Customizable and Adaptable Modular Construction:
An Efficient Housing Model For Dense Urban Living

A Thesis

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By

Leah Marie Penza

Miami University

Oxford, Ohio

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Advisor_____
Ben Jacks

Reader_____
John Weigand

Reader_____
John Blake

ABSTRACT

Are there more sustainable construction techniques that should be better utilized to provide customized, adaptable, and efficient homes for urban residents? Efficient modular and prefabricated construction has the potential to rebuild rundown cities, economically, socially, and sustainably. Many cities are scattered with old buildings that once thrived in the hectic environment, but now submit to disrepair. Buildings don't last forever, and cities cannot last without them, but our cities need rebuilding before their residents resort to more detrimental urban sprawl. Constant maintenance and occasional refurbishing is necessary, but building from the ground up can be a more cost-effective option in many cases. The main problem with this is that proper construction methods and community interests for urban environments are not currently being implemented in conventional housing construction. This paper examines modular and prefabricated construction to show why it is a good solution for many urban sites, and how to make resilient city buildings thrive in sustainable city environments. Modular construction is an efficient way to build that can save residents time and money, while remaining customizable with the ability to adapt to the future. Modular housing can be economically and sustainably built for infill lots, or built as a community that grows together. Baltimore, Maryland, a city that has been losing many of its residents, is used as a starting place for a new dense housing model. A variety of case studies in cities such as Philadelphia and New York support the argument of utilizing more efficient construction technologies and enforcing a strong sense of community to stabilize cities and the people who reside in them.

INTRODUCTION

Growing up on the edge of Baltimore City, Maryland, I experienced many of the good and bad aspects that cities can provide. High urban density allows convenient access to work, home, and recreation, but many cities become rundown and increasingly scattered with poorly maintained and vacant buildings. Baltimore often referred to as "Charm City" but the charm is somewhat difficult to find throughout the whole city. There is a lot of rich history and tradition shown through the buildings of any city, but it is discouraging in the areas where the history deteriorates with the buildings. The streets of Baltimore are home to more row houses than any other city in America, and over 16,000 sit vacant. We must provide homes that can revitalize city-life by engaging with the individual resident's needs, building resiliently, and implementing a stronger sustainable trend in our cities. We need to offer an array of efficient, yet affordable housing types that bring people back to the city and eliminate rows of vacancies. Modular construction that engages with the community can be the key to doing so. Not by offering affordable standardized (cookie cutter) buildings, but by providing *completely customized* homes based on standard sized pieces. Building with prefabricated modular parts is an efficient and more affordable way to provide homes for many people, especially in dense, urban areas. Modular and sustainable construction practices can eliminate high construction, labor, and energy costs, while offering the ease of customization and addition. Modules can be easily built in controlled environments for proficient construction, and assembled in place quickly in any city and for any inhabitant. When lives of the residents change, their houses can adapt and change at the same

time, with a simple attachment (or even detachment) of an extra module and a short displacement time. As individual families change, the entire community changes with it, promoting community experiences. This paper examines how sustainable, resilient, and inexpensive dwellings through modular construction can provide people with a diverse community that will remain in tact for many years to come.

METHODOLOGY

To tackle the notion of creating buildings that can last in a city, we must first briefly examine how cities evolve throughout history and generally uncover why certain areas become neglected. Through historical research, the reasons that rundown neighborhoods develop will be examined in order to prevent similar behaviors. To back up the feasibility of building modularly for affordability sake, I must also look at the history of modular housing. Modular construction has been around since the beginning of the 20th century, but it is not used as often as it should be. It has primarily been used in rural environments, and the reasons it hasn't been implemented in cities needs to be addressed, through *SmartMarket Reports* and news articles.

The main research method used to explore modular and mixed-income housing is case studies. Two projects are discussed: *The Stack,* a seven story modular building in New York City, and *Folsom Powerhouse*, in Philadelphia, PA, which was not built modularly, but is a model for successful mixed-income and mixed-use residences. Along with specific case studies, I examine existing companies and manufacturers to show some readily available options. There are many companies in different parts of the United States that provide a wide variety of modular and prefabricated housing, including *Nationwide Homes, Greenpod, and Resolution 4.* It is important to know what is currently offered in the broad category of modular building in order to obtain certain ideas and successes, or to avoid failures that have happened in the past.

CITIES



Figure 1: Baltimore City

Dense urban design has many advantages, especially when it comes to sustainability and convenience. All necessary amenities can be within walking distance to eliminate the need for cars, building surface area is reduced to mitigate heat-loss, and dense communities can grow much stronger for healthier social environments. The introduction of the American Interstate Highways after post-World War II allowed for inexpensive housing to be developed in rural areas, initiating the move towards suburban neighborhoods. It was necessary to house many American soldiers and their families around 1950, and it started a trend that spread the population out across the country and drastically increased the dependency of fuel.[i] Suburbs encapsulated the American

dream, and people continued to leave the heart of the cities, abandoning many buildings. During the 1980s-90s, energy was very inexpensive and led to an increase in production of much larger homes and large corporate buildings outside the city lines[ii]. Housing prices dropped in major cities and many low and middle-class families moved into homes they could not afford to maintain. Baltimore City, in particular, has lost about 300,00 residents since 1960, and about 1,000 people are currently leaving per year. People began to leave the city when many of its factories were shut down, but people continue to leave due to high property taxes and poor living conditions. To account for any type of resident, new construction should be resilient enough to reduce the amount of maintenance required, and have the ability to adapt for a sustaining and more efficient city.

WHY MODULAR CONSTRUCTION?

There are many benefits of prefabricated modular construction, in terms of efficiency and cost. Construction of modular units or panels occurs offsite in a closed factory environment preventing all weather related issues, allowing people to work on inclement weather days, and even into the night if necessary. It is much quicker to build multiple standard pieces at the same time, with a reduced chance for mistakes because the same parts are produced in a more organized way, and factory precision results in a better final product. When the modules are finished and transported to the site, it is much quicker to assemble the pieces together resulting in a lot less noise and disruption for the surrounding neighbors. The faster construction time minimizes construction and labor costs for a more affordable and simple construction process on and offsite.

There are many different types of prefabricated construction, including manufactured, modular, panelized, and a hybrid of modular and panelized that can provide many options for clients.

Manufactured homes are most typically known as 'trailer homes' that are entirely built in a factory and shipped on its own wheels to the site as a completely finished product.



Figure 2: Manufactured Home

Modular homes are built by assembling multiple prefabricated box-like modules together to create a 90% finished product. Finishes and special equipment are usually added after all the modules are put together.



Figure 3: Modular Home

Panelized construction breaks the design into standard sized wall, floor, and roof panels. The panels are easier to transport than full modules, but the on-site assembly time is slightly increased. Many finishes and special equipment can be applied before shipment to the site if proper steps are taken to ensure the safety during transport.



