Montgomery County, MD found that in the 17 county government buildings that reached substantial completion in 2009-2013… there was an 8% overall increase in

contract costs due to change orders.[29] Comparatively, modular construction projects have substantially fewer change orders as all aspects of the project, from structural and mechanical systems to appliances and finishes, are digitally designed and optimized before assembly even begins, therefore controlling the cost of the project at the outset.[30] Interviews with developers and contractors agreed that because the design is finalized before module construction begins, the possibility for large costly changes to design or construction is reduced.

	Conventional Construction	Modular Construction
Labor Per Hr.	$60-$80	$15-$30[31]
Total Module Cost Per SF	$250-$275	$80-$100

Table 2: Average labor and material cost comparison
Source: General Contractor Interview (February 22, 2016), Modular Manufacturer Interview (April 6, 2016)

Time Savings

The most significant benefit of modular construction is in time saved during construction. Developers, contractors, and modular manufacturers alike claim that modular construction reduces multifamily construction time by as much as 50%, which translates to an average of a 7-month construction period as compared to a 14-month construction period. This is because unit construction can occur off-site while on-site preparation and foundation building occurs.

[29] Perm Smith, R. E., & Rice, T. (2015, April). Off-Site Studies - Permanent Modular Construction - Process Practice Performance [Editorial]. *Modular Building Institute*. Retrieved May 11, 2016, from http://www.modular.org/HtmlPage.aspx?name=foundation_offsite_PMC_report , 18.
[30] Is Prefab Pretty Fab? (2016). Retrieved May 11, 2016, from http://www.spur.org/publications/urbanist-article/2016-01-19/prefab-pretty-fab
[31] The hourly wage for a factory worker varies significantly based on geographic location of the factory. A factory in the Bay Area quoted hourly wages of between $20-$30/hr. while a factory outside of California quoted $15-$17/hr.

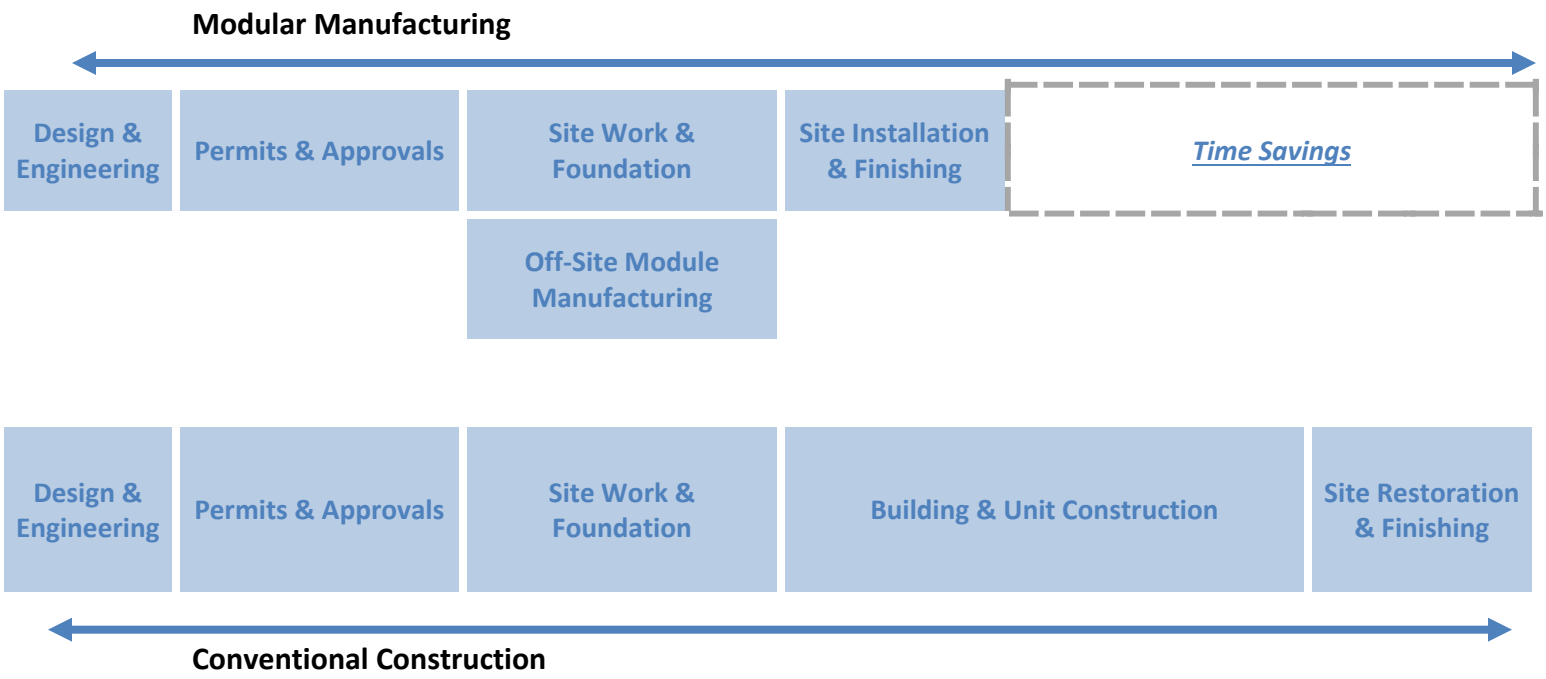

Figure 2: Comparison of construction duration

The Modular Building Institute conducted a study to validate anecdotal evidence of the shortened development timeline when using modular construction. Their research found that a modular project took an average of 9.29 months to build, while a conventional project of a similar size and scale would take 16.86 months for conventional construction.[32] Interviews with developers and contractors, and case studies of modular projects that have been built in the Bay Area confirmed this schedule reduction, with completed projects in the region reporting an estimated 50% reduction in construction schedule.

