SOLVING THE HOUSING CRISIS IN SAN FRANCISCO WITH FACTORY-BUILT HOUSING TECHNOLOGY AND REGULATORY REFORM

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Submitted to the Program in Real Estate Development in Conjunction with the Center for Real Estate in Partial Fulfillment of the Requirements for the Degree of Master of Science in Real Estate Development

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ABSTRACT
The San Francisco Bay Area is in the midst of a housing crisis as population and economic growth outstrip the ability of developers to build enough housing, resulting in a significant supply-demand imbalance that is expected to last well into the foreseeable future. San Francisco, in particular, faces the most severe housing crunch as demographic trends favor increasing demand in already dense, transit-rich cities. Developers are unable to supply the necessary housing due to significant barriers to development including a lengthy and convoluted planning and entitlement process, zoning restrictions on density and height, neighborhood opposition, and a high cost of land. Supply needs to outpace demand if housing is to become affordable, and this requires regulatory reform and cost reduction. Based on case studies, interviews and development analysis, this thesis will demonstrate how developers and municipal leaders can address the crisis by embracing factory-built housing while reforming regulations.

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1. Introduction

> *Housing development in California is a complex and lengthy process. San Francisco in particular is one of the more challenging environments to build housing. Factors including high land and construction costs, protracted entitlement and permitting processes, and organized opposition pose real obstacles to developing housing in San Francisco. (SF Planning HE 2014, pp. I.76)*

1.1. Economics and Demographics: Housing Supply-Demand Imbalance

San Francisco has a housing crisis because supply does not keep pace with demand. According to the San Francisco Planning and Urban Renewal Association (SPUR), 36,423 jobs were created in San Francisco between 2011 and 2012. (Hogan 2014) Along with the growth in jobs is a growing population: between 2010 and 2013 the city added over 32,000 residents, but for the past 20 years just 1,500 units of housing per year have been built. (Cutler 2014) San Francisco and high cost housing is not a new phenomenon and in fact has resulted in protectionist politics and policies that strive to control the market; however, the problem has become more acute as a larger demographic shift occurs whereby more people are moving to cities.

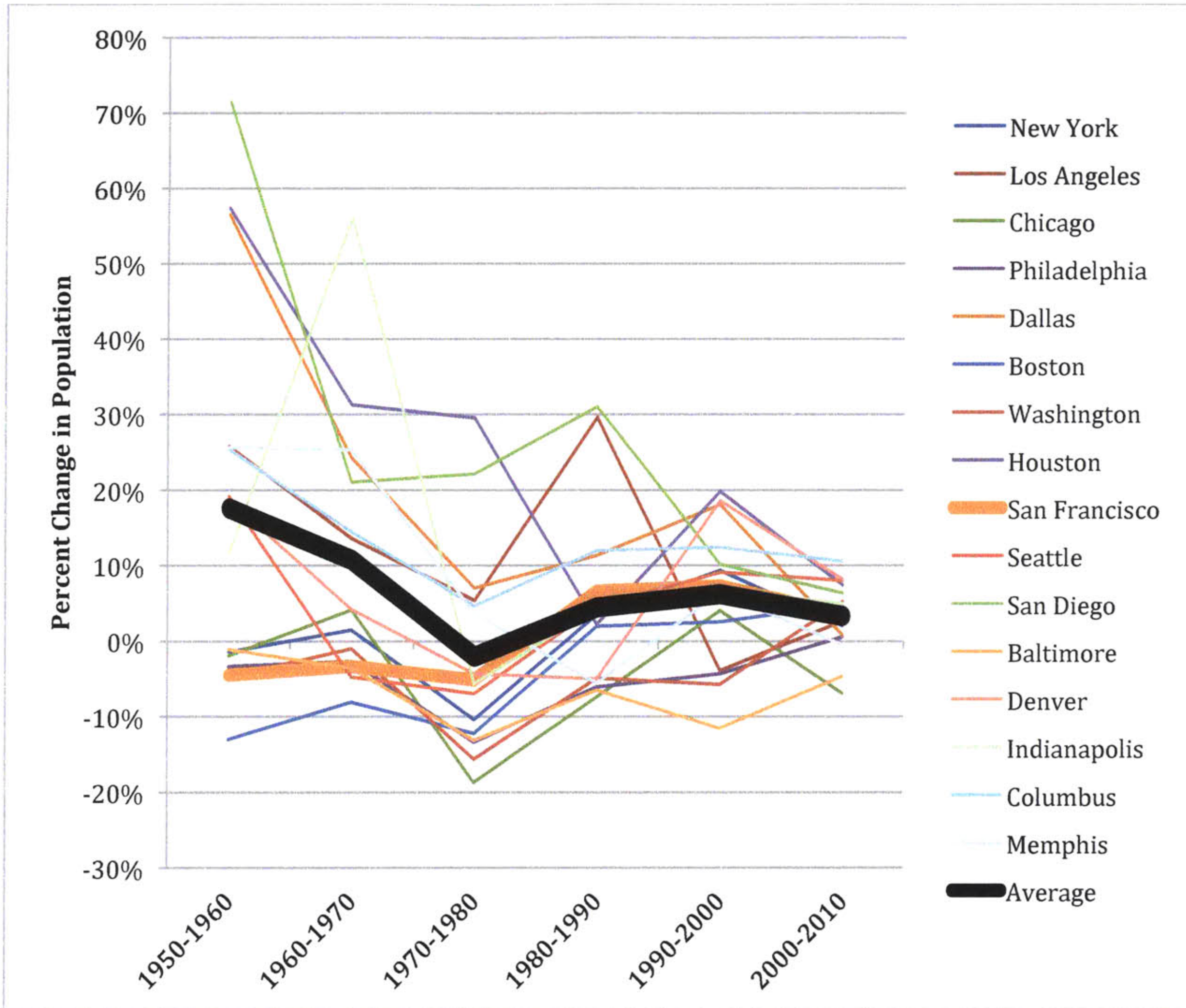
There has also been a significant increase in the formation of smaller households among singles and couples without children as well as an increase in the preference for urban living. The average household size has decreased from 4.6 persons per household in 1900 to 2.6 in today. This shift is the result of several phenomena, including couples delaying marriage and deciding to have fewer or no children when they do marry. The higher rate of divorce also results in a greater number of smaller households. The available supply of housing has not kept pace with this trend as the average size of housing built has more than doubled between 1950 and 2011, from 983 square feet to 2,480 square feet, leading to a general mismatch between household size and available supply of housing. (Shore 2014) The two generations most affecting this mismatch are the Echo Boomers and Baby Boomers.

The Echo Boomers, who are delaying marriage and forming smaller households when they do, are the group most interested in walkable, mixed-use neighborhoods, and shorter commutes. This is the first generation since the dawn of the automobile age that are eschewing car ownership, with one result being a steady decline in average daily vehicles miles traveled (VMT) since 1995. (Srivastava and Nemirow 2012)

The aging population is also affecting the composition and size of households. Baby boomers have been becoming empty nesters for the past 10 years, and their households may continue to shrink as "boomerang" children who returned home during the economic slump form their own households or as they become single households due to divorce or death. Many Boomers will leave the suburbs and move to cities increasing demand for urban housing. (Shore 2014) The Center for Transit Oriented Development projects that the percentage of people over 65 living near transit in amenity-rich neighborhoods will increase by 10 percent by 2030. (Srivastava and Nemirow 2012)

The shift in preference for urban living is not unique to San Francisco; the trend is occurring throughout the country in cities old and new. Figure 1 shows U.S. city populations rebounding since bottoming out in 1980.

Figure 1 - Population Change for U.S. Cities with 2010 Population over 600,000* - 1950-2010

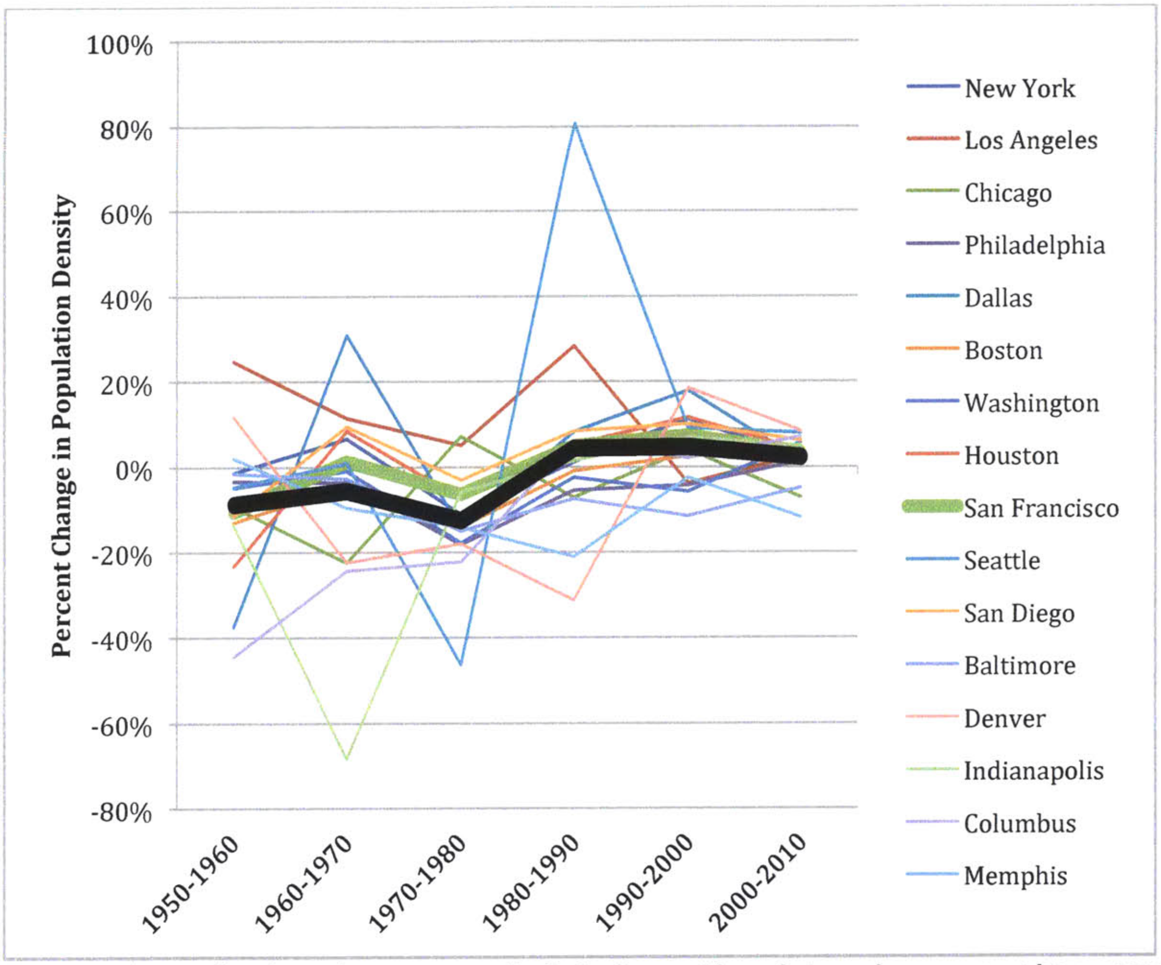


* Detroit and Phoenix are excluded from the data above as they represent extreme anomalies in population and density change. Source: U.S. Census Bureau

Not only has the population of many American cities reversed the downward trend, as Figure 2 shows, population density is also once again increasing.

Throughout history, as technology improves humans urbanize. The only exception to this trend occurred in the middle part of the 20th Century, when U.S. city population declined significantly as suburbanization expanded. But now cities are "in" again, and in the United States they are resurging to their historical prominence, causing additional strain in many cities that already struggle with high housing costs and limited space to grow.

Figure 2 - Population Density Change for U.S. Cities with 2010 Population over 600,000* - 1950-2010



* Detroit and Phoenix are excluded from the data above as they represent extreme anomalies in population and density change. Source: U.S. Census Bureau

1.2. Research Hypothesis

Basic economic theory can be used to solve the problem: decrease demand or increase supply. Reducing demand is undesirable because it requires limiting economic growth and prosperity, essentially attempting to control the natural human desire of housing location with many unintended consequences. In the San Francisco housing market, these consequences include price inflation, animosity towards "newcomers", household income stratification as middle income families are squeezed out, and byzantine policies that aim to fix but instead exacerbate the problem. Increasing supply can come with it's own problems including short-term disruption due to construction, temporary or long-term displacement and poor design; however many of the supply issues are easily addressed through proper planning and outreach. The only real option to increasing affordability is to significantly increase supply.

Reducing the time and cost of developing housing in San Francisco requires regulatory reform and lower building costs. Factory-built housing technology ("FBH") shows promise as a means to quickly and more affordably construct buildings, from single-family houses to mixed-use high-rise and industrial products. Factory-built housing (also known as modular housing or pre-fabricated construction) involves the fabrication of entire units or components of units in a controlled factory setting, which can have multiple benefits ranging from higher quality to lower waste. There is also the potential for significant cost savings and reduction in risk to workers. This thesis will consider the potential for FBH technology to help developers increase the supply of housing.

The first part of this research will summarize the wealth of information on supply constraints, which range from a lack of land and a byzantine planning and entitlement process to zoning restrictions and community opposition, all of which help limit supply, resulting in an extremely high cost to build housing.

The second part will introduce FBH and its potential time and cost savings, innovations in tall timber residential building technology, and provide a number of local and international case studies.

The third part will consider the potential market for FBH delivery in San Francisco. There are two potential paths for FBH to be a significant component of the housing crisis solution. The first is fewer but larger-scale modular projects. The second is a greater number of smaller projects, taking advantage of the relative abundance of smaller in-fill parcels throughout the city. The result of this evaluation will uncover the potential of FBH to address the supply-side crisis in San Francisco and potentially throughout the Bay Area.

The final part will evaluate FBH construction opportunities, constraints and provide recommendations on implementation of regulatory reform that could support large-scale adoption of FBH. Opportunities include a reduction in project delivery time, risk, construction cost and an increase in affordability. Constraints include labor, site availability, building codes and general unfamiliarity of FBH technology among developers, designers, contractors and municipal officials.

2. San Francisco Housing Crisis Explained

Much has been written on the housing problem in San Francisco, both directly and indirectly. Site to what seems a perennial housing crisis that becomes more pervasive during economic boom times but never quite goes away during busts, San Francisco housing seems to always be unaffordable. Economists, developers, planners, and community activists have written on how to address (or not address) the problem and this section will draw upon these writings to explain the current state of the housing market and the various struggles to address its shortcomings, including physical, regulatory and community constraints.

To many, the physical land constraints symbolize that San Francisco is built-out - that there is no more open space available for development and therefore growth must occur elsewhere. Physical land constraints, however, are only part of the issue; San Francisco housing development is constrained by regulation and opposition, as limitations on density and height as well as a byzantine planning and regulatory environment inhibit the construction of more housing units across the city. Opposition from residents creates significant risk, even for infill development that is well defined and in theory at least strengthens neighborhoods. Both the regulatory restraints and general opposition to new development partially exist due to a lack of leadership and a fragmented political structure in the city. One political consultant stated,

> *"Why stand up against something where 60 to 70 percent are going to vote with the other side?" (Cutler 2014)*

The answer, of course, is to stand up for something because it is smart and responsible; even necessary if the city is serious about making sure there is sufficient supply of housing to meet the needs of those that wish to stay or move to the city. Of course, the lack of political will stems partially from the significant tools that individuals wield, including the ballot initiative process and costly lawsuits, interchangeable if one or the other fails.

This section will first discuss the land constraint issue in depth, including historical development patterns. Next, the intertwined regulatory and anti-growth sentiment will be discussed as they relate to housing production and affordability. The regulatory section of this thesis is long and the anti-growth sentiment contentious, but such is the development process in San Francisco and understanding the housing crisis requires an understanding of these issues.

Finally, there is a discussion on how these issues result in a high cost of building housing in San Francisco and the end of this section.

2.1. Historical Development in San Francisco

San Francisco measures seven miles by seven miles (49 square miles) and is surrounded by water on three sides. The city largely developed in two phases. Prior to the 1906 earthquake and fire that devastated the city, growth was limited largely to the eastern half of the peninsula with industrial activity focused on the shoreline and commercial and residential neighborhoods stretching to the west. After the earthquake, the city was re-built and spread out with population and economic growth pre-WWII. Starting with the expanding streetcar lines operated by the Municipal Railway (Muni) and subsequently with the spread of automobile culture, San Francisco grew through and across its hills to the south and west in a lower density pattern. In San Francisco, this type of development resulted in large sections resembling post-war, low-density suburbs serviced by automobile-friendly commercial uses such as service stations and drive-thru restaurants.

2.1.1. Unlocking Land; Unleashing Developers

According to Edward Glaeser, professor of economics at Harvard University and author of *Triumph of the City*, if regulators and activists "unleash" developers, the market will solve the housing crisis. (Glaeser 2011, pp. 193) Plenty of land-constrained cities have found ways to house their burgeoning populations, usually by building up and more densely. The desire of those who wish to preserve the character of San Francisco is not antithetical to the need for more housing; it just requires a careful and less contentious dialogue. Developers must work with many different stakeholders including the community and neighbors, municipal officials, investors and finance professionals, architects, consultants and builders, none of whom specialize in the development process but all of whom play an integral role in ensuring successful projects that create vibrant communities.

In San Francisco, the balance of power lays largely with the community and neighborhood activists who perform the bidding of landowners. This situation, along with onerous municipal and state regulations, have limited the ability of developers to provide housing by driving the cost and risk associated with the entire development process higher and higher. The physical land constraint of San Francisco is only partially responsible for the high cost of development; because of such restrictions the potential of the limited supply of land is constrained to the point where existing landowners are today's robber-barons, essentially oligarchs according to a well-written article on the cost of San Francisco housing appearing in The Economist. (R.A. 2014)

These regulations range from complex land use codes to environmental review that can seem endless. The city imposes project review requirements that allow any neighbor to put the brakes on a project for any reason, adding layers of complexity and cost. There is also the threat of lawsuits, which increase risk and add carrying costs with the real possibility a project will be scrapped altogether.

The strong barriers to entry means there are only a few players willing to work within the system, resulting in a significant underinvestment in housing. The lengthy development process can take more than seven and sometimes 10 years to complete a project, if at all, helping to make the cycle of boom and bust ever stronger. All the while housing production remains significantly below demand, driving prices higher.

Taking a step back, it is good to review the basics of city growth. Traditionally, growth occurs gradually and always along the edge in greenfields due to the lower cost of land. Growth in the nine-county Bay Area largely followed this pattern for much of its modern history, and only recently has this changed as the remaining open space became protected from development. Traditionally, once land runs out, land prices rise until it becomes feasible to replace existing development with new, denser development that can accommodate new demand; unless it doesn't. In 1982, University of California - Berkeley City Planning Professor David E. Dowall, writing in the Cato Journal, stated,

> *"A suburban land squeeze has hit the nine-county San Francisco Bay Area. Extensive post-war land development, increasing use of growth-management controls, more restrictive land-use and environmental regulations, and a 'go-slow' development posture created by the passage of Propositions 4 and 13 have combined to reduce land conversion opportunities in the region considerably." (Dowall 1982, pp. 709)*

Dowall continues that this "is not the exclusive result of immutable natural constraints. It is the outcome of restrictive land use and development regulations imposed by many of the region's 100 local governments." Throughout the Bay Area, even in 1982 it was evident that "continued suburban land conversion [was] viewed as undesirable, and efforts to limit residential development are well organized and increasingly effective." He cited fiscal concerns such as Proposition 13's restrictions on the ability of cities to raise revenue through property taxes, and "awareness of the environmental impacts of land conversion." Even then Professor Dowall saw this trend as "very alarming." (Dowall 1982, pp. 711)

Although Dowall cited the "greater recognition of the environmental impacts of development" by existing residents, this sentiment should only apply to the then-rampant desire for continued suburbanization. Today, this "go slow" mentality has metastasized into a general anti-growth activism that restricts the supply of housing not only in growing suburbs and exurbs but in centralized urban areas. It has also resulted in the perverse situation where housing activists are helping drive up the price of land. They "put out the fire with gasoline." (Metcalf 2013) This anti-growth mentality was firmly established in the late 1970s and early 1980s and continues to this day, resulting in the current housing crisis that exists from San Francisco to the north and south.

Even infill development faces opposition. Activists, as discussed later on, rely on environmental arguments to decry growth. But, the increasing desire to "re-urbanize" makes moot the argument against growth, as denser, smarter growth can help reduce emissions by encouraging car-free or car-less living through mixed-use infill instead of suburban greenfield development. Even in 1982, Dowall noted the significant hurdles developers faced with infill development. Here, he wrote, "the strident opposition of neighborhood groups to any use of vacant urban land makes developing such parcels difficult if not impossible. Because of neighborhood opposition, a national study of infill potential found that vacant urban parcels were often too small and too expensive for housing development. Also, parcels were frequently withheld from the market by owners unwilling to sell them." (Dowall 1982, pp. 712)

San Francisco is only "built-out" to the extent that it no longer has any vacant greenfield land to develop. In order to grow, San Francisco must convert existing low-density land uses into higher density uses. Prior efforts to redevelop in San Francisco, as in other parts of the country, faced large obstacles due to implementation. Witness the redevelopment era of the 1960s and 1970s, which featured large-scale demolition and displacement of entire neighborhoods throughout America. The anti-change sentiment that resulted from this experience is understandable and today, changes in neighborhoods must be thoughtfully conceived and have demonstrable community benefits.

Land ownership in San Francisco, as in most American cities, is fractured such that the thousands of parcels of land making up the city owned by thousands of people/entities. In San Francisco, all new development occurs on land previously developed, meaning it is likely the project proponent will need to assemble the necessary parcels to make a project work. The need to assemble parcels results from the fact that as projects grow in size they achieve the economies of scale necessary to pencil out. Parcel assemblage, even if all owners are willing sellers, is tedious and risky as the actions of one owner can delay or kill a project, rendering it infeasible. For this reason, on any given block there may be a parcel or parcels that would make a good development site with little disruption, for example a parking lot or an abandoned building.

Larger developers, who have the financial means to quickly develop that parcel or parcels, may pass over the opportunity because the site is too small and assemblage; the return on the time and money the project would require is not worth the effort when they wish to focus their resources on larger projects or on site assembly if the return on the investment is significant, such as in a hot market.

Smaller developers usually focus on smaller sites; however, they are often more at the liberty of the credit market meaning again, the investment return must be significant enough to warrant the time and effort. For these reasons, vacant parcels or those with low quality structures remain a blight on what may otherwise be a nice street for years. Developers insist that lowering the cost to develop these smaller sites would help change this equation.

One of the primary questions of this thesis is whether factory-built housing can adequately address the housing crisis by bringing down the cost of developing smaller, infill parcels. Section 4 answers this question, analyzing both small and large project potential.

2.2. Regulatory Opportunities and Constraints

Understanding the housing crises in San Francisco requires understanding the regulatory structure and hurdles to development. This section explains laws and regulations that, while at times well intentioned, have had the effect of slowing housing production.

2.2.1. Proposition 13

The foundation for the housing crisis was poured in 1978. Proposition 13 was enacted after homeowners, fearing fast-increasing property tax bills, revolted and limited the amount by which the property tax on any property can increase in any one year to the lesser of one percent of assessed value, or two percent of the existing tax, per year, no matter how much the value of the property might have appreciated. The only time the tax can increase beyond these limits is when it is sold, or "reset". During the campaign for Proposition 13, renters were assured that homeowners would pass along property tax savings to them, garnering even more support. Of course this did not occur, and the result was additional market controls in the form of rent control (see Section 2.2.3). (Cutler 2014)

Proposition 13 applies to both residential and commercial property, but its imposition has affected land development patterns throughout the state. "Caught in a fiscal squeeze, many towns have stepped up efforts to increase their tax base by attracting more commercial, office, and light industrial development" and less housing. (Dowall 1982. Pp. 712)

Dowall wrote that it was evident Proposition 13 would lead to a housing crisis: by "attempting to attract economic development, most communities have not concomitantly adjusted their zoning to provide housing for additional employees. Consequently, new employees, particularly those migrating to the region, find it extremely difficult to acquire affordable housing." (Ibid)

The result we live with today,

> *"Cutthroat behavior [between cities and towns has] escalated to alarming proportions… The game is now more of a pushing match to see who can push the most fiscally and environmentally costly growth off onto other communities [having] enormous implications for the long-term development of the region." (Ibid)*

2.2.2. California Environmental Quality Act

CEQA can act as a constraint to housing development because it can increase both the costs and the time associated with development review. Environmental analysis can take upwards of 18-24 months to complete. In San Francisco, environmental review fees are calculated based on a project's calculated construction costs and can easily exceed $100,000; independent consultants are often involved, also at a substantial cost. Moreover, under state law CEQA determinations may be appealed directly to the Board of Supervisors, an appeal body that is available to very few other types of land use decisions in San Francisco. It is not uncommon for the Planning Department's CEQA documents of any type to undergo lengthy appeals processes, further increasing the time and costs associated with environmental analysis. (SF Planning HE 2014, pp. I.87)

The California Environmental Quality Act (CEQA) was adopted as a means to assess, minimize and mitigate the environmental impact of state and local projects and to ensure public participation. The Environmental Impact Report (EIR) is the typical vehicle for project assessment, allowing for adequate public review and comment. In San Francisco, the Environmental Planning division of the Planning Department administers CEQA review.

According to the Planning Department website, the following projects require a "discretionary" decision by the city: "public works construction and related activities, developments requiring permits (which in San Francisco are discretionary and thus not exempt from CEQA), use permits, activities supported by assistance from public agencies, enactment and amendment of zoning ordinances, and adoption or amendment of the General Plan or elements thereof. No action to issue permits, allocate funds, or otherwise implement a discretionary project may be taken until environmental review is complete." (SF Planning Environmental 2011)

Typically, EIRs must be completed for complex public or private development proposals, or those with significant environmental impacts. Jurisdictions complete an EIR for their General Plans encompassing all land use and development considerations within the General Plan.

At the project level, an EIR may be required when a proposal may not be consistent with a jurisdiction's General Plan and zoning. Some projects are exempt from CEQA requirements, including "small scale new construction or demolition, some changes of use, some additions, an other generally small-scale projects." (Ibid) The list of exemptions is fairly long, and significantly includes a Class 32 exemption for infill development projects. (SF Planning CEQA 2000)

The Class 32 urban infill exemption is applicable if a project conforms with the General Plan and zoning, "the site is five acres or less and surrounded by urban uses, is not habitat for endangered, rare or threatened species, does not have any significant effects relating to traffic, noise, air quality or water quality, and is adequately served by utilities and public services. Other exemptions are available for high density housing projects near major transit stops (CEQA Guidelines Section 15195) and affordable housing projects of up to 100 units (CEQA Guidelines Section 15194)." (Goetz and Sakai 2012)

While the urban infill CEQA exemption is significant, it does not apply for projects where the application of the density bonus causes the project to exceed the existing CEQA approval of the General Plan, specific plan or other project.

ABAG and MTC recognize how CEQA challenges can stymie development. Additional CEQA relief is provided by Plan Bay Area:

> *"A project may qualify for CEQA relief under SB 375 if it is: 1) consistent with the approved Plan Bay Area Sustainable Communities Strategy (SCS), including all land use designations, employment distribution densities, building space intensities and applicable policies; or 2) considered a residential/mixed-use residential project or a transit priority project (TPP)." (ABAG and MTC 2013, pp. 60)*

Much of San Francisco qualifies as a TPP, as it is defined as a place "within one-half mile of a major transit stop or a high-quality transit corridor." The project must also contain 50 percent residential use (if it has 26-50 percent nonresidential uses then the floor area ratio must be 0.75 or higher, and provide at least 20 units/acre (net). (Ibid, pp. 62)

Plan Bay Area supports the overall goals of CEQA, but recognizes its abuse:

> *"Over the four decades since it was enacted, CEQA has undoubtedly helped to improve environmental quality in California. At the same time, it is commonly used as a tool by project opponents who are more interested in halting a project than minimizing its harm to the environment. Sensible CEQA reform is needed to create a more economically vibrant state and region. (Ibid, pp. 129)*

Research shows that most CEQA lawsuits are more often aimed at infill projects versus greenfield projects, even when the project goes under an extensive EIR. In fact, 59 percent of challenged projects were infill, 64 percent were private and 19 percent of the challenged projects were for mixed-use development. Further, projects are "rejected 50 percent of the time when a court challenge is brought under CEQA, resulting in major revisions, increasing delay and costs." (Ibid, pp. 130)

The effects of CEQA challenges on developers are significant. Both ABAG and MTC recognize the challenges and will support measures to update CEQA in support of infill development because it can reduce sprawl; however, just because a project is exempt or gets other relief from CEQA requirements, it is not exempt from court challenges to its exemption status, itself an impediment to development.

The threat of CEQA challenge often encourages developers to prepare an EIR, but that still does not prevent challenges to the EIR's findings. CEQA environmental challenges "have even been used to slow or stop environmentally friendly projects, such as the four-year legal battle against a San Francisco plan to add 34 miles of bike lanes. A more recent example: A labor union's attempt to stop a downtown San Jose high-rise under CEQA, in part to pressure the developers not to use out-of-area subcontractors." (SFGate.com 2013)

State Senator Darrell Steinberg recognizes that CEQA is "irretrievably broken", and has made attempts to reform the law at the state level with Senate Bill 731, but that too falls short of the goal of reducing the exploitation of the law to achieve objectives that relate little to the environment. Steinberg's bill, while easing some regulations on in-fill projects, fails to improve disclosure of CEQA challenges, promote other types of environmentally friendly projects such as transit, and includes new requirements on follow up to environmental mitigation measures that could further muck up the approvals process. (Ibid)

The city recognizes the significant burden that environmental review may impose on housing development, and the draft Housing Element offers suggestions on improvements. One improvement is including impacts and their mitigation in ordinances so they are handled in the permit process, increasing the number of projects eligible for exemption. (SF Planning HE 2014, pp. I.88) The city and state should consider further reforms that tighten the language of the infill exemption to insure that frivolous challenges are determined early and discouraged. Another reform would be to apply the exemption to projects whereby applying the density bonus law will not affect the projects' exemption status if the bonus' application causes the project to exceed the existing CEQA approval of the General Plan, specific plan or other project.

2.2.3. Rent Control

Proposition 13 and the resulting deficiency in housing production led those affected by rising housing costs to seek other remedies. Renters, following the passage of Proposition 13 and its failed promise that property tax savings would be passed along to renters (Cutler 2014), voted in 1982 to control their rents to help reign in escalating rents. Rent control applies to all units built prior to 1979 (it does not apply to newly developed units), when Proposition 13 took effect, and allows for rent to increase along with the rate of inflation. Landlords may to apply for greater increases due to capital improvements (with approval from the Rent Board) and reset when existing tenants move out.

A controversial loophole exists in the Ellis Act, a state law called that allows a landlord to evict a tenant if they intend to get out of the rental business, perhaps to convert the property to condominiums or co-ops. During the recent housing boom, a surge in Ellis Act evictions is encouraging tenants rights organizations to seek even greater restrictions and financial burdens on property owners.

> *"Yet landlords ask whether further regulating and even prosecuting them in some instances, as the tenant groups propose, is the best way to encourage more people to get into the rental-housing business, which is what's needed to increase supply and reduce rents. It's an old economic rule that you get less of whatever you punish." (Greenhut 2013)*

While rent control may have a direct benefit to some tenants by preventing unexpected rent increases, it does not prevent macro-level rent increases across the city and region, and it serves to drive up the rents of new apartments unless supply can keep up. Further, rent control provides little motivation to those who are in controlled units to advocate for new rental housing to get built, creating two classes of renters with different priorities. (Cutler 2014) They remain separate, until rent-controlled renters face possible Ellis Act eviction. Then, activists use stories of families or the elderly being evicted to protest against 'greedy developers'.

Rent control has other negatives. It provides disincentives for landlords to keep up on maintenance and capital improvements, as they are unable to recoup the cost of those investments, having detrimental effects on the entire community. In San Francisco, rent control has even gone as far as encouraging some apartment owners to keep their vacant units off the market rather than face the difficulty in evicting a tenant should the need arise. (Greenhut 2013) Owners (and even other renters) have embraced short-term rental services such as AirBNB to skirt rent control as well. (Said 2014)

Rent control also suppresses the value of non-rent controlled property, as evidenced by the elimination of rent control in Cambridge, Massachusetts in 1994. In the decade following decontrol, the value of non-controlled properties rose more than the value of controlled property. (Autor, Palmer and Pathak 2014)

To summarize, rent control has been proven to reduce property values, lower maintenance and capital improvements, and reduce the supply of rental units by discouraging property owners from being in the business. It also encourages a significant portion of the population to remain indifferent or even become hostile to new development, further restricting housing supply.

2.2.4. Affordable Housing Initiatives

The continuing low-income housing problem (combined with the high prices commanded by limited new supply) led to inclusionary housing policies and redevelopment programs that sought to raise funds through incremental tax regimes for affordable housing development. Once redevelopment ended, new fees were imposed on all development to generate funding for affordable housing development. These affordable housing initiatives are described below.