Figure 4: Panelized Home

Modular construction has been around for over a century, but has never become very popular despite its many advantages. It was primarily used in rural areas to avoid contractors from traveling long distances every day. The highest percentage of modular building was seen in 2009, according to the NAHB Research Center, where 2.8% of the total home production were modular single-family homes, and 0.8% were multifamily buildings.[iii] Over the past century, prefabrication has been associated with mass-production and has the implication of cheap, poor quality, cookie-cutter homes that give modularity a bad connotation. Standard, modular pieces can be put together in a variety of ways for customized homes that cater to individual clients, but these homes are simply built with higher efficiency.

Building modularly does in fact have limitations that need to be taken into account. The sizes of each module are limited by the width of the roads and the trucks transporting them from the factory to the site, so city streets need to be analyzed for module size. The design of the building must be based off of modules or panel sizes, which can limit certain unique shapes and forms, however modular, panelized, and typical construction can be mixed to achieve many designs, while still keeping the cost down. It is still unknown how large a modular building can be, but it looks hopeful that it is a feasible construction method for any sized building. For example, the new modular development of Atlantic Yards, Brooklyn, New York has been struggling during the construction of the 32-story *B2 Brooklyn Tower*. It was taking much longer than anticipated to assemble the factory-built modules due to certain design flaws, lack of knowledge of the particular construction method, and it ultimately led to major money issues and a lot of finger pointing between the developer and contractor. Construction was shut down to settle the dispute, but it will be continued after adjustments are made to the tenth floor. The tolerances were designed too tight for such a large-scale project, making it necessary yet extremely difficult to fit the pieces together *perfectly*.

For projects at a smaller scale than a skyscraper, modularity is definitely a great way to build in the city. For maximized efficiency and limited travel distance, a temporary shop could be set up closer to the site to build certain pieces. This could also promote awareness and interest of the new system for increased production. If city residents have the chance to be involved with construction and promotion, it could give people knowledge and direction towards a trade and a better future.

CASE STUDIES



Figure 5: The Stack, Gluck+

Large modularly constructed buildings have been popping up in New York City since *The Stack* was put together in 2013. It has been a construction method used for smaller scale projects in the city, including row houses for low-income families, but never seen for such large buildings. New York City has very high construction costs, and modular construction allows builders to cut prices by 20-30%. The former Mayor of New York, Michael Bloomberg, advocated for more modular projects in the future:

"Modular construction…is faster, less expensive, allows for high levels of quality control and significantly reduces waste and truck traffic. It's also safer for workers as construction is done inside in controlled environments."[iv]

The Stack is seven stories tall, made out of 56 modules that were built in a factory in Pennsylvania. Even though it uses the same modular pieces, it does not mean that every floor is stacked to be the same. It consists of 28 rental apartments, including studio, one, two, and three bedrooms with 19 different floor plans to choose from. A small construction management firm, Jeffrey M. Brown Associates, designed it along with Gluck+, a better-known construction and development firm. Gluck+ describe themselves as "Architect Led Design Build" and are focused on change and innovative solutions while trying to incorporate more modular housing for a long time. "Factory construction offers builders controlled weather conditions, better supervision and the opportunity to offer more stable jobs, all of which 'lead to better quality construction.'" [v] The construction of the building took just about a month, with eight ironworkers, a crane operator, and half-a-dozen miscellaneous helpers. All the parts were assembled in a month, but the façade and was not finished until three months after that. Some of the amenities the building offers include a high-tech virtual doorman, a building-wide video intercom system, a central laundry facility with pre-wired units for personal machines, private terraces along with a community courtyard, private storage and bike storage, and it is located just a couple blocks from the subway. New York City is the perfect place to build modularly, and Peter Gluck is glad to finally be a part of it: "Building any building is a nightmare, but this was not a nightmare. Given that this is the first one we've ever done, this went amazingly smoothly."[vi]



Figure 6: Folsom Powerhouse, Philadelphia

In Philadelphia, PA, a long block was recently redesigned for a new mixed-income and mixed-use community, called Folsom Powerhouse. It is a traditionally built, eco-friendly stretch of 31 residential units with commercial space incorporated on the corner of 18th and Folsom streets, just minutes away from the heart of the city. There is a mix of two-story duplexes either with full backyards or a roof deck, and four-story townhomes with an attached roof deck. ISA Architects designed the project, while Postgreen Homes and Equinox Management & Construction LLC teamed up for construction. The project was requested by the city to convert a vacant city-owned property into mixed-use and mixed-income housing, and it has been successful so far. It was built in two phases, and due to its popularity, every home in Phase I was presold before construction even started. Its residents are of different income levels with a common interest in "ecological urbanism."[vii] The entire project is aimed towards a community driven lifestyle. Revitalizing the streetscape was an important goal that is shown by "super-stoops"[viii] and the incorporation of benches on the sidewalk. There is an organic vine pattern cut into steel sheets that was used for the railing on the super-stoops and benches to create a cool urban streetscape and encourage outdoor use and community interaction.



Figure 7: Folsom Powerhouse Streetscape

Sustainability is a crucial aspect that makes the Folsom Powerhouse project so successful. The buildings exhibits energy-efficient design with high insulation, triple pane windows, healthy indoor air quality, and advanced storm water management practices. The buildings in Phase II are equipped with a photovoltaic system that's energy is shared between all tenants. Each homeowner is expected to save $20,000 in energy costs throughout the next thirty years. Other than the cost-savings the residents will see, the construction company will also see some beneficial cost implications. Equinox will receive $850-$1,000 per home from the Philadelphia Energy Company (PECO) Smart Builder Rebates for meeting Energy Star standards for all of the homes. Chad Ludeman, the President of Postgreen Homes is highly concerned with sustainability: "The Powerhouse name is indicative of our commitment to extreme energy efficiency, giving residents the power to live with community and environmental consciousness in mind."[ix]

EXISTING COMPANIES

The following three companies will explain some of the different modular housing types that are already on the market.



Figure 8: Nationwide Homes Options

Nationwide Homes is a company that has been producing modular homes all over the country for

over 50 years, when a home could be bought with a five dollar down payment. There are many pre-designed homes to choose from, but they also provide custom designs as well. For many years they stuck to the trend at the time and built large houses as big as 5,000 square feet for rural and suburban lots. In 2011, they finally started scaling down the sizes of their houses to adapt to people's needs. They designed homes that were between 1,500-1,800 square feet with selling costs between the high $60s-$120 per square foot. This appealed to the new economic state, but they also introduced a new urban infill series called *Renew Avenue* that was intended for narrow lots to expand to more sites. These houses are still not designed to be narrow enough for inner-city lots, and are more appropriate for suburban areas. There are a few available houses that could be adapted for a city, but *Nationwide* mostly caters to suburban living.[x]