[32] Smith, R. E., & Rice, T. (2015, April). Off-Site Studies - Permanent Modular Construction - Process Practice Performance [Editorial]. *Modular Building Institute*. Retrieved May 11, 2016, from http://www.modular.org/HtmlPage.aspx?name=foundation_offsite_PMC_report , p. 20

This time savings translates to a cost savings. By reducing the construction time by +/- seven months, the developer is saving seven months of carrying and operating costs. A general contractor estimated that for a project of 100 units their general conditions (i.e. overhead costs such as site management, material handling, and project management throughout the duration of the project) cost around $100,000 per month. Reducing construction schedule by seven months and eliminating this cost alone saves the project $700,000. Developers also save in interest paid on construction loans and other financing. Construction loans typically account for 80% of the total project cost and account for a 20-24 month construction duration (including a six month cushion on either side). Using modular construction, the development timeline is cut in half, reducing the interest carry on the construction loan significantly. In addition to the dollar for dollar interest savings a developer accrues, there is the added unquantifiable benefit of bringing the project to market faster, which may allow a developer to lease up or sell their property more quickly than if they had used conventional construction. Table 2 details the actual time of construction of several modular projects in the Bay Area as compared to the estimated construction time using conventional stick frame construction:

Project	Stick Frame Construction	Modular Construction
5830 Third Street	20 months	13 months
Marea Alta	19 months	16 months[33]

Table 2: Modular construction duration vs. estimated stick construction duration
Source: Developer interview (February 17, 2016), General contractor interview (February 18, 2016)

[33] This includes a 3 month delay due to ZETA's late delivery of modules

Labor

Modular manufacturers are able to offer competitive pricing in large part because they move their labor costs to less expensive areas. The high cost of housing in the San Francisco Bay Area coupled with lower labor supply means that wages in the Bay Area are generally higher than in other parts of the state or cities outside of California. Modular manufacturing allows for more than 80% of the building's construction to take place in lower cost labor markets where factories are located. The wage rates of factory workers in less expensive labor markets like Lathrop and Boise is roughly 35-40% of the hourly wages of Bay Area union construction workers. For example, one Bay Area manufacturer employed factory workers whose hourly wage rate was $20-$30 per hour as compared to site wage rates of $60-$80 per hour.[34] A modular factory outside of the Bay Area only pays its factory workers $15-$17 per hour including health care and other costs.[35]

Additionally, labor in a factory can be more efficient and more productive in a day than on site labor. As one contractor put it, in the factory, the work comes to the worker, but in the field, the worker has to go to the work. In a manufacturing facility, the labor force remains stationary while their work is delivered to them by the assembly line.
In a site-built situation, the (more expensive) worker has to spend time moving themselves, their tools, and their equipment from unit to unit. All of these small steps

[34] Modular Manufacturer Interview, March 8, 2016
[35] Modular Manufacturer Interview, May 5, 2016

and movements are eliminated in a factory environment, resulting in a higher degree of efficiency and productivity.

Quality Control

Modular construction is made possible by building information modeling (BIM) technology. The 3-D digital design tool allows architects, engineers, contractors and subcontractors to coordinate information and digitally model the components of the building before it is constructed. This technology allows for optimization of production and also allows for the creation of a "digital twin" of the building therefore streamlining the quality control process. Additionally, most modular developers contract with a third party inspector such as NTA or RADCO who not only conduct state inspections but also conduct quality control checks in the factory before the modules are transported to the construction site. One modular manufacturer explained their quality control program as involving a four-step process: i) training the factory workers and associates, ii) employing one supervisor for every two manufacturing stations in the factory, iii) employing separate quality control inspectors, and iv) employing third party inspectors to conduct quality control checks who are at the factory every day.[36]

Site Impact

One of the most important advantages of modular construction is the reduced impact to the neighborhood and construction site. When visiting her first modular site, one

[36] Modular Manufacturer Interview, May 5, 2016

industry professional could not believe how quiet the site was and how few construction workers were there compared to a conventional construction site. Contractors, developers, neighbors, and visitors agree that modular construction sites are quieter, less chaotic, and there is less impact to the surrounding community. Because more than 80% of the unit construction is conducted off site in a factory, there are fewer workers on site, which reduces the impact to traffic in the surrounding area. This also reduces the amount of heavy machinery on site and translates to improved air quality on the construction site and in the surrounding neighborhood. Additionally, the substantially shortened construction timeline means neighboring residents reduce the amount of time they are exposed to the nuisance of a construction site.