San Francisco, like many cities, has an inclusionary housing requirement for new housing projects. Developers building new housing must either pay a fee[1] into the affordable housing fund or provide below market rate housing averaging 12 percent of total units for households earning up to 120 percent of Area Mean Income on-site or 20 percent off-site for projects greater than 10 units. (SF MOHCD 2014) In the present market, the generally preferable option is to pay the fee because one market rate luxury unit can translate into five affordable units based

[1] The Affordable Housing Fee for San Francisco is $191,349 (studio), $261,271 (one bedroom), $357,034 (two bedroom), $407,890 (three bedroom), $509,863 (four bedroom). (SF MOHCD 2014)

on the raw cost of constructing the unit. One developer put it this way,

> *'Why sell one unit worth $1.25 million on the open market for $250,000 when five units can be built in another location?'*

The state density bonus law (see Section 2.2.5) can help developers meet the inclusionary requirements by allowing the development of more units than local zoning ordinances alone would allow, particularly in areas where the in-lieu-of fees are high or non-existent.

Inclusionary housing requirements are essentially a subsidy from market rate homebuyers to below market rate homebuyers, and in a supply-constrained market, can help drive up the cost of market-rate housing. The cycle creates more incentive for activists and their allies in city hall to try to control the market even more by proposing ever increasing inclusionary requirements. (SFHAC Balanced 2014)

Through a series of events in 2011, Redevelopment in California ended. In 2012, San Francisco voters approved an Affordable Housing Trust Fund to help fund affordable housing initiatives, effectively replacing the Redevelopment Authority but with fewer funds. When it reaches its expected funding levels, it should support $50 million annually and is projected to total about $1.2 billion over its 30-year life cycle. (SFHAC Trust 2014)

Rent control, inclusionary housing and the affordable housing trust fund are important tools that help keep and provide affordable housing in San Francisco, but they are not enough to keep prices in check for middle income households not under rent control or enable those who want to live in San Francisco to actually do so. According to a presentation by Jonathan Woetzel of the McKinsey Global Institute, by 2025 San Francisco will have an $11 billion housing affordability gap[2]. (Woetzel November 14, 2014) With an annual city budget of just under $8 billion (SF Controller 2013), subsidizing affordable housing is not feasible without a massive cash infusion. Up to 90 percent of the affordability gap exists because of regulatory hurdles (that lock land thereby restricting supply) and high construction costs. (Woetzel, et. Al. 2014, pp. 6-7) This suggests that the best way to address the affordable crisis is to unlock land use

[2] "This estimate is based on an analysis of incomes and housing…and counts households earning less than 80 percent of area median income that cannot secure a minimum acceptable housing unit for 30 percent of their income." (McKinsey 2014, pp. 2)

constraints imposed by excessive regulation, and promote methods to reduce construction costs. These two critical issues are addressed in Sections 4 and 5.

2.2.5. Density Bonus

With Proposition 13 and general anti-growth sentiment rampant throughout the state, California enacted a density bonus law in 2012 that allows developers who provide affordable housing to increase the number of total units by up to 35 percent. The law provides for a number of incentives including "reduced parking requirements, other incentives and concessions such as reduced setback and minimum square footage requirements, and the ability to donate land for the development of affordable housing to earn a density bonus." The law also provides cover for municipalities that want to increase density but face local opposition. The law also creates disincentives for municipalities opposed to increased density by holding them responsible for paying developers' legal fees in disputes over compliance with the law. (Goetz and Sakai 2012)

The density bonus law allows a range of options based on the income category and percentage of below market rate (BMR) units proposed. An example of the density bonus application follows. Suppose a developer is to provide 12 percent of total units as affordable to households in the Very Low Income category, or those earning up to 50 percent of AMI, on-site, for a 100-unit project. With the density bonus law, the developer can now build 135 total units (a 35 percent increase). Alternatively, the developer can build 123 units (23 percent increase) if the BMR units are in the Low Income category (up to 60 percent). The increase in total units can make a project pencil out and results in the affordable housing being built on-site. (Ibid)

San Francisco has yet to implement the law and is functionally not in compliance with the statute. The city is currently exploring the best way to implement the law, and held a meeting in September 2014 with the goal of seeking advice from the development community on useful strategies that will enable compliance. At the meeting, the city presented an option that would allow an increase in the density of a project if the percentage of affordable housing built onsite is greater than the existing minimum requirement (12 percent at up to 120 percent of AMI). City planners also floated the idea of creating a middle-income category in the inclusionary housing requirements tied to the density bonus.

2.2.6. The General Plan

State law requires each jurisdiction to maintain and comply with an approved General Plan with guidelines set by the California Office of Planning and Research. The General Plan is a long-term guide for development and provides the basis for jurisdictions to develop Community Plans, Area Plans and Specific Plans as well as "elements," which form the backbone of planning for each jurisdiction. These elements include one each for Land Use, Circulation, Housing, Conservation, Open-Space, Noise and Safety. The most relevant for this thesis is the Housing Element, which is discussed below.

The General Plan process also includes an Environmental Impact Review (EIR) requirement that will be discussed along with CEQA application at the local level in Section 2.2.8.

2.2.6.1. The Housing Element

The housing element of the General Plan has statutory requirements, must be reviewed by the state and must be updated every five years. The state rationalizes this by stressing the importance of housing to the state and that each jurisdiction should adequately plan to meet its projected growth while including its "share of the regional housing need." (GPG 2003)

Each jurisdictions' housing element must quantify projected housing needs according to the regional housing needs allocation, describe the effort taken to include the public from all economic segments, assess housing needs and analyze inventory and constraints, and develop a five-year schedule of implementation.

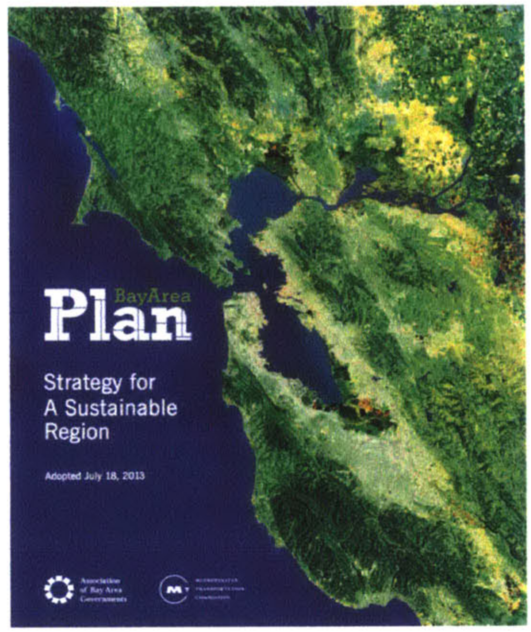
The housing element must identify adequate parcels with appropriate zoning, development standards and public facilities to accommodate housing development. Jurisdictions must also plan for the provision of affordable housing and address constraints to housing development. (Ibid)

2.2.6.2. Regional Housing Needs Allocation

The General Plan requires regional planning agencies to develop a Regional Housing Needs Allocation (RHNA) for each jurisdiction within its purview. In the Bay Area, the Association of Bay Area Governments (ABAG) fulfills this requirement while attempting to stem the jobs-housing imbalance. ABAG's RHNA attempts to encourage all cities in the Bay Area to build their 'fair share' over the next five to eight years.

The most recent ABAG RHNA determination is 187,990 units across the nine-counties of the Bay Area between January 2015 and 2023. (ABAG 2014) A total of 78,714, or 42 percent of those units are allocated to San Francisco, San Jose and Oakland, the regions three largest cities.

2.2.6.3. Plan Bay Area



An additional regulatory requirement now facing California cities and towns is 2008's Senate Bill 375 (SB 375). SB 375 requires consistency between the RHNA and the "development pattern included in the Sustainable Communities Strategy (SCS) of the Regional Transportation Plan (RTP)," meaning that housing and its complementary land uses be "supported by a transportation investment strategy with a goal of reducing greenhouse gas (GHG) emissions from cars and light-duty trucks." The result of this legislation in the Bay Area is the coordination between ABAG and the Metropolitan Transportation Commission (MTC) in the development of Plan Bay Area.

Plan Bay Area identifies strategies and requirements that will increase the supply, diversity and affordability of housing, promote infill development and more efficient land uses, and improve the relationship between jobs and housing while protecting the environment and promoting socioeconomic equity.

As a result of these goals and objectives, Plan Bay Area establishes Priority Development Areas (PDAs), which are "existing neighborhoods near transit nominated by local jurisdictions as appropriate places to concentrate future growth... The PDAs represent many types of places, from regional centers to neighborhood commercial nodes." ABAG and MTC encourage jurisdictions to support the RHNA through "targeted transportation investments funded under the One Bay Area Grant (OBAG)" program, whose funding criteria takes "into account local jurisdictions' past housing production and the 2014-2022 RHNA." (ABAG 2014)

San Francisco has nine PDAs, eight of which are "planned" and one of which is "potential." The following are the San Francisco PDAs:

Table 1 - San Francisco Priority Development Areas

19th Avenue Corridor: County Line to Eucalyptus Drive*
Bayview/Hunters Point/Candlestick Point
Better Neighborhoods: Balboa Park/Market & Octavia
Downtown Neighborhoods & Transit Rich Corridors
Eastern Neighborhoods
Mission Bay
Port of San Francisco
San Francisco/San Mateo Bi-County Area (with Brisbane)
Transbay Terminal
Treasure Island

*Planned. Source: Plan Bay Area 2013

To comply with objectives of SB 375 and determine a jurisdiction's RHNA, One Bay Area has several components including sustainability, fair share, an income allocation adjustment and a "sphere of influence" adjustment. The sustainability component promotes compact development and allocates 70% of the regions housing need to PDAs and 30% to non-PDAs. The fair share component ensures that all cities and towns participate in providing additional housing, even if they do not identify any PDAs and "allocates [the] housing need to expand access to communities with good transit access and employment opportunities." (Ibid)

The Sphere of Influence [SOI] is "considered the probable future boundary of a city and that city is responsible for planning within its SOI," and depending on the county, housing need allocations is assigned by formula. In San Francisco, the entire city and county is one SOI, and San Francisco is fully allocated within its boundary. (Ibid)

Finally, the income allocation adjustment divides each jurisdictions RHNA into four income categories: very low (less than 50 percent), low (51 to 80 percent), moderate (81 to 120 percent) and above moderate (greater than 120 percent) income. The income allocation method is designed to create greater income diversity within jurisdictions by requiring more housing in categories that the individual jurisdiction lacks. "For example, jurisdictions that already supply a large amount of affordable housing receive lower affordable housing allocations. This promotes the state objective for reducing concentrations of poverty and increasing the mix of housing types among cities and counties equitably." (Ibid)

The final result of the RHNA process is that, understandably, fully 42 percent of the regional housing need is allocated to the three largest cities in the region, Oakland, San Francisco and San Jose. Table 2 shows the income allocation breakdown for each city and that city's percentage of the regional housing total. San Francisco, by the nature of its relative size is expected to build almost 29,000 units of housing during this housing element cycle, or 15.4 percent of the region's total housing. Of this total, 56.6 percent should be affordable housing.

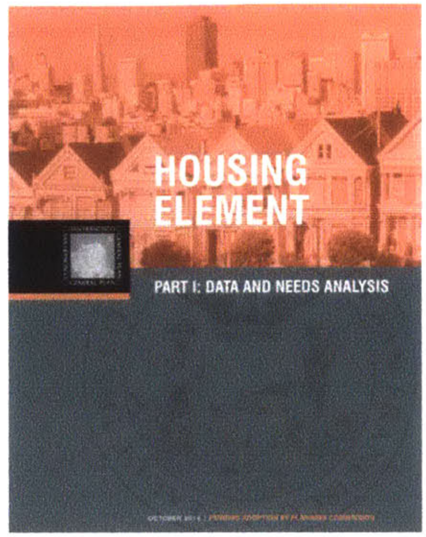
Table 2 - 2015-2022 Regional Housing Need Allocation for the Three Largest Bay Area Cities

	Income Level					
	Very Low	Low	Moderate	Above Moderate	Total	% of Region Total
Oakland	2,059	2,075	2,815	7,816	14,765	7.9%
% of City Total	13.9%	14.1%	19.1%	52.9%		
San Francisco	6,234	4,639	5,460	12,536	28,869	15.4%
% of City Total	21.6%	16.1%	18.9%	43.4%		
San Jose	9,233	5,428	6,188	14,231	35,080	18.7%
% of City Total	26.3%	15.5%	17.6%	40.6%		
9 County Total	*46,680*	*28,940*	*33,420*	*78,950*	*187,990*	*41.9%*

Source: ABAG 2014.

As discussed above, jurisdictions use their RHNA to guide the development of their housing element components of the General Plan. During the course of this research, many jurisdictions in the Bay Area were contacted about the status of their housing element updates. The response on the topic varied widely, from taking the process seriously and attempting to realistically meet the need, to planning officials completing the process to 'check the box' of state General Plan requirements.

2.2.6.4. San Francisco Housing Element



The 2015-2023 San Francisco Housing Element provides both an update on the progress the city has made since the 2009 Housing Element and makes adjustments to objectives, policies and implementation measures. The following discussion presents the city's plan to provide it's fair share of the regional housing need. The draft Housing Element also provides an opportunity for the city to self-reflect, as the city identifies constraints and opportunities for policy related to development.

Since the 2009 Housing Element, San Francisco has implemented several policies including the following:

- Passage of Proposition C in 2012 established the Affordable Housing Trust Fund following the dissolution of the Redevelopment Agency. (SF Planning HE 2014, pp. A.18)
- Establishment of Preliminary Project Assessments (PPAs) in 2011. PPAs are now required for projects over six units and/or 10,000 square feet and to allow for internal review and provide project sponsors with feedback before environmental review and entitlements. (Ibid, pp. C.24)

When questioned on the latter, developers indicate that PPAs have added yet another layer review on an already complicated process; however, the city recognizes the new burden and has recently altered the process so that environmental review can begin simultaneously with the PPA. Again, this adds complexity to the entire process that does not help build housing.

The city recognizes that more policy developments need to occur and that during the new housing element cycle, the city will develop policy on implementing the state density bonus and improvements to the planning department process. One of these that relates to infill development involves historical significance of existing structures. Currently, any project that involves demolishing a structure older than 50 years is subject to environmental review. The planning department is looking to survey every structure for historical significance to help remove this burden on infill developers or owners who want to make property improvements.

The draft Housing Element lists several objectives in Part II of the draft Housing Element, most of which are pertinent to this research and focus on the following needs:

- Lack of adequate sites
- Lack of equal housing opportunities
- Need to facilitate permanently affordable housing
- Need to remove constraints to housing construction and rehabilitation
- Desire to maintain the uniqueness and character of neighborhoods
- Need to balance housing construction and infrastructure
- Prioritization of sustainable development

To address these issues, the draft Housing Element includes city policies that focus on creating a greater supply of housing at different affordability levels that fits well within the character of the city. Here are some examples:

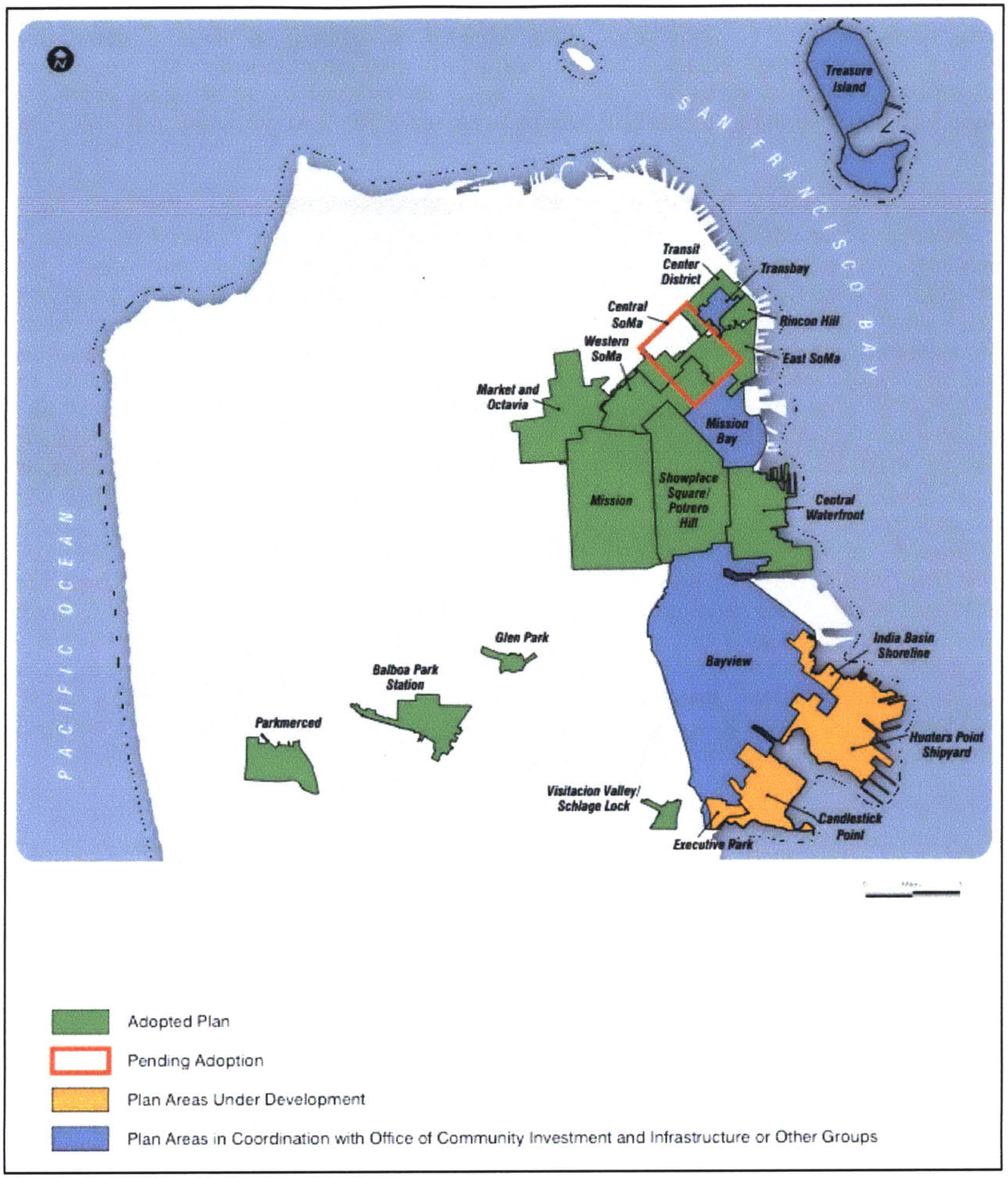
- Policy 1.6 instructs the city to "consider greater flexibility in number and size of units within established building envelopes … especially if it can increase the number of affordable units in multi-family structures."
- Policy 1.8 and 1.9 encourages the promotion of mixed-use development that includes housing in new commercial, institutional or other single use developments and requires new commercial and higher educational institutions to meet the housing demand they generate.
- Policy 4.4 encourages the development of sufficient and suitable rental opportunities.
- Policy 4.5 ensures that permanently affordable housing occurs in all neighborhoods.
- Policy 7.5 encourages affordable housing production with priority review and approval processes. One suggestion in the draft Housing Element is the assignment of a planner or planners to affordable housing projects to guide them through city processes.
- Policy 7.7 supports the development of middle-income housing that requires no subsidies.
- Policy 8.2 encourages San Francisco employers to work together to advocate for employee housing.
- Policy 8.3 aims to build community support for new affordable housing.
- Policy 10.1 aims to create certainty and consistency in the entitlement process.
- Policy 10.2 and 10.3 aims to reduce undue delay for project review and local CEQA application.

- Policy 10.4 aims to support environmentally favorable projects at the state level.
- Policy 11.2 promotes innovative design that respects the existing neighborhood character.
- Policy 11.5 aims to ensure the density of new projects is consistent with existing neighborhoods.
- Policy 12.1 encourages transit, bicycle and walkable development.
- Policy 13.1 supports the co-location of housing and jobs.
- Policy 13.2 directs the city to work with other cities in the region to produce affordable housing
- Policy 13.4 promotes green development.

The premise of this thesis agrees with the policies listed above, and as discussed in Section 4 and 5, factory-built housing can have a direct and indirect effect on the policies above. Other policies show that the city understands the housing crisis is a supply issue and may help address some of the issues this thesis identifies throughout Section 2.1.1, 2.2 and 2.3.

Furthermore, the city is developing Area Plans to plan for significant housing projects focusing on a "community accepted housing vision for the neighborhood." These Area Plans are in the southeastern half of the city, largely south of a line extending along Market Street (see Figure 3). In just these areas, the city projects over 70,000 units could be constructed, exceeding the San Francisco RHNA by over 40,000 units. (Ibid, pp. I.65)

Figure 3 - San Francisco Plan Areas



Source: SF Planning HE 2014, pp. 4

Further flexibility in density standards (see Figure 4) may allow for more form-based zoning as opposed to the traditional requirements specifying the number of units per square foot of lot area (see section 4.1.4). Form-based zoning sets requirements for volume, set-back, bulk, etc. and allows flexibility for unit type and size. While recognizing the potential to add density, the draft Housing Element provides relief in some existing lower density neighborhoods to "protect neighborhood character", (Ibid, pp. 6) which could be used to restrict necessary housing development in large swaths of the city.

The draft Housing Element provides additional weight to the idea of design flexibility when addressing the lack of middle-income housing. These households have incomes that fall in the gap between those qualifying for subsidies (less than 120 percent AMI) and those who can afford market rate units (greater than 180 percent AMI). For these units, the city suggests "creating smaller and less expensive unit types that are 'affordable by design.'" The city recognizes that "pre-fabricated housing and other low cost construction types can decrease overall housing costs, making it affordable to middle income households without subsidy. Industrialized wood construction techniques used in lower density housing and light-weight prefabricated, pre-stressed concrete construction in moderate and high density housing also have the potential of producing great savings in construction time and cost." (Ibid, pp. 27-28)

The city also recognizes the strong role community opposition has on affordable housing development, which consequently also applies to housing projects that increase overall supply lessening pressure on the housing market in general.

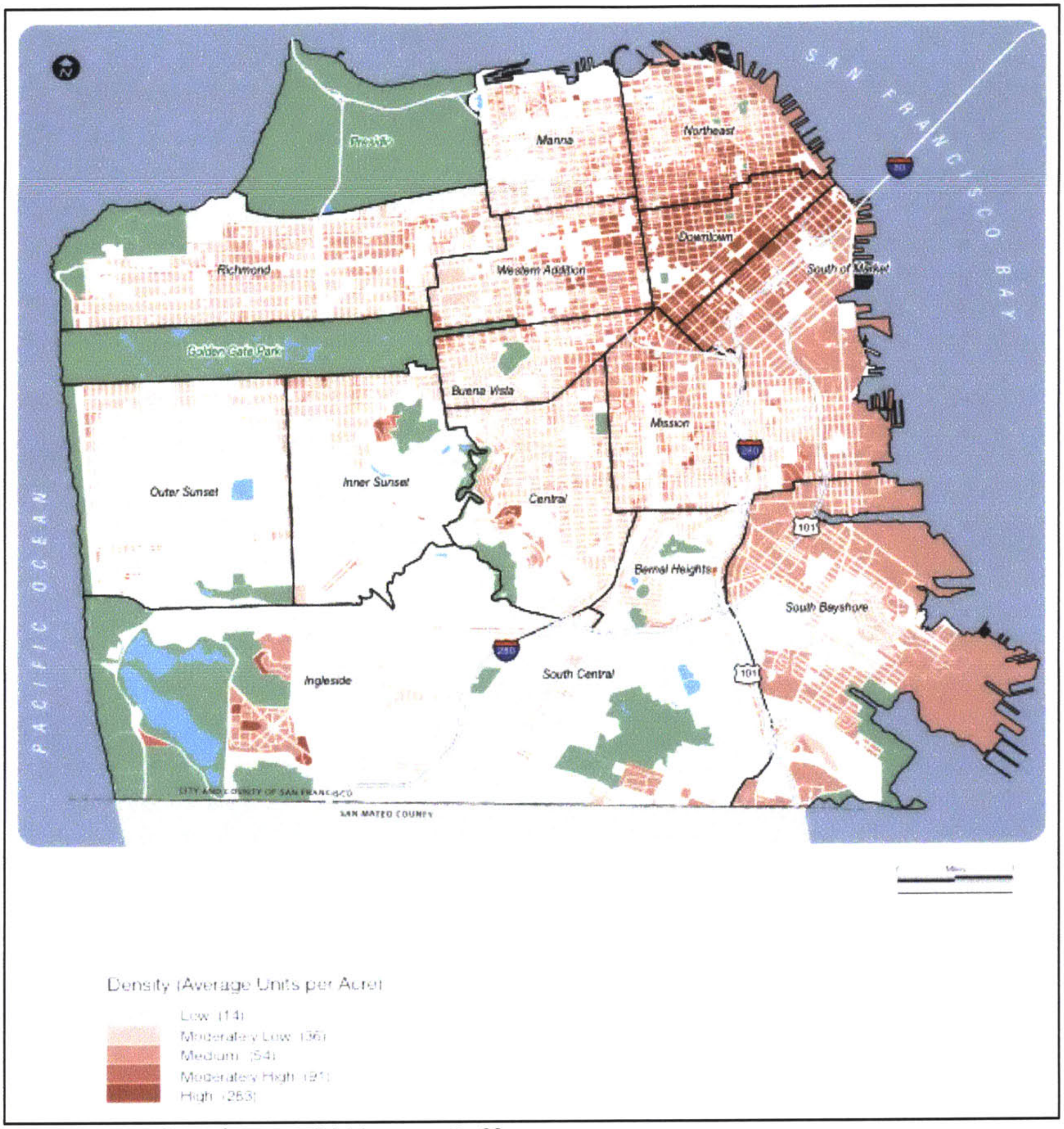
> *"Affordable housing projects are sometimes delayed or withdrawn because of community opposition. Greater public awareness of affordable housing challenges and potential solutions would generate broader long-term support for housing. San Franciscans, faced with one of the most expensive housing markets in the [country], generally support the notion of providing more affordable housing options and understand the range and severity of affordable housing needs in the City. However when individual projects are presented the macro understanding of the affordable housing crisis gets lost in fears about changes to an individual neighborhood or block. The City, in coordination with affordable housing providers, should work to showcase successful affordable housing projects that improve neighborhoods, help households, and provide much needed workers for our City." (Ibid, pp. 29)*

The city also understands the need for CEQA reforms, but stresses that maintaining community participation is critical. The city states that "using best practices, Community Plan exemptions and tiered environmental reviews can help enable CEQA to be more closely tuned to its initial intent, and to become a strong mechanism for smart growth planning and development." (Ibid, pp. 32)

Promoting environmentally sound projects is also a policy identified to be consistent with SB 375, which legislates greenhouse gas reduction through regional and local planning efforts. Here, the city notes the SB 375 relief identified in the Plan Bay Area and the related smart growth goals that can tie in with new housing production. (Ibid, pp. 33)

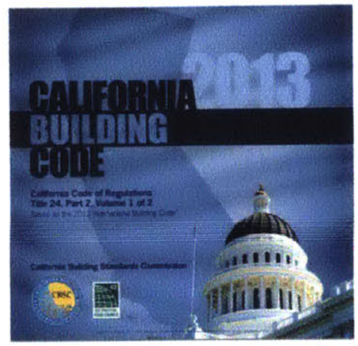
The draft Housing Element also significantly covers design and the city's desire for rehabilitated and new housing to provide a quality environment for residents while fitting in with the character of existing neighborhoods. Similarly, the city recommends that densities fit in with the prevailing neighborhood character, and the draft Housing Element includes the following map outlining permitted housing densities by zoning district.

Figure 4 - Generalized Permitted Housing Densities by Zoning Districts, San Francisco, 2013



Source: SF Planning HE 2014, pp. I.68

2.2.7. Building code



All buildings need to conform to the California Building Code (CBC), which is based on the International Building Code (IBC). Cities can amend the state building code, and the San Francisco Building Code (SFBC) contains amendments to the CBC where appropriate. The CBC regulates building constructions types and height and area limits based on performance criteria. Excerpts from the CBC relevant to this thesis are included in the appendix.

There are some exceptions to state and local building codes. For example, while the building code provides a standard for construction, it also provides a mechanism for construction innovation in the form of performance-based codes. Through rigorous design detail and analysis, different building materials and construction methodologies can be used so long as the proposed structure provides equivalency to the existing code. It also requires educating local building departments, not all of which are as amenable to innovative building methods.

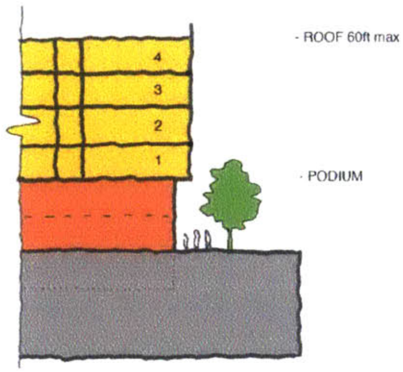
Another important relevant exception relates to modular buildings, which in California are approved according to the California Building Code by the Department of Housing and Community Development (HCD). Here, the CBC preempts local authority for code review and construction approval, which occurs at the factory by HCD or an approved third party. HCD approves plan checks and all factory-built housing modules must have an insignia of approval; local jurisdictions cannot charge additional plan check fees (HCD 2007). In practice, however, developers indicate that there is disconnect between HCD's authority and local jurisdiction understanding and compliance (see Section 3.1.2)

While San Francisco has several pertinent amendments to the CBC, there are none to chapters 5 or 6. The San Francisco housing code does require wood-frame buildings three or more stories used as apartment house or hotel to have materials with a fire-resistive rating of one hour. (SFBC 2014).

Further, "interior wood construction of Type III (III-A and III-B) and IV buildings shall conform to the same fire-resistive requirements as for Type V (V-A and V-B) buildings. Type III (III-A and III-B) buildings five or more stories in height shall be of fire-resistive construction if constructed, altered or converted for use as an apartment house or hotel after August 17, 1923." (Ibid)

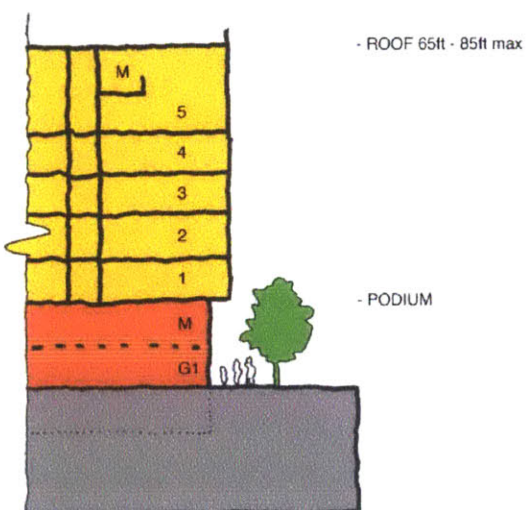
The building types can be combined to provide flexible structures for mixed-use projects. David Baker Architects, a leading San Francisco housing designer, provides a good guide to the allowable building type mixes for residential or mixed-use construction. The following are examples of how different construction types can be combined in the city and their maximum heights.

Figure 5 - Type V over Type I Example



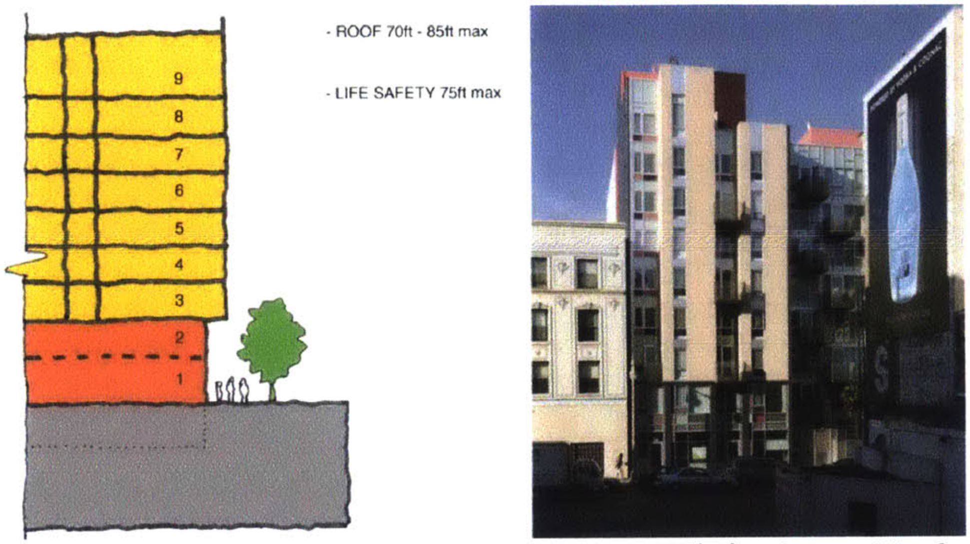
Four stories of wood frame over one-or two-story podium, typically concrete, with total height 60 feet. (left) Representative project at 8th Street and Howard Street (right). Source: DBA 2014

Figure 6 - Type III over Type I Example



Type III, more robust wood, over Type I allows for five stories over a one-or two-story podium, typically concrete, with maximum height of 85 feet (left). Representative project at Station Center (right). Source: DBA 2014

Figure 7 - Type I Mid-Rise Example



Type I is typically made of concrete, limited to 75 feet at life-safety floor. The building can reach up to 95 feet and have a total of 8 or 9 stories (left). Representative project at Curran House (right). Source: DBA 2014

2.2.8. The San Francisco Planning Code

In addition to state and regional requirements, San Francisco has a number of planning-related issues developers must work through to move projects forward. Discussed in section 2.2.6.4, these include the planning code, discretionary review, building permit and development impact fees.