Figure 9: Greenpod

Greenpod development is a firm located in Seattle that designs modular homes with healthy interiors. They offer custom homes, and pre-designed "pods" with the ability to join and stack multiple pods. They focus on low impact and efficient design, clean water and air, natural light, temperature control, and "art that you live in". They have multiple product lines, including the WaterHaus line, which was the first to explore healthy interiors. This particular line includes movable walls, cost-efficient lighting and interior glass to maximize smaller spaces and reduce the environmental footprint down to 450 square feet. All homes can be factory-built and transported as a whole house, or a kit of parts to be assembled on site. For tight budgets, you can choose an efficient home that complies with both budget and needs. For higher budgets, you have many customizable add-on options to choose from. These houses are designed primarily for Washington residents, with cabins tucked into the woods and even floating houses. The notion of healthy interiors is being implemented in already healthy environments, but healthy interiors would be even more beneficial in cities where clean air is less prevalent.[xi]

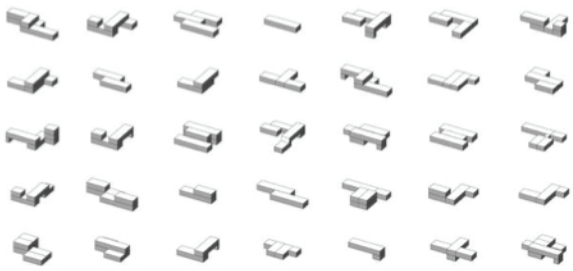


Figure 10: Resolution: 4 Architecture

A more personalized company, *Resolution: 4,* works with individual clients to produce completely custom homes that are just built modularly. They do not mass-produce their homes, but they have standard shapes and plans that can be individually personalized. They have a variety of series: single wide, double wide, triple wide, T & Z shaped series, and a courtyard series. Within each series, there are options of how many modules are needed and a variety of ways they are put together. These homes are designed for optimum

efficiency for production with flat roofs and simple modern forms.

"Through extensive research and design, Modern Modular provides a full line of houses to fit different uses... Through a focus on modular living units, houses are fully customizable to meet functional requirements of different locations and climates, and the specific needs of different households. Homes are easily expandable and transformed, allowing Modern Modular homes to grow and adapt to its residents."[xii]

This statement on *Resolution: 4's* website captures many things I want to accomplish while designing for individuals in a standardized way. Complete customization and adaptability allow homes for many different lifestyles in any city.

WHERE CAN WE GO FROM HERE?

Cities constantly have new projects in an attempt to revitalize an area or to provide new amenities that will bring more money to the city. Many of these projects are built on large subsidies and giveaways that take funds and resources from foundation government operations including infrastructure and schools. A major project was proposed in 2013 for a large mixed-use development on the last large plot of open land in the Baltimore Harbor. Named *Harbor Point*, the proposed three million square foot complex will include close to ten acres of open space, with separate buildings for retail, residential, hotel, and office space. This project could only happen with considerable subsidies, tax breaks, and other giveaways, sparking disapproval from many Baltimore residents. Harbor Point is located very close to Harbor East, a fairly new, upscale mixed-use neighborhood. City residents would highly prefer that the government focus on areas in terrible condition at a smaller scale before taking on such a large project that is expected to fail.[xiii] The project-manager and president of the Beatty Development Group, Michael Beatty, argues against subsidies and tax breaks for an "equal playing field for everybody"[xiv] and proposes that the tax rate should be significantly reduced to increase property value: "The assessments of those neighborhoods will go up right away… Reduce the tax rate, and the value will go up. People will invest more. The city will get more revenue."[xv]

I can change the urban environment at a smaller scale by creating a system of designing customized homes with a unique hybrid modular system that can be implemented in any urban setting. This system will include first floor retail to give jobs to the neighborhood and revitalize the area, and it will cater to each client's diverse necessities. Lower-income residents can assist in the construction process and have a future job involving the maintenance of surrounding buildings. The ability to adapt each home separately ensures that families can remain in the same house for generations, or new owners can adapt any house to their family. While taking a certain amount of politics into consideration, I will search for the best solutions to rejuvenate cities and their inhabitants.

SITE ANALYSIS

Baltimore neighborhoods are extremely distinct and either filled with rich families in large houses on the outskirts, young business professionals closer to the center of the city, or poor families living in dilapidated or government properties dispersed throughout the city, especially in East and West Baltimore.



Figure 10: Baltimore Inner Harbor

The Inner Harbor was once filled with industrial factories with a major cargo port and was considered the second-largest entry point for immigrants. The loss of many factories meant the loss of 100,000 factory jobs that left the residents and the government in search of income. The harbor consisted of abandoned warehouses until the late 1970's, when a major redevelopment project was proposed to revitalize the inner harbor and turn it into a tourist attraction. While there was an increase of tourists, the city residents continued to leave, including municipal workers and police officers. The amount of crime in the city is often paralleled with the fact that 77% of police officers live outside city lines.[xvi]

Cities all over the world have their issues that stem far beyond architecture and urban planning. There are a number of political and economic reasons for the less than ideal conditions in Baltimore city that need to be addressed before the city can reach its maximum potential. According to the United States Census Bureau, 1 in 4 Baltimore residents live below the poverty line, with a 1 in 5 unemployment rate.[xvii] I am not attempting to solve the governmental issues and crime that cities face, but new community oriented architecture in our cities can inspire its people and maybe even inspire different governmental policies. The community can have the opportunity to be actively involved in the construction process with teaching and job opportunities, giving underprivileged residents a chance to improve their city and individual lives. By providing many people with a job as well as a comfortable place to reside, crime can potentially decrease while city income increases.



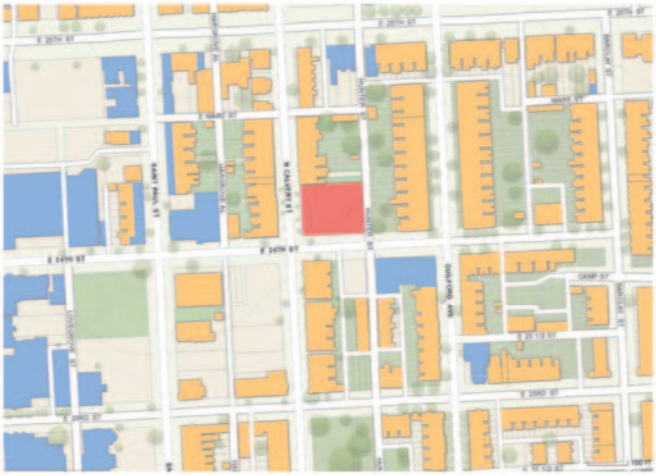


Figure 11 & 12: Site Context

The site chosen for this development is an empty 24,600 square foot lot, two miles north of the Inner Harbor. It is in the *South Charles Village* neighborhood, surrounded by a variety of housing types, and a variety of commercial buildings in every direction. The site is located on the corner of N Calvert Avenue and E 24th St.

Calvert Ave is a busy one-way street that leads people out of the city, and this site is a perfect place to intrigue them to stay. Just one block south, there is a community garden, a large open park, and a smaller park with a playground. It is a very active and diverse neighborhood that would be open to accepting new housing solutions, therefore a perfect place to introduce this new system.