Environmental Sustainability

Conventional construction sites are notorious for excess material and waste. According to some sources, the construction of a 2,000 square foot home generates in excess of 8,000 pounds of waste.[37] When building in a controlled environment such as a factory, there is less potential waste and more opportunity to recycle and reuse discarded material on another module or aspect of the building. Scrap that is unable to be reused can be ground up and recycled. Additionally, because the modules are designed using a

[37]Modular Construction, A Better Way for Green Building | EarthTechling. (n.d.). Retrieved May 11, 2016, from http://earthtechling.com/2014/05/modular-construction-a-better-way-for-green-building/

BIM model and each component of the mod is precision cut, the likelihood of waste resulting from inaccurate measurement is reduced.

Material Use and Economies of Scale

Larger-scale modular manufacturers can negotiate better pricing because of the volume and consistency of their orders. Many modular companies perform their own design, so they can specify their standard materials in the units before they begin fabrication. This means they have control over a portion of the specifications, for example they can always use the same bolts, so because they always purchase a certain type of bolt they can negotiate better pricing and drive down the cost of the module. By contrast, a site built contractor is at the mercy of the structural engineer who specifies what type of bolts are used, and therefore is less able to negotiate pricing discounts for volume.

Additional price negotiation is possible through the streamlined material acquisition process. A site built contractor may be buying $5 million of material via five or ten different subcontractors whereas the modular manufacturer is buying everything themselves. Generally, an individual buying $5 million worth of material will receive more favorable pricing than ten individual subcontractors purchasing $500,000 in material each.

Other Benefits

- Increased labor safety through reduced exposures to inclement weather, temperature extremes, and ongoing or hazardous operations;
- Better working conditions (i.e. components traditionally constructed on-site at heights or in confined spaces can be manufactured off-site and then hoisted into place using cranes)
- Reduced construction schedule disruptions due to construction in a weather protected work environment
- Fewer weather delays

Barriers to Use of Modular Construction

There are several challenges that must be addressed in order to realize the use of modular construction at scale in the Bay Area. This section will discuss the barriers to implementation of a modular approach to multifamily housing in the Bay Area and identify which of these challenges will be addressed as the modular industry matures and which require further investigation and potential change in policy.

Industry Wide Drawbacks and Challenges

Capitalization

One of the primary reasons ZETA Design + Build went out of business in the spring of 2016 was due to lack of capital. Those who worked with the company over its 8-year

tenure cited regular issues with ZETA's procurement and ability to deliver on time and on schedule - issues that were likely due to a lack of capital. Factory manufactured housing requires a large upfront capital investment in order to procure materials in advance of manufacturing and to deliver modules on time and on schedule. This is a challenge for both the manufacturer and the developer and his/her financial partners. The question of who should provide the upfront capital and how much is complicated as each stakeholder has different and at times conflicting motivations and constraints.

Modular manufacturers ask for as much as 50% of the total project budget upfront to finance procurement and production, a proportion that developers generally feel is too high. Due to the conventional construction-financing model, most construction lenders won't release any construction draws until the modules arrive on-site. Thus, any up-front capital investment would have to come from the developer or his/her equity partners. Developers and general contractors agreed that while a small deposit of 10-25% of the project contract would be appropriate, the responsibility of financing procurement and production lies with the manufacturer.

Modular manufacturers on the other hand, tended to criticize the financial industry and developers for their unwillingness to release funds in the predevelopment phase of the project for material procurement and module production. One modular manufacturer explained the predicament current industry standard impose on the modular

manufacturing industry as follows: module production begins as much as six months before the first module is delivered on site depending on the size of the project and material procurement should be conducted 6-7 weeks before module production begins. This means that the modular manufacturer has to purchase and pay for materials several weeks before the modules start production and then has to pay for labor throughout the months it takes to produce the modules for the project. Only once modules are received on site does the bank release construction financing to pay for those modules. Depending on the site of the project, the modular manufacturer may need as much as $16-$20 million in advance of receiving any compensation from the construction lender.[38]

For example, a 100-unit project would require about 60 modules, which costs about $8 million. At a rate of 3 modules per day it would take would take a manufacturer 4-5 weeks on average to produce the modules. Due to shipping constraints, the modular manufacturer can only ship three mods per day and it takes two days for the modules to arrive on site from the factory. Additional staging constraints on site may also limit the amount of modules that can be shipped and held on site at a time. Thus, using conservative estimates, a factory can ship 10 modules per week, meaning it will take 6-7 weeks for all of the modules to be delivered on site and construction financing to be incrementally released to the general contracts who then releases it to the

[38] Modular Manufacturer Interview, May 5, 2016

manufacturer. So over the course of 10-14 weeks the manufacturer must front $8 million for the cost of production. This represents a tremendous financial burden to modular manufacturers who, depending on the capacity of their factory, can only produce modules for four or five projects a year.

The challenge of capitalization is perhaps the largest barrier for the widespread adoption of modular manufacturing. Several changes will need to occur on an industry wide basis to address this problem:

Developers should be prepared to put down a deposit of 10-25% of the manufacturing contract as early as 6 months in advance of the production of modules. This deposit may be required before a project is substantially designed or approved and this of course, presents a new risk to the developer.