2.2.8.1. Planning Code

One developer speculates that the San Francisco Planning Code is the most complex Planning Code in the country. The city recognizes its complexity as well; however, when questioned why the city's planning code is more complex than New York's (which has eight times the population) the response was that San Francisco is beautiful and needs to have a more complex code as a result.

The planning code establishes basic requirements for different zones for standards such as density, setbacks, and use. For the latter, San Francisco's zoning code generally allows for residential development in most zoning districts, except the Service-Light Industrial (SLI) in the South of Market district where the only housing allows is affordable to low-income households and the Production, Distribution and Repair (PDR) districts. (SF Planning HE 2014, pp. I.64) The latter was created in an attempt to control industrial use conversion to residential and office use permitted in industrial zones when economic and population growth increased during the dot-com boom. (Sabatini 2012) Zoning controls for height and density were introduced in section 2.2.6.4 and will be discussed further in section 4.

Planning code complexities include conditional use permits, variance, and discretionary review. Many projects, particularly larger projects, might require a Conditional Use authorization for aspects such as dwelling unit density. Variances are required to deviate (even slightly) from dwelling unit exposure requirements and parking minimums, and a Discretionary Review in order to demolish an existing dilapidated building. (SF Planning HE 2014, pp. I.90)

The Planning Department has made some effort at simplifying the process for smaller projects but the complexity remains for larger projects. Reforms such as the Priority Processing (see section 2.2.8.4) help, but the fact remains that, "the overwhelming majority of projects which seek to create additional housing" require public notice for discretionary entitlement such as Conditional Use authorization or Planning Code "provisions which apply to as-of-right projects and seek to inform and solicit input from the broader community." (Ibid, pp. I.90-91)

The Planning Department projects that a new permit tracking system will help reduce processing time when implemented in the fall of 2014, as it "will establish a single intake application system for all Planning and Building cases to provide early and comprehensive information to applicants." (Ibid) However, keeping track of permits is barely scratching the surface.

2.2.8.2. Discretionary Review

> *Currently, anyone for any reason can file a Discrtionary Review ("DR") Application and bring a project before the Planning Commission for a public hearing. While this ensures that neighbors are provided an* ***opportunity to express their concerns*** *about a project to the Planning Commission, it* ***does not result in a predictable and consistent development process.*** *It also makes the development process* ***more lengthy*** *and* ***costly*** *for all involved, and takes time away from the Commission to address larger planning issues. (SF Planning DR Reform Hearing 2008, emphasis added)*

San Francisco's Planning Code Section 311 (d) and 312 (e) gives the Planning Commission the power of discretionary review over all building permit applications. While permit application review is delegated to the planning department, the Commission maintains authority to review the application through the discretionary review process. A member of the public initiates the DR process, typically during a 30-day window after the planning department notifies all surrounding neighbors of the proposed project. (SF Planning DR) The Planning Commission may also initiate a DR for a project and it is required for demolition of a dilapidated building (SF Planning HE 2014, pp. I.90), meaning almost any in-fill project will require Discretionary Review. This process sets in motion a chain of events that usually leads to a public hearing on the project where planning presents all of the public's comments on the proposed project, increasing significant time and cost. (Bevk 2013)

Along with CEQA, Discretionary Review "has been wildly abused by NIMBYs and feuding neighbors hell-bent on stopping projects." (Bevk 2013) It does not help that the project sponsor has to pay for hearings, public notification and for Planning staff time, in addition to adding significant time delay and cost to projects. The requester is required to pay a $535 application fee, not nearly enough to cover the expense of the process, which the Planning Department puts at $3,680. Part of this cost is recovered through a Board of Appeal surcharge of $25 for every building permit application, adding to the overall construction cost in the city. (SF Planning HE 2014, pp. I88-89)

Some reform has occurred with Discretionary Review; for example, there is now the pre-application meeting requirement with neighbors to discuss the project and help address potential issues. Still, these meetings do not guarantee a Discretionary Review will not be requested, leading to development uncertainty and risk.

Another reform proposal deals with the lack of a definition for "exceptional and extraordinary circumstances," which allows just about any type of complaint against a project to be permissible under Discretionary Review. This reform would define "exception and extraordinary circumstances" to those that "occur where the common-place application of adopted design standards to a project does not enhance or conserve neighborhood character, or balance the right to develop the property with impacts on near-by properties or occupants. These circumstances may arise due to complex topography, irregular lot configuration, unusual context or other conditions not addressed in the design standards."

(Bevk 2013) This reform was approved by the Planning Commission in 2010, but has yet to be approved by the Board of Supervisors.

A more significant reform could protect the Discretionary Review option for the community but reduce the potential for abuse would be to shift the cost burden (fees for the hearing, notification and Planning staff hours) onto the initiator(s) for the Discretionary Review if the Planning Commission decides in favor of the project proposer.

Notably, there is also interest on the part of the city to create a class of non-discretionary projects that would simultaneously increase the amount of affordable housing while significantly reducing the amount of time necessary for project review by city staff. (Dennis-Phillips 2014) Factory-built housing, due to its potential cost savings, is one way developers can provide more affordable housing on-site. These savings can be compounded if combined with a shorter city review process.

Opponents to Discretionary Review reform may cite the city charter, whose preamble encourages participation of all persons and sectors in city affairs. Interpretation of the charter statement is up to policymakers and they have discretion to insure that policies such as Discretionary Review do not cause a disbenefit to the broader population.

2.2.8.3. Permit Application and Development Impact Fees

Development in California is subject to a variety of permit and impact fees, which vary by jurisdiction. The Housing Element law requires that jurisdictions report on and compare their fees to nearby jurisdictions and how they may affect development. Permit application fees are used to fund environmental and land use planners as well as building inspectors. As a result, permit fees generally increase with the complexity of a project. (SF Planning HE 2014, pp. I.92)

Development impact fees also vary by project but more due to size, as larger projects usually have a greater impact on public infrastructure such as affordable housing, water and sewer hook-ups, and schools. Some developments require additional fees for transportation infrastructure, open space, childcare or other community facilities. (Ibid) The city states that the average fees per unit in San Francisco of $15,476 is lower than both the Bay Area ($25,859) and California ($20,327) average. (Ibid, pp. I.91)

2.2.8.4. Permit Processing

The most significant regulatory hurdle to larger multi-family development in San Francisco is the permit processing and environmental review under CEQA. According to the Planning Department, a 50-to 100-unit multi-family project can take between one year and 2.5 years from initial project review with the city and the start of construction. Fortunately, the city's entitlement review and CEQA can occur concurrently, but the EIR process can take up to two years. Once the EIR is complete, it is presented to the Planning Commission and if approved, there is a 30-day where appeals can be filed before the Board of Supervisors. (SF Planning HE 2014, pp. I89)

Once the entitlements are secure, the proponent submits building plans for Department of Building Inspection (DBI), which can then take up to six months before issuance of building permits. Again, there is another 15-day appeal period following building permit issuance, and if there are no appeals, construction can commence. (Ibid)

Developers have long known and the city recognizes the need to reform the entitlement process. As early as 2008, the Planning Department began procedural and operational reforms, but in 2014 the process remains laborious.

Mayor Lee has convened an interagency working group to focus on the housing crisis, with a goal of building 30,000 units, involving every agency to expedite housing production. One recent reform is the "priority processing" rule, a step in the right direction toward providing (at least) some affordable housing.

The priority processing rule allows a developer to jump to the front of the project review processing queue if the project includes on-site affordable housing in-lieu of paying an off-site affordable housing fee for 100 percent affordable housing projects and for market rate projects providing at least 20 percent affordable units on-site or 30 percent of units off-site. Jumping the queue can shave up to six months off the project review process, not an insignificant amount of time; however, this can be more than offset by the inherently more difficult development process for affordable housing, where developers must jump through numerous hoops in the pursuit of the relevant financing mechanisms. (Dennis-Phillips 2014)

2.2.9. Regulatory Summary

The San Francisco regulatory environment is arduous, confusing and adds development risk, driving the cost of housing higher (see section 2.4). The city recognizes these governmental constraints to development but argues that they are necessary; otherwise unfettered development will lead to even more opposition. (SF Planning HE 2014, pp. I.84) While the city has made some effort at easing regulatory hurdles, these changes do not affect larger housing developments and will not until the Mayor's newly established Housing Working Group identifies ways to streamline the development process.

The city has embraced the community plan process to help streamline regulations and increase development capacity, and reduce parking and open space requirements. However, the only recent changes have been the priority processing rule for affordable housing and the easing of restrictions on accessory dwelling units. (SF Planning HE, pp. I.84-85)

While the city has made some effort in easing the regulatory burden, the development community still finds significant hurdles that add delay and cost to projects. For example, several developers state that the new PPA process added two months to the entitlement process when it began, and even though the city now allows the PPA to be submitted simultaneously with environmental notification, the window of review for the PPA increased from 60 days to 90 days.

Developers also note that the 'clock does not start' on review until an application is first reviewed, not at submission. An environmental application can 'sit in a pile on a desk for three months' before the six month clock starts for a decision. Developers cite both the amount of workload and low staff levels, in addition to planners' unfamiliarity with what makes development actually work. The workload on planning staff is the result of both unprecedented (in recent history) development activity and the slow hiring process.

2.3. Community Constraint

> *"San Francisco has a strong tradition of public involvement in policy discussions and possesses a very engaged citizenry on development issues. This activism often takes the shape of organized opposition to housing projects across the City, especially affordable housing for low-income residents and even towards well planned and designed developments. Such vocal opposition poses*

very real impediments to project sponsors and can lead to significant time delays, additional cost, or a reduction in the number of residential units produced. The City is committed to the involvement of citizens in the planning process and to the need to expound on the importance of working towards citywide housing objectives."
(SF Planning HE 2014, pp. I.83-84)

This section will evaluate many of the concerns that arise when housing projects are proposed. These concerns include evidence that new supply only drives up prices, so the laws of supply and demand do not apply in San Francisco (they do), environmental concerns (stopping growth in San Francisco does not stop growth), and aversion to change (it can be startling). These irrational arguments often carry weight and come with plenty of statistical back-up, but as other advocates have expressed, they are somewhat out of touch with reality and are counterproductive.

2.3.1. Myth: Supply and Demand is Working Very Well

Among some housing advocates in San Francisco, the basic laws of supply and demand do not apply in their argument for more regulation and price controls of existing housing stock. Activists such as Peter Cohen claim the supply-side solution is "superficial" in that it does not address the varying ways new development drives up land values across a neighborhood. (Lamb 2014) While this thesis does not evaluate or debate the merits of various affordable housing programs, many of which provide much needed housing for very low and low income individuals and families, the argument that not building more housing as part of the solution to increasing affordability is worth dissecting.

In *SF Controller Shows "Supply & Demand" Does Not Work in the San Francisco Housing Market,* Calvin Welch claims that the issuance of building permits over a 16-year period was followed only by price increases as evidence that increasing the supply of market rate housing does not reduce prices. (Welch 2013) Welch's supply-side argument sounds compelling, but fails to address the other major force in supply-demand theory: demand.

Dowall, in 1982, wrote, development control policies [if remain unchanged] will lead to higher land costs, and subsequently higher rents and building costs. Dowall predicted that the higher rents will force wages up and firms unable to meet these higher costs will relocate. This pattern would reduce the balance of jobs from a mix of "professional, blue-collar, clerical, and service types to exclusively high-wage, high-productivity executive types." (Dowall 1982, pp. 713) Dowall already noted that this occurred in San Francisco and could spread region-wide. Today, this lack of job diversity in San Francisco exacerbates the divide between the poor and the rich, with the middle class exceedingly squeezed out. This was occurring 30 years ago, and today we are still grappling with how to provide affordable housing.

Evidence in other cities shows that increasing supply helps push rents down. For example, Business Journals are littered with articles with titles such as "Downtown Boston apartment rents slide" 1.1 percent as units come online. "So far, an additional 5,714 units are scheduled to come online in 2015, which could mean that more downward pressure on rent could occur…it's common for landlords and property owners to cut rents to attract more tenants in the face of new supply", say rental market analysts. (Convey 2014)

Similar results are found in Seattle. In it's 3rd Quarter Seattle Apartment Report, KidderMathews states what should be the obvious: "Vacancy rates generally have an inverse relationship with changes in rent; as vacancy rates increase the rate of rent growth generally decreases." (KidderMathews 2014) In their report, they predict that increasing vacancy rates (due to new supply) will help moderate rent growth in the next few years, until that new supply is absorbed.

2.3.2. Supply and Demand Work Simultaneously

But supply is not the only factor affecting the housing market; one must also consider the equally important demand factor. In order to moderate the increase in rent growth, supply must better match the high demand, which is why it seems San Francisco cannot ever build its way out of the crisis.

San Francisco is experiencing a boom in job creation and economic activity, particularly as the economy has improved and the social and mobile technology revolution has taken hold. But it is not just tech workers causing the spike in demand for housing – cities are hip again and demand is increasing everywhere there are walkable and culturally interesting neighborhoods. Both the jobs increase and the broader demographic shift are discussed below.

ABAG projects that over the next 30 years, the top 15 cities in the Bay Area will have employment growth between 28 to 46 percent. Of the over 1.6 million new jobs expected in the region, the three largest cities will experience job growth of

40 percent. In San Francisco, ABAG projects a 34 percent increase in jobs with 190,780 new jobs totaling almost 760,000 jobs.

The increase in jobs will accompany an increase in housing demand, and the number of housing units. Over the next 30 years, San Francisco is expected to add 92,480 housing units, or grow by 25 percent of the 2010 total of 376,940. Similar growth is expected in San Jose (129,280) and Oakland (51,450). (ABAG and MTC 2013, pp. 55) Most (94 percent) of the housing growth in San Francisco will occur in the predefined PDAs, where housing units are projected to increase 43 percent over 2010 levels. In the San Francisco PDAs, jobs are expected to grow by 34 percent (see Appendix A).

Simultaneously, the dream of urbanists and city planners is coming true as cities are now hip and attractive. Millennials are eschewing car-ownership in favor of alternative transportation including bicycles, public transit, and good old walking. As Baby Boomers age, many are seeking to downsize and live in more walkable, mixed-use communities.

A research memo produced by the Center for Transit Oriented Development came to the following conclusions after analyzing Bay Area demographic trends:

1. Bay Area TOD demand may increase in the short- to – mid-term as Echo Boomers enter adulthood and when "combined with the disproportionate effect of the housing crisis and recession on Gen X'ers.

2. In the longer-term, the attractiveness of the Bay Area to younger, working age adults, and an "increasing population age 65 and over, may help generate ongoing demand for TOD.

3. "The aging of the Baby Boomers is likely to have an incremental, rather than sudden and dramatic, effect on the Bay Area housing market."

Source: (Srivastava and Nemirow 2012, pp. 16)

In short: demand is going up and supply has been unable to keep pace. There are many reasons for this, and anti-growth activists use them liberally when new development is proposed. The following sections discuss commonly used rationale for denying the laws of supply and demand in San Francisco.

2.3.2.1. Myth: new building results in higher prices

Many anti-growth activists in San Francisco bemoan that new housing only results in higher prices or that supply increases are not the answer to the housing crisis. (Ruiz and Smooke 2014) However, while increasing supply has been met with rising rents in the recent past, it occurs because the number of jobs is still outpacing the amount of housing supply coming online. (Pender 2014)

There is a belief in San Francisco that building more housing results in higher rents. This experience largely results from the fact that the new housing supply fails to keep pace with demand, resulting in gentrification. This macro economic price pressure encourages owners to seek more creative ways to increase rents, resulting in an uptick in Ellis Act evictions when the demand-supply imbalance is especially acute.

Activists use social media and online journals to expand their audiences and propagate their ideology. For example, in October 2014 in the progressive Truth-out.org blog, Dyan Ruiz and Joseph Smooke try to dispel the "myth" that the housing crisis is not the result of limited supply, but rather the result of too much demand. Their first myth is that "housing is expensive because there isn't enough supply," which other affordable housing activists use to argue against increasing housing supply. In describing this myth, the authors blame the rise in prices on "techies and investors" and twist the words of experts as support. The first supporting claim is true, the tech world is centered in Silicon Valley and salaries and benefits are high as technology and supporting companies vie for qualified employees. Ruiz and Smooke then cite financial theorist William Bernstein who wrote that people who make more money will help drive up prices in an article that analyzes how people decide how much housing to buy based on income and mortgage rates. Ruiz and Smooke seem surprised by this, and claim that the reason housing is so expensive in San Francisco is because jobs pay too much, failing to mention that Bernstein holds supply constant in his theoretical analysis.

In their attempt to dispel this myth, Ruiz and Smooke cite a February 2014 New York Times article on a decline in rents in New York City. They pick facts from the article that support their argument, such as the fact that rents have increased much faster than incomes, while ignoring important facts, such as, "supply, predictably, has increased." (Hughes 2014) Attempting to not 'indict' tech workers, foreign investors or developers, Ruiz and Smooke feed the animosity towards all three groups while focusing only on the demand side of the supply-demand equation, attacking the very premise that increasing supply will not bring prices down.

Further support to the belief that increasing supply will not help bring prices down even receives support from the city. The city's chief economist estimates it would take 100,000 market rate housing units to stabilize prices. (Lamb 2014) Significantly, that is the number of units built in the city over the past nine decades! Fatalists thus argue that increasing supply is meaningless and prices will continue to increase, advocating for regulatory price-control measures.

Economist Edward Glaeser, however, begs to differ and writes in his book that factory-built housing has the potential to lower prices significantly. He notes correctly that mass production has made everything from clothing to cars much more affordable for everyone. (Glaeser, pp. 174)

Another recent article in The Economist clearly sums up the issue:

> *"Housing affordability activists like to point out that most new construction is for luxury housing, meaning that supply of non-luxury units is not growing by very much. Others love to say that price declines have historically gone hand in hand with falling construction.*
>
> *"These arguments are both nonsense. The latter point gets causation the wrong way around; given an unexpected decline in demand due to financial crisis or other shocks prices fall and interest in new construction dries up until existing inventories are cleared. The former point misses the fundamental fungibility of housing. When new construction of luxury units lags, the very rich buy up older housing stock at exorbitant prices and pay to have them redone. You see this in London, for instance, where literally every house in the city is now being rehabilitated, including those that were rehabilitated last year." (R.A. 2014)*

The author nails the supply-demand balance nail on its head:

> *Tight supply limits mean that the gap between the marginal cost of a unit of San Francisco and the value to the marginal resident of San Francisco (and the*

> *market price of the unit) is enormous. That difference is pocketed by the rent-seeking NIMBYs of San Francisco. However altruistic they perceive their mission to be, the result is similar to what you'd get if fat cat industrialists lobbied the government to drive their competition out of business. (Ibid)*

The author makes another economic argument for building more housing borrowing from UC Berkeley economist Enrico Moretti: the money being spent by the wealthy on housing could be used to drive investment in other parts of the economy and those who control land through zoning are extracting "an outsize share of the surplus generated by job creation." (Ibid)

In his article, R.A. makes a strong case for reigning in the power of the "oligarchs" by generating better zoning outcomes, but is unclear how support for such an effort can grow particularly since the intellectual battles are quite difficult. Strong leadership capable of intelligent debate is necessary to challenge misconceptions that are the cause of the housing crisis.

2.3.3. Myth: Being Anti-Growth is Being Green

CEQA was born out of the noble concern for the environment. Much of the land in the Bay Area is protected against development in one form or another. Organizations such as Save the Bay oppose development on the waterfront in the name of protecting the San Francisco Bay, even on sites that are already disturbed and in need of rehabilitation. Neighbors oppose new development projects that will add housing because of traffic concerns, even if those projects are in walkable neighborhoods with good transit access. While some neighborhoods, such as Hayes Valley, are more welcoming to new development and even support development with zero parking in an effort to encourage car-free living, many are in opposition, which results in leap-frog development which has the unintentional effect of being more destructive to the environment.

Edward Glaeser writes extensively on this issue in his book *Triumph of the City*, where he claims that California's anti-growth policies have only resulted in increasing America's carbon footprint. Glaeser recognizes the importance of environmental protection, but also that "taken to the extreme, [it] becomes mere NIMBYism, the reflexive opposition to any new building development". He continues:

"California's growth controls have...reduced the amount of new construction and pushed prices up…In America's expensive coastal regions, housing supply is restricted not by lack of land but because public policies make it hard to build." (Glaeser, pp. 192)

He contrasts the experience of Houston and other sunbelt cities where sentiment is more pro-growth, resulting in lower housing prices but much higher carbon emissions due to cooling, heating and commuting. Glaeser argues that environmentalists that seek to block development only encourage that development to occur elsewhere, that "advocates of California's growth limitations are often put forward as ecological heroes. But they're not." For example, a San Francisco household emits 60 [percent] less carbon than a household in Memphis. (Glaeser, pp. 210) (Ibid, pp. 210-212)

Glaeser also notes that a major flaw with the environmental impact review process is that it only evaluates a project if a project is built, but not disapproved and built elsewhere and argues for "assessing the full environmental cost of preventing construction in California would make that state's environmental policies look more brown than green". (Ibid) Glaeser coins the phrase the "law of conservation of construction" to describe the effect of growth restrictions in one area causing it to occur elsewhere. He asks,

'Why does the greenest place in the country do this?' (Ibid)

2.3.4. Aversion to Change

There is a conception that many in San Francisco and the Bay Area overall, once arrived, try and make it hard for newcomers to follow, creating an "oversized gated community." (Salam 2014) "This is sometimes referred to as the 'gangplank syndrome.' Such a characterization is incorrect; it is over simplistic, and it erroneously places too much emphasis on elitist citizen pressure. Other factors are at work, including intergovernmental finance, (perceived) environmental degradation, and the general but hard-to-pin-down effect of what Toffler calls 'future shock': the inability of people to cope with rapid social and cultural change." (Dowall, pp. 717-8)

Overcoming opposition to change requires leadership and interaction. Successful planners and developers work with citizen groups and neighbors when considering development plans. Witness the recent passage of Proposition F in November 2014, which approved a height limit increase for Forest City's Pier 70 project. Voters approved the project with over 70 percent approval, following extensive community outreach. (Ballotpedia 2014) Of course, the vote was necessary following 2013's Proposition B that required citywide approval for height limit increases on the waterfront.

2.3.5. Affordable Housing Needs Unmet

Dowall noted, "cities [were] more aggressively seeking their own objectives and [were] placing less importance on regional development needs or the regional implications of their local actions". (Dowall, pp. 782)

"Communities are still interested in high-quality development; the proverbial dream industry of research and development…but they are also interested in exporting or blocking undesirable growth. Communities will accept new tax-revenue-generating R&D, but they will at the same time curtail housing production, even if the housing is targeted towards the R&D workers." (Ibid)

At a recent panel discussion on Housing sponsored by the Bay Area Council, panelist Michael Carrabuvius of TMG Partners recommended the one sure fire way to change the dynamic Dowall noted in 1982 was to reverse the way tax dollars flow to municipalities. Currently, sales tax dollars stay local and property tax dollars flow to the state, which then redistributes those dollars to jurisdictions. Reversing this flow, allowing municipalities to collect and keep property tax dollars would encourage housing production at the local level.

2.4. Regulations and Growth Restrictions Contributes Significantly to the High Cost of Building Housing

The cost of building housing is the sum of land, entitlement and development, and construction cost. Physical land scarcity or regulations on land use affect the cost of land. Entitlement and development costs include design and engineering fees, impact fees and permit fees. The cost of development can also include of the related carrying costs (employees, office space) that developers must maintain before a project begins earning revenue. Construction costs are the cost of materials and labor to actually build the building.

In San Francisco, regulatory and other constraints to development drive up the cost of land. While there is a physical constraint, the city is just 49 square miles after all, height and density limits means that much of the city has the potential to support more housing, as evidenced by Figure 4, which shows much of San Francisco's land is height restricted to just four stories. As a result, in San Francisco land cost – the direct result of regulatory constraints on development – averages about 25 percent of the total cost to develop a unit of multi-family housing.

While the city estimates there are a total of over 1,700 vacant or nearly vacant and over 5,400 underdeveloped available parcels (see Section 4.1.2 and Appendix C), restrictions and the slow overall development process drives up the cost of development. The city recognizes that the ability to achieve the potential housing growth identified above is only possible if landowners are willing to sell.

The draft Housing Element shows that the price of land varies greatly by district, as shown in Table 3.

Table 3 - Average Price per Square Foot of Vacant Lands Sold, San Francisco, 2008-2013

Zoning Districts	# of Transactions	Average Price (per SF)
Residential	88	$204
Downtown Residential	4	$738
Downtown Commercial	5	$323
Neighborhood Commercial	26	$369
Mixed-Use	18	$398
Industrial	16	$78

Source: SF Planning HE 2014 pp. I.78

The entitlement and other development soft costs noted above contribute to another quarter of the project cost. Table 4 shows the fees for various development permits by construction cost and Table 5 shows these fees for a typical 1,000 square foot housing unit.

Table 4 – San Francisco Development Impact Fee by Estimated Construction Cost

	Fee (if required)				
Est. Construction Cost	Building Permit (DBI)	Conditional Use	Variance	Coastal Zone	Environmental Evaluation
$100,000	$2,378	$2,053	$4,019	$417	$8,466
$500,000	$13,054	$4,549	$4,019	$917	$17,373
$1,000,000	$17,314	$7,789	$4,019	$1,569	$27,881
$10,000,000	$30,672	$69,964	$4,019	$13,857	$184,746
$25,000,000	$31,422	$103,117	$4,019	$20,624	$263,646
$50,000,000	$32,672	$103,117	$4,019	$20,624	$332,625
$100,000,000	$35,548	$103,117	$4,019	$20,624	$356,710

Source: SF Planning HE 2014, pp. I.92.

Table 5 - Average Development Impact Fees for a 1,000 SF Housing Unit in San Francisco

Affordable Housing	$46,230
Transit, Open Space and Community Facilities	$10,540
Water and Wastewater	$2,543
Schools	$2,910
Total Average Impact Fee per 1,000 Sf unit	$62,223
Average Processing Fee per 1,000 SF unit	$6,000

Source: Ibid

Construction costs make up the remaining 50 percent of the cost of building a housing unit in San Francisco. These estimates were developed by SPUR, which, when added up, total almost $470,000 per unit to build. Table 6 shows a breakdown of these costs, including land, fees, and construction.

Table 6 – Estimated Multi-Family Housing Development Costs Per Unit, San Francisco, 2013

Cost Category	Cost	% of Total Cost
Land	$120,000	25.5%
Building Construction ($300/SF)	$240,000	51.1%
Permits, city fees and professional services (20% of construction costs)	$48,000	10.2%
Subsidy to build below-market rate units (12% of total units) based on a $200,000 per unit subsidy for a year, divided by the remaining 88 market-rate units	$27,000	5.7%
Selling expenses	$34,800	7.4%
Total Development Cost	**$469,800**	**100.0%**
Total Cost/SF (Average Net Unit Size = 800 SF)	$587.25	

Source: SF Planning HE 2014, pp. I.79

2.5. Section 2 Summary

Addressing the concerns identified above is important if meaningful housing supply increases are to come to fruition. With better procedures that make development easier and the acceptance that San Francisco needs more housing, the city can address the crisis by better matching supply with demand and bending the price curve toward affordability for all, not just the very wealthy and very poor (through affordable housing initiatives).

Edward Glaeser writes that, "the only way to provide cheap housing on a mass scale is to unleash the developers," (Ibid, pp. 193) and that if Bay Area progressives really want to tackle affordability, they must accept greater density. Denser growth in locations with temperate climates such as San Francisco is ecologically ideal and that Bay Area environmentalists must accept more development because the climate is ideal for living. (Glaeser, pp. 210)

There is ample space available to develop in San Francisco and surrounding areas, but it requires filling in the gaps. It means identifying areas large and small where density can increase, sometimes a little and sometimes a lot. Increasing density does not necessarily mean big changes to the look and feel of existing neighborhoods; heights do not necessarily need to increase to achieve significant densification.

Factory built housing construction can drive down the cost of housing and help reduce the carbon footprint by allowing more people to live in an environmentally-sound location. The remainder of this thesis will consider how factory-built housing can help achieve an increase in housing affordability through a reduction in construction cost and increase in development speed.

3. Innovative Construction Technologies

While the primary focus of this section will be factory-built housing (FBH), it also considers innovations in timber construction. Both technologies provide opportunities to help the construction industry increase sustainability and reduce cost by saving construction time and site disruption. The research in this section draws upon numerous interviews and research with FBH builders, developers, timber engineers and architects, and provides case studies for a variety of relevant projects.

The first part provides a primer on FBH. The second part provides details on three FBH case studies in the Bay Area. The third part looks more closely at heavy-timber and cross-laminated timber (CLT) construction with two international case studies.

3.1. Factory Built Housing Construction

> *'There has been a revolution in the production of goods, but we still construct buildings the way our grandfathers did – inefficiently' – Factory-Built Housing Manufacturer*

From computerization and robots to just-in-time inventory management and advanced logistics, manufacturing has been revolutionized, with increasing efficiency and worker productivity. From technology to cars to furniture, the cost for both producer and buyer has been driven down, opening markets and allowing consumer dollars to go further. Yet the last revolution in construction occurred over 100 years ago with the development of steel-framed construction, and as a result construction costs have only risen, exacerbating housing costs and leading to a growing affordability gap. (McKinsey 2014, pp. 1)

Development costs consists of both soft and hard costs. Soft costs include design and engineering consultants, real estate taxes and insurance, fees and financing costs, while hard costs include construction labor and materials. The use of FBH can reduce both categories of cost, resulting in significant project savings; however, these can vary widely depending on location and size of project. In many places, hard costs are the primary driver of development costs, but in San Francisco soft costs can result in a significant portion of the total development cost due to the lengthy entitlement process and impact fees assessed to each project.

Reducing both soft and hard costs is possible using FBH. The primary driver of lower soft costs is the reduced amount of construction time, leading to lower financing and time-based costs such as insurance, real estate taxes, and project management personnel. This is evidenced by sample projects and discussions with those who have completed FBH projects in San Francisco and elsewhere. Hard cost reduction is achievable due to a reduction in waste and travel to construction sites, as well as potential labor cost reduction.

This section will review FBH construction methodology, provide case studies in the Bay Area, provide a special discussion on sustainable materials and innovative projects, and summarize the benefits and constraints of "going modular".

3.1.1. What is Factory-Built Housing?

> *"Factory-built homes are constructed almost entirely in a factory and arrive at the site 30 to 90 percent complete. In manufactured and modular homes, 70 to 90 percent of the work – framing, insulation, roofing, siding, doors and windows, electrical, plumbing, appliances, and interior finishes such as painting and carpeting—are completed in the protected, secure environment of the factory."* (HUD 2001)

Factory built housing is essentially prefabrication of entire housing modules that can form complete housing units or portions of units, in either single-family or multi-family projects. The manufacture of FBH modules can occur simultaneously with site preparation, saving valuable construction time. As they are completed, the modules are then transported, usually by truck, to the site where they are lifted by crane into position beside and atop one another.

FBH brings industrial process to the construction industry, and along with it the benefits of mass production. This section will detail the characteristics of FBH, its advantages and potential issues that can arise. It will also profile a FBH manufacturer local to the San Francisco area, Zeta Design + Build.

3.1.2. FBH Characteristics

There are several factors that set FBH apart from site-built residential construction. The characteristics of FBH and differences with site-built construction are described below.

3.1.2.1. FBH is Process Driven

Factory-built housing production is process driven, as opposed to site-built construction, which is project driven. This means that in order for FBH to achieve efficiency, the production must adhere to a process and the various players need to participate fully. With site-built projects, many decisions can be made much later in the development process, sometimes during construction, which cannot occur with FBH. As with any manufacturing process, FBH reaches economies of scale through repetition.

General contractors usually become involved in development projects once design is complete or nearly complete, and expect to work from complete drawings with limited interaction with the design team. As developers explore using FBH for their projects, they need to consider involving general contractors earlier in the development process.

The general contractor and others involved in setting the modules on-site need to visit the factory and participate in early design meetings, so that they become familiar with how the modules are designed and how they "fit" together, and what elements must be provided on the site and how the modules interact with site-built foundations, utility connections, etc. Costly delays can occur if the general contractor is learning how to assemble a project as FBH modules are arriving on-site. Further, involving the general contractor early can lead to new innovations that can be designed into the manufacturing process. For example, at Zeta (described below) early general contractor participation led to the development of a metal peg device that allows for more accurate stacking and setting of modules, saving time and potential problems later. Once developers and contractors have experience and understand FBH, efficiencies grow and costs come down.