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All other Figures made by Leah Penza

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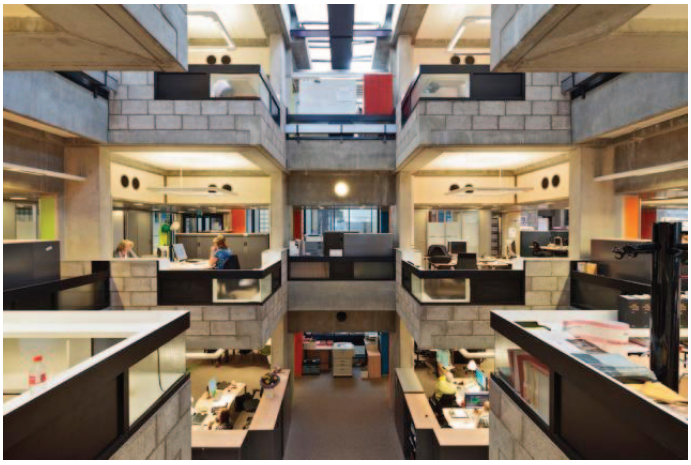
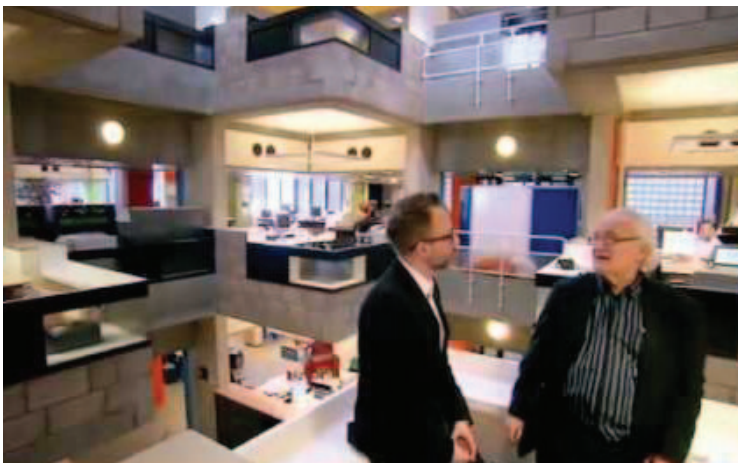
ADDENDUM

Throughout the design process, I was striving to figure out ways to fit modular pieces into different sized narrow urban lots with the highest efficiency possible. I created a hybrid modular and panelized system (using SIPS-Structural Insulated Panels) with a 2-foot module for a high amount of customization. The leftover dimension of the site is filled with a custom-width continuous glass piece on the front and back facades and roof. This mitigates the amount of waste from cutting down the panel sizes, allows homes to fit on any width site, and brings plenty of light to lower floors through the vertical stairwell. The main vertical core is made up of one module per floor, which holds the stairs, bathrooms, and a mechanical wall for plumbing and ventilation. The core is in the center of the home with program spaces on either side, which can be opened or closed by sliding, hinging, or pivoting walls. Even though there is a standardized structural and programmatic system, each home is uniquely designed to fit the client's needs. Each home can also uniquely adapt, whether it be for hosting a party, increasing balcony space, or adding rooms horizontally to the rear, or vertically with another floor. Using SIPS Cam-lock system, the exterior façade walls can be unlocked, slid along tracks, and locked in another place after removing floor and wall materials to allow for more or less balcony space. The Cam-lock system also allows for roof panels to be unlocked and used for vertical additions, instead of demolishing the roof to add another floor. Everything was designed around customizability with standard parts, and daily and long-term adaptability with little to no waste in the process.