Financial institutions should consider reconfiguring the model of construction financing to allow for release of substantial funding (sometimes 50% of the overall modular production budget) during the predevelopment material procurement and production phase. There are two concerns banks raise in releasing capital: first, banks are concerned with the ability to identify collateral in a manufacturing facility where the same materials could be used for multiple projects. One possible solution would be for the modular manufacturers to establish itemized and traceable inventory logs to

establish which material was procured for which project. Another solution would be for banks to actually purchase the materials for module production, giving them an asset to collateralize. Second, banks raise concerns about completing construction in the event the modular manufacturer going out of business. Contractors who have experience with modular projects noted that it is possible to build conventionally around a partially completed modular project.[39]

When releasing construction funding, conventional industry standards require a bank inspector to visit the project site and certify percent completion to release the next round of construction funding. One possible adjustment to the construction-financing model would be to send a bank inspector to the modular factory to assess percent completion and allow release of funds based on the number of completed modules rather than waiting for the modules to arrive on site to certify percent completion.

Modular manufacturers should adjust the amount of upfront capital they require, as 50% of the total project budget is too high for most developers to agree to. Manufacturers could take out a business line of credit, much like other small businesses, to allow for material procurement in advance of a deposit from a developer or draw from a construction lender. One modular manufacturer deposits the developers down payment into an escrow account that the manufacturer draws on for procurement and

[39] General Contractor Interview, February 16, 2016

initial production. While the escrow model may work in development projects where there are only a few financial partners, this model proves challenging in affordable housing projects where there are multiple financing partners releasing funding at different times.

Early Commitment to Design

In conventional construction developers and architects are able to make changes to the design and construction of the project down to the last possible minute. This allows for maximum flexibility in design and allows the developer to adjust budget and cut costs throughout the construction of the project. Modular manufacturing requires all parties to commit to a design before the modules are produced in the factory. If changes are made to the design once production has begin, modules may have to run back through the line to be tweaked which results in additional time on the line and a loss of efficiency. Additionally, changing the design of the project during production will increase costs especially if the change requires procurement of different materials or the line to be reconfigured.

Permitting and Inspection

In California, the state-permitting agency that certifies code compliance of modular manufactured housing is the Department of Housing and Community Development.

Manufactured homes have been built to federally prescriptive construction standards since June 15, 1976. The Department of Housing and Community Development was the exclusive HUD approved inspection agency for new manufactured home construction, however since July 1, 1986, HUD shares that responsibility with approved private inspection agencies such as NTA.[40]

In addition to state inspections, each modular development project undergoes local jurisdictional inspections and code compliance review on site. This dual process increases cost and adds to the logistical challenge of modular manufacturing. There is potential to streamline this code compliance process by certifying the modular manufacturers rather than the individual modules. This is much the same model as implemented in other manufacturing industries such as car manufacturing.

Additional Material

Modular construction requires more raw material than stick built. Transportation on a flatbed truck requires each module to be structurally sound, so each module is a structurally contained and complete unit. Each module has individual wall, ceiling and floor assemblies which give the unit structural integrity for transportation. Executives from one modular manufacturer estimated that the double walls, double thick floor/ceilings and extra material at each joint line/stud/joist in modular projects adds 8-

[40] California Department of Housing and Community Development (HCD). (n.d.). Retrieved May 11, 2016, from http://www.hcd.ca.gov/codes/factory-built-housing/

10% more lumber than traditional stick built projects.[41] In a conventional project, units typically share wall assembly with each their neighbors and the floor-ceiling assembly is one piece (meaning it's also shared with the neighbor above/below). Although this translates into is more material in a modular project, as mentioned earlier manufacturers may still achieve economies of scale and negotiate favorable pricing for repetitive procurement.[42] While this challenge may be unavoidable for wood frame modular construction, it is important that developers and contractors understand that modular manufacturing does not in fact save in material quantity or cost.

Transportation

Most modular deliveries are made via truck over the highway and thus governed by a complicated web of national and state agencies. Regulations and permitting dictate time of day of transportation and delivery, limit the amount of trips across bridges in a single day, and limit size of modules based on the truck's capacity. Generally, maximum width allowed is 16', maximum height is 13'6", and maximum length is 60-65 feet long.[43] Exceptions to these regulations often require additional permitting and fees.

The cost of transportation of modules from manufacturing facility to the construction site is relatively small when compared to the overall development cost of a large

[41] Modular Manufacturer Interview, March 31, 2016
[42] General Contractor Interview, February 22, 2016
[43] Cameron, P. J., Jr., & Di Carlo, N. G. (2007). *Piecing Together Modular: Understanding the Benefits and Limitations of Modular Construction Methods for Multifamily Development* (Unpublished doctoral dissertation). Massachusetts Institute of Technology. Retrieved May 11, 2016, from https://dspace.mit.edu/bitstream/handle/1721.1/42038/228657327-MIT.pdf?sequence=2

multifamily project. Interviews confirmed that shipping using a flatbed truck accounts for roughly 8% of the total cost of the project.[44] A project in the San Francisco Bay Area paid $2,500 per module to transport from a manufacturing facility in Sacramento. For a 100-unit project, which would require about 300 modules, this amounts to $750,000 in transportation costs. Additional transportation fees are accrued for permits depending on the size of the modules. In California, permits for modules under 12' wide are inexpensive while modules in excess of 16' wide require police escorts and cost an extra $3,000 per trip.[45] The added cost of permitting for an extra wide load varies depending on the amount of extra wide modules in the project design.