Finally, to aid in the coordination between design teams, FBH builders should be Construction Specification Institute (CSI)-based to match the general contractor and procurement firms because the order sheets are usually specified based on CSI.

3.1.2.2. FBH Requires a Design Lock

The FBH process requires a "design lock" early in the process to achieve the cost efficiency of FBH by minimizing change orders for finishes or other components. Early design lock requires that developers stick to their design decisions. One recommendation is that developers considering FBH have a design-guide, or owners project requirements, ready early in the process.

3.1.2.3. FBH Design

Innovative and interesting design is achievable with FBH. One common misconception is that modular technology inhibits design diversity and results in boring, blocky projects; however, efficient design does not imply boring design.

Completion of the exterior may be done on-site using pre-fabricated materials. Interesting exterior design is possible, as the pre-fabricated building cladding of the envelope attaches to the modules on-site. Further, design variation can and should occur on the exterior to help FBH projects integrate into the architectural context of the project, and provide visual interest. For San Francisco and west coast climates, it is possible to adapt the design to allow for outdoor decks, which serve the additional benefit of allowing the units to feel larger. (Macht 2008)

Another concern is that FBH interiors will look the same; however, while the internal units may have similar dimensions in a project, unit sizes can vary based on manufacturer and design specifications between projects. For example, FBH modules can form entire units or be combined to form two or three-bedroom units. Two or even three-story volumes can be integrated into the design, just as spaces larger than the dimension of a single module can be achieved with careful design. They can also be single-or double-loaded allowing for greater design flexibility. (Ibid) Fixtures and textures can and should vary between projects as appropriate; it is just important that these design decisions are made early.

3.1.2.4. FBH Quality

FBH products are usually of higher quality compared to site-built construction, due to numerous factors. For example, factories are usually climate controlled and FBH modules can be manufactured in dry, well-lit conditions. These factory conditions can also help reduce human errors. At the Transform factory in Washington, building information modeling (BIM) links up directly with computerized equipment that reads the three-dimensional computer-assisted design (CAD) files and translates them into the computer-assisted manufacturing (CAM) for the optimizing saw and other robotic equipment, guiding the machinery to precisely cut and assemble components, reducing waste. A framing station uses automated nail guns, nail plate presses and multistage drills and routers to assemble walls in full lengths, horizontally. Floors and ceilings are assembled on rolling platforms at separate stations, while licensed professionals install plumbing and wiring in easily accessible open sections. Insulation is easily applied. Walls are run through a multifunction bridge that nails, screws, glues, and staples sheathing to them. (Ibid)

> *"Because most work is done while module components are lying flat, men and machines use the force of gravity to improve quality with easy access without ladders. Sliding ceiling cranes then lift walls onto the floor platforms. Sheetrock compound and tape are applied in a closed environment that captures dust from sanding and fumes from painting. Flooring, windows, cabinets, fixtures, and appliances are installed in nearly finished modules that are shrink-wrapped for transport to the site." (Ibid)*

Superior acoustic separation is possible as using FBH modules will often result in double party walls between units, as opposed to site-built units that have a single party or demising wall. Floors and ceilings are often decoupled between modules, creating greater vertical sound isolation, and sound-deadening material can be laid in the floors at the factory to further minimize noise between floors. The end result is a product that is solidly and consistently built, with often-superior acoustic and thermal building performance.

3.1.2.5. FBH is the Complete Package

FBH modules typically leave the factory "complete" and sealed, including insulation, appliances, cabinets, electrical components, kitchen and bathroom fixtures, etc. Because they are complete, FBH reduces the amount of work on-site including delivery and installation of interior building components, which can be installed in the factory at substantially lower cost and with less effort. FBH modules leave the factory completely sealed and protected from the elements.

Once on-site, FBH modules are connected to the structure and each other, and main mechanical, electrical and plumbing (MEP) systems. Because they are sealed until set on-site, the risk of vandalism or theft can be lower relative to site-built construction.

3.1.2.6. Plan Checks and Building Codes

FBH must meet the same building codes as site-built housing; however, FBH modules are (typically) approved according to the prevailing state Building Code. In California, FBH modules receive an insignia from the Department of Housing and Community Development (HCD), which also approves Plan Checks. Typically, an HCD-approved third-party inspects and affixes the insignia on each FBH module before it leaves the factory. While the units are approved according to state building code, the complete building must still meet local building codes with regard to assembly and life-safety.

3.1.2.7. Hard Costs

Development projects are comprised of hard and soft costs. FBH construction hard costs relate to materials and labor, both in the factory and onsite. FBH construction can result in significant hard cost savings, due to volume purchasing of materials and lower labor costs. Further hard cost savings can result from greater precision, resulting in lower waste, and a reduction in deliveries. Other potential savings include reduced risk of injuries, as more work occurs in a safer, controlled environment, and reduced disruption at the site (traffic interruption, police details, security, etc.).

One modular builder serving northern California places the base cost of modules at about $78-84 per square foot for everything 'in the box', including design but not including transportation or installation on site. The price increases from there based on the project requirements. One San Francisco developer considering FBH for a large luxury project estimates the cost, with high-end finishes and utilizing union factory labor, to run $170-220/SF, compared to $240-300/SF for a comparable site-built project.

3.1.2.8. Logistics

Logistics is one of the most important considerations for FBH construction. The primary issues revolve around distance, storage, site constraints and cost.

Transportation cost can vary, but one estimate is that a standard module can cost $9 per mile to move in California.
The size of the FBH modules can also affect transportation costs significantly. For example, while 16-foot wide modules require a flag car when traveling on public roads a 17'8"-wide module can

cost four times as much due to the need for police escort. A narrower 12-foot wide FBH module does not require a flag car.

Some factories are "full-service" in that they require their vehicles to transport modules to the site while others do not transport the modules. In the latter case, the general contractor may be responsible for arranging transportation. This method may be beneficial as transportation can be bid among many different logistics companies. A drawback is that some may not have experience transporting "complete" homes. Also, careful negotiation is necessary to determine liability and "ownership" of modules in case of transport damage.

Another cost relates to the necessity of a crane to lift modules into place, even for small projects. Each module can weigh between 25,000 and 45,000 pounds, so it is critical to work with the crane contractor early in the process to make sure they have the proper equipment, such as a spreader bar, and that necessary precautions are taken with regard to the swing dimension and overhead utilities, etc. It is also important that timing is such that the crane is only on-site when it is in use. One developer had a small crane on site for a part of the project, removed it for two weeks for additional site work, then brought it back to set the final FBH modules. It is important for developers do their homework before bidding crane operators.

Storage is another cost consideration. Many sites, particularly urban infill sites, are space-constrained and simply have no room for FBH modules if they arrive too early. For this reason, it is important to work with the FBH manufacturer and/or logistics contractor to identify potential storage or (nearby) shuttling location(s) if the need for it arises.

The transportation costs can be partially offset by a reduction in deliveries to the site relative to site-built construction.

3.1.3. FBH Advantages

The following is a summary of FBH advantages that range from lower costs related to fewer change orders and design decisions to quicker marketability of housing units. All of these advantages result in lower overall risk for the project.

3.1.3.1. Design Simplicity

FBH often involves simpler design, which can help reduce conflict and lower the number of change orders on a project. The advent of building information modeling (BIM) and software such as Autodesk's Revit allow for better coordination between design disciplines and procurement specialists. BIM allows for greater visualization when designing buildings and infrastructure and can result in significant waste reduction. On a typical project, while the three-dimensional design process can take up to a couple of months, it can occur simultaneously with permitting.

One big advantage for developers is that FBH module manufacturers already have base design complete for many product types, reducing the need to reinvent the wheel for each subsequent project. Essentially, once the "box" is designed in the BIM, new projects only require decisions on interior finishes and exterior design.

FBH factories can help developers reduce design conflicts early in the process, before modules go under construction, resulting in significant savings through elimination of change orders. This compares to site-built building where site conditions, supplier issues or other unknown events can necessitate costly change orders and cause delays.

3.1.3.2. Significant Time Savings

FBH can also help developers bring housing units to market faster, primarily though shorter construction cycles, resulting in both lower financing and time-based soft costs, and earlier project stabilization, as revenue streams can be realized sooner. As a result of the faster development cycle, FBH can help developers move on to new projects more quickly, which in a market with perennially tight supply such as San Francisco, can help ease the affordability crisis if they can move on to new projects quickly. It also reduces developer overhead costs on a per-project basis.

The shorter construction period inherent with FBH delivery can help smooth out the boom and bust nature of the real estate cycle. Construction lag contributes to the mismatch of supply and demand, which results in the boom/bust problem of the real estate cycle. This occurs because the longer it takes developers to bring product to market, the less likely the new supply will exactly meet demand. By enabling quicker development, FBH can help smooth out these swings by bringing product to market faster.

3.1.3.3. Potential Cost Savings

As developers continue to seek ways to reduce high construction costs, they are leaning on general contractors to bring costs down. Both sides recognize the cost-saving potential of FBH construction and they are working with modular factories to realize these savings. Total project cost savings by using FBH construction versus site-built construction are project dependent.

Time savings is perhaps the biggest effect of FBH construction on project budgets. FBH construction can lower construction time by up to 50 percent because FBH modules can be manufactured simultaneously during site work. However, the construction time savings does not translate proportionally to project cost savings as total project cost can vary widely. For instance, soft costs can add significantly to overall project budgets as can labor costs. Logistics can add significant cost as well, particularly if the factory is far from the project site or if timing does not align and FBH modules arrive too soon. Finally, project size can affect the total cost savings as larger projects benefit more from the economies of scale that FBH can provide. FBH manufacturers claim a minimum of 100 FBH modules is the "sweet spot" to achieve the full benefit of factory efficiency. In total, overall project cost savings may range from 5 to 20 percent.

In summary:

- FBH can result in significant savings, both from construction costs to lower carrying costs that result from shorter project timelines.

- It is important to involve the necessary contractors and consultants early in the design process if a developer is considering FBH construction. All actors much play within the rules, including the general contractor, architects, logistics and engineers.

- Achieving cost effectiveness on small projects is challenging because the level of pre-construction effort is similar to that of large projects, therefore smaller developers need to consolidate their needs upfront.

- FBH Modules can start as low as $78-84/square foot; this is for the box and its contents only; 100 units or more is the sweet spot for cost efficiencies.

- Overall project cost savings may range from 5 to 20 percent or greater.

- BIM and Revit help reduce risk. Also, they help reduce waste and inefficiency as all components are ordered directly from the software. As a result there are usually fewer change orders.

- The more modules that are set per day, the less risk there is vandalism and exposure to weather.

3.1.4. Potential Concerns with FBH

Factory built housing is not without issues that could reduce or eliminate the potential cost savings that a developer might expect. The following summarizes the important issues that developers should be aware of as they pursue FBH.

- Sub-contractors need more experience on bidding, as many remain unfamiliar with FBH processes. FBH manufacturers can help.

- FBH manufacturers should coordinate specifications systems (such as CSI) among all involved parties to aid in transferring drawings and procurement.

- The perception of "modular" as a lower quality solution can be overcome through education and touring high quality FBH projects.

- Permit and building inspectors usually vary project to project, so their level of expertise with FBH may differ significantly. The education process can be lengthy. San Francisco and San Jose now have experience with modular, while Oakland has had some hiccups due to experience with a subpar project. Developers should work with FBH manufacturers to involve the city in the process intensely.

3.1.5. A Note on Trade Unions

Developers express pessimism when asked about FBH because of concerns about trade unions, particularly in cities such as San Francisco where unions wield a lot of power. These concerns revolve around reducing construction time and increasing off-site production; however, just because materials are made off-site do not imply they are being made without union participation. Labor groups may also have concern that existing crews do not have training for new construction innovations such as FBH or taller timber buildings. For initial projects, training may be necessary, and in the case of Stadthaus (see

Section 3.3.2), the developer brought in builders with experience erecting cross-laminated timber (CLT)-framed structures for the first project who then also trained local workers from the community on the techniques so that future buildings could be built with local labor.

There are several aspects of FBH (and in prefabricated CLT), though, that are appealing to trades, including the following:

- Trade unions offer good training and often higher quality workmanship, which is important for assembling FBH modules.

- FBH construction is safer as some trades do not have to work on active construction sites.

- FBH construction requires less physical strain enabling more women to participate.

- FBH construction can provide greater job stability if the real estate cycle becomes smoother due to shorter development and construction time lag.

- During housing downturns, factories can shift to other products, for example hospital, dormitory, or assisted living facilities.

- Electricians/plumbers will have less on-site work, but some new factory work; their work should be easier as modules come "plug-and-play", ready to receive connections from the factory. The amount of work may increase if projects can be completed more quickly and become more numerous.

- If more advanced machinery is used, technicians may be necessary to operate the equipment creating higher skilled jobs.

- Often, plumbing and electrical connections are provided in the corridors so that when they are "set" on-site, these trades are necessary to connect each unit to the main conduits. This eases the work on-site, but requires close scheduling coordination.

- In a housing-supply constrained region such as the Bay Area and with a goal of FBH to provide housing more quickly, there is potential for more projects resulting in more overall work for all workers.

3.1.6. Local FBH Manufacturer Profile: Zeta Design + Build

Zeta Design + Build is a northern California FBH manufacturer based in San Francisco with a factory in McClellan, just outside of Sacramento. The following is a summary of the operations.

3.1.6.1. The Factory

- 100,000 square foot facility with outdoor storage for completed modules.
- Operates on one shift with a total of about 70 employees, including management and a design team.
- Produces 4-5 modules per day.
- Could increase the number of shifts but preference is first given to overtime if production spikes. Operating three shifts could yield 10-12 modules per day (reduced due to shift changes).

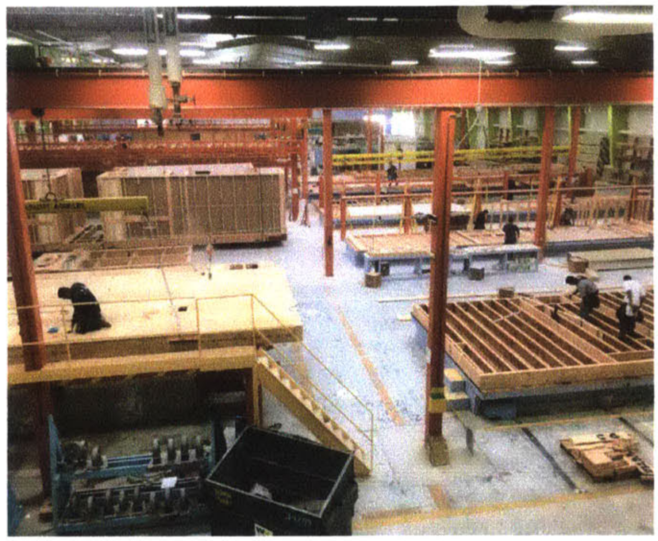


Figure 8 – Zeta Factory Floor
Image taken November 7, 2014

3.1.6.2. The Modules

- Typical module width is 16′; can go up to 17′8″.
- Modules can be designed for single-loaded or double-loaded building types; for double-loaded the central corridor is built with the FBH modules in the factory.
- Modules are usually complete when they leave the factory. If there is a problem with a supplier, the production line continues and the missing supplies are added on-site, for example windows, cabinets, faucets, etc. The goal is to have the modules 80-90% complete at the factory.
- Elevators are installed on-site, but stairs and shafts can be built at the factory.

- Sprinklers are installed and can be inspected at the factory.
- All exterior work that can be is done on-site.

- Zeta has no upcharge for introducing sustainable components; for example, the baseline includes ecological friendly insulation such as Ecobatt.

Figure 9 - FBH Modules Under Construction

FBH module designed for a double-loaded building with central corridor (left). Modules are complete when they leave the factory, including doors, windows and cabinets (right). Images taken November 7, 2014.

3.1.6.3. Zeta's Quality Control Process

- Quality control is an important facet of FBH. At Zeta, all modules have a unique SKU and quality control checklist that remains with the FBH module through construction. When complete, the module is inspected and receives a seal from the third party inspector.

- Zeta uses a third party building code and permit review team, approved by the California HCD.

- Zeta welcomes building departments staff/inspectors, as well as developers, contractors, investors, etc. to visit the facility.

3.1.6.4. Working with Trades

- Zeta does not erect the modules or transport them and recommends that this become the expertise of the general contractor, whom they are a sub-contractor to.

- The factory is set up for wood only; but heavy-gauge metal and steel options are under investigation for product diversification. For example, under current CA codes, wood cannot be used for medical facilities or for more than five stories of residential construction, either independently of as part of a six- or seven-story building with a one- or two-story non-combustible base.

- Zeta generally supplies the modules to the GC who then warranties the project. The GC is also responsible for transportation and setting the FBH modules on-site.

- The carpenters union is a signatory to the factory; they are most affected by FBH and want to be involved as they see that this is where the industry is going. Due to lower risk of factory work, labor costs may still be lower relative to on-site.

- Zeta's interests are aligned with union interests as unions offer organizational support and training for workers.

- Zeta was already paying a living wage and estimates that working with the union did not add significant cost.

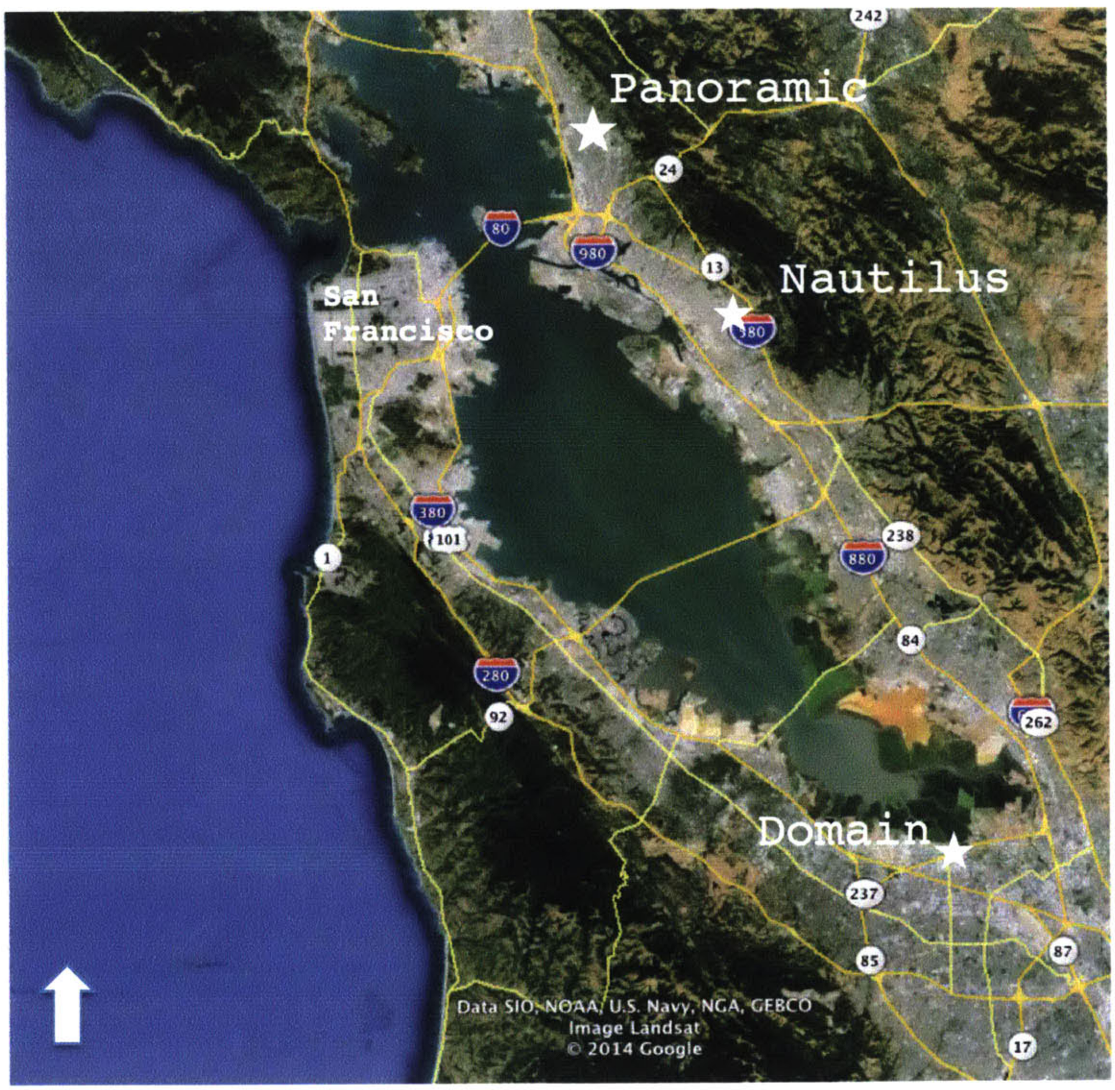
3.1.6.5. Cost

- Zeta focuses more on creating a high quality product and invests time in working with developers, contractors, etc. in insuring project success. In the Bay Area, the focus is more on quality control; Zeta expects that FBH can reduce costs by up to 20 percent.

3.2. Bay Area Factory-Built Housing Case Studies

FBH is relatively new to San Francisco and the Bay Area; however, there are a few projects completed over the past few years and several are currently under development. This section includes three Bay Area case studies. Each case study is unique. The first is by a smaller Berkeley developer (Panoramic Interests) that is now working on a second FBH project. The second is a Sam Jose project (Domain) by Equity residential that recently completed their first FBH project. The third is by Nautilus, a vertically integrated firm that has developed their own factory and is pursing FBH for several projects. Figure 10 shows the location of the Bay Area projects.

Figure 10 - Bay Area Factory-Built Housing Case Study Locus Map



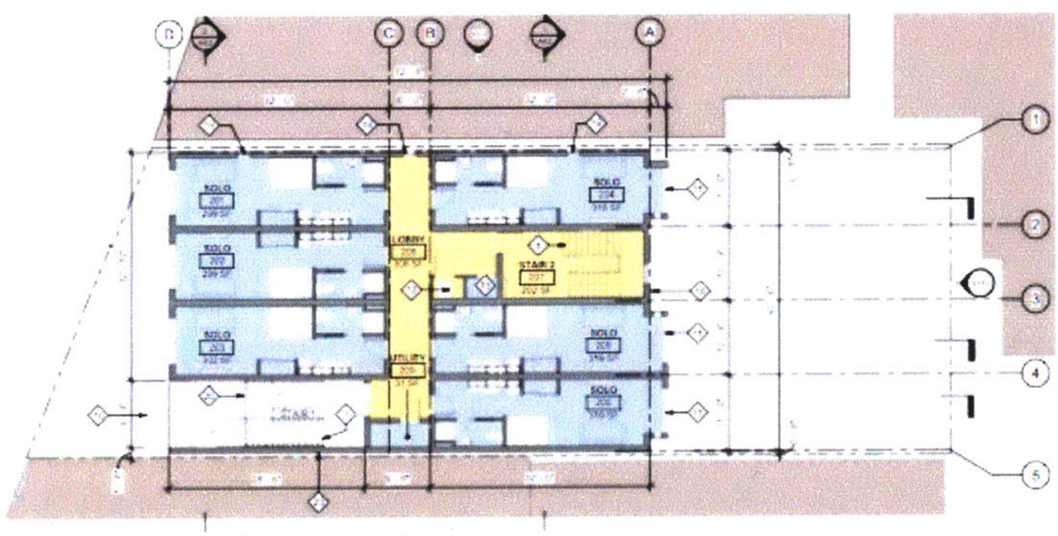
3.2.1. Panoramic Interests

Figure 11 – 2711 Shattuck Avenue Rendering
Source: Panoramic Interests

Panoramic Interests is an innovative Bay Area real estate developer with experience in FBH construction and was a pioneer of the methodology with the development of 38 Harriet Street in San Francisco's SOMA neighborhood, completed in 2010. Panoramic estimates that 38 Harriett Street, being its first FBH project, cost about the same as a site-built project; however, subsequent FBH projects would benefit from the experience as the developer and general contractor were both new with the process.

Panoramic is again pursuing a FBH project at 2711 Shattuck Avenue in Berkeley, just across the bridge from San Francisco. Specializing in micro-units, Panoramic is proposing to develop 22 micro units in a 4-story building on a 0.13-acre site. The project summary is below.

Figure 12 - 2711 Shattuck Avenue Floor Plan



Source: Panoramic Interests

Table 7 - 2711 Shattuck Avenue Project Summary

	Zoning	Proposed Project
Lot Area		5,674 SF / 0.13 Acres
Allowable FAR	4.0	1.78
Height	50', 4-stories	46'5", 4-stories
Building Footprint		3,084 SF
Floor Area		10,119 SF
Lot Coverage	35% Max	54%
Units		22
Open Space	880 SF	1,983 SF
Development Cost		$5 – 5.5 million

Source: Panoramic Interests

With FBH experience under its belt, Panoramic was aware of the potential cost savings of FBH but as any good developer they compared the cost of FBH with site-built construction. Numerous bids reveal the potential cost savings that FBH can provide for a small project are found mostly in soft costs, as the construction time period and subsequent carrying costs is reduced. The owner also benefits by beginning rent collection significantly earlier for a gain in revenue of about $160,000 total for the 22-unit project.

With a development time savings of six months for FBH construction versus site-built construction, Panoramic estimates a reduction in soft costs of about 32%, or about 7% of the total project cost. This time advantage also allows Panoramic to begin rent collection six months sooner, yielding about $160,000 in additional revenue.

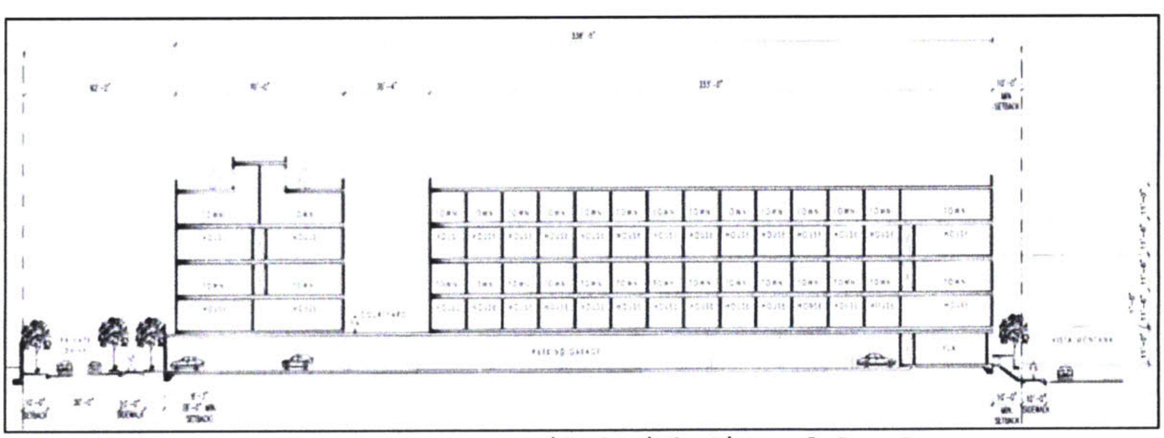
3.2.2. Domain – San Jose

Figure 13 - Domain
Source: Equityapartments.com

Equity Residential is the developer of Domain in San Jose, a 444-unit apartment community built using FBH construction. The project is located in north San Jose, a growing mixed-use, transit-friendly region of Silicon Valley. Development began before the downturn, stalled and was resurrected in 2011. Completed in 2014, Domain is one of the largest FBH projects in the state.

Domain consists of stacked-townhome units of Type V construction over one level of at-grade parking (see Figure 14). Table 8 shows the project summary.

Figure 14 - Domain Stacked Townhome Section Drawing



Source: General Development Plan Filed with City of San Jose

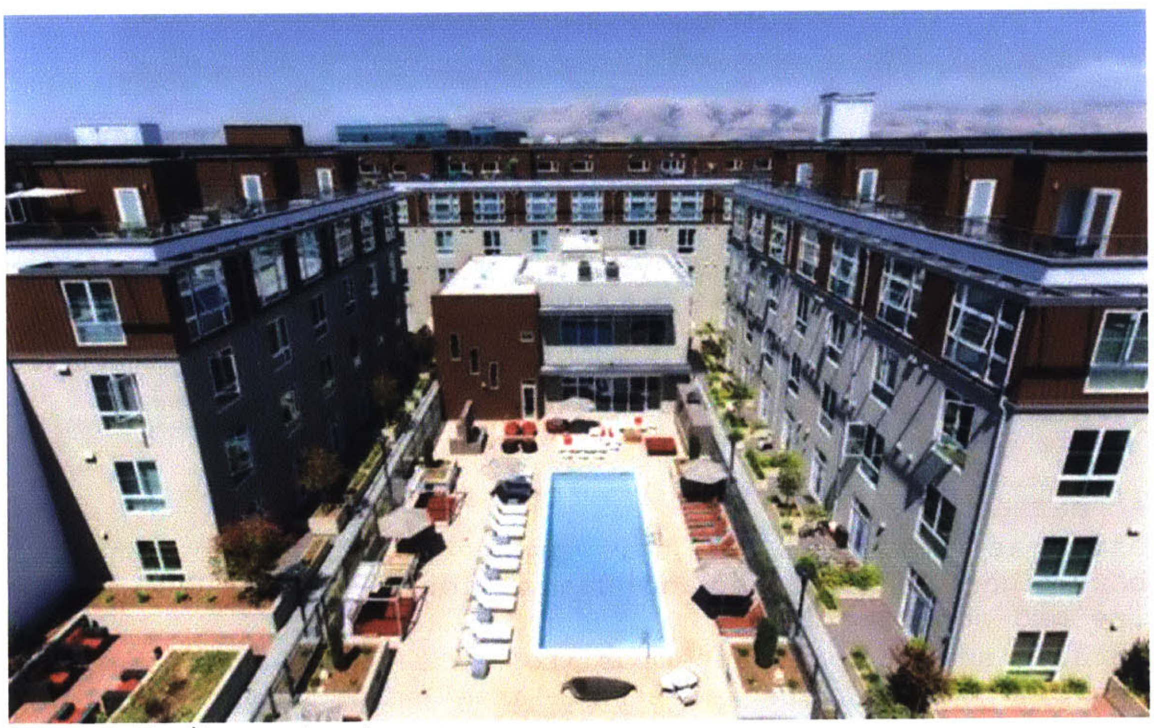
Table 8 - Domain Project Summary

	Zoning	Proposed Project
Lot Area		6.9 Acres
Height	75'	4-stories over parking
Building Footprint		~226,700 SF
Floor Area		~450,000 SF
Lot Coverage		75%
Units	55 du/acre minimum	444 (~64 du/acre)
Open Space	160 SF/du	5 acre park land dedication (98 SF/du)*
Parking Spaces	670	679
Development Cost		$154.6 million/$338 NRSF

* Not included roof decks or other on-site open space)
Source: Equity Residential and City of San Jose

The project features amenities common in large planned communities, including a pool and spa, clubroom, fitness and business centers, and Equity donated an adjacent 5-acre parcel to satisfy the open space requirements. To showcase the flexibility of FBH construction, 234 units have private roof decks.

Figure 15 - Domain Outdoor Common Area



Source: Equityapartments.com

Equity purchased FBH modules from Boise, Idaho-based Guerdon Homes, who manufactured and delivered the FBH modules to the site. Guerdon Homes is a FBH supplier for western parts of the U.S. and Canada, with an annual capacity of about 1,200 modules. Each Domain FBH module measures 15-feet by 70-feet, and delivery of all FBH modules took two months while setting them took a total of six months. In total, the using FBH construction saved just under three months in total construction time and saved between five and ten percent in cost. (Interviews with developer and builder, Azevedo 2012)

Figure 16 - Domain Under Construction

Source: Equity Residential

Lessons Learned

- Design is important. On this project, Equity had concerns about the flat façade and limitations to the FBH module size and construction.
- Overall quality is superior to site-built construction; however, there were some failures with lower-cost MEP systems.
- Double-thick party walls, floors and ceilings improve sound insulation.

- Manufacturing costs need to be low enough to compensate for transportation and craning costs on-site.
- For such large projects, there are limited suppliers.