DESIGN DEVELOPMENT

CENTRAAL BEHEER | HERMAN HERTZBERGER

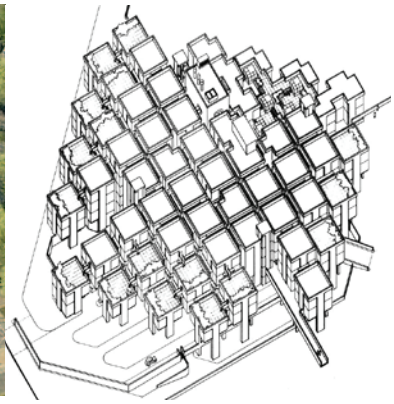




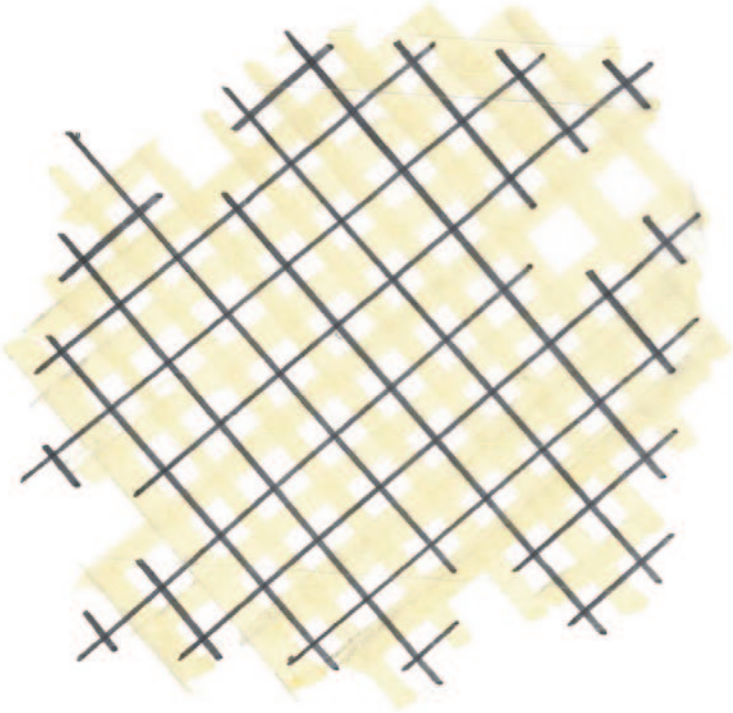


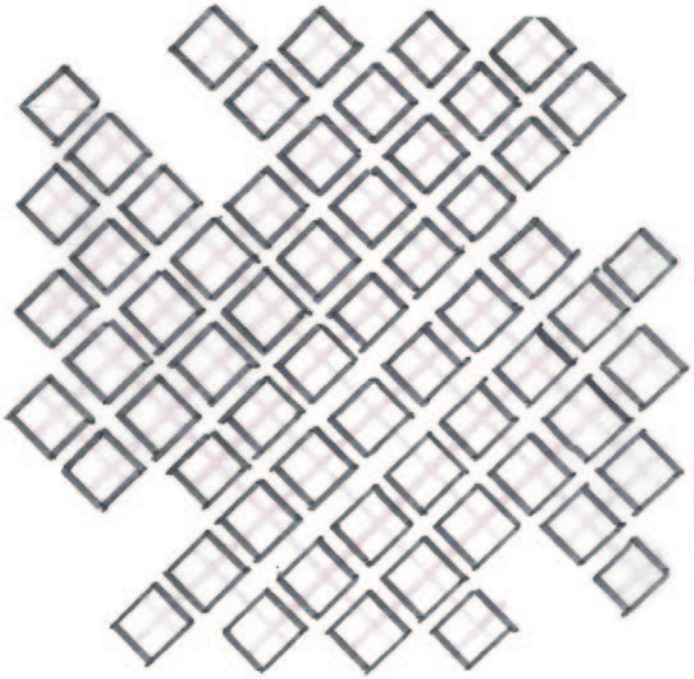


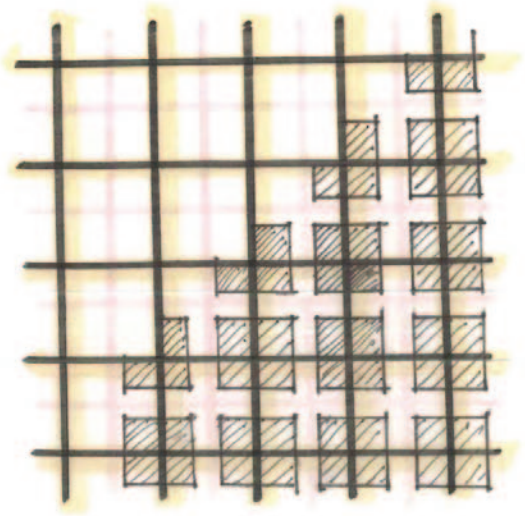


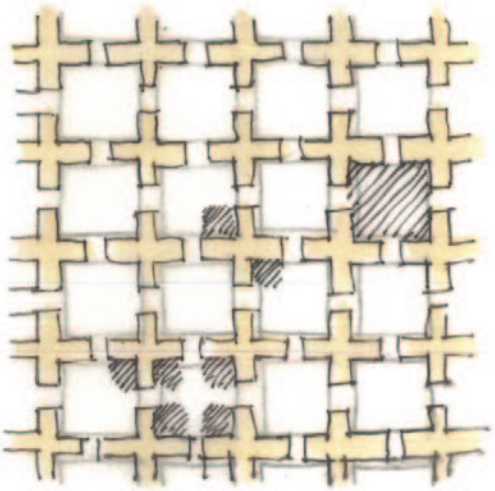


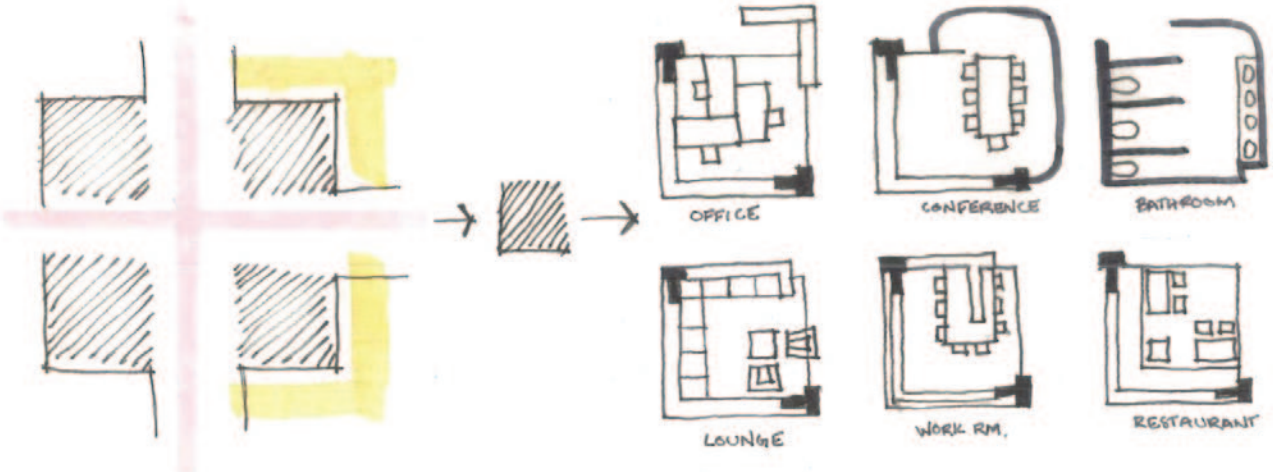
SPATIAL ARRANGEMENTS



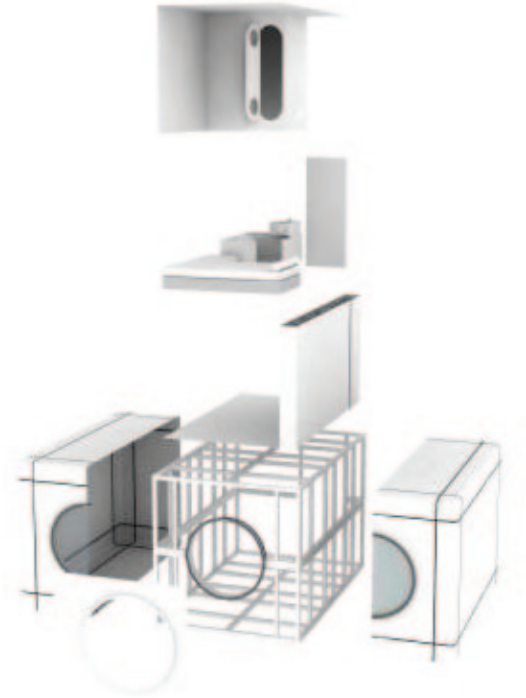