For example, a project containing 300 total modules estimated that 20 of those were extra wide modules, so there was an extra $60,000 in permitting fees for the project. These estimates all pertain to transportation and permitting costs in California. Additional research would need to be conducted to estimate the costs for other states and for transporting from another state.

Site Equipment and Constraints

Once modules arrive on site, a mobile tower crane is used to hoist units onto the podium and stack them on top of one another. The cranes used in multifamily modular projects in the Bay Area are some of the largest mobile cranes in the United States –

[44] General Contractor Interview, February 18, 2016
[45] General Contractor Interview, February 18, 2016

usually between 80 and 160 tons depending on the size of the modules and the distance from the base of the crane that the module must travel. The LR1400 crane used on the Domain in San Jose had the ability to handle 70,000 lbs and move units 320 feet in each direction.[46] Due to their size, these cranes are one of the highest costs associated with modular construction at $10,000 per day.[47]

While modular housing is in many ways ideal for infill development, the ability to store modules on site while they wait to be placed is an important consideration. Based on completed projects and those under construction, a general contractor can place 10-12 modules per day at most. The contractor would prefer to store one week's worth of modules on site to allow for consistent daily placement and provide a cushion in case of factory manufacturing or shipment delays. Therefore, in an ideal situation, the project site would have storage capacity for 50 modules within crane's distance of the project. At an average size of 16' x 72' per double unit module this translates to 1.32 acres of storage space needed to house 50 modules. This estimate does not factor in space needed for the contractor to load, unload, and coordinate module placement.

[46] Cameron, P. J., Jr., & Di Carlo, N. G. (2007). *Piecing Together Modular: Understanding the Benefits and Limitations of Modular Construction Methods for Multifamily Development* (Unpublished doctoral dissertation). Massachusetts Institute of Technology. Retrieved May 11, 2016, from https://dspace.mit.edu/bitstream/handle/1721.1/42038/228657327-MIT.pdf?sequence=2

[47] Modular Manufacturer Interview, May 5, 2016

Waterproofing on Site

The most commonly faced challenge of modular projects both completed and under construction in the Bay Area relates to protecting the modules from water and weather once they are placed on site. Although the modules are shipped with weather proof roofs and wrapped in plastic waterproof material, once they are placed and stacked on top of one another on site they are unprotected from the elements. Several projects have experienced significant issues with water exposure, which causes damage to the finished interiors and can travel between the connection points of the modules down to lower levels. General contractors and modular manufacturers are working together to address this concern by creating water barriers during module placement and stacking.

Challenges For Modular Manufacturers

Module Manufacturing

Currently, there are two different methods of producing modules in a manufacturing facility. The single-unit modular manufacturing line can accommodate one module that is 16’ (w) x 32’ (d) x 12’ (h). The “saw-box” manufacturing model generates modules that contain two 16’ x 32’ units plus a 6’ hallway; the saw boxes are 16’ x 72’ in total. These double-unit modules are delivered and either placed in their entirety on the project site or sawed in half to create two separate modules. Producing two boxes at a time, regardless of whether you separate them on site, creates extra efficiencies in the factory because two boxes travel down the manufacturing line at once. Saw-boxes are also

shipped two units at a time, which reduces the amount of trips and trucks needed to transport modules between the manufacturing facility and the site.

Manufacturing Facility

Modular manufacturing lines are generally comprised of 20-24 different manufacturing stations. Often size constraints of the production factory dictate whether the factory produces single-unit or double-unit modules. For example, ZETA's factory was 85,000 square feet (200' x 400' with 39' clear height) and could only accommodate single-unit modules on its manufacturing line. Not only does a factory need the capacity to house 20-24 stations, it also needs staging area for quality control checks to be conducted. The factory also needs space to store completed modules before they are shipped to the project site. One manufacturer stores as many as 130 completed modules at a time in their outdoor storage yard.

Production Time and Manufacturing Capacity

A double-unit module takes 7 days and 600-700 man-hours to complete. The module spends roughly 1.5 hours at each of 22 different stations and then undergoes extensive quality controls checks. Modular manufacturers are targeting a reduction in overall module production time from 600hrs – 400 hrs. One modular manufacturer is targeting a production time of 250hr per module.