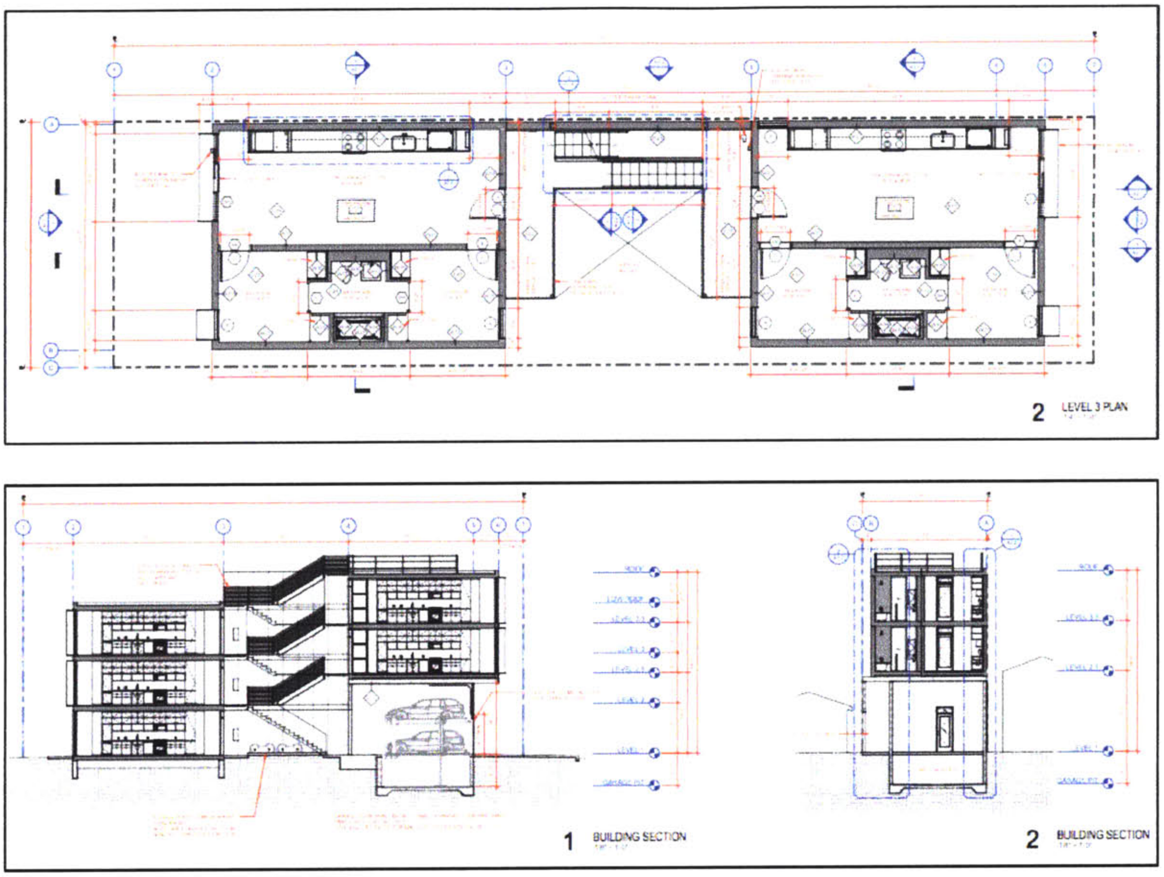
3.2.3. Nautilus – Oakland Prototype Project

Figure 17 - Nautilus: Oakland Prototype Project
Source: The Nautilus Group

The Nautilus Group is a Berkeley-based, vertically integrated design and development company that is planning several projects using FBH. Uniquely, Nautilus purchased a factory to manufacture FBH modules in Lathrop, California under the name NEMO Building Systems, with the goals of reducing "the industry standard material waste by 90 percent, improve the quality of our buildings, and minimize the impacts associated with site-built construction techniques." (Nemo 2014)

After several years of development and a steep learning curve, Nautilus recently completed a 5-unit project near Mills College in Oakland. The site measures 2,500 square feet (25 feet by 100 feet) with existing residential abutters. The project has two buildings: one with three units in the rear of the site, a central courtyard, and a second building with two units above a below-grade podium at the front of the site. (see Figure 18)

Figure 18 - Typical Floor Plan (top) and Building Section (bottom)



Source: The Nautilus Group

Each 690 square-foot two-bedroom unit is comprised of two FBH modules: the living/dining/kitchen area is one 30-foot by 13-foot module connected to a second 30-feet by 10-feet module with two bedrooms and a shared bath in between them.

The Mills College project is Nautilus' first FBH project and is a prototype to test out its vertically integrated process. All design, engineering and manufacturing occurred in-house. Construction began with sitework in August 2014 and was substantially completed in December 2014. Nautilus estimates that building everything on-site would have probably taken a similar amount of time and that the lack of time savings had to do specifically with the layout of the site.

Construction staging was such that the foundation for the first three units was poured and three modules stacked. At this point, the small crane was removed from the site while the podium was built at the front of the site. Once complete, the crane returned to lift the remaining modules into place, at which point there was some disruption at the sidewalk and adjacent roadway due to the lack of staging areas for the crane.

Nautilus estimates that future FBH projects will achieve about a 20 percent development cost reduction, not to mention the significant time savings in construction.

Figure 19 - Nautilus Prototype Rendering

Source: Nautilus Group

3.3. Timber and Cross-Laminated Timber Construction

The three Bay Area case studies are of Type IV or V construction. In fact, there have been no high-rise FBH projects in the Bay Area and few in the United States. The potential exists, however, to bring the sustainability and time savings benefits of wood and timber to taller projects. As part of the research for this thesis, site visits and interviews were conducted at two European projects that demonstrate the potential for timber and FBH: Treet in Bergen, Norway and Stadthaus in London, UK. Each project is described below and the innovative construction methodology of Treet is included in the Appendix. A summary of the benefits and potential issues concludes this section.

Figure 20 - Treet: The World's Tallest Modular, Timber-framed Building

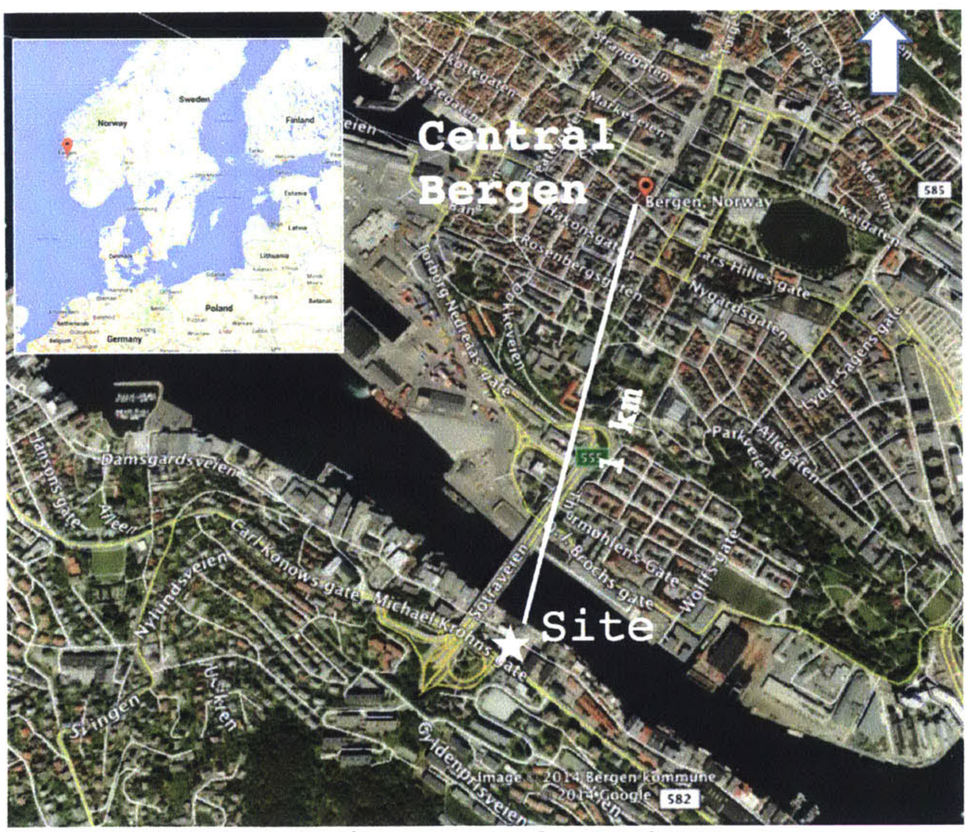
3.3.1. Treet – Bergen, Norway

Bergen og Omegn Boligbyggelag (BOB) is the developer for Treet, the world's tallest (14-story) timber-framed, FBH building, currently under construction in Bergen, Norway. Treet is part of a larger redevelopment project one kilometer (as the crow flies) from the center of Bergen on the northern bank of the Damsgårdssundet adjacent to the Puddefjord Bridge (see Figure 21).

Table 9 - Treet Project Summary

Height	147-feet 14-stories over parking
Building Footprint	5,199 SF
Floor Area	62,754 SF
Units	62
Development Cost	Undisclosed

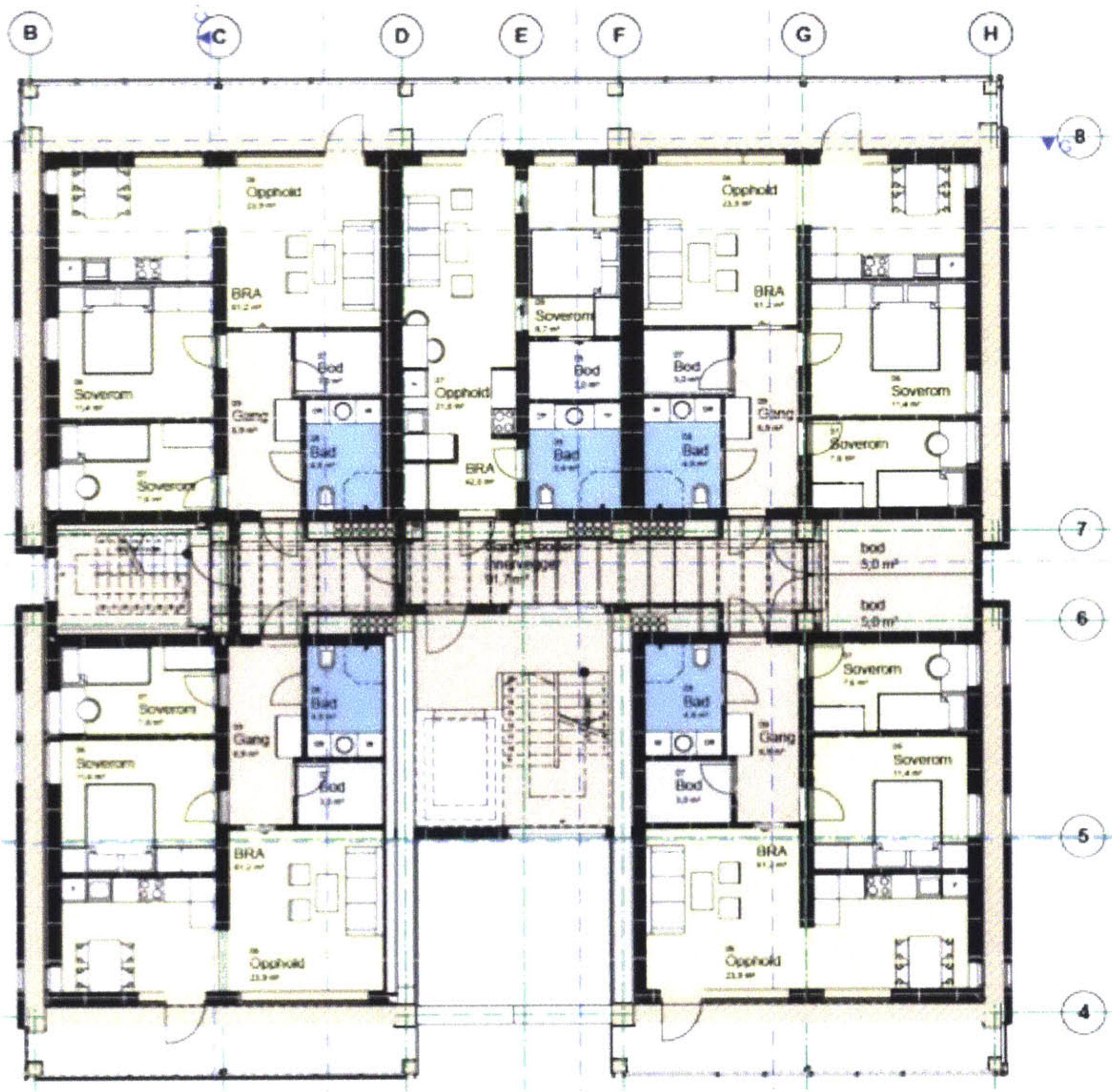
Figure 21 – Treet Locus Map



Source: Google Maps (inset), Google Earth

The project has 62 units: 52 two-bedroom units and 11 one-bedroom units. Each unit is comprised of multiple FBH modules and elimination of two vertical modules provides space for a double-height fitness center.

Figure 22 - Treet Typical Floor Plan



Source: Abrahamsen

The driving principles for the project are to increase density, build using wood, and industrialize construction. Development for Treet began when the master planning for the redevelopment site ended in 2004 and completion will occur by November 2015.

The lengthy timeframe from conception of the project is partially due to market conditions, but also from delays by planning officials, who had trouble with the building's innovative construction and height. Even after a public referendum in support of the project, planning officials took six months to process necessary paperwork. BOB persisted, though, because if they followed the Master Plan to a tee they'd be 'building the city of the past, not the city of tomorrow'. This goal ultimately led the team to pursue building the tallest wood structure in the world. As a "lighthouse project", BOB hopes to inspire other developers to go taller with wood, and estimates the upper limit for the technology to be about 30 stories. (Kleppe 2014)

Figure 23 - Treet Structural System
Source: Abrahamsen 2014

The first principle for the project is to build taller, due to the increasing need to densify as cities become built-out. The second principle of the project is to build from wood, a sustainable construction material widely available in northern Europe. Combined with the third principle, industrialization of building construction, BOB's decision was clear that wood modules supported by thick glulam timber (see Figure 23) was the way forward because they recognize that building with concrete and wood using hammers, saws and heavy equipment on-site is inherently inefficient, though is done because it's familiar.

Treet is innovative not only in being one of the world's tallest timber-framed buildings, but also because it combines timber-framing with high-rise FBH construction. Details on the construction techniques are available in Appendix D.

There are three different module types, one for the one-bedroom units, one for standard two-bedroom units, and one for units where the glulam beam goes through the module. Two of the FBH module types are about 13 feet by 26.2 feet and the third is 16.5 feet by 26.2 feet.

According to the developer, it is ideal for manufacturing to minimize variation, so the architect is limited to designing 'within the box'. The modules, built in Estonia, are shipped to the site and off-loaded on-site. Ideally, modules would arrive as the site is ready to receive them, but this logistical issue can be challenging. At Treet there is available space to store units until the structure is ready (Figure 24).

Figure 24 - FBH Modules Stored at Treet Site

Image taken October 15, 2014.

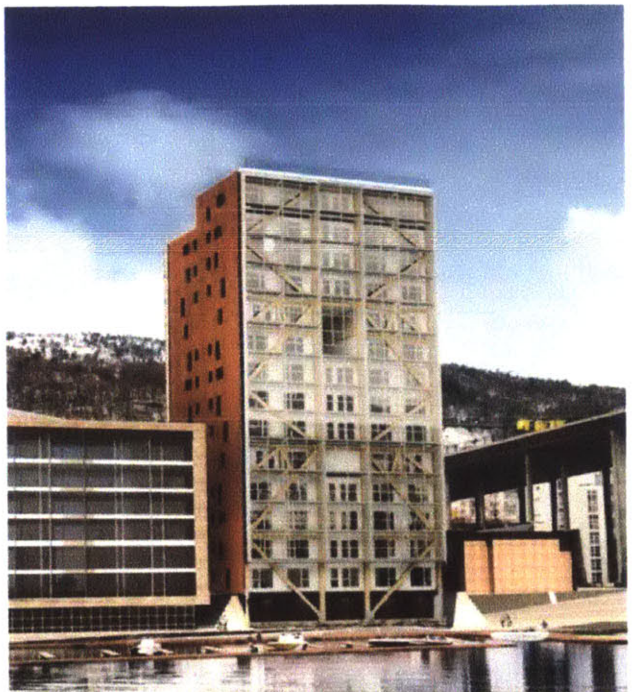
Due to Bergen's heavy rainfall (over three meters annually), the external glulam frame will be protected by a metallic material on the sides and glass-faced balconies on the front and back, facing the street and water. The balconies will be attached after the modules are in place, requiring a unique adjustable scaffold attached to a lift (see Figure 25).

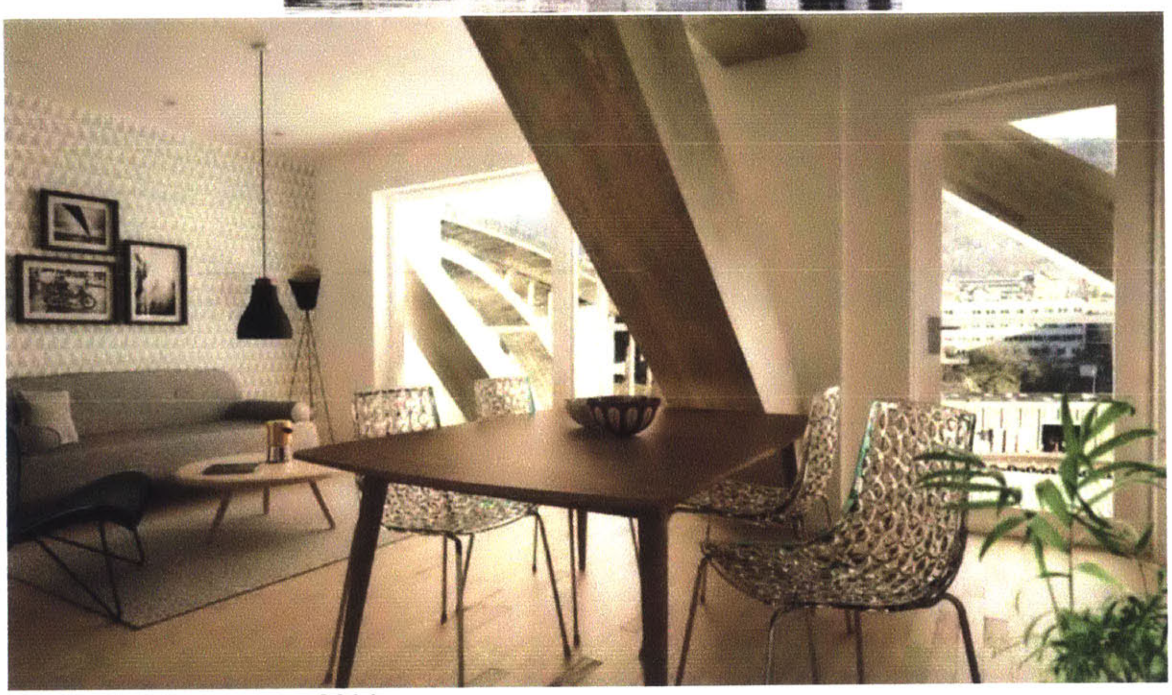
Figure 25 - Innovative Adjustable Platform Tower-Lift Scaffold

Image taken October 15, 2014.

The final step will be the installation of the steel side curtain wall and glass balconies to protect the glulam timber from the elements. The resulting building is architecturally interesting with the structural glulam clearly visible from the outside as well as within some units (see Figure 26).

Figure 26 - Exterior (top) and Interior (bottom) Renderings





Source: Abrahamsen 2014.

In Bergen and Europe, as in many parts of the United States, increasing density is the only way to support increasing urban populations. As part of a larger redevelopment project, as in parts of San Francisco such as SoMa and the Dogpatch, Treet is bringing housing to a former industrial area, within easy walking, biking and transit distance to the city center. Bergen, site of a UNESCO World Heritage Site, clearly understands that density and height are necessary to grow, but the historic, picturesque city is maintaining it's character by specifying where density and height can increase, again similar to San Francisco. Politicians and citizens are supportive of the project, and planners were happy so long as the project conformed to the master plan.

3.3.2. Stadthaus – London, United Kingdom

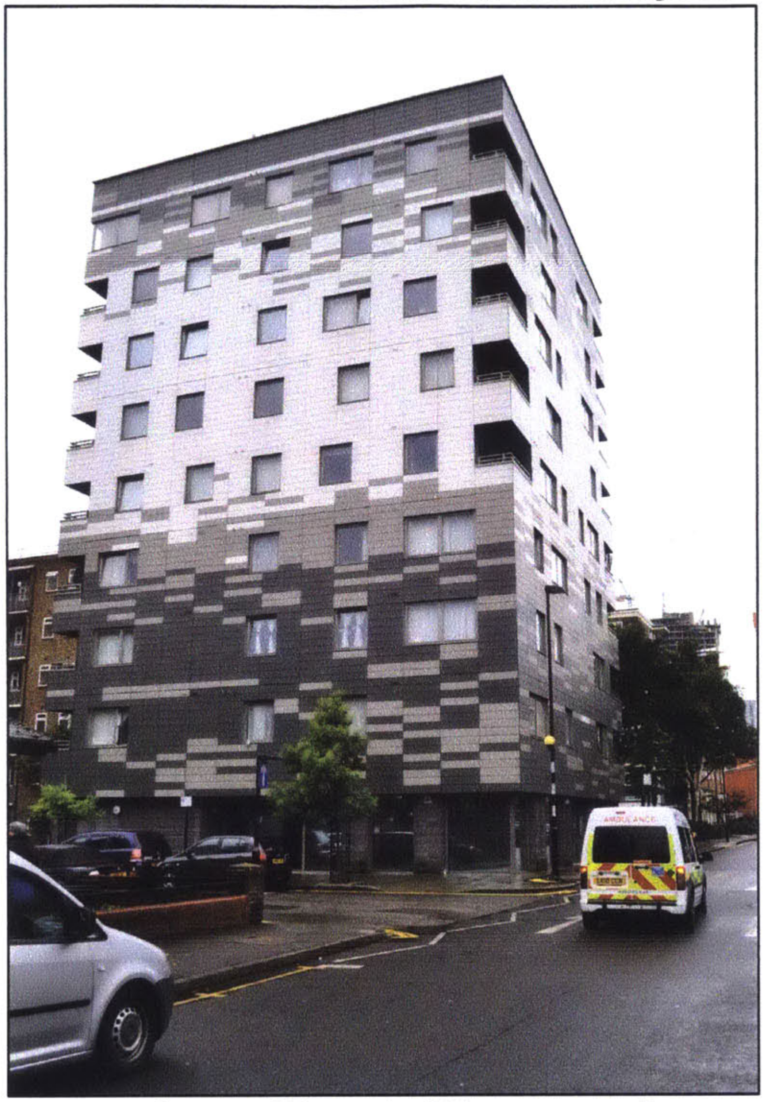


Figure 27 - Stadthaus, London
Image taken October 8, 2014

> *"Substituting concrete for timber reduced the carbon offload of Stadthaus by 300,000 kg. This is equivalent to the entire carbon use of the building over 20 years of occupation." (Thompson 2009, pp. 26)*

Stadthaus was designed by Waugh Thistleton Architects for developer Telford Homes and completed 2008. One of the primary goals was to quickly and affordably build sustainable and dense housing. The construction technology was chosen partially in response to 2016 government regulations that mandate all housing will need to be zero carbon.

Table 10 - Stadthaus Project Summary

Height	Nine-stories
Building Footprint	3,289 SF / 56′ x 56′
Floor Area	29,600 SF
Units	29 (11 1BR, 10 2BR, 5 3BR, 3 4BR
Development Cost	$5.9 million / $199 per GSF

Source: Thompson 2009

Stadhaus is located in London's Hackney area, and when completed, was the world's tallest timber residential building. The building consists of ground floor commercial space and storage, floors one through three social housing, and four through eight private housing. (Thompson, pp. 29) The change of use between the ground floor and higher floors necessitated the need for a concrete podium to handle the load transfer, reducing some of the carbon gains of using CLT.

The project is made largely of cross-laminated timber (CLT), which is basically "timber planks stacked, glued and laminated in perpendicular layers…manufactured in sheets" up to 54′ by about 10′. These sheets can be precision cut in a factory setting and assembled on-site. (Ibid) CLT is very strong, and provided structural support at Stadthaus while in Treet is used to support the stairwells and elevator shaft.

The designer notes that it is important to address concerns about using timber for taller structures, but the environmental advantages are "too great to ignore." (Ibid, pp. 11) The following details the benefit and concerns when considering CLT as structural elements.

3.3.2.1. CLT Benefits

Cross-laminated timber offers the following benefits:

- Carbon storage - Typically, a project of this type made of reinforced concrete would create 125,000 kilograms of carbon, but by using wood and timber, the building instead stores 185,000 kilograms.

- Using CLT saves time - the project took 47 weeks to complete; the timber framing was completed in just 27 days by four men. By comparison, a typical concrete building would have taken 72 weeks to complete. (Ibid, pp. 8)

- CLT is compatible with other building materials such as steel, glass and aluminum.

- CLT is dry and ready to assemble, compared to concrete, so it is quicker to attach other materials.

- There is less disruption to the surrounding community because there is less dust and noise. "A construction site for a timber building is unrecognizable compared to its reinforced concrete equivalent. The working conditions are extremely favorable, being clean, relatively dust-free and quiet. (Ibid, pp. 84)

- There is no need for a tower-crane – which would require separate foundations – or large storage areas, as the lightweight panels can be installed directly from the lorry using a mobile crane. Heavy machinery" use was minimal and noise was so low there were no neighbor complaints. (Ibid)

- Design changes are easy to implement because the material is flexible and can be worked on with a handsaw.

- CLT weighs less than steel or concrete, resulting in in less foundation work.

- CLT is made of thin panels, resulting in a gain in net usable space.

- Wood has the best thermal insulation of any structural building material, reducing insulation requirements. Wood is five times better than concrete, 10 times better than brick and 350 times better than steel (Ibid, pp. 26)

- Tolerances can be kept very tight making it easy to drop in staircases and elevator casings. (Ibid)

3.3.2.2. CLT Concerns

"The biggest challenge in the engineering of this tall timber building was refraining from reverting to standards intended for concrete or steel structures. Timber has its own qualities and characteristics to form the starting point for a design developed from first principles to achieve an appropriate result. The one criterion which was adopted from the start therefore was a prerogative to respect the material, to know and understand its boundaries, and not to over-engineer it." (Ibid, pp. 83)

- Fire – One of the important characteristics of timber is that "in a fire, a solid wall of timber will benefit from the protection of a charred layer and therefore does not deteriorate in the same way as a joist or stud. CLT panels, at their thinnest three-layer construction, can conform to a fire protection class of F30 – which means they will retain their structural integrity for at least 30 minutes. In Stadthaus, five-layer panels are used to obtain a fire protection class of F60. A timber beam will retain structural integrity much longer than a steel beam, which loses strength above a certain temperature and buckles. Through board and [gypsum] layer constructions[,] the fire resistance period of timber can be still further increased," (Ibid, pp. 11-12) by about 30 minutes per gypsum layer. (Havel 2013)

- Similar to FBH construction, all CLT panels are pre-cut requiring finalization of design decisions at the drawing board.

- Over time CLT will compress so it is important to design appropriately, for example handrails need to have tolerances for eventual building compression. Compression is minimal though, at Stadthaus just 25 mm for a nine-story building.

- Final waterproofing is critical to prevent wood rot.

- One of the biggest concerns was the shipping of CLT – that can offset some of the CO2 storage gains of using timber. Consider local sources of timber to mitigate shipping emissions.

- "Stadthaus was carefully designed to distribute and minimize compressive stresses throughout the wall panels. However the nature of the construction, with wall panels building up above one another, combined with the fact that the floor layout changes half-way up the building, means that in certain places loads are sufficient to crush the side grains of timber, In such locations, panels are reinforced with arrays of screws to carry forces into the body of the material." (Ibid, pp. 81)

Figure 28 - Stadthaus Under Construction (Week 5)

Note CLT elevator shaft. Source: (Ibid, pp. 41)

3.3.3. Timber and CLT Summary

In Europe, construction of taller timber-frame buildings is occurring with greater frequency. Entire buildings constructed of timber, including cores, use cross-laminated timber (CLT), laminated veneer lumber and laminated strand lumber for walls, floors and roofs (Woodworks 2014). Glulam, "a versatile engineered wood product that has the strength, stability, and long span capabilities" (APA 2014), can be used for beams and columns (Woodworks 2014) in place of steel or concrete. According to Woodworks, characteristics of CLT include:

- Complementarity to both light and heavy-timber framing options
- Sustainable alternative to concrete, masonry and steel in mid-rise buildings
- Strength, versatility and low shrinkage
- Structural simplicity
- Fast installation
- Lower waste
- Better thermal performance

- Utilization of "smaller wood elements from sustainably managed forests"
  (Ibid)

There are numerous issues to overcome as well as opportunities when considering timber for taller buildings. In California, seismicity is a significant concern, while across the country there may be fire-safety concerns. Both of these, as described below, should not impede the use of timber in taller buildings. The benefits of using timber are numerous and include greater sustainability, potential cost savings and construction improvements, as noted in the Stadthaus case study and summarized below.

3.3.3.1. Timber and CLT is a Carbon Sink

> *"Timber is one of the only truly sustainable building materials in existence. Because trees absorb CO2 as they grow (approximately one ton for every cubic meter), wood is carbon neutral: a building made using enough timber – if it comes from sustainably managed forests – can achieve a negative carbon footprint."* *(Thompson, pp. 24)*

One of the primary benefits of timber construction is that it's a natural carbon sink. As governments consider measures to limit carbon dioxide (CO_2) emissions and find ways to remove CO_2 from the atmosphere, the building industry can do its part by using timber more extensively. Additionally, the use of concrete and steel is energy intensive, and a switch to timber in place of steel or concrete nets a significant reduction in the carbon footprint of a building.

Timber construction has environmental benefits over steel/concrete that include its renewability and carbon-storing characteristics. "The amount of energy required to produce a ton of brick is four times the amount for sawn softwood, concrete is five times, glass six times, steel twenty-four times and aluminum 126 times. Using wood instead of other building materials saves on average 0.9 tons of carbon dioxide per cubic meter." (Ibid) Similar to Treet, architect Waugh Thistleton sees timber as the construction industry's answer to reducing carbon emissions. While timber is common in low-rise buildings in the U.S., there are successful taller timber buildings abroad. Waugh Thisleton's Stadhaus is one such example.

3.3.3.2. CLT is Easy to Work With

Constructing buildings with CLT and timber framing is easier as it is lighter and easier to work with on-site than steel or concrete. For example, drilling into concrete produces dust that is a health hazard to workers. Drilling into solid concrete also puts enormous strain on workers' shoulders. Drilling into wood/timber, a softer material, is much more worker-friendly.

3.3.3.3. Timber and CLT is Precision-Cut

As with all wood-framed FBH, CLT is lighter than concrete or steel, and can be prefabricated in a controlled environment and cut with computer-aided precision directly from architectural drawings (as can FBH made from other materials). Tolerances can be very small relative to on-site construction.

3.3.3.4. Lower Site Disruption due to Construction

Because much of the structure can be produced off-site both with all FBH and CLT, the amount of on-site disruption is lower than with traditional on-site construction.

3.3.3.5. Reduced Construction Time

Building with FBH and/or using CLT prefabrication can occur while site work is underway, helping to reduce total project time. Both of these benefit the surrounding community and the builder.

3.3.3.6. Waste Reduction

FBH construction offers an additional benefit: reduction in waste achievable through precise design and procurement. Seventy-six percent of builders using modular construction report waste reduction relative to site-built construction; more than half report a greater than five percent waste reduction. Factory settings can also improve recycling of waste materials as they are less likely to be damaged or exposed to the elements. (Bernstein 2011, pp. 40)

3.3.3.7. Reduced Site Disturbance

In addition to waste reduction, other environmental benefits that could help projects achieve green certification include lower site disruption, particularly in environmentally sensitive areas. For example, impacts on endangered species can be mitigated using modular technology (Bernstein 2011, pp. 40) due to lower site disturbance and a reduction in truck trips to sites can reduce local air pollution effects of construction vehicles.

3.3.3.8. Seismic

In California and other areas with strict seismic codes, there may be concern that taller wood buildings may not fare well in a significant earthquake. Research continues with regard to establishing R-factors for glulam and CLT buildings; however, a 2009 test of a seven-story CLT structure carried out by the Trees and Timber Research Institute of Italy on the world's largest shaking machine in Japan shows that a properly designed CLT building can withstand shaking similar to the Kobe earthquake.

According to FPInnovations' shearwall and assembly tests, it is important that "nails or slender screws are used with steel L-brackets to connect the walls to the floors below (this ensures a ductile failure in the connection instead of a brittle failure in the panel). The use of hold-downs installed with nails on each end of the walls tends to further improve their seismic performance." (Karacabeyli and Douglas, pp. 13)

Figure 29 - CLT Building on Shaking Platform (Japan)

Image Source: Karacabeyli and Douglas 2013

3.3.3.9. Fire-safety

Another concern with wood construction is with fire-safety, as fire codes were put in place after many cities burned due to their abundance of wood construction in prior centuries. In San Francisco, a large portion of the city was destroyed not by the earthquake in 1906, but by the subsequent fire. While timber is combustible, so are other building materials such as steel and concrete. Under extreme temperatures, steel will melt and concrete will explode, often unpredictably.

When timber burns the first thing that occurs is the formation of an outer char layer protecting the inner timber. According to FPInnovations, "results of the full-scale fire tests show that CLT panels have the potential to provide excellent fire resistance
often comparable to typical heavy construction assemblies of non-combustible construction. Due to the inherent nature of thick timber members to slowly char at a predictable rate, CLT panels can maintain significant structural capacity for an extended duration of time when exposed to fire." (Ibid, pp. 17)

3.3.4. Timber Summary

Taller, timber-framed construction, similar to FBH, is a new trend in the construction industry, historically change-averse. Building trades are understandably conservative, as new technology is unproven and the training requirements for builders are extensive. The old mantra, 'if it ain't broke, don't fix it' widely applies to construction, but arguably, the energy intensive nature of manufacturing steel and concrete is broken in our world facing climate change due to CO_2 emissions. Furthermore, constructing buildings with timber framing is easier as it is lighter and easier to work with on-site. For example, drilling into concrete produces dust that is a health hazard to workers. Many of these benefits also apply to FBH construction.