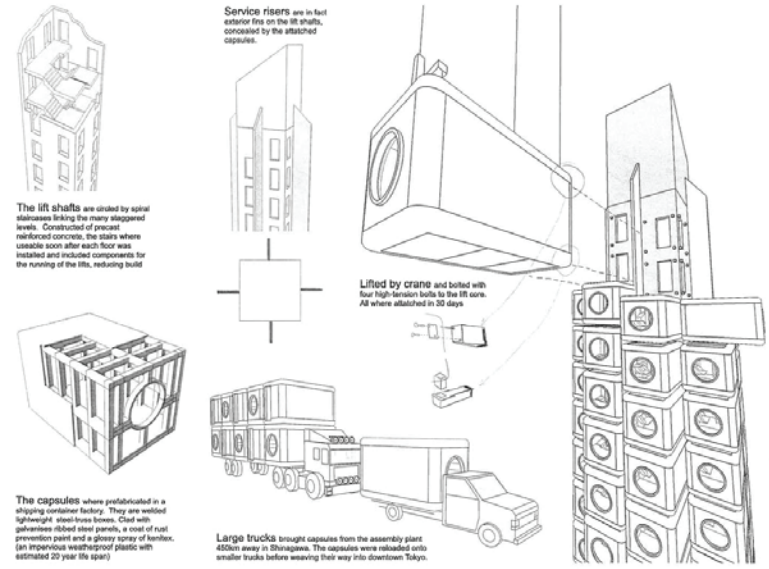
NAKAGIN CAPSULE TOWER | KISHO KUROKAWA











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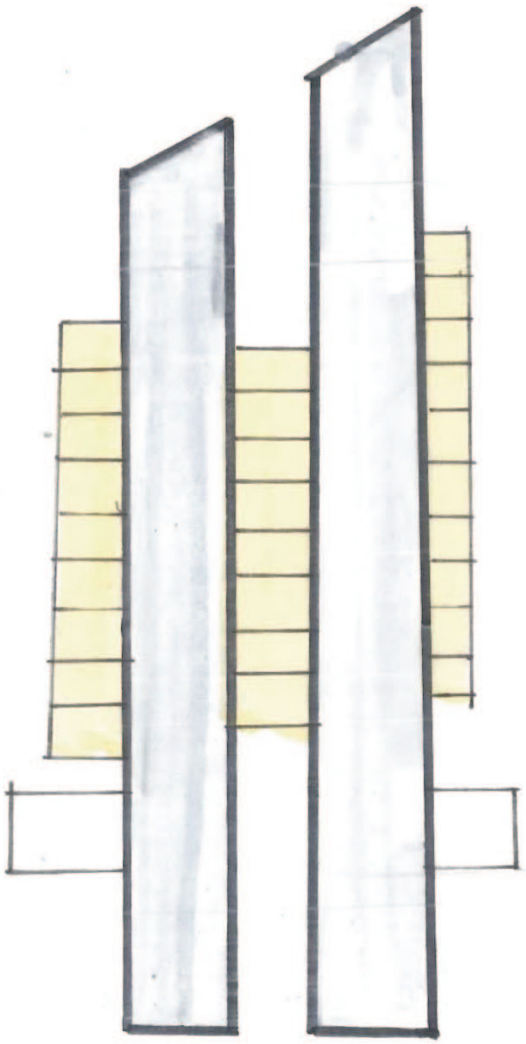
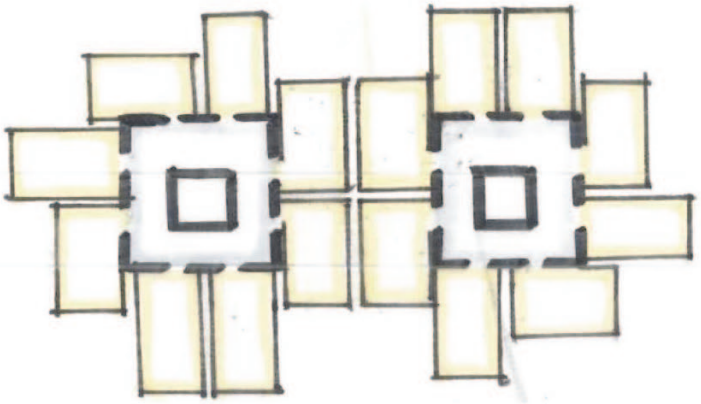
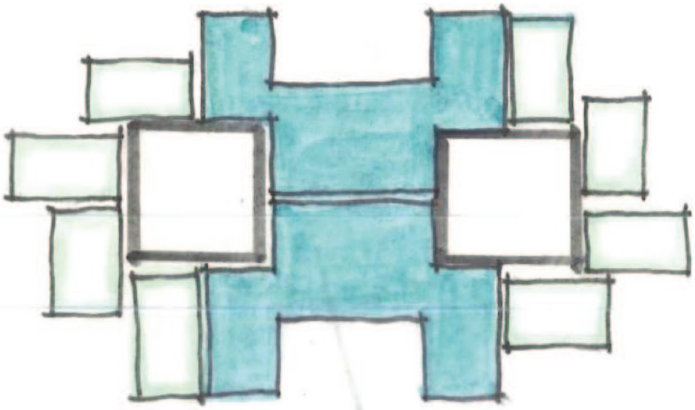
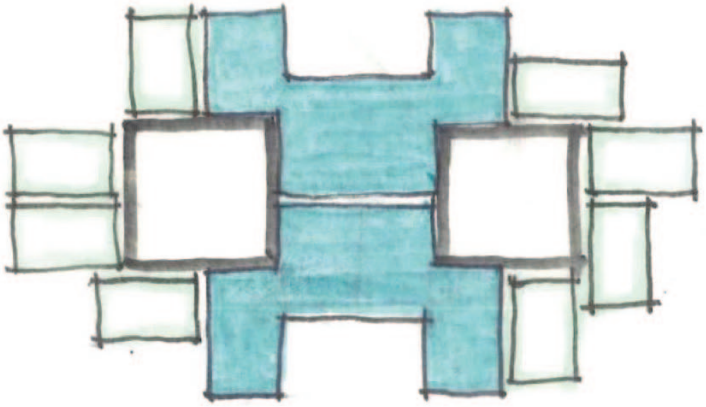
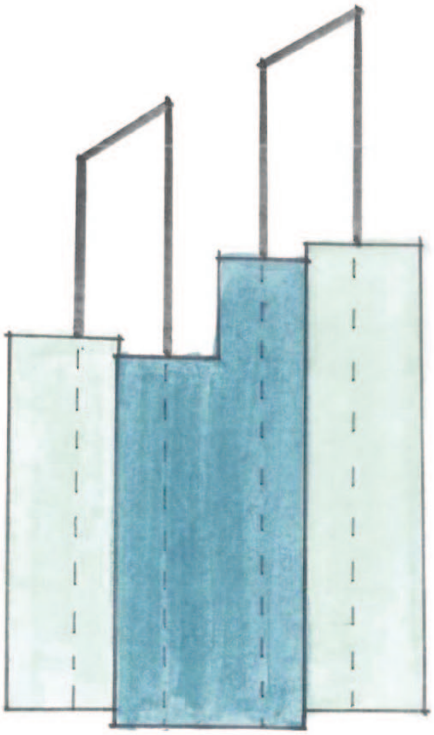
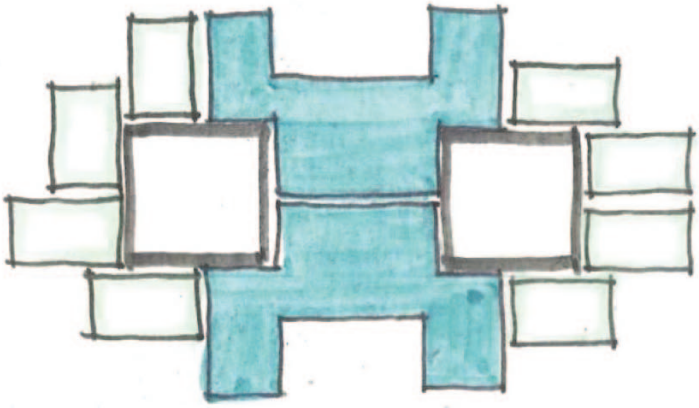