Modular Production Cost

Modules typically make up about 1/3 of the total construction cost of a multifamily development project. In a typical factory, the sales price of a module is comprised of 55-60% for materials, 15-20% for labor. These two inputs alone account for almost 80% of the sale price of a single module. Overhead (including rent, insurance and utilities) for a factory can cost as much as $1 million per month with electricity accounting for as much as $30,000-$40,000 per month. Thus, profit margins for modular manufacturers fluctuate between the single digits and low teens. One modular manufacturer targets a 10% margin and finds this hard to achieve.[48]

Using these proportions, the estimated cost of production of one module is:

- Materials – 60% = $32,000
- Labor – 20%: 700 hrs. /module at $15/hr. = $10,500 per module
- Overhead & Margin – 20% = $10,500

Total Module Cost: $87,700 for 1,152 SF = $76 PSF

Comparatively, modular manufacturers provided cost estimates of $100 PSF. The discrepancy in estimates most likely accounts for the manufacturer's mark-up and profit for manufacturing the modules. Below are suggestions for how efficiencies can be achieved in each of these inputs, which will reduce the overall cost of a module.

Material: As mentioned in previous sections, the amount of material in a module is generally more than the material used per unit in site built construction. While

[48] Modular Manufacturer Interview, May 5, 2016

commodity costs remain relatively fixed, there is opportunity for cost cutting in material procurement. Both conventional and modular projects use a bill of materials (BOM) to track the amount of materials that will be required b a contractor to complete a contractor or by a supplier or vendor to complete an order. The BOM contains a list of all of the raw materials, parts, and subassemblies with their quantities and descriptions that will be required by the overall project. In a manufacturing facility it is crucial that the inputs of a project are quantified to facilitate bulk ordering. Additionally, tracking how much material is used on a daily basis allows the manufacturer to schedule material procurement for in time production. The automation of the BOM and procurement process is one key area where modular manufacturers can achieve efficiencies and reduce overall production costs. In addition to bulk procurement discounts, one manufacturer notes that material suppliers will give prompt pay discounts of 1-2% if payment is received within 10 days of delivery.[49]

Labor: One modular factory that produces 3 modules per day across 22 different stations employs roughly 225 factory workers. The same manufacturer employs an additional team of roughly 100 people spanning supervisor, foreman, inspector, engineering, design, and sales roles.[50] Industry experts agree that an ideally lean factory should employ roughly 70 fewer people. In particular, one modular expert notes that factories should reduce the amount of expensive drafters and engineers by contracting

[49] Modular Manufacturer Interview, May 5, 2016
[50] Modular Manufacturer Interview, May 5, 2016

these functions out to a third party. These roles are the most expensive staff and they are only needed during the initial stages of a project. As a comparison, a smaller manufacturer that employs only 80 factory workers and 4 designers and engineers produces 6-8 modules per day.

Overhead: One area of significant potential cost reduction is in overhead to operate a manufacturing facility. By contracting out expensive staff such as designers, engineers and architect, a modular manufacturer can shrink their overhead costs significantly and reduce the overall sales cost of a module.

Waterproofing

Weatherproofing is a concern for both conventional and modular construction, however water damage due to rainstorms has been a challenge to modular projects in the Bay Area for multiple projects. Modules are bolted together along the floor and ceiling joists and marriage walls are connected with a series of steel fasteners and strapping. Generally, modules are then quickly weatherproofed for transportation by sealing them with building wrap that blocks moisture yet lets the structure breath and condensation to escape. This temporary weatherproofing does a fairly good job of protecting the modules on site while they await setting. However, care needs to be taken around protecting modules once they are set and stacked. While tarps may be used to protect the unwrapped modules from rain if necessary, this is an imperfect solution. Two large

multifamily projects in the Bay Area experienced serious delays due to water damage after rainstorms. Additional, water protection would also reduce the insurance costs of modular manufacturers. One modular manufacturer utilizes an EPDM roof in addition to wrapping the boxes. However, this waterproof membrane adds an additional cost of $500-$600 per module.

Pipeline and Capacity

As discussed, there are significant overhead costs associated with maintaining, operating, and staffing a modular factory. Depending on these costs, there are different estimates as to how many modules need to be produced annually to breakeven and cover the costs. The same modular manufacturer that employs only 80 factory workers needs to produce an average of 1-2 modules per day to breakeven.[51] Another large manufacturer projects that they need to produce 400 modules annually to breakeven. Based on these estimates, factories need to have between four and five 100-unit projects in their pipeline annually just to keep the lights on in their factories. However, manufacturers must strike a balance between the amounts of different projects they produce modules for annually versus the amount of modules that need to be produced. Coordinating procurement, manufacturing, production and delivery schedules on four different projects annually is difficult and ZETA, for example, struggled to balance several projects at once.

[51] Modular Manufacturer Interview, April 7, 2016

Modular manufacturers struggle to maintain the pipeline necessary to keep the factory running at maximum efficiency. There is a fundamental difficulty in relying on multifamily housing, a cyclical market, to fill a factory's pipeline and maximize capacity. Modular manufacturers should consider strategic partnerships with other market segments to fill pipeline in down cycles. For example, one manufacturer is considering a partnership with a hotel developer and another is considering affordable housing. Other possible partnerships include manufacturing homeless housing, accessory dwelling units, tax credit units and workforce housing. Sustained pipeline is key for factory efficiency. Each time a factory shuts down and then ramps back up, it loses skilled laborers and momentum, both factors that increase overall production costs.