3.4. Section 3 Summary

There is great potential benefit of using factory-built housing as well as CLT in San Francisco and the experiences of other projects can help guide developers and builders in the California on how to move forward with FBH and CLT buildings. In San Francisco, construction imposes a heavy toll on neighborhoods, with roads and sidewalks often blocked for months while work occurs behind ugly fences. Trucks carrying materials to be assembled on-site cause traffic snarls and jackhammers keep neighbors awake and disrupt business. Because much of the structure can be produced off-site, on-site disruption can be reduced relative to traditional site-built construction methods. Prefabrication can occur while site work is underway, helping to reduce total project time and cost. Developers and FBH manufacturers estimate the range of savings that are achievable by using FBH construction is in the range of zero to 20 percent. The case of no monetary savings may be the result of extreme customization or small size of an FBH project, whereas projects using standard FBH construction should achieve at least five percent monetary savings, from carrying and finance costs alone. If interest rates rise, these finance savings will only increase. The higher range of savings (~20 percent) is an estimate for larger standardized projects, such as those with at least 90 to 100 FBH modules.

Still, while some projects may not realize any monetary savings, a FBH project will still provide time savings and reduced site disruption. Both of these benefit the surrounding community and the builder. Using FBH or CLT for more projects could alleviate a lot of the problems people associate with construction, and potentially reduce opposition.

4. Factory-built Housing Delivery in San Francisco

The potential for factory-built housing to play a role in solving the housing crisis in San Francisco depends on a number of factors. Achieving the cost and time efficiency of factory-built housing requires a clear and concise entitlement and permit phase, currently a barrier to all forms of construction in the city. Identifying adequate land resources and unlocking its potential is also necessary, as mentioned in Section 2.1.

Section 4.1 describes the methodology used in this analysis. Section 4.2 and 4.3 then analyzes the potential for FBH in San Francisco. Section 4.4 then summarizes the findings of this analysis.

4.1. Methodology

Through its housing element process, the city has determined that almost 70,000 units of housing could be built on under-developed parcels scattered throughout the city ("soft sites") and in former redevelopment areas. Section 4.1.1 reviews the city's process for determining the undeveloped capacity; however, assessing the potential for FBH in the city requires further parcel-level analysis. Section 4.1.2 determines the number of sites at three "soft site" levels for this analysis and Section 4.1.3 breaks these sites into small and large site categories for further analysis. Section 4.1.4 provides insight into how density can vary greatly depending on density restrictions in the zoning code, reflecting the inherent problem with basing land use restrictions on this metric.

4.1.1. City Development Potential Analysis

Fortunately, the city understands the need for adequate development sites for housing and is required to assess development potential as part of its Housing Element. To determine the number of potential housing units that could be built, the city maintains a database that enables tests of rezoning scenarios, and using this database the city can estimate development potential at varying zoning capacities. The analysis in the draft Housing Element presents a conservative estimate by analyzing a maximum capacity at less than what zoning code allows to take into account "neighborhood character wherein existing residential structures typically fall below building densities and heights allowed by zoning." (SF Planning HE 2014, pp. D1) Due to this conservative estimate, the number of housing units potentially allowed under existing zoning is artificially lower, and one of the tenets of increasing broadbased affordable housing is unlocking regulatory-locked land. (Woetzel, pp. 4)

The city's methodology used a "batch treatment" to analyze the database as an individual parcel assessment would encompass more than 150,000 parcels. The residential analysis is based on the city's existing permitted land uses and development standards, dependent on zoning and height limits. The city considers sites not built out to full potential to be "soft" sites, with varying degrees of softness. There are two levels of softness, five percent and 30 percent. Parcels developed to five percent or less of potential capacity are vacant or "near vacant" and those developed between five percent and 30 percent are underdeveloped. (SF Planning HE 2014, Appendix C)

The analysis also considers the average new dwelling unit to be 1,200 gross square feet for circulation, building inefficiencies, parking, etc. The analysis also omits many sites that are not projected to be developable such as deeded open space, public facilities such as fire stations, historic sites, or buildings with more than 10 residential units. Also, those currently in the development pipeline were left out. (Ibid)

The result of the city's analysis estimates an additional 47,019 units plus 22,873 units in the programmed/redevelopment areas for a total of 69,892 units. (Ibid) Details from the draft Housing Element are in Appendix C.

4.1.2. Number of Parcels at Three "Soft Site" Levels

San Francisco maintains a geographic information system (GIS) database containing parcel data that was queried for this study. As in the housing element process, this analysis considers soft sites as being those not developed to the zoned capacity. However, this zoning-based developed-capacity approach is inherently conservative because it bases the determination on existing zoning density restrictions, limiting the potential for more innovative housing unit types, such as smaller units using FBH. To compensate for this restriction while still utilizing the city's database, this analysis considers three soft site categories as follows:

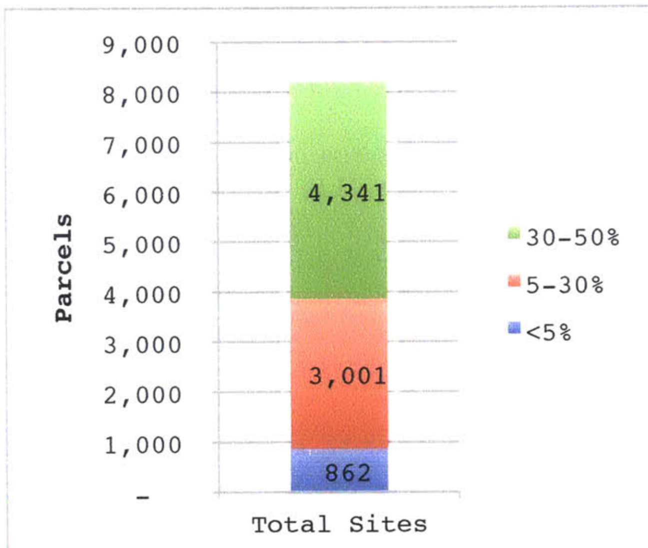
- Vacant or nearly vacant soft sites at five percent or less of zoned capacity developed. These are the low-hanging fruit, the easiest to develop.
- Soft sites at 30 and 50 percent of zoned capacity developed.

The GIS database query also eliminates parcels that are on slopes greater than 10 percent. This maximum slope is selected as steeper grades may present a challenge to FBH construction for logistical reasons, including maneuvering and unloading trucks and siting/operating cranes.

These parameters help establish a baseline for the total number of parcels at the three soft site levels[3].

Table 11 and Figure 30 – Total Number of Sites at Three Zoned-Capacity Developed Levels

Zoned Capacity Developed	Sites
<5%	862
5-30%	3,001
30-50%	4,341
Total Sites	8,204



4.1.3. Determining the Size of Large and Small Project Sites

The next step in determining the number of available sites for this analysis is to divide the sites identified above into small and large. Sample projects were sketched out on a variety of lot sizes to determine natural breaks for the two groups, with the following result:

- Sites between 2,500 and 15,000 square feet are small sites
- Sites 15,000 square feet or greater are large sites

[3] These parcels do not include those less than 2,450 square feet aside from those that are adjacent to other parcels in a similar category that could be assembled to form a larger development site. Due to the large dataset for the 30% and 50% categories, the threshold was lowered to 2,000 SF to compensate for the large number of potential adjacent sites that could be assembled to form adequate development sites for this analysis.

The result of the following analysis is that small project sites are those between 2,500 and 15,000 square feet. This result is based on an initial project assessment that determined a minimum feasible lot size (2,500 SF) scaled linearly until a significant leap in unit-count would qualify the site as being feasible for a large project (15,000 SF), as defined by the ability of the single site to accommodate around 100 FBH modules. To illustrate the feasibility of FBH on the minimum parcel size, consider the following analysis.

Minimum Project Site Size

To determine a minimum lot size for this analysis, a typical San Francisco parcel was chosen from the database, measuring 25 feet by 100 feet for a total of 2,500 square feet. A sample project was sketched out.

Sample Project A: 2,500 Square Foot Lot Sample Project

To determine a minimum lot size feasible for FBH construction, a sample project is sketched on a typical San Francisco parcel from the city's database. The parcel measures 25 feet by 100 feet (2,500 SF), equal to the Nautilus prototype project described in Section 3.2. The Nautilus project is five two-bedroom units comprised of 10 FBH modules. If several projects of this size are under concurrent development, this size project may be feasible for FBH module production (the small but many hypothesis of this thesis). In San Francisco a typical parcel size is about 2,500 SF in many neighborhoods, representing a good test case for FBH.

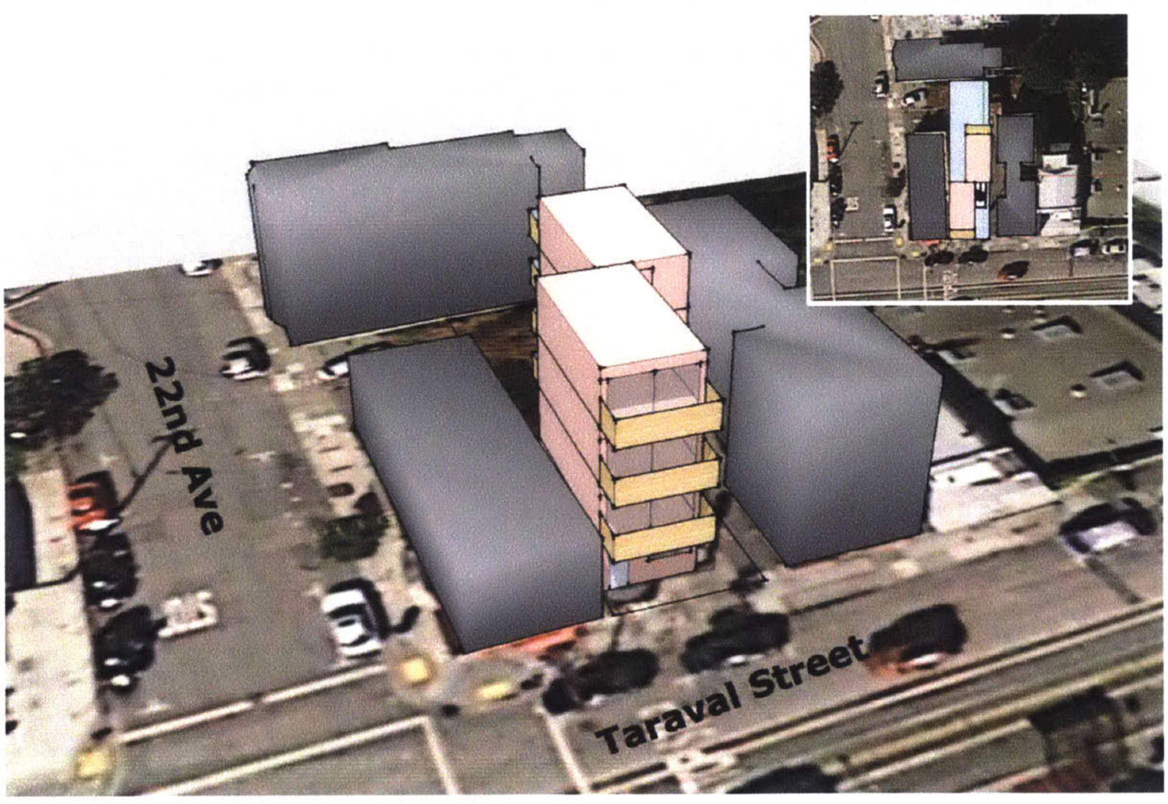
For simplicity, this same project is labeled Sample Project A, and the following assumptions are used in its analysis:

- 2,500 square foot parcel size.
- Height limit of 4-stories, typical for many San Francisco neighborhoods.
- Building is Type V construction.
- Housing is the only land use, maximizing housing capacity on the parcel and reducing project complexity.
- FBH modules measure 16 feet by 30 feet; 480 gross square feet (GSF) or about 460 net square feet (NSF), chosen as a standard size due to requirements for both transportation (width) and fenestration (length).

- On average, one FBH module equals one housing unit [4]. Multiple FBH modules could be combined to form larger units or a single unit split to create a micro-unit.
- Zoning requirement for density is not a constraint.
- Zoning open space requirements, if any, are met by use of an attached balcony.
- One internal and one shared external stairway provide two means of egress for each unit.
- No parking is provided on the site.

With the above assumptions, a total of eight FBH modules "fit" on the parcel chosen on Taraval Street in the Sunset district (see Figure 31).

Figure 31 - Sample 8-FBH Modules Infill Project on 2,500 SF parcel in San Francisco



For the size and scale of the neighborhood, this project type can fit the minimum size project prescribed for this analysis. Table 12 summarizes Sample Project A.

[4] 480 GSF is less than the 1,000 SF standard used in the city's analysis.

Table 12 – 2,500 SF Parcel Size Sample Project Summary

	Sample Project A
Parcel Size (SF)	2,500
Module Size (GSF)	480
Building Footprint (SF)	960
Residential Stories	4
Residential Floor Area (GSF)	3,840
Gross Floor Area (GSF)	3,840
Floor Area Ratio	1.5
Dwelling Units*	8
Density (du/acre)	139

*Represents a potential maximum and assumes unit of about 460 NSF with exterior stairwells; If larger units are appropriate, the number of dwelling units would decrease, but the number of modules would not.

Sample Project A represents a minimum for FBH construction following the assumptions above, and yields a density of 139 dwelling units per acre (du/acre) if one FBH module equals one unit. Module count is important when analyzing the potential for FBH construction and while one eight-FBH-module project may be too small to warrant FBH, simultaneously development of multiple small lots could make FBH feasible. As a result, the minimum lot size this analysis will consider is 2,500 square feet.

4.1.3.1. Difference between Small and Large Projects

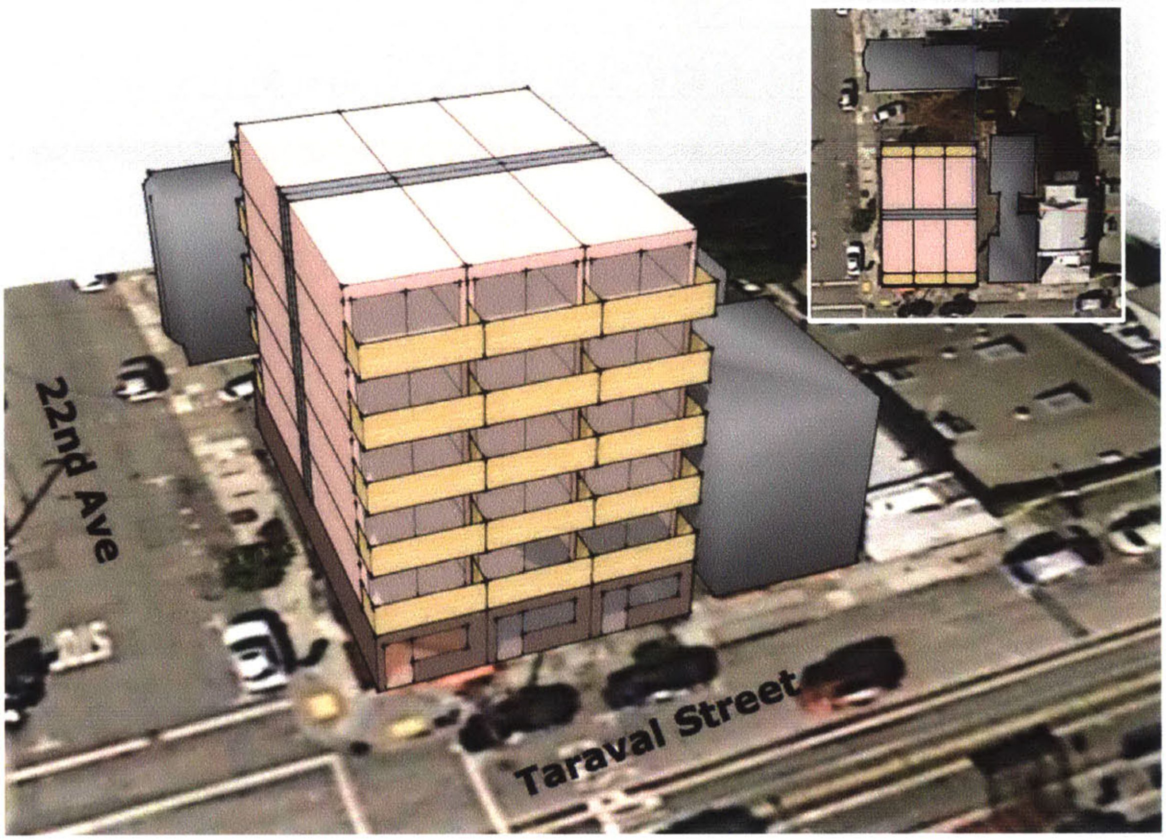
Another design exercise helps determine the break point between sites suitable for small and large projects (i.e. one close to achieving the 100 module scale considered by many FBH producers to be necessary to achieve greatest efficiency.) Consider another example that doubles the lot size of Sample Project A from 2,500 square feet to 5,000 square feet (identified in Table 13 as Sample Project A*2). With the same assumptions (4-story maximum height, 16′ x 30′ module), doubling Sample Project A yields a project with 16 FBH modules. However, a larger lot allows greater building design and FBH module siting flexibility. It may also allow for taller structures. Consider Sample Project B.

<u>Sample Project B: 5,000 square foot lot</u>

Sample Project B is a design exercise with the following assumptions:

- 5,000 square foot parcel size.
- Height limit of 6-stories.
- Housing is Type III construction above a one-story Type I podium, which can be used for residential amenities, commercial use or parking.
- Podium extends across maximum lot coverage allowance with 25-foot rear yard setback.
- Podium is included in total building floor area.
- FBH modules measure 16 feet by 30 feet; 480 gross square feet (GSF) or 400 net square feet NSF to account for corridor and other common space.
- On average, one FBH module equals one housing unit. Multiple FBH modules could be combined to form larger units or a single unit split to create a very small micro-unit.
- Zoning requirement for density is not a constraint.
- Zoning open space requirement is met as each module has an attached balcony.
- No parking is provided on site, but could be accommodated.
- Residential units are in a double-loaded configuration.

Figure 32 – Sample Project B: 30-FBH Modules Infill Project on 5,000 SF parcel in San Francisco



Similar to Sample Project A, up to 30 FBH modules can fit within the size and scale of the neighborhood, particularly where there is good transit access. Table 13 summarizes this mid-size project example while also comparing it to Sample Project A doubled.

Table 13 - 5,000 SF Parcel Size Sample Project Summary

	Sample Project A*2	Sample Project B
Parcel Size (SF)	5,000	5,000
Module Size (GSF)	480	480
Building Footprint (SF)	1,920	3,600
Residential Stories	4	5
Podium Stories	0	1
Residential Floor Area (GSF)	7,680	14,400
Podium Floor Area (GSF)	0	3,600
Gross Floor Area (GSF)	7,680	18,000
Floor Area Ratio	1.5	3.6
Dwelling Units*	16	30
Density (du/acre)	139	261

* Represents a potential maximum and assumes unit of about 400-460 NSF.

The above example demonstrates that scaling up the simple design of Sample Project A on a parcel that is twice the size of the original parcel doubles the number of FBH modules feasible; however, the following shows that as the parcels become even larger, the design and siting flexibility of these larger results in even greater potential for siting FBH modules.

Sample Projects C and D: 10,000 and 15,000 square foot sites

Additional siting exercises were completed for 10,000 square foot and 15,000 square foot parcels to determine a maximum number of standard sized FBH modules to better understand how larger sites allow for greater flexibility in building design and FBH module siting (see respectively, Table 14, Figure 33 and Table **15**, Figure 34). Sample Project A could again be scaled up to fit these two lot sizes, but as with Sample Project B, these larger sites provide more flexibility for siting FBH modules, and developers will want to maximize the potential for these sites so long as there is demand.

The assumptions in these two exercises are similar to those for Sample Project B, except a second story is added to the podium, increasing the height to 75-feet. The second story of the podium could also have residential units, but they would not be factory built because the podium would be of a different construction type (Type I).

Figure 33 shows 60 FBH modules sited on a two-story podium on a 10,000 square foot lot. A 60 FBH module project is in the range of a mid-size project.

Figure 33 - Sample Project C: 60-FBH Modules Infill Project on a 10,000 SF parcel in San Francisco

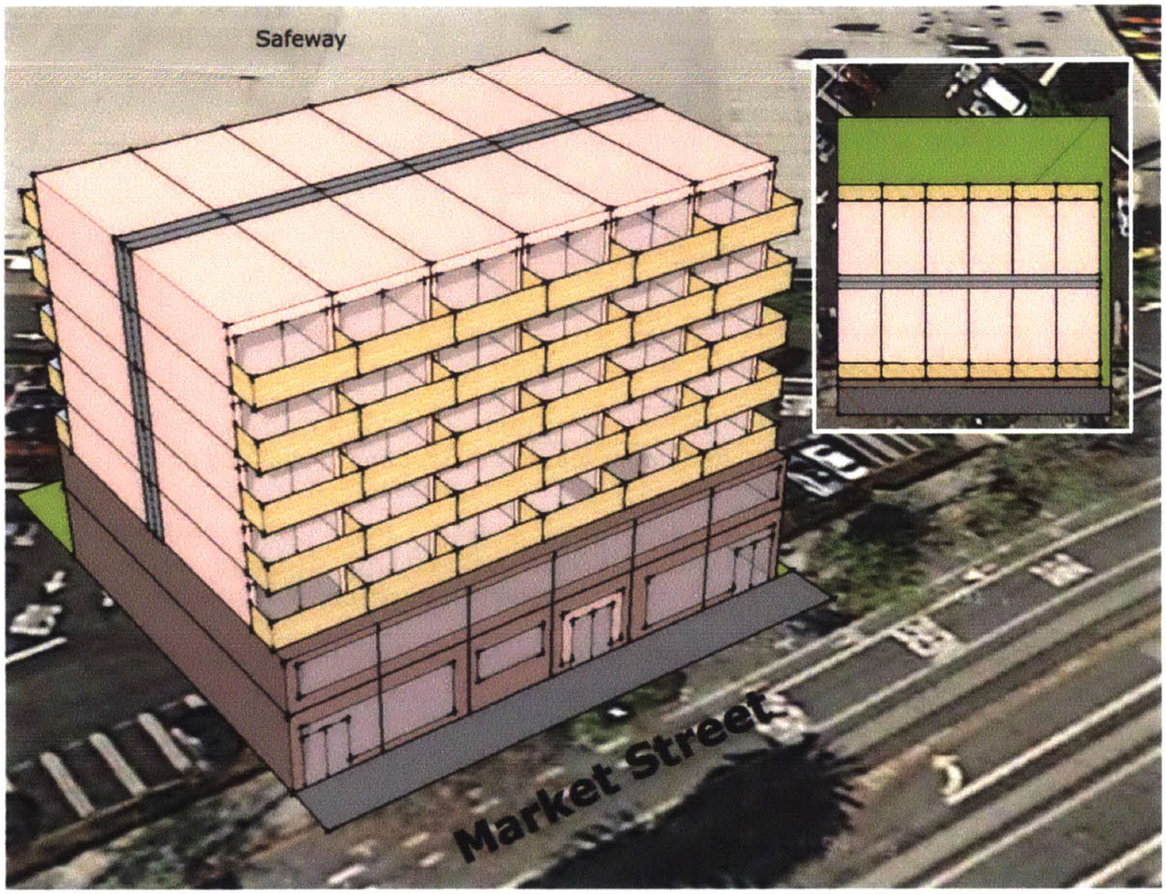


Table 14 - 10,000 SF Parcel Size Sample Project Summary

	Sample Project C
Parcel Size (SF)	10,000
Module Size (GSF)	480
Building Footprint (SF)	7,200
Residential Stories	5
Podium Stories	2
Residential Floor Area (GSF)	28,800
Podium Floor Area (GSF)	14,400
Gross Floor Area (GSF)	43,200
Floor Area Ratio	4.3
Dwelling Units*	60
Density (du/acre)	261

*Represents a potential maximum and assumes unit of about 400 NSF.

Repeated for a 15,000 SF parcel, this exercise shows even greater potential for FBH modules and building design as between 90 and 120 FBH modules fit on the parcel. **Figure 34** shows and

Table 15 summarizes both a 90 FBH module example and 120 FBH module project on the same 15,000 square foot parcel.

Figure 34 - FBH modules placed on 15,000 SF parcel (90 FBH modules – top, 120 FBH modules – bottom)

Table 15 - 15,000 SF Parcel Size Sample Project Summary

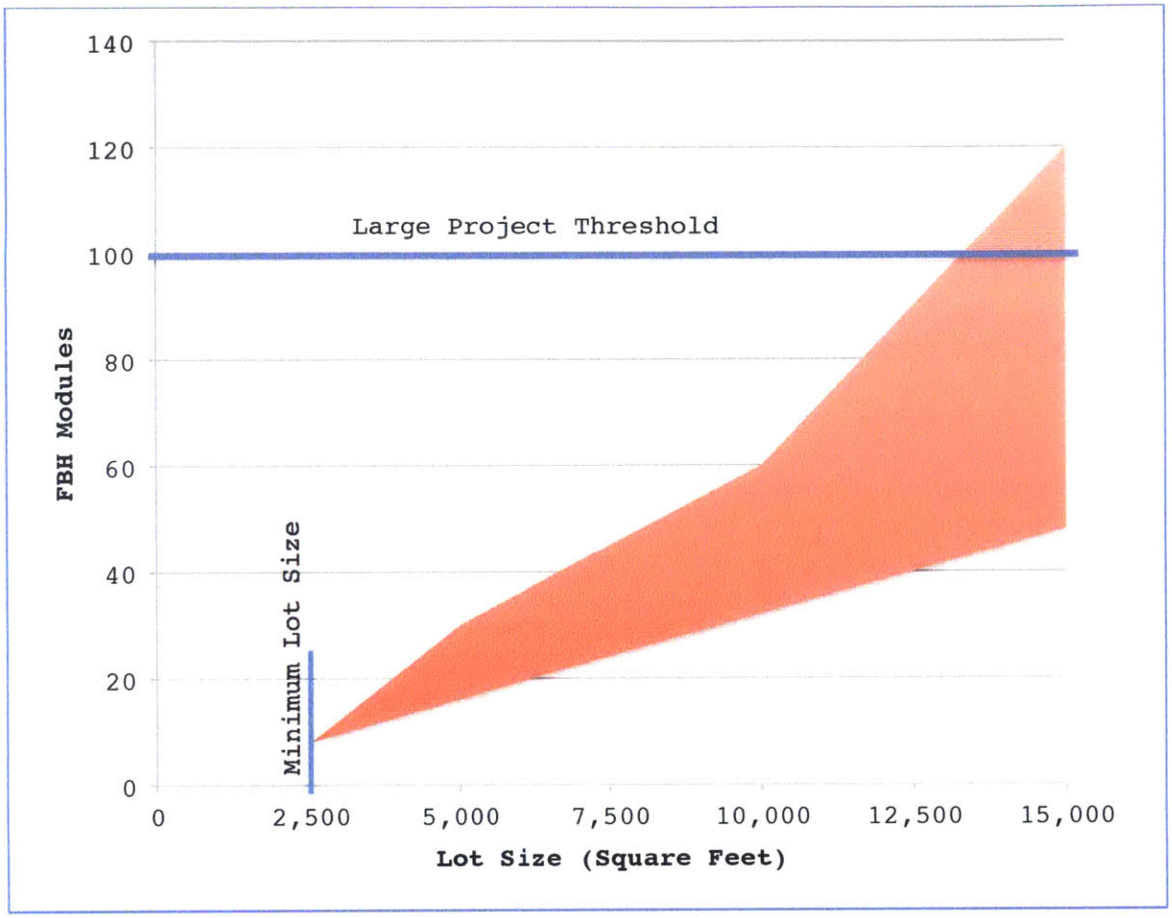
	Sample Project D.1	Sample Project D.2
Parcel Size (SF)	15,000	15,000
Module Size (GSF)	480	480
Building Footprint (SF)	10,800	15,000
Residential Stories	5	5
Podium Stories	2	2
Residential Floor Area (GSF)	43,200	57,600
Podium Floor Area (GSF)	21,600	30,000
Gross Floor Area (GSF)	64,800	87,600
Floor Area Ratio	4.3	5.8
Dwelling Units*	90	120
Density (du/acre)	261	348

*Represents a potential maximum and assumes unit of about 400 NSF.

Currently in the Bay Area market, there are few manufacturers of FBH modules, and they consider projects of at least 100 modules to be best able to achieve the efficiencies of factory production. Crossing this 100 FBH module threshold establishes a dividing line between small and large lot size for this thesis, because at this volume, a single project can stand-alone as a significant order from a manufacturer and achieve maximum savings.

As Figure 35 shows, the 100 FBH module threshold is crossed at around the 15,000 SF parcel size. Furthermore, at these larger parcel sizes, other constructions types, such as concrete and steel may make more sense if zoning height limits allow buildings taller than seven stories.

Figure 35 - Range of FBH Modules relative to Parcel Size



Summary

The threshold for lot size between small and large projects is 15,000 square feet for the purpose of this analysis. FBH manufacturers serving the San Francisco market indicate that 100 units is a "sweet spot" for achieving efficiency and this analysis arrives at the threshold lot size by testing a standard FBH module on a range of lot sizes.

Factory-built housing projects around a 100-module minimum should be able to achieve sufficient economies of scale to maximize potential cost savings. The above analysis shows that as sites become larger, the potential number of FBH modules increase as larger sites allow for greater flexibility in building design and siting of FBH modules such that at around 15,000 SF the 100 FBH module threshold is crossed. While projects that use fewer than 100 modules are possible, it is likely they are only feasible if several occur simultaneously to achieve economies of scale at the factory. These smaller projects may still achieve time savings, as demonstrated in the

Panoramic and Nautilus case studies, but hard cost savings may be difficult to achieve under current market conditions.

Further, this analysis only considers Type V or Type III over Type I as the development standard for FBH modules. This restriction limits the height of the sample projects to a maximum of 75-feet, including a two-story podium with a total height of 25-feet. High-rise FBH construction is addressed in later in this section, but it is not considered for near-term feasibility in this study due to current building code restrictions, and the lack of non-combustible module capacity in the FBH industry serving the west coast.

4.1.4. A Note on Density and Zoning Restrictions

The sample projects above present an excellent illustration that density as a land use metric represents a problem in the zoning code and can limit housing affordability by reducing the overall number of developable units. Table 16 shows the range of densities for the sample projects in the previous section.

Table 16 - Simple Density Array for Sample Projects

Description	Parcel Size	Stories above Podium	Units*	Density (du/acre)
Sample Project A	2,500	4	8	139
Sample Project B	5,000	5	30	261
Sample Project C	10,000	5	60	261
Sample Project D	15,000	5	90-120	261-348

*Assumes 400-460 NSF unit size.

The densities of the sample projects range from 139 du/acre to 348 du/acre; however, these ranges all assume that each unit is one size, 480 gross square feet (one FBH module = one unit); however, the simplicity of this assumption deserves another look.

Let us re-consider Sample Project A under two scenarios. Scenario one divides each module into two dwelling units to form micro-units, resulting in 16 units instead of eight, and doubling the density (to 277 du/acre) while not changing the volume, height or other physical characteristics of the building.

Similarly, if the modules in Sample Project A are combined such that two modules form one dwelling unit, the project will have four units and density is halved to 69 du/acre. This simple illustration shows how zoning density requirements affect housing unit production by artificially limiting housing unit supply, thus driving up the cost to potential renters and buyers.

Density limitations can have a significant effect on housing affordability. Again, we consider the site for Sample Project A and B above. This site is located in the Inner Sunset Neighborhood Commercial District (NCD) with zoning of NC-2, which allows 54 du/acre for a maximum of three units (regardless of the height allowance for this site, which is 65 feet). Based on the city's density requirements, the project is limited to three units, instead of the eight units in the sample projects. Even if the eight FBH modules in Sample Project A are formed into four 960 GSF units, the project would still exceed the zoned density for the site. The result of density zoning restrictions on this site is that any multi-family project built there will have up to five fewer units and thus be more expensive, potentially unmatched to demand, and overall less helpful to solving the housing crisis.[5]

The zoning code can also restrict housing potential by limiting height. Sample Project C and D are shown on the current Safeway site on Market Street and is zoned NCT-3 with a height limit of 40 feet. The sample projects are designed to a height of 75 feet (with a 25', 2-story commercial podium), and in fact surrounding new projects have been built to 85 feet. If the FBH Sample Project is confined to the 40-foot height maximum, up to 36 fewer units could be built, an indication that existing zoning height limits deserve another look.

Zoning code restrictions are not only problematic for the provision of housing, the problem must also be addressed for the next step in this analysis. To complete the parcel-level analysis, this study considers several scenarios with regard to density.