MIMA HOUSE | MIMA ARCHITECTS

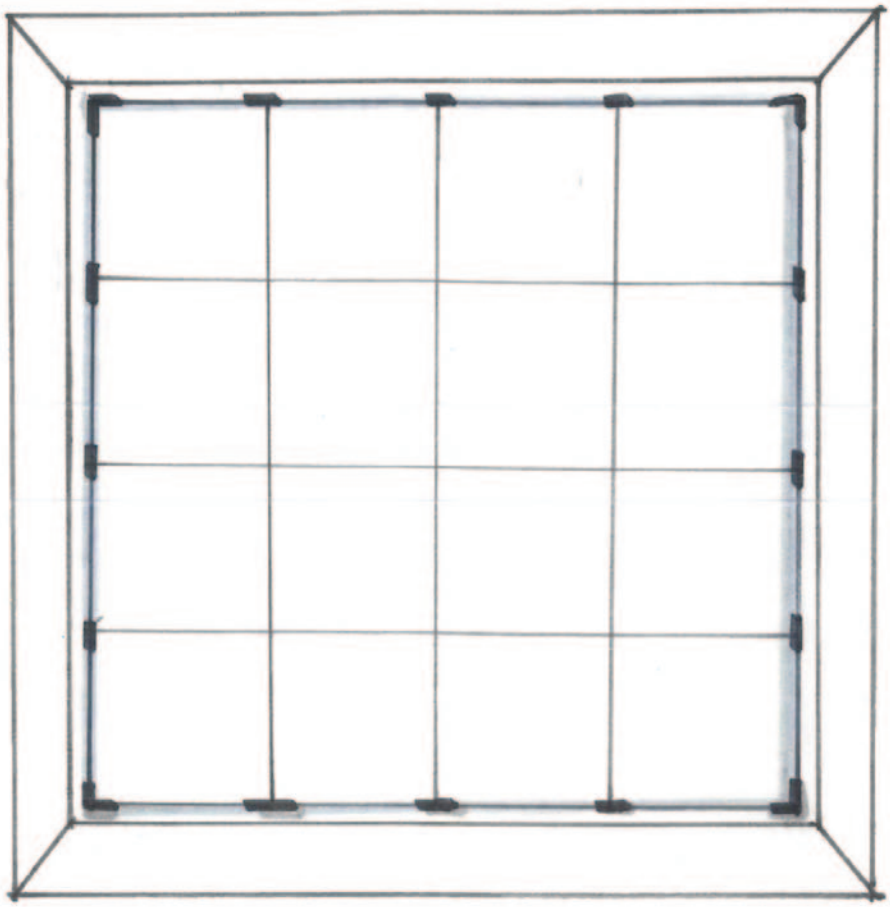




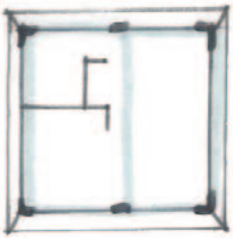


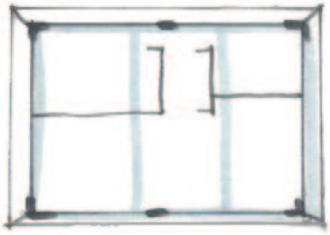


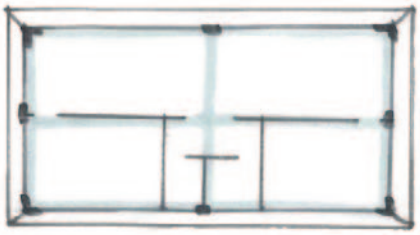
CUSTOMIZATION & ADAPTABILITY

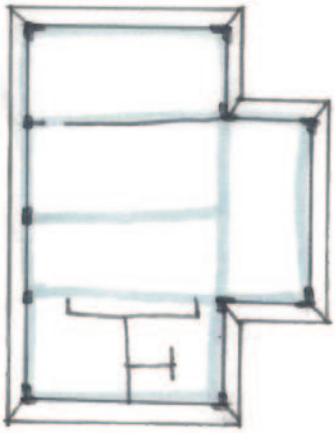


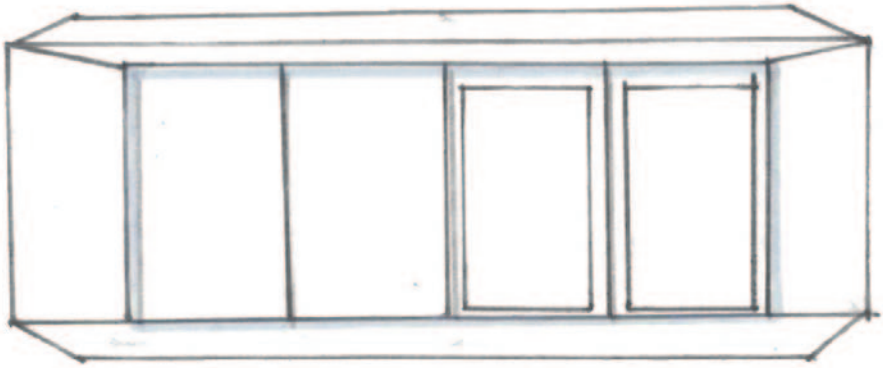


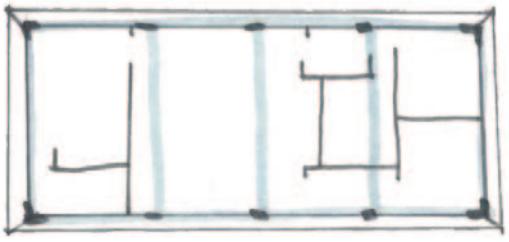








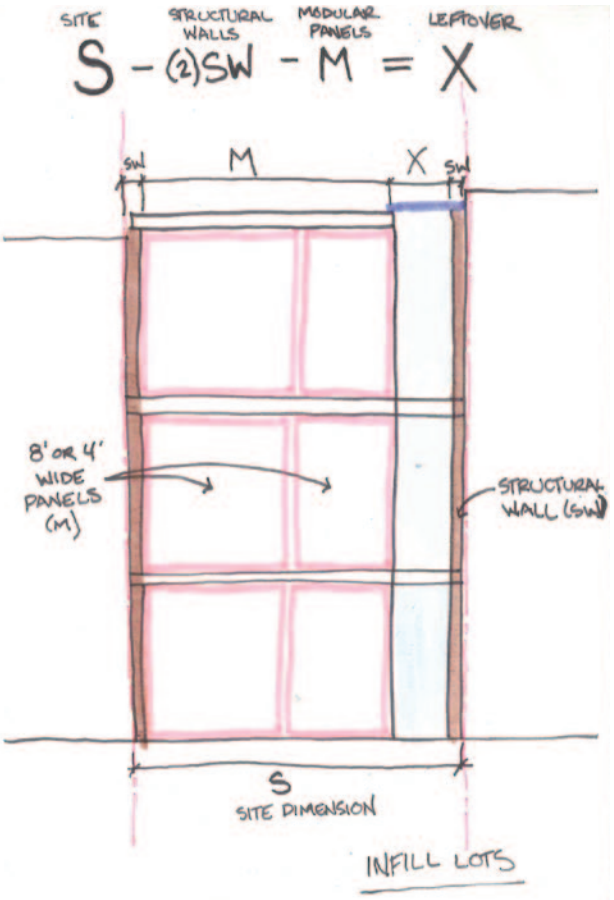


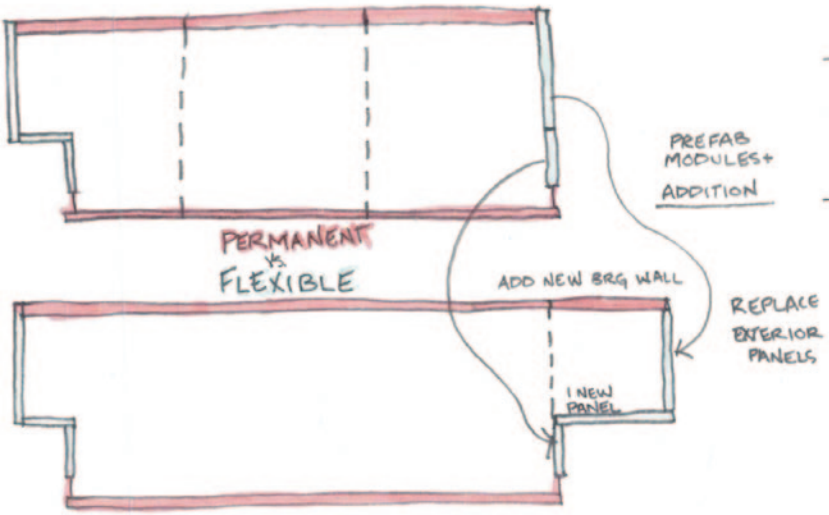