Next Steps Towards a Scalable Model

Adopting modular as a standard means of construction in multifamily development projects will require several small and large changes. In the following section, I outline the immediate and longer-term solutions to improve the modular manufacturing industry. I then suggest best practices for modular manufacturers based on the research and interviews conducted for this report. I conclude by outlining areas and questions where further research is required.

Immediate Solutions

Collaboration

As modular construction in multifamily development is relatively new to the Bay Area, it is critical that all trades be engaged early in the process to increase understanding and knowledge sharing. This is especially true of coordinating factory work and site work. Both contractors and modular manufacturers spoke of the benefits to engaging the contractor early in the process to coordinate the installation of modules.

Developers, contractors and manufacturers cited lack of familiarity as one of the challenges with modular construction. Specifically, they noted that subcontractors in the MEP trades have a hard time understanding the scope of their work and navigating between on and offsite work. Ongoing collaboration will address the issue of familiarity with modular.

The MBI's report explains, "there is a critical point in the project schedule where all major trades need to be well versed in the projects needs and possible mishaps. This point is far before construction begins as the modules must be completely designed before construction starts."[52]

[52] Smith, R. E., & Rice, T. (2015, April). Off-Site Studies - Permanent Modular Construction - Process Practice Performance [Editorial]. *Modular Building Institute*. Retrieved May 11, 2016, from http://www.modular.org/HtmlPage.aspx?name=foundation_offsite_PMC_report , p. 27

Design Process

To realize the benefits of modular, developers and designers must plan to use modular construction from the outset and commit to a building design earlier than in conventional construction. Unlike when using stick built construction, developers cannot change small details of the project throughout the construction phase. For maximum efficiency, every detail of the units must be finalized well before the modules are manufactured. Manufacturers have to procure materials for the project 4-6 weeks in advance of manufacturing and the efficiency of the line is compromised if changes are made during the production process.

Future Changes and Solutions

The modular multifamily industry is in its infancy. In the Bay Area we have barely utilized this disruptive technology. There are a variety of changes that can be made to facilitate the widespread adoption and utilization of modular construction ranging from small tweaks to time-consuming policy changes. Taken together, these best practices will pave the way for modular multifamily construction on a broad scale in the Bay Area.

Design

Most modular manufacturers partner with the developer to produce customized modules for each unique development project. Manufacturers will try to accommodate

the developer by promising that modular can achieve all of the same design features as conventional construction. However, you wouldn't have a custom car coming off a factory line every time because it is inefficient for the factory line. In order to truly realize the efficiencies of modular manufacturing, both modular manufacturers and architects should move toward a standardized design and production model. Repeatability is key to realizing efficiencies in this market, however with standardized design comes sacrifices in customization and control. In the future, the modular multifamily industry should adopt a catalogue approach to module manufacturing where each factory produces standard floor plans for different unit types (studio, one, two and three bedroom units for example) and allow for different levels of finishes to upgrade the units. This standardization would also allow for permitting to be streamlined in that HCD or another agency could certify the code compliance of the standard units produced by the factory. While standard units may not be appealing to every segment of the multifamily housing market, the affordable housing industry for example is one market sector where a lean, standard product, would help drive down costs and expedite development.

Permitting and Plan Check

Currently, modular projects undergo two separate permitting and plan check processes. In the jurisdiction where the development is located, the project's site built components undergo local plan check and permitting. Then the modules in the factory undergo a

statewide permitting process administered by HCD. This dual permitting process is redundant and could benefit from streamlining. One architect suggested that rather than permit the product, we should move toward a model of permitting the process. In the future, the modular industry should look toward certifying individual modular manufacturing facilities as capable of producing code compliant product. This is much like the model used for (lumber? cars?) where the initial prototype is certified and then it is assumed that every product thereafter, which has followed the same process of production, will meet the same quality and safety standard.

Financing

Attitudes and conventional best practices of the financial industry present some of the largest barriers to scaling modular manufacturing. The risk-averse nature of the industry is fundamentally at odds with an industry or method that is in its infancy and relatively untested. Additionally, the current structure of construction financing is incompatible with the needs of a manufacturing facility. There are longer-term attitudinal and policy changes that need to be made regarding both of these changes.

Risk Aversion

As one architect noted, banks want to finance what their competitors are financing. Banks want to mitigate their risk and the best way to do that is to continue to finance tried and true construction methods in tried and true markets. Currently, there is no incentive for a bank to finance a risky project. There is no value for banks in the

developer bringing a project to market faster since banks value having debt on their balance sheet and want to accrue interest. Can banks be incentivized to finance modular construction?

Construction Financing

Another challenged raised by the financial industry is in the timing of construction draws and release of funds. Given that modular manufacturers require an upfront deposit to begin design and procurement, it would be prudent for the financial industry to adapt to this by releasing funds to the developer to distribute to the modular manufacturer as part of pre-construction.

Future Research and Questions

While this paper provides an introduction to the benefits and challenges of modular manufacturing for multifamily housing in the San Francisco Bay Area, there is still work to be done. The biggest challenge facing the industry today is the inherent conflict between conventional construction financing and the upfront capital needs of a manufacturing facility. Finding a solution to this challenge will require collaboration between financial partners, developers, modular manufacturers, and general contractors. Standardizing design is another area to be further researched. Market research should be done to understand industry demand and tolerance for this kind of

production model. Additionally, the standardization of design may help with the standardization of permitting which is another question that can be explored further.