In San Francisco, the zoning code defines density allowances ranging from one unit per lot in large residential areas (11 du/acre) to unlimited in other areas. There are natural breaks in the range of densities allowed: between 11 and 54 du/acre are allowed in one, two and three-family house residential areas, low-density apartment and light and heavy industrial zones. Greater densities are allowed starting at 77 du/acre (one unit per 600 SF of lot area). Table 17 summarizes San Francisco's

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[5] This is particularly interesting because this site is also on a corner with a Muni stop directly in front.

zoning district density restrictions[6]. (SF Planning HE 2014, pp. D24-32)

Table 17 - Summary of San Francisco Zoning Density Requirements

Zoning District	Density Max (du/acre)
RH-1 (D)	11
LAKESHORE PLAZA SUD	15
RH-1	17
RH-1(S), RH-2	35
RH-3,	52
RM-1, NC-1, NC-2, NC-S, INNER SUNSET NCD, SACRAMENTO NCD, WEST PORTAL NCD, C-2, M1, M-2	54
RM-2, RTO, NC-3, CASTRO NCD, INNER CLEMENT NCD, OUTER CLEMENT NCD, UPPER FILLMORE NCD, HAIGHT NCD, UNION NCD, 24TH-NOE VALLEY NCD, BROADWAY NCD, UPPER MARKET NCD, NORTH BEACH NCD, POLK NCD	77
RM-3, RC-3, RTO-M, RED	109
RM-4, RC-4	218
PACIFIC NCD	44
NCTD, NCT-2, NCT-3, RH-DTR, SB-DTR, MUG, MUR, MUO, UMU, TB DTR, VAN NESS SUD, FOLSOM/MAIN RESIDENTIAL SUD, VAN NESS/MARKET DOWNTOWN RESIDENTIALL SUD	NO LIMITS/ CONTROLLED BY BULK
CCB, CVR, CRNC, RSD, SLR, SLI, SSO, NORTH OF MARKET SUD Subarea No.2	218
C-M, C-3-O, C-3-R, C-3-G, C-3-S, NORTH OF MARKET SUD Subarea No.1	348
PDR, P	NOT ALLOWED

Source: SF Planning HE 2014, pp. I.70

4.1.5. Determining the Number of Parcels Available for FBH Construction

The above methodology can help determine the number of parcels available for FBH construction. The initial list of soft sites at the five percent developed-capacity threshold received from the city includes 862 parcels in an array of zoning districts. The following analysis separates the sites into three categories: one containing all sites without regard for density limits, and two additional categories that exclude (1) low density single house zones (all RH and PDR districts) and (2) all low density districts (RM1, C2, M1, etc.) to better understand what effect these density restrictions may have on potential housing unit production. The following table breaks down the number of soft sites under the unlimited density and two reduced-density scenarios.

Table 18 - Vacant or Nearly Vacant Parcels (<5% zoned-capacity developed)

	Small Sites	Large Sites
All Parcels (All Zones)	718	144
- minus RH, PDR zones	-228	-20
SubTotal	*490*	*124*
- minus All Low Density zones	-135	-69
Total (High Density Sites)	**355**	**55**

As a result of this filtering of soft sites by zoning density restrictions, more than half of the potential development sites for both large and small projects are eliminated.

Table 19 shows a summary of available parcels across the city after the above analysis is repeated at the 30 and 50 percent zoned-capacity developed levels.

Table 19 – Available Vacant/ Nearly Vacant Underdeveloped Parcels

Zoned-Capacity Developed	Small Sites	Large Sites
<5%	355	55
5-30%	1,787	138
30-50%	1,275	66

With these parcel quantities in mind, it is now possible to determine the potential number of units using FBH for both large and small projects at the three zoned-capacity development levels, being considerate of existing zoning restrictions in low-density industrial and single-family areas.

4.2. FBH Project Potential Analysis

The next step in analyzing the feasibility for FBH construction in San Francisco is to determine the number of units that could be constructed on the available sites. For this part of the analysis, the following parameters apply:

- All buildings have a maximum height of 5-stories for the FBH portion of the building (above the podium). Some areas of the city allow for much greater heights where timber construction is not currently allowed (see Section 3.3 for more detail) and this analysis does not consider Type I high-rise modular construction. The likely effect of this is a reduction in the number of available sites as sites with higher height limits are not considered candidates for FBH.
- Podiums are not of FBH construction and are irrelevant for this part of the analysis.
- For small and large project sites the average lot size is used.

At the three soft site levels, there are 3,417 small sites and 259 large sites available for this analysis in the three soft site levels, not including former redevelopment areas such as Hunter's Point and Treasure Island. Table 20 shows the average parcel square footage for both large and small sites.

Table 20 - Average Lot Square Footage for Small and Large Project Sites

	Small Sites (SF)	Large Sites (SF)
<5%	5,360	46,153
5-30%	3,646	51,104
30-50%	3,329	36,105

<u>FBH Potential</u>
The following formulas determine the total number of FBH modules for each soft site group based on the gross floor area available on the average parcel and assuming 75 percent lot coverage:

(1) Average Gross Floor Area = Total floors * average parcel area*0.75

(2) Total Potential FBH Modules = Average Gross Floor Area / FBH module area * Number of Large Sites

With both equations, the total potential market for FBH modules can be determined, and is shown for each soft site group for small and large sites in Table 21.

Table 21 - Summary of FBH Module Potential on Three Zoned-Capacity Developed Levels

	Large Sites	Small Sites	
Floors of Residential	5	4	5
<5%	19,832	11,893	14,867
5-30%	55,097	40,723	50,904
30-50%	18,617	26,531	33,163
Total	93,545	79,147	98,934

As a result of the analysis, the relatively fewer number of large sites presents a potential FBH market similar to that of the many smaller sites (93,545 FBH modules for large sites compared to between 79,147 and 98,934 FBH modules for small sites). Translated to housing units, these numbers are likely on the higher range as the average FBH module size they are based on is just 440-460 NSF. Doubling the FBH modules into 880-920 NSF would result in halving the numbers above, with a result in the range of 40-48,000 units on small sites and 47,000 units on large sites.

The vacant or nearly vacant (less than five percent) and underdeveloped sites in the five to 30 percent category present a greater opportunity on large sites (totaling over 74,000 FBH modules). Combined with the fact that it is easier to achieve FBH efficiencies on these larger sites, the significance of this is that, at least in the short term, FBH construction may have a greater impact on addressing the housing crisis on larger sites.

However, developers capable of developing numerous smaller sites simultaneously at different locations across the city could also achieve the cost the savings potential of FBH with careful planning and attention to exterior design that fits the context of the site's surroundings. The city could play a role in the opportunity that FBH presents on these smaller sites and could help package sites of similar scale and design to allow for simpler replication. This type of development would not be unlike large-scale small-lot housing production in the past.

4.3. Section 4 Summary

This section presents an analysis for the potential of factory-built housing delivery in San Francisco through careful analysis of San Francisco parcel data based on developed zoned-capacity. The analysis breaks the developed zoned-capacity of parcels into three groups: less than five percent developed (vacant or nearly vacant sites), five to 20 percent developed, and 30 to 50 percent developed. The three groups are then divided into two sub-groups for their potential for large and small FBH projects with a cutoff between the two of 15,000 square feet, based on development scenarios that site a maximum number of FBH modules on a range of parcel sizes. The analysis results in the potential for almost 94,000 FBH modules on large project sites and/or 99,000 on small project sites. If just 10 percent of the potential is realized, the market for FBH modules would be almost 20,000 FBH modules, or 10,000 to 20,000 housing units. Extrapolation to the Bay Area as a whole, including San Jose and Oakland, would easily double this potential market.

The analysis is conservative due to significant limitations. First, and most importantly, the analysis only considers modules of wood construction (Type III at its most robust), which limits the height of FBH projects to five stories of FBH construction. There are two potential ways this could change. First, taller FBH buildings using heavy gauge metal or steel FBH are technically feasible, but currently there are no such manufacturers serving the west coast. Second, there are encouraging signs that the U.S. will embrace wood/timber for taller buildings. For example, the U.S. Department of Agriculture is sponsoring the 2014 U.S. Tall Wood Building Prize Competition, which has the goal of showcasing the potential for wood to be a viable structural material in tall buildings. Acceptance of wood/timber for taller structures and/or the development of a steel or concrete FBH manufacturer means that on larger sites in San Francisco, taller FBH might one day be feasible, increasing the potential market for FBH above the results of this analysis.

5. Modular Opportunities and Constraints

The preceding three sections (1) outline the planning, regulatory and community constraints facing development in San Francisco, (2) provide case studies of innovation in construction that can help reduce the time and cost of constructing multi-family housing, and (3) show how factory-built housing can be applied in San Francisco on both small and large projects and analyzes the potential market for FBH.

The following discussion summarizes the opportunities, constraints and recommendations to realizing the potential for FBH in San Francisco.

FBH presents an opportunity to increase certainty and predictability for developers for the construction phase. There is also the potential for entitlement reforms that encourage developers to build housing more affordably, reducing the total development risk in San Francisco. Lowering the cost and risk of development could open the market up to more developers, and potentially achieving greater production through greater competition.

In the entitlement phase, there is an opportunity to implement Discretionary Review and environmental reforms and align these reforms with affordable housing goals. As discussed in Section 2.2, Discretionary Review and CEQA are two of the biggest entitlement impediments that slow or kill projects. The city is also exploring policies to implement the state's density bonus law and increase middle-income housing production without subsidies. Tying these together is possible with FBH, as discussed below. Another potential is to assign the cost of the entire Discretionary Review process to the losing party, not automatically to the project proponent.

The planning department could also begin its effort to survey all structures over 50 years old on the large sites (over 15,000 SF) this thesis identifies. This requirement automatically triggers Discretionary Review and delays the issuance of building permits for infill projects no matter the type of structure being demolished.

Also during the entitlement phase, neighborhood opposition can form for numerous reasons. One of those reasons is the potential disruptive effect of construction on neighboring buildings and traffic. With proper communication, these issues can be overcome using FBH because of its inherent reduction in construction time, noise and dust and materials delivery traffic.

Another concern that may arise during the entitlement phase is concern about the quality and design of FBH, particularly for pioneer projects. FBH can often be of similar or greater quality than site built construction and can have interesting design that fits within the existing neighborhood context.

Developers can and should reach out to neighbors to address both design and construction concerns before submitting the preliminary project application. This is particularly important if the above Discretionary Review reform effort is implemented, as this would represent the best opportunity for neighbors to have their concerns addressed. Addressing these concerns early and appropriately is of great importance in securing certainty and predictability in the entitlement phase.

During the construction phase, using FBH can help improve certainty and predictability as well. FBH can result in higher workmanship quality, shorter construction time and a reduction in change orders. To achieve these benefits developers must adhere to design lock and both developers and general contractors must follow the process-driven parameters of FBH.

FBH, by accelerating the increase in housing supply (if necessary reforms are in place to support its widespread use) can expand opportunity for building trades. Developers and general contractors are under pressure to reduce costs, and this requires a new approach to building. There are numerous opportunities that FBH can present to trades, including factory jobs that offer locational stability and the increased safety of not working on a construction site. FBH can also simplify the role of some on-site trades such as electrical and plumbing. In the event of opposition, leadership is necessary if there is serious desire to address the housing crisis.

With some regulatory reform, FBH housing can help solve the housing crisis by quickly increasing the supply of housing. As a result of significantly increased supply, FBH can help bring the cost of purchasing or renting housing more into alignment with what people can afford. Quicker entitlements and construction can help reduce the development lag that results in the boom/bust pattern of the real estate cycle.

Finally, FBH offers an opportunity to decrease the environmental effect of construction. Not only does FBH result in lower waste (due an increase in accuracy that results from computerized procurement and construction) but it can also result in more sustainable materials selection. For example, increasing economies of scale that FBH can achieve could reduce the cost burden of using more sustainable and non-toxic materials such as insulation. Furthermore, innovation in structural technology could facilitate the use of wood and timber in taller structures. Wood, a renewable material that is also a carbon sink, is one of the most sustainable building materials and has the potential to play a significant role in mitigating climate change.

Factory-built housing poses a number of challenges, but they are not insurmountable. The primary constraints involve a lack of interior design flexibility, logistics, few manufacturers and lack of familiarity with FBH.

Developers may be uncomfortable using FBH because of the perception that it can limit the design of multi-family buildings. Factory-built housing may not be ideal for incorporating certain design features, such as lofts with double-height ceilings or significantly open floor plans, but even when site-built, such features are not essential to middle income households. The developer and architect still have the opportunity to create perfectly marketable interior and exterior designs, as demonstrated by the case studies.

Another constraint to FBH is logistics, particularly in dense urban environments and on small project sites. While projects using FBH benefit from fewer overall deliveries to and construction activity over a shorter period of time, FBH housing modules require transport between the factory and the site. In San Francisco, this can pose challenges because of the potential need to cross the Bay Bridge, the often-hilly terrain, and the presence of overhead utility and muni wires in some areas. The project itself can be constrained by neighboring buildings and the overall lack of storage if FBH module arrival is not carefully timed. Finally, the project needs to be able to accommodate a crane to lift the FBH modules into place. These logistical constraints should not doom a project; they just require adequate planning.

Another challenge is the limited capacity to build FBH modules in the San Francisco region, and increasing factory capacity requires certainty of demand. Municipalities can help increase certainty and predictability by implementing entitlement reforms that encourage FBH. In San Francisco, this includes smoothing the entitlement process and encouraging developers to build denser housing with on-site affordable housing.

Finally, the lack of familiarity with FBH among municipal officials and general contractors can be overcome with education and training. Developers and FBH builders can work together to organize tours of FBH projects and factories for municipal officials and project team members, and it is important that these educational efforts occur early in the development process.

Recommendation

FBH presents an opportunity to address the housing supply crisis and the city can seize this opportunity by encouraging developers to use this technology to build more housing in less time, at potentially lower cost. In the short term, San Francisco can pass Discretionary Review reform to the 55 vacant or nearly vacant parcels over 15,000 square feet, allowing greater density so long as projects include unsubsidized on-site middle-income housing. This first step can help encourage developers of larger projects to use FBH proving that the cost and time savings can be beneficial to developers and the community. It can also spur an increase in factory capacity and expertise amongst contractors and subcontractors.

In the longer term, the city should explore an expansion of Discretionary Review reform to the 355 vacant or nearly vacant smaller parcels. One recommendation is to establish a class of pre-approved product types, such as well-designed and replicable housing that could be built using FBH that is exempt from Discretionary Review. These projects could be exempt up to a certain size throughout the city, perhaps suitable on many of the smaller existing infill sites that are described in Section 4.2. Further, smaller projects typically do not fall within the existing inclusionary housing requirements (minimum 10 units), and in exchange for the Discretionary Review exemption, the city could require a percentage of units to be affordable to middle income households. If the city is apprehensive about exempting projects completely, for certain classes of projects the city could allow Discretionary Review petitions but assign the cost of the entire review to the losing party, not automatically to the project proponent.

Together, the two recommendations could lead to the development of over 30,000 FBH modules, or 15-30,000 housing units. Both of the above recommendations could be expanded over time to include the 3,062 small sites and 204 large sites in the five to 50 percent of existing zoned-capacity developed. Including these parcels could yield up to 35-70,000 additional housing units for a total 50- 100,000.

Another recommendation is to reform CEQA by strengthening the infill exemption to discourage frivolous challenges that tie up the process. Allowing the exemption to apply to projects that utilize the density bonus even if the bonus' application causes the project to exceed the existing CEQA approval of the General Plan, specific plan or other project can also encourage housing development.

Finally, the development community should seriously explore the opportunity to build higher using wood/timber construction to increase the sustainability of the construction industry.

6. Conclusion

San Francisco's housing crisis is the result of decades of under supply, a byzantine regulatory structure and shifting demographics. The demographic shift that is resulting in greater urban migration will only serve to exacerbate the crisis if supply is not accelerated, otherwise prices will continue to escalate putting decent housing out of reach of more and more middle income households.

San Francisco is no outlier: demographic trends show that cities are growing in population and becoming denser. Over the next 30 years, ABAG projects San Francisco will see a 34 percent increase in jobs and 25 percent increase in housing units. But, as the law of supply and demand applies in San Francisco, if housing units are not built, the cost of existing housing will only rise faster. Reducing demand, (if even possible) as some advocate, is undesirable because it limits economic growth. The only solution is to build more housing, more efficiently.

San Francisco's regulatory and entitlement structure results in development timelines of up to 10 years, resulting in a boom-bust cycle that is detrimental to long-term housing market stability. The byzantine entitlement process and a plethora of regulations can kill worthwhile projects. Regulatory controls affecting development include Proposition 13, rent control, Discretionary Review, CEQA, and zoning density and height restrictions, to name a few. Some of these tools were intended to provide a voice to community stakeholders, or protect the environment, but many have had unintended consequences. For example, Discretionary Review enables individuals to hold up progress for the greater good, while CEQA has been used to successfully squash development without regard for where that development might elsewhere occur, potentially at greater environmental cost. Density and height restrictions, as demonstrated in this thesis, serve to limit the potential for developers to build more housing units on existing sites, instead they promote the development of larger, more expensive homes. These regulations represent very real land constraints, contributing to the housing crisis. While possibly well intentioned, they have only resulted in the perverse situation where they are driving up the price of the land.

Local and state leaders need to stress the fact that increasing supply is the only feasible way to address the housing crisis. Over thirty-five years of market and regulatory controls have not made San Francisco affordable for those who wish to live in the city; they have only protected those who already enjoy homes in the region. Municipal officials and the development community need to work with neighborhood groups to demonstrate how well-designed new development can fit reasonably within the context of existing neighborhoods, and point out that opposition to new construction will only result in pressure on existing housing stock owners to convert that stock to achieve higher prices.

Factory-built housing has the potential to contribute significantly to addressing San Francisco's housing crisis by helping to shorten development time and lower costs. Developers who use FBH can mitigate many of the neighborhood objections to an increase in development, as FBH is less disruptive and quicker to build. Not only that, but with proper encouragement from the city, developers could use FBH to build more units that are affordable to middle income households, the very ones getting squeezed out of the city's housing market. The potential market for FBH is big: based on the analysis in this thesis, if just 10 percent of the potential is realized, the market for FBH modules could reach 20,000 FBH modules in just San Francisco alone, representing between 10,000 and 20,000 new dwelling units. Extrapolated to the entire region, this number could multiply tenfold. But the housing affordability crisis does not depend solely on the ability of developers to reduce costs; it relies on a fundamental change in sentiment towards development in general. As Edward Glaeser writes, the developers need to be unleashed if we're to solve the housing crisis.

Appendix A: San Francisco County PDA Jobs and Housing Units Growth Projections

San Francisco County PDA Jobs and Housing Units Growth Projections

Jobs				
	2010	2040	Change	% Change
Regional Center				
Downtown-Van Ness-Geary	315,570	368,140	52,570	17%
Transbay Terminal	7,950	37,660	29,710	374%
Transit Town Center				
19th Avenue	9,980	13,570	3,590	36%
Treasure Island	260	3,010	2,750	1058%
Transit Neighborhood				
Balboa Park	2,690	3,460	770	29%
San Francisco/San Mateo Bi-County	1,720	2,580	860	50%
Urban Neighborhood				
Bayview/Hunters Point	19,590	29,260	9,670	49%
Shipyard/Candlestick Point				
Eastern Neighborhoods	61,070	70,890	9,820	16%
Market & Octavia	31,850	34,790	2,940	9%
Mission Bay	2,770	27,200	24,430	882%
Mixed-Use Corridor				
Mission-San Jose Corridor	12,680	18,760	6,080	48%
Port of San Francisco	5,430	24,400	18,970	349%
Total	471,560	633,720	162,160	34%
Housing Units				
	2010	2040	Change	%
Regional Center				
Downtown-Van Ness-Geary	101,520	128,660	27,140	27%
Transbay Terminal	490	5,210	4,720	963%
Transit Town Center				
19th Avenue	5,220	11,170	5,950	114%
Treasure Island	690	7,950	7,260	1052%
Transit Neighborhood				
Balboa Park	1,270	3,120	1,850	146%
San Francisco/San Mateo Bi-County	1,630	6,880	5,250	322%
Urban Neighborhood				
Bayview/Hunters Point	11,610	22,510	10,900	94%
Shipyard/Candlestick Point				
Eastern Neighborhoods	34,270	45,690	11,420	33%
Market & Octavia	11,950	18,150	6,200	52%
Mission Bay	3,470	6,850	3,380	97%
Mixed-Use Corridor				
Mission-San Jose Corridor	31,230	32,490	1,260	4%
Port of San Francisco	120	1,950	1,830	1525%
Total	203,470	290,630	87,160	43%
Source: Association of Bay Area Governments. Jobs Housing Connection Strategy Appendices. May 2012. http://onebayarea.org/pdf/JHCS/May_2012_Jobs_Housing_Connection_Strategy_Appendices_Low_Res.pdf. Accessed September 30, 2014.				

Appendix B: California Building Code

For residential construction, the CBC adopts the following categories:

- R-1 – transient housing including boarding houses, hotels, motels, etc.
- R-2 – permanent residences including apartment houses, boarding houses (non-transient), convents, dormitories, fraternities/sororities, hotels (non-transient), live/work units, monasteries, motels (non-transient), vacation timeshares, etc.
- R-2.1 - Supervised residential including assisted living, social rehabilitation facilities, etc.
- R-3 – Permanent residences that are not R1, R2, R2.1, R3.1 R4 or I, generally single-or two-family detached.
- R-3.1 – Small group living facility
- R-4 – 24-hour group living facility

(Source California Building Code 2013)

The CBC also regulates general building height and area maximums based on its Construction Type and use. Construction types include the following:

- Type I and II – Non-combustible materials building elements.
- Type III – Non-combustible materials for exterior walls. Interior building elements are of any material permitted by this code. Fire-retardant wood framing shall be permitted within exterior wall assemblies of a 2-hour rating or less.
- Type IV - (Heavy Timber) is where exterior walls are of non-combustible materials and the interior building elements are of solid or laminated wood without concealed spaces. Fire-retardant-treated wood framing shall be permitted within exterior wall assemblies with a 2-hour rating or less. Minimum solid sawn nominal dimensions are required for structures built using Type IV construction. For glued-laminated members the equivalent net finished width and depths corresponding to the minimal nominal width and depths of solid sawn lumber are included in the Appendix.

Further requirements for wood include columns (602.4.1), floor framing (section 602.4.2), roof framing (section 602.4.3), floors (602.4.4), roofs (section 602.4.5), partitions (section 602.4.6) and exterior structural members (section 602.4.7).

- Type V - Structural elements, exterior walls and interior walls are of any material permitted by this code.

Section 603 of the CBC clarifies the types of combustible materials permitted in Type I and II construction. Specifically, section 603.1 allows the use of fire-retardant-treated wood for the following:

- "Nonbearing partitions where required fire-resistance rating is 2 hours or less.
- Nonbearing exterior walls where fire-resistance rated construction is not required.
- Roof construction, including girders, trusses, framing and decking." (CBC 2013)

Chapter 5, Table 503 (Table 22 on the following page) of the CBC guides general building heights and areas by Group and Type of Construction, depending on Fire-rating (A or B). For example, Type I-A requires 3-hour structural frame while I-B requires a 2-hour structural frame (defined in Section 602 of the CBC).

Section 504.2 provides for increases in building heights and areas beyond those defined in Table 22. A 20-foot or one-story increase in all building heights is permissible if a building is equipped with an automatic sprinkler system. Further building area increases may be allowable due to frontage on a public way and automatic sprinkler system protection. The frontage increase is formula based (see Appendix) while an automatic sprinkler system permits an increase in the building area by 200 percent (section 506.3) for buildings with more than one story above grade and 300 percent for single story buildings.

Table 22 California Building Code Residential Height and Floor Area by Construction Type

Group		Type of Construction								
		Type I		Type II		Type III		Type IV	Type V	
		A	B	A	B	A	B	HT	A	B
	Height (feet)	UL	160	65	55	65	55	65	50	40
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2.1	S	UL	6	3	NP	3	NP	NP	3	NP
	A	UL	55,000	19,000	NP	16,500	NP	NP	16,500	NP
R-3/R-3.1	S	UL	11	4	4	4	4	4	3	3
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
R-4	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,0	16,000	24,000	16,000	20,500	12,000	7,000

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The following are excerpts from the CBC sections 602.4 and 506.1.

602.4 Type IV. Type IV construction (Heavy Timber, HT) is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of solid or laminated wood without concealed spaces. The details of Type IV construction shall comply with the provisions of this section. Fire-retardant-treated wood framing complying with Section 2303.2 shall be permitted within exterior wall assemblies with a 2-hour rating or less. Minimum solid sawn nominal dimensions are required for structures built using Type IV construction (HT). For glued-laminated members the equivalent net finished width and depths corresponding to the minimum nominal width and depths of solid sawn lumber are required as specified in Table 602.4.

TABLE 602.4
WOOD MEMBER SIZE EQUIVALENCIES

MINIMUM NOMINAL SOLID SAWN SIZE		MINIMUM GLUED-LAMINATED NET SIZE	
Width, inch	Depth, inch	Width, inch	Depth, inch
8	8	$6^3/_4$	$8^1/_4$
6	10	5	$10^1/_2$
6	8	5	$8^1/_4$
6	6	5	6
4	6	3	$6^7/_8$

For SI: 1 inch = 25.4 mm.

602.4.1 Columns. Wood columns shall be sawn or glued laminated and shall be not less than 8 inches (203 mm), nominal, in any dimension where supporting floor loads and not less than 6 inches (152 mm) nominal in width and not less than 8 inches (203 mm) nominal in depth where supporting roof and ceiling loads only. Columns shall be continuous or superimposed and connected in an approved manner.

602.4.2 Floor framing. Wood beams and girders shall be of sawn or glued-laminated timber and shall be not less than 6 inches (152 mm) nominal in width and not less than 10 inches (254 mm) nominal in depth. Framed sawn or glued-laminated timber arches, which spring from the floor line and support floor loads, shall be not less than 8 inches (203 mm) nominal in any dimension. Framed timber trusses supporting floor loads shall have members of not less than 8 inches (203 mm) nominal in any dimension.

602.4.3 Roof framing. Wood-frame or glued-laminated arches for roof construction, which spring from the floor line or from grade and do not support floor loads, shall have members not less than 6 inches (152 mm) nominal in width and have not less than 8 inches (203 mm) nominal in depth for the lower half of the height and not less than 6 inches (152 mm) nominal in depth for the upper half. Framed or glued-laminated arches for roof construction-that spring from the top of walls or wall abutments, framed timber trusses and other roof framing, which do not support floor loads, shall have members not less than 4 inches (102 mm) nominal in width and not less than 6 inches (152 mm) nominal in depth. Spaced members shall be permitted to be composed of two or more pieces not less than 3 inches (76 mm) nominal in thickness where blocked solidly throughout their intervening spaces or where spaces are tightly closed by a continuous wood cover plate of not less than 2 inches (51 mm) nominal in thickness secured to the underside of the members. Splice plates shall be not less than 3 inches (76 mm) nominal in thickness. Where protected by approved automatic sprinklers under the roof deck, framing members shall be not less than 3 inches (76 mm) nominal in width.

602.4.4 Floors. Floors shall be without concealed spaces. Wood floors shall be of sawn or glued-laminated planks, splined or tongue-and-groove, of not less than 3 inches (76 mm) nominal in thickness covered with 1-inch (25 mm) nominal dimension tongue-and-groove flooring, laid crosswise or diagonally, or 0.5-inch (12.7 mm) particleboard or planks not less than 4 inches (102 mm) nominal in width set on edge close together and well spiked and covered with 1-inch (25 mm) nominal dimension flooring or $^{15}/_{32}$-inch (12 mm) wood structural panel or 0.5-inch (12.7 mm) particleboard. The lumber shall be laid so that no continuous line of joints will occur except at points of support. Floors shall not extend closer than 0.5 inch (12.7 mm) to walls. Such 0.5-inch (12.7 mm) space shall be covered by a molding fastened to the wall and so arranged that it will not obstruct the swelling or shrinkage movements of the floor. Corbeling of masonry walls under the floor shall be permitted to be used in place of molding.

602.4.5 Roofs. Roofs shall be without concealed spaces and wood roof decks shall be sawn or glued laminated, splined or tongue-and-groove plank, not less than 2 inches (51 mm) nominal in thickness, $1^1/_8$-inch-thick (32 mm) wood structural panel (exterior glue), or of planks not less than 3 inches (76 mm) nominal in width, set on edge close together and laid as required for floors. Other types of decking shall be permitted to be used if providing equivalent fire resistance and structural properties.

602.4.6 Partitions. Partitions shall be of solid wood construction formed by not less than two layers of 1-inch (25 mm) matched boards or laminated construction 4 inches (102 mm) thick, or of 1-hour fire-resistance-rated construction.

602.4.7 Exterior structural members. Where a horizontal separation of 20 feet (6096 mm) or more is provided, wood columns and arches conforming to heavy timber sizes shall be permitted to be used externally.

SECTION 506
BUILDING AREA MODIFICATIONS

506.1 General. The building areas limited by Table 503 shall be permitted to be increased due to frontage (I_f) and automatic sprinkler system protection (I_s) in accordance with Equation 5-1:

$A_a = \{A_t + [A_t \times I_f] + [A_t \times I_s]\}$ **(Equation 5-1)**

where:

A_a = Allowable building area per story (square feet).

A_t = Tabular building area per story in accordance with Table 503 (square feet).

I_f = Area increase factor due to frontage as calculated in accordance with Section 506.2.

I_s = Area increase factor due to sprinkler protection as calculated in accordance with Section 506.3.

506.2 Frontage increase. Every building shall adjoin or have access to a public way to receive a building area increase for frontage. Where a building has more than 25 percent of its perimeter on a public way or open space having a width of not less than 20 feet (6096 mm), the frontage increase shall be determined in accordance with Equation 5-2:

$I_f = [F/P - 0.25]W/30$ **(Equation 5-2)**

where:

I_f = Area increase due to frontage.

F = Building perimeter that fronts on a public way or open space having 20 feet (6096 mm) open minimum width (feet).

P = Perimeter of entire building (feet).

W = Width of public way or open space (feet) in accordance with Section 506.2.1.

506.2.1 Width limits. To apply this section the value of W shall be not less than 20 feet (6096 mm). Where the value of W varies along the perimeter of the building, the calculation performed in accordance with Equation 5-2 shall be based on the weighted average calculated in accordance with Equation 5-3 for portions of the exterior perimeter walls where the value of W is greater than or equal to 20 feet (6096 mm). Where the value of W is greater than 30 feet (9144 mm), a value of 30 feet (9144 mm) shall be used in calculating the weighted average, regardless of the actual width of the open space. W shall be measured perpendicular from the face of the building to the closest interior lot line. Where the building fronts on a public way, the entire width of the public way shall be used. Where two or more buildings are on the same lot, W shall be measured from the exterior face of each building to the opposing exterior face of each adjacent building, as applicable.

Weighted average $W = (L_1 \times w_1 + L_2 \times w_2 + L_3 \times w_3 \ldots)/F$.
(Equation 5-3)

where:

L_n = Length of a portion of the exterior perimeter wall.

w_n = Width of open space associated with that portion of the exterior perimeter wall.

F = Building perimeter that fronts on a public way or open space having a width of 20 feet (6096 mm) or more.

Exception: Where the building meets the requirements of Section 507, as applicable, except for compliance with the 60-foot (18 288 mm) public way or yard requirement, and the value of W is greater than 30 feet (9144 mm), the value of W divided by 30 shall be limited to a maximum of 2.

Appendix C: City of San Francisco draft Housing Element Estimate of New Housing Construction Potential

The draft Housing Element prepares an inventory of available land suitable for housing development. The inventory does not include sites already slated for development over the next five to seven years – this existing residential pipeline totals 47,020 units. The city projects that almost 70,000 additional housing units could be built on existing vacant or underutilized[7] sites in zoning districts where housing is permitted and in the Mission Bay, Treasure Island and Hunter's Shipyard redevelopment areas. (SF Planning HE 2014, pp. I.63) Figure 36 through Figure 38 summarize the city's estimated new housing construction potential under existing zoning.

[7] Underutilized is defined by the city as a parcel having less than 30 percent of its zoned capacity developed. The draft Housing Element notes that parcels with existing capacity over 30 percent are being redeveloped, but for this analysis are not included.