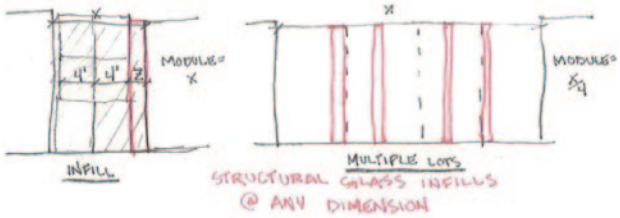
INITIAL DESIGN PROCESS

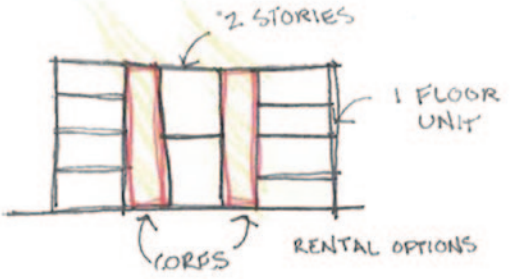
SITE INFILL | LIGHT WELL CONCEPT

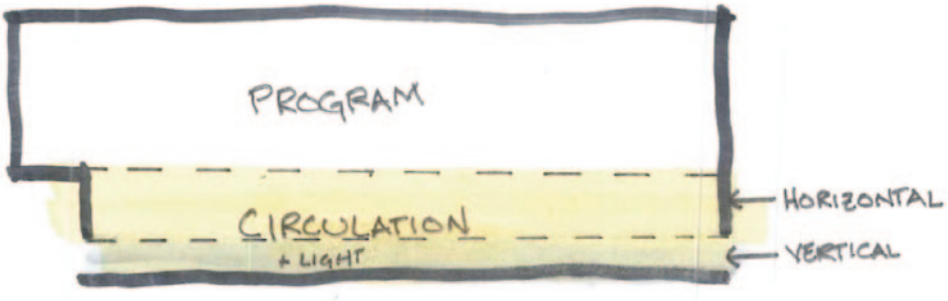


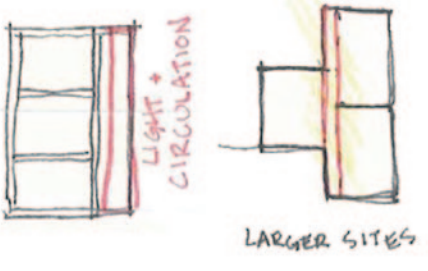












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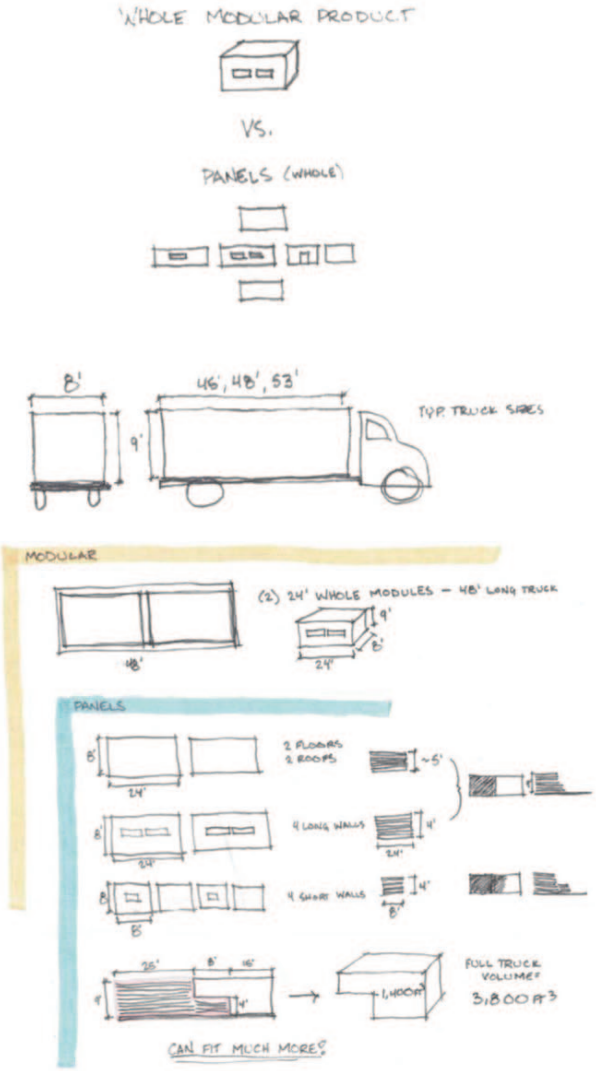

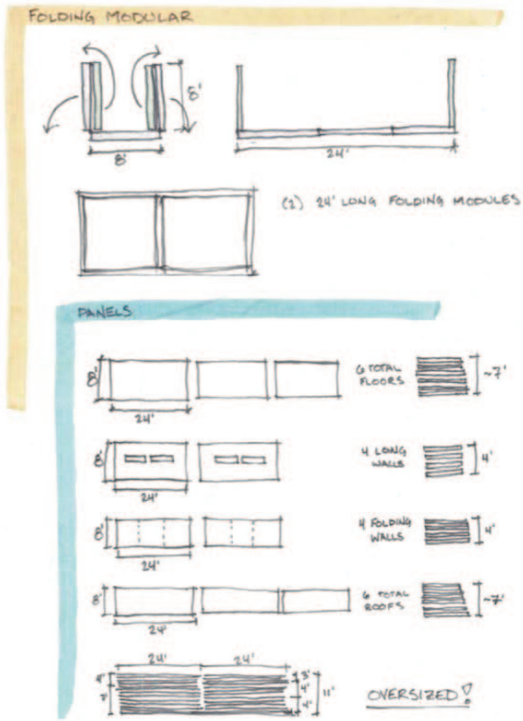

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