Conclusions

Modular manufacturing can change the way we approach housing production in the San Francisco Bay Area. There is an acute need to address the lack of housing supply and dearth of affordable in the Bay Area through innovative thinking and creative solutions. Modular manufacturing, though an industry in its infancy, has the potential to increase the speed and decrease the cost of housing production. The modular manufacturing industry is on the cusp of disrupting the model of housing construction in the Bay Area and will change the way developers, contractors, architects and policy makes approach real estate development in the future.

Appendix

Modular Manufacturers - Multifamily

ZETA Design + Build

- Location: Sacramento, CA[53]
- Projects:
  - 38 Harriet Street
  - Parkside Studios
  - 5830 Third Street
  - Marea Alta

Guerdon

- Location: Boise, ID
- Projects:
  - The Domain (San Jose)
  - EVIVA (Sacramento)

NEMO

- Location: Lathrop, CA
- Projects:
  - 2201 Dwight
  - 4801 Shattuck
  - 4700 Telegraph
  - 5110 Telegraph

Modular Manufacturers - Other Product Types

Nashua

- Location: Boise, Idaho
- Product: Workforce housing, work camps

SilverCreek

- Location: Perris, CA (Southern California)
- Product: Commercial, education, office, residential

[53] During the research of this report, ZETA Design + Build went out of business and was acquired by Oakbrook Partners

Palomar Modular Builders

- Location: Dallas
- Product: Commercial

Polcom

- Location: HQ – Poland, Office in New York, NY
- Product: Hotel

CIMC Modular Building Systems

- Location: HQ Guandong, China
- Product: Hotel, student accommodations, workforce accommodations, residential

Sources

Primary Sources

The primary source of research for this report was interviews with developers, architects, contractors, consultants and manufacturers related to, working with, or considering utilizing modular construction. The information given in these interviews was provided on a confidential basis, so information from them is provided on an aggregate basis.

1. General Contractor Interview, February 18, 2016
2. General Contractor Interview, February 22, 2016
3. General Contractor Interview, March 15, 2016
4. Modular Manufacturer Interview, March 8, 2016
5. Modular Manufacturer Interview, March 31, 2016
6. Modular Manufacturer Interview, April 7, 2016
7. Modular Manufacturer Interview, May 5, 2016
8. Developer Interview, February 1, 2016
9. Developer Interview, February 17, 2016
10. Developer Interview, March 17, 2016

11. Developer Interview, March 3, 2016
12. Developer Interview, April 18, 2016
13. Architect Interview, March 31, 2016
14. Architect Interview, April 11, 2016
15. Modular Manufacturing Round Table, February 5, 2016

Secondary Sources

A Brief History of Prefab. (n.d.). Retrieved May 11, 2016, from http://www.architectureweek.com/2012/1003/design_1-1.html

ArchitectureWeek. (n.d.). Retrieved May 11, 2016, from http://www.architectureweek.com/cgi-bin/wlk?http://en.wikipedia.org/wiki/Nissen_hut

Building costs go through the roof: The Bay Area's new affordability crisis. (2014). Retrieved May 11, 2016, from http://www.bizjournals.com/sanfrancisco/print-edition/2014/11/21/constuction-costs-rise-sf-real-estate-development.html?page=all

California Department of Housing and Community Development (HCD). (n.d.). Retrieved May 11, 2016, from http://www.hcd.ca.gov/codes/factory-built-housing/

Cameron, P. J., Jr., & Di Carlo, N. G. (2007). Piecing Together Modular: Understanding the Benefits and Limitations of Modular Construction Methods for Multifamily Development(Unpublished doctoral dissertation). Massachusetts Institute of Technology. Retrieved May 11, 2016, from https://dspace.mit.edu/bitstream/handle/1721.1/42038/228657327-MIT.pdf?sequence=2

Final Regional Housing Need Allocation Adopted. (n.d.). Retrieved May 11, 2016, from http://abag.ca.gov/planning/housingneeds/

Is Prefab Pretty Fab? (2016). Retrieved May 11, 2016, from http://www.spur.org/publications/urbanist-article/2016-01-19/prefab-pretty-fab

Modular Construction, A Better Way for Green Building | EarthTechling. (n.d.). Retrieved May 11, 2016, from http://earthtechling.com/2014/05/modular-construction-a-better-way-for-green-building/

Prefab: From Utilitarian Home To Design Icon. (n.d.). Retrieved May 11, 2016, from http://www.npr.org/templates/story/story.php?storyId=94119708

Smith, R. E., & Rice, T. (2015, April). Off-Site Studies - Permanent Modular Construction - Process Practice Performance [Editorial]. Modular Building Institute. Retrieved May 11, 2016, from http://www.modular.org/HtmlPage.aspx?name=foundation_offsite_PMC_report

Why Sweden beats the world hands down on prefab housing. (n.d.). Retrieved May 11, 2016, from http://www.globalconstructionreview.com/trends/why-sweden-beats-world-h8an0ds-4d2own0-6p4r2e0f8ab/