Figure 36 - Estimated New Housing Construction Potential in Vacant or Near Vacant and Underdeveloped Sites by Generalized Zoning Districts, San Francisco, Q4 2013

General Zoning Districts	Vacant or Near Vacant Sites			Underdeveloped Sites			No. of Parcels	Net Units	Total Acres
	No. of Parcels	Net Units	Acres	No. of Parcels	Net Units	Acres			
Residential	850	2,647	87	2,144	7,104	294	1,922	9,751	234
Neighborhood Commercial	293	4,418	58	1,987	15,648	234	2,280	20,066	292
Mixed Use Districts	146	2,446	28	459	7,423	93	605	9,869	121
Downtown Commercial	70	623	14	181	1,751	64	251	2,374	78
Downtown Residential	11	1,656	6	7	146	1	18	1,802	6
Industrial/PDR	373	1,890	241	701	1,267	448	1,074	3,157	690
Sub-Total	1,743	13,680	434	5,479	33,339	1,134	6,150	47,019	1,420
Programmed /Redevelopment Areas									
Mission Bay								4,373	
Treasure Island								8,000	
Hunter's Point Shipyard (Phase II)								10,500	
Sub-Total								22,873	
TOTALS								69,892	

Table I-56
Estimated New Housing Construction Potential in Vacant or Near Vacant and Underdeveloped Sites by Generalized Zoning Districts, San Francisco, Q4 2013

* Remaining units to be built

SOURCE: SF Planning Department

Source: SF Planning HE 2014, pp. I.65

Figure 37 - Estimated New Housing Construction Potential in Vacant or Near Vacant and Underdeveloped Sites by Generalized Zoning Districts, San Francisco, Q4 2013

Zoning Group	Zoning District	Current Utilization: Vacant or Near Vacant Sites (Less than 5% of zoned capacity)			Underdeveloped or "Soft Sites" (From 5% - 30% of zoned capacity)			Total Parcels	Total Sum of Net Units	Total Sum of Acres	Zoned Units/ Acre
		Parcels	Net Units	Acres	Parcels	Net Units	Acres				
Residential		**850**	**2,647**	**87**	**2,144**	**7,104**	**294**	**1,922**	**9,751**	**234**	
	RH-1	442	602	39	83	336	21	525	938	59	16
	RH-1(D)	106	105	14	3	8	0.2	108	113	15	8
	RH-1(S)	3	3	0.2	319		31	3	3	0	15
	RH-2	163	605	17	195	729	14	482	1,334	48	28
	RH-3	46	182	4	146	480	42	241	662	18	37
	RM-1	39	198	4	28	2,084	6	185	2,282	46	50
	RM-2	7	95	1	59	412	12	35	507	8	66
	RM-3	12	210	2	23	1,081	4	71	1,291	14	95
	RM-4	12	393	2	2	612	0.1	35	1,005	6	163
	RSD	3	65	1	214	15	18	5	80	1	111
	RTO	18	189	2	1,072	1,347	147	232	1,536	20	See note 1
Neighborhood Commercial / Neighborhood Commercial Transit		**293**	**4,418**	**58**	**1,987**	**15,648**	**234**	**2,280**	**20,066**	**292**	
	NCD	42	434	7	527	3,196	53	569	3,630	59	See note 1
	NC-1	28	135	3	250	910	21	278	1,045	24	43
	NC-2	56	914	17	397	1,686	38	453	2,600	56	47
	NC-3	84	1,157	16	460	3,647	54	544	4,804	69	69
	NC-S	11	58	1	32	1,148	26	43	1,206	27	45
	NCTD	36	634	6	231	3,005	26	269	3,639	32	See note 1
	NCT-2	2	167	2	3	106	1	5	273	3	See note 1
	NCT-3	29	910	6	69	1,839	14	98	2,749	20	141
	SoMa NCT	3	9	0.1	18	111	2	21	120	2	See note 1
Commercial / Downtown Commercial		**70**	**623**	**14**	**181**	**1,751**	**64**	**251**	**2,374**	**78**	
	C-2	19	82	6	31	658	45	50	740	51	14
	C-3-G	26	444	5	61	735	9	87	1,179	14	84
	C-3-O	1	2	0.1	19	154	3	20	156	3	54
	C-3-O(SD)	10	57	1	28	91	3	38	148	4	39
	C-3-R	-	-	-	13	42	1	13	42	1	30
	C-3-S	13	34	1	23	62	3	36	96	4	24
	C-M	1	4	0.1	6	9	0.4	7	13	1	24
SUD / Downtown Residential		**11**	**1,656**	**6**	**7**	**146**	**1**	**18**	**1,802**	**6**	
	RH DTR	5	862	1	6	103	0.5	11	965	2	See note 1
	SB-DTR	4	100	1	-	-	-	4	100	1	See note 1
	TB DTR	2	694	3	1	43	0.2	3	737	3	See note 1

Source: SF Planning HE 2014, pp. I.66

Figure 38 - Estimated New Housing Construction Potential in Vacant or Near Vacant and Underdeveloped Sites by Generalized Zoning Districts, San Francisco, Q4 2013

Zoning Group	Zoning District	Current Utilization: Vacant or Near Vacant Sites (Less than 5% of zoned capacity)			Current Utilization: Underdeveloped or "Soft Sites" (From 5% - 30% of zoned capacity)			Total Parcels	Total Sum of Net Units	Total Sum of Acres	Zoned Units/ Acre
		Parcels	Net Units	Acres	Parcels	Net Units	Acres				
Mixed Use		**146**	**2,446**	**28**	**459**	**7,423**	**93**	**605**	**9,869**	**121**	
	CCB	1	8	0.05	6	97	1	7	105	1	180
	CRNC	3	51	0.3	10	143	0.8	13	194	1	178
	MUG	1	3	0.1	18	191	3	19	194	3	See note 1
	MUO	16	270	3	18	268	3	34	538	6	See note 1
	MUR	26	498	3	61	1,019	7	87	1,517	10	See note 1
	RC-3	6	86	3	22	381	14	28	467	17	27
	RC-4	24	641	3	88	2,717	14	112	3,358	17	199
	RED	18	167	2	55	279	3	73	446	5	88
	SLI	13	24	1	18	68	4	31	92	5	17
	SLR	-	-	-	6	33	1	6	33	1	41
	SPD	-	-	-	2	3	0.1	2	3	0.1	30
	UMU	38	698	13	155	2,224	43	193	2,922	56	See note 1
Industrial / PDR		**373**	**1,890**	**242**	**701**	**1,267**	**449**	**1,074**	**3,157**	**690**	
	M-1	94	1,331	76	90	587	35	184	1,918	111	17
	M-2	26	441	27	9	394	24	35	835	51	17
	PDR-1	1	-	0.4	-	-	-	1	-	0.4	-
	PDR-1-B	3	-	0.2	-	-	-	3	-	0.2	-
	PDR-1-D	6	-	5	18	-	13	24	-	18	-
	PDR-1-G	43	2	21	187	24	102	230	26	123	0.2
	PDR-2	200	116	112	397	262	275	597	378	386	1
Sub-Totals		**1,743**	**13,680**	**434**	**5,479**	**33,339**	**1,134**	**6,150**	**47,019**	**1,420**	
Programmed / Redevelopment Areas									**22,873**		
Mission Bay									4,373		
Treasure Island									8,000		
Hunter's Point Shipyard (Phase I)									10,500		
TOTALS									**69,892**		

SOURCE: SF Planning Department

Notes

1 These districts do not nominally restrict residential density, but regulates it based on factors such as lot cover, exposure, and unit mix requirements.

Source: SF Planning HE 2014, pp. I.67

Appendix D: Building Treet

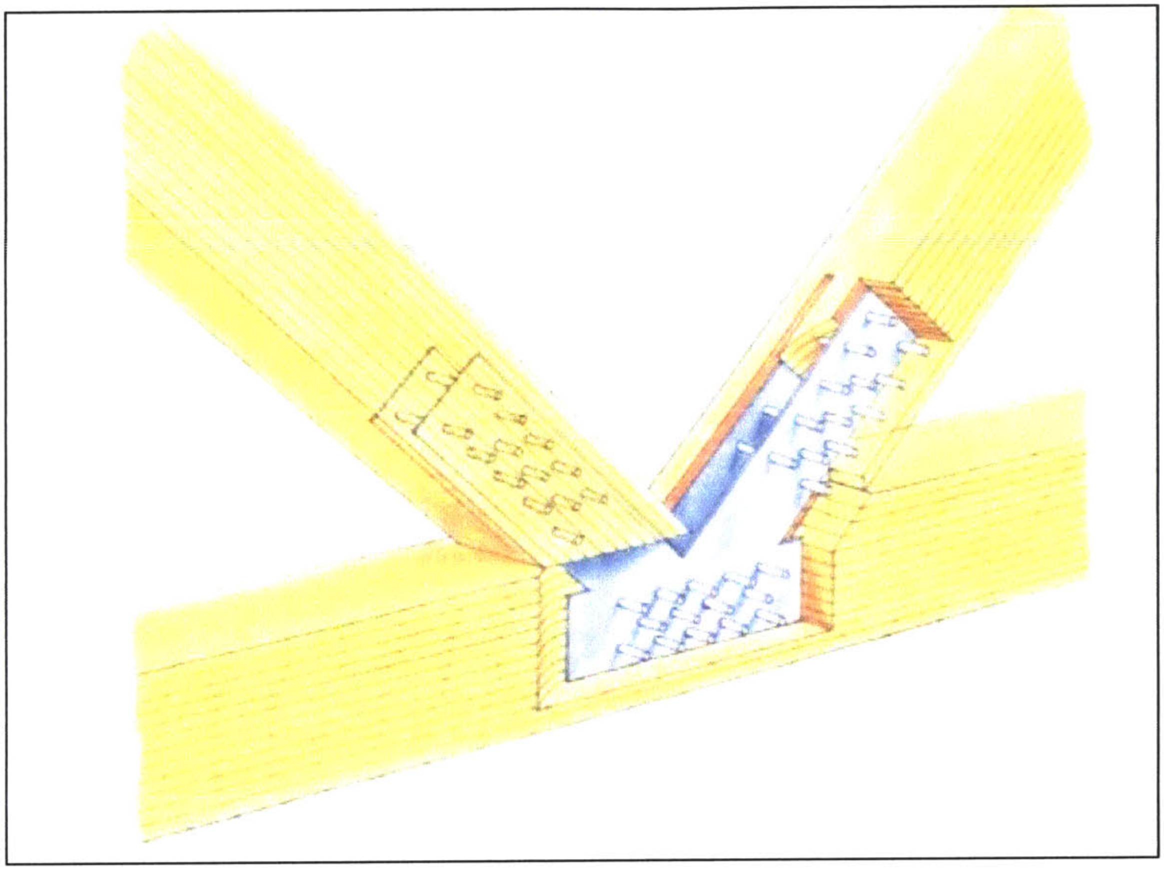
The project team includes:

- Moelven Limtre AS (glulam manufacturer, Norway)
- Artec Prosjektteam (architect, Bergen)
- Sweco (structural engineering, Bergen)
- Kodomaja (modular manufacturer, Estonia)

Engineering
Originally, Treet was proposed as a 12-story building. As the engineering progressed and the building's height increased from 12 stories to 14, the thickness of the glulam had to increase to support the dynamic loads on the structure as the building would start to sway in 30 m/s winds. As a result, the thickest glulam beams are one meter wide with loads transferred to them on "power floors", floor five and ten, which are 20 cm thick concrete slabs. Essentially, Treet is three five-story modular buildings set atop each other, over a concrete podium with basement parking.

The glulam structural timber beams are attached to each other with hidden steel connections inside the timber "slotted-in steel plates and dowels, a proven method for connecting large timber structures. (Abrahamsen, see Figure 39).

Figure 39 - Slotted-in steel plates and dowels



Source: Abrahamsen 2014

The modules are not attached directly to the glulam; instead they are stacked atop each concrete slab, which is fastened to the glulam on floors five and ten. In fact, there is 25 mm of separation between the modules and glulam. Again, manufacturing ensures these tight tolerances and on-site assembly must be precise requiring an experienced crane operator.

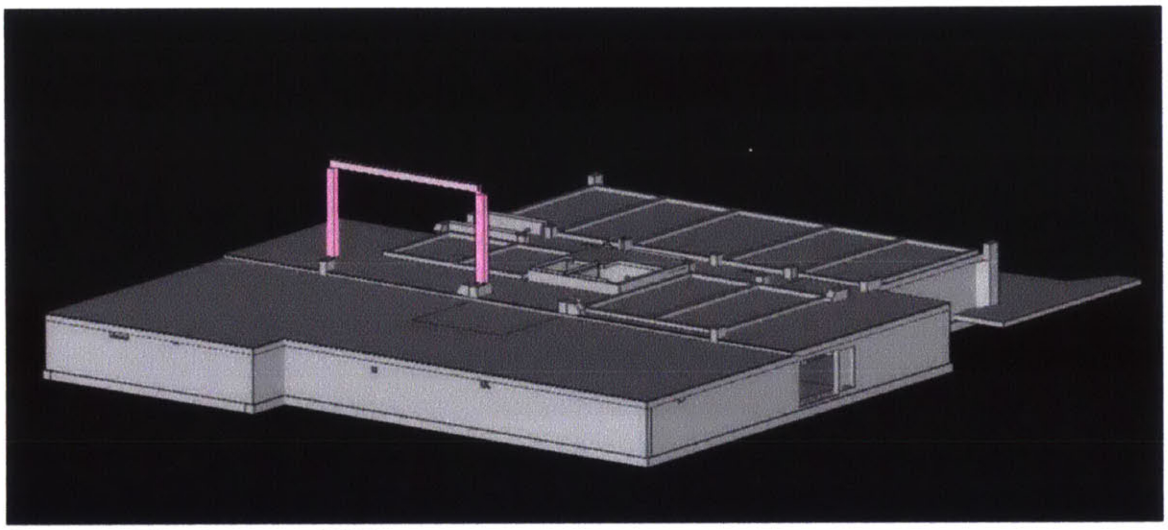
Construction Process

Initial sitework included the foundation piles and concrete podium (see Figure 40). The first five stories of modules rest atop the podium (Figure 41 through Figure 43), and once in place, glulam timber structural beams are attached to the concrete foundation. Inserting the second set of modules (floors 5-9) requires precision by the tower crane operator because the modules must lowered completely horizontal due to the glulam beams, with tolerances for placing the modules less than 34 mm. Another challenge during certain parts of construction (particularly in rainy Bergen) is that any work completed when wood is exposed must be done in dry conditions.

The construction process is described in the following set of figures. The CAD drawings provided during a presentation by SWECO in a Wood-Works Canada meeting in January 2014 are complemented by images taken during the on-site visit in October 2014.

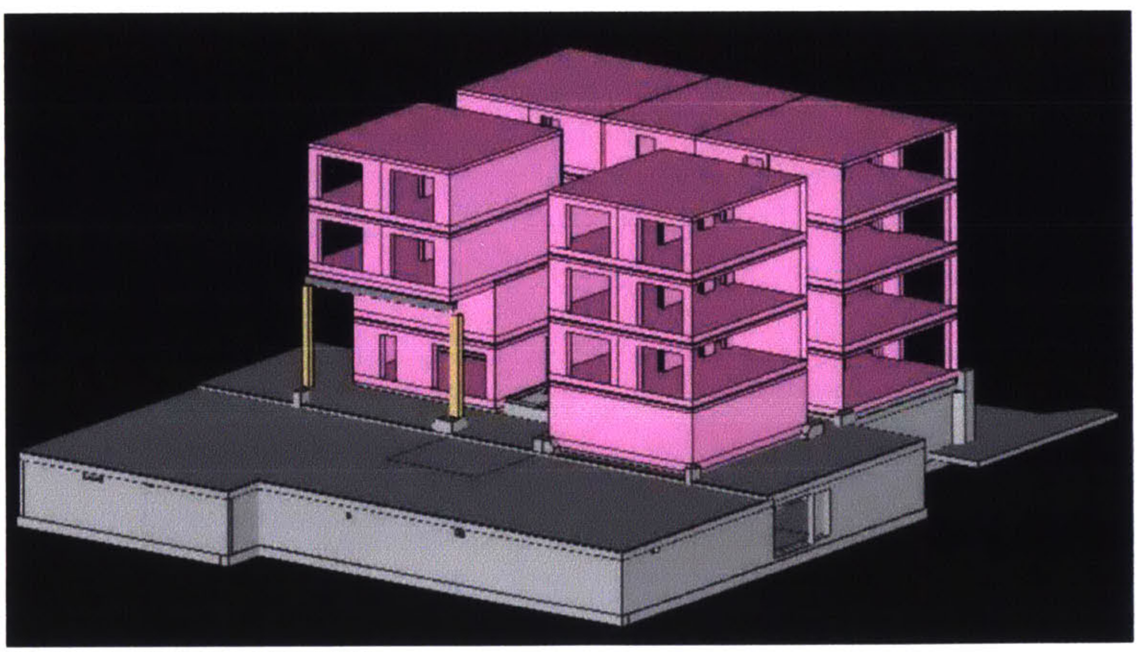
Step 1: Build foundation and concrete podium.

Figure 40 - Initial glulam timber to support balconies of street-facing units set atop concrete podium



Source: Abrahamsen 2014

Figure 41 - Modules set atop concrete podium



Source: Abrahamsen 2014

Figure 42 - Initial modules are set atop the concrete podium

Image taken October 15, 2014.

Figure 43 - Modules that extend over those below are supported by glulam timber beams

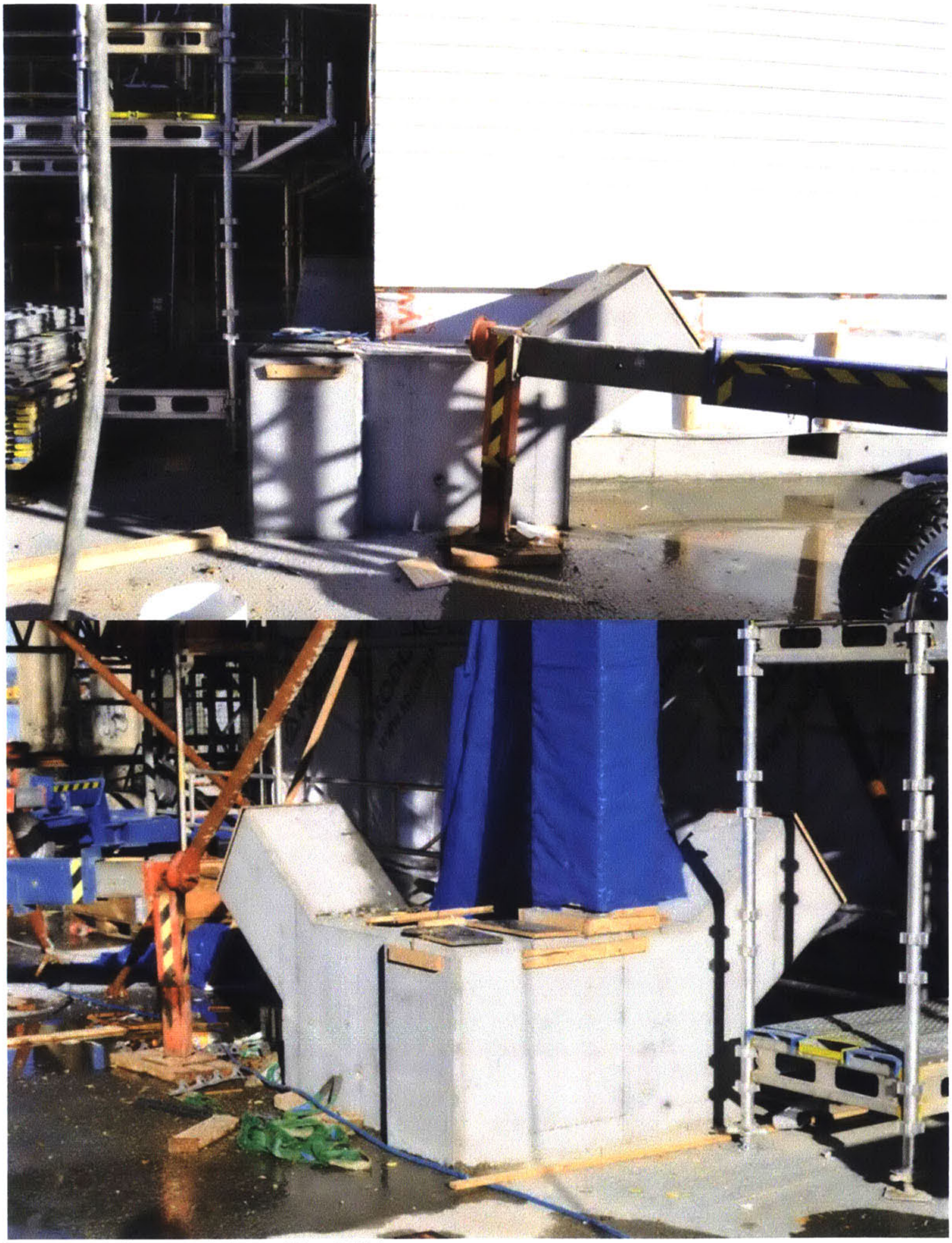
Image taken October 15, 2014.

Figure 44 - Glulam timber beam set atop concrete support

Image taken October 15, 2014.

Concrete supports for the glulam timber structural beams are poured as part of the concrete podium and modules must be set within these protrusions (Figure 45).

Figure 45 - Concrete structural support for glulam timber beams is a part of the concrete podium. Modules must be lowered into position by crane with precision

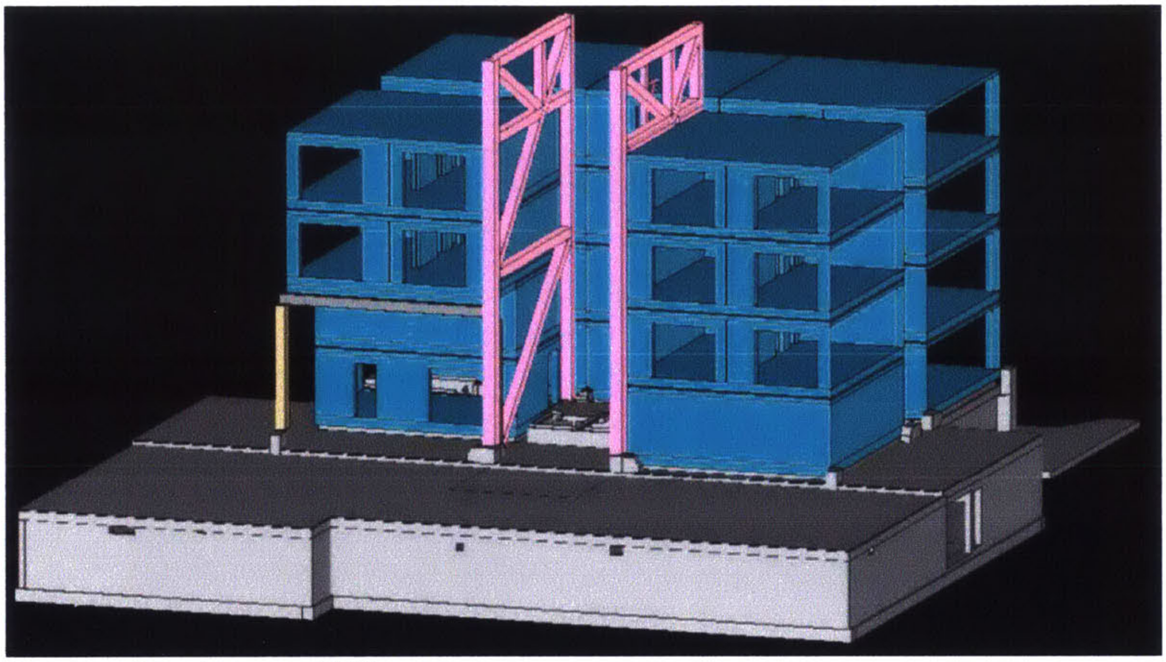


Images taken October 15, 2014.

Steps 2 and 3: Initial glulam timber beams and elevator and stairwell shafts installed

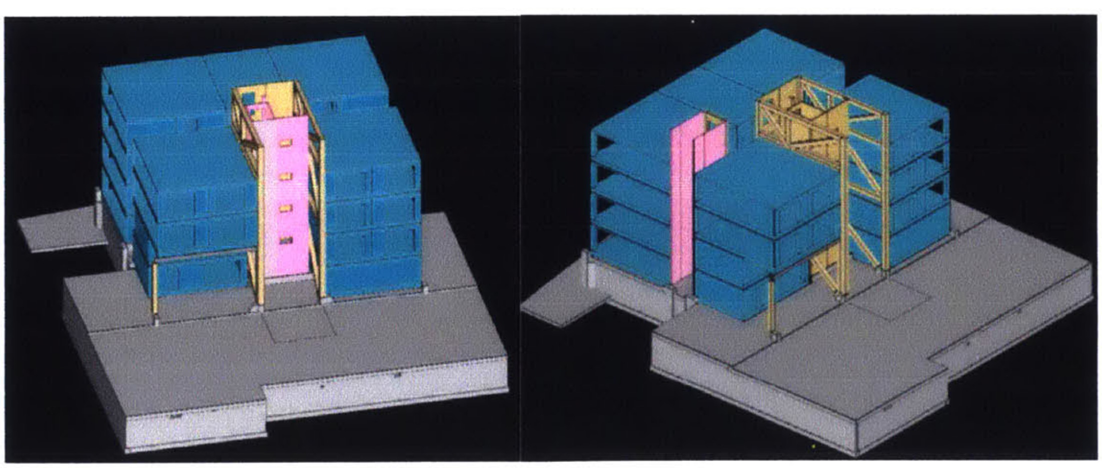
Once the initial set of modules are atop the concrete podium, glulam timber beams will be inserted (see Figure 46), which along with 5-story tall CLT boards, will form the elevator shaft and exit stairwell (see Figure 47).

Figure 46 - Glulam timber beams are inserted between modules



Source: Abrahamsen 2014.

Figure 47 - Along with glulam timber beams, CLT is inserted between modules to support the elevator and exit stairwell shafts

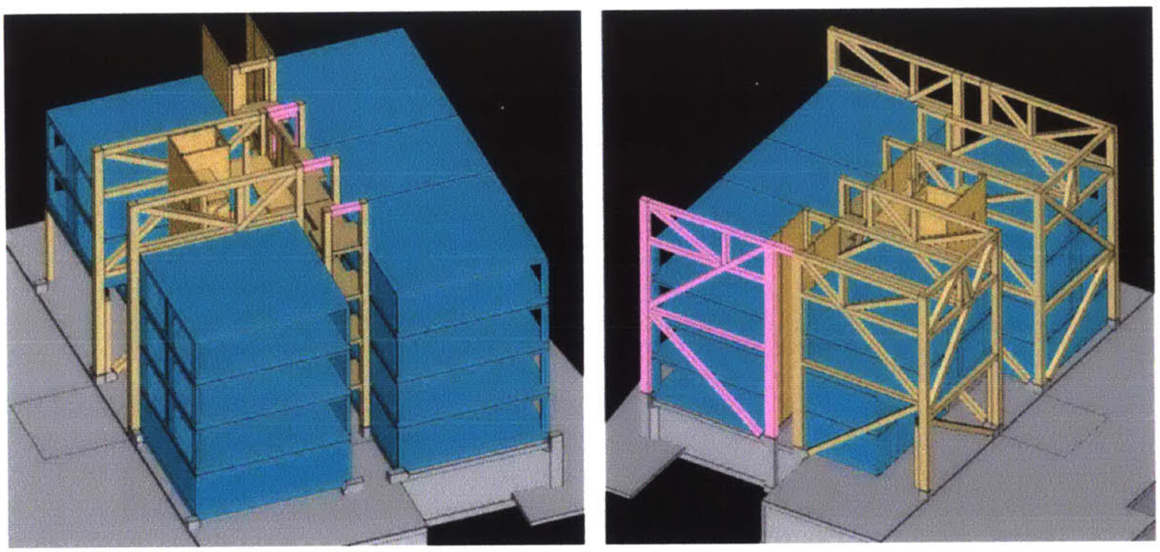


Source: Abrahamsen 2014.

Step 4: Install corridors along with electrical and plumbing connections

Corridors (also made of CLT) will then be inserted and at this point electrical and plumbing connections will be made between the modules and the main building systems running the length of the corridors. Once the CLT corridor is lowered and attached to the structure, plumbing and electrical work must be completed correctly as the lower floors are "sealed". (see Figure 48).

Figure 48 - Corridor and external glulam timber structural beams are installed

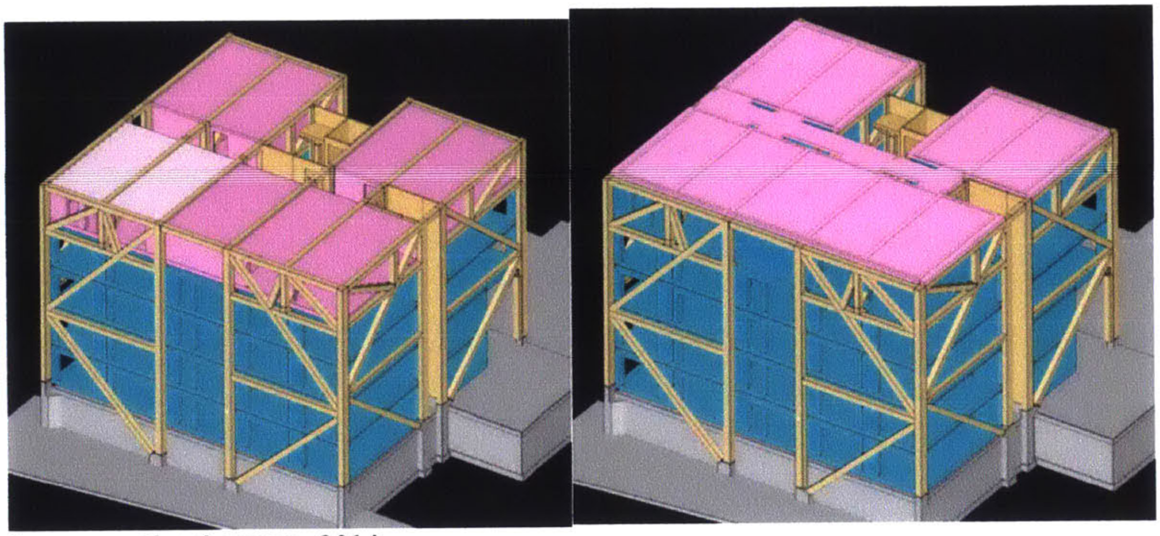


Source: Abrahamsen 2014.

Step 5: Insert fifth floor of modules and pour concrete pad.

Following the installation of the structural glulam beams, the fifth story of modules will be carefully lowered into place (Figure 49 left). Then, the concrete pad will be poured and secured to the glulam structural beams (Figure 49 right). The modules of floors one through five are not attached to the structural glulam, but are supported by the concrete podium.

Figure 49 - Fifth story of modules inserted between structural glulam (left) and concrete slab poured and attached to structural glulam beams (right)

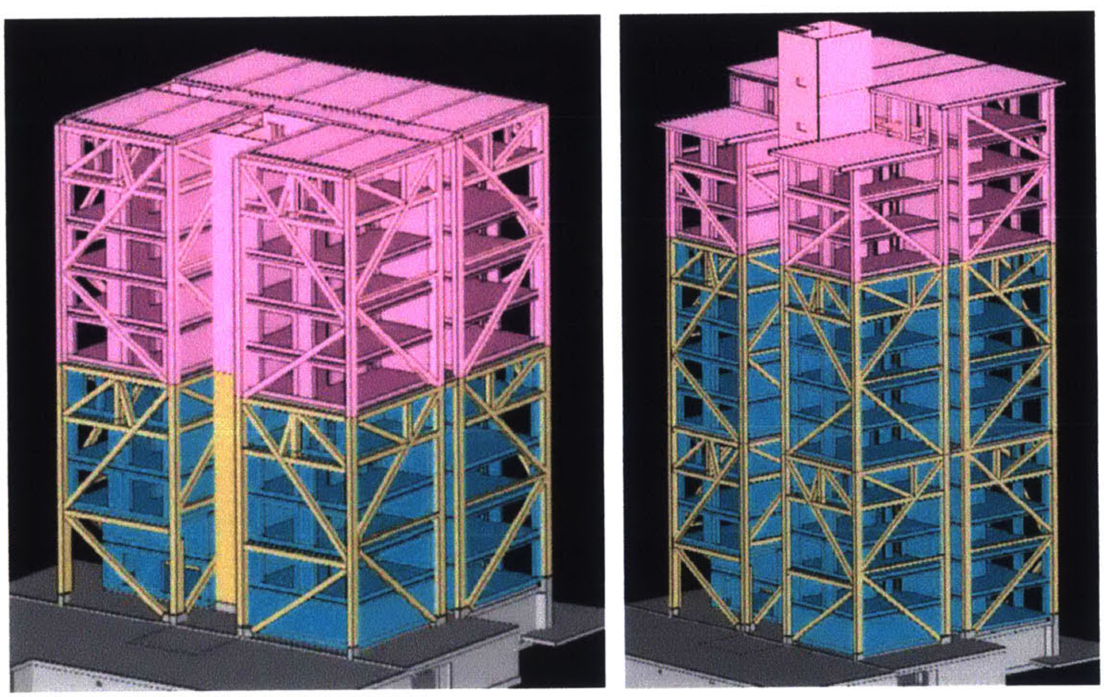


Source: Abrahamsen 2014.

Step 6: Repeat the above to complete the main structure

This process will be repeated two more times for floors six through ten and then floors eleven through fourteen (see Figure 50).

Figure 50 - The upper floors are built by repeating the process



Source: Abrahamsen 2014.

The final step will be the installation of the steel side curtain wall and glass balconies to protect the glulam timber from the elements. The resulting building is architecturally interesting with the structural glulam clearly visible from the outside as well as within some units.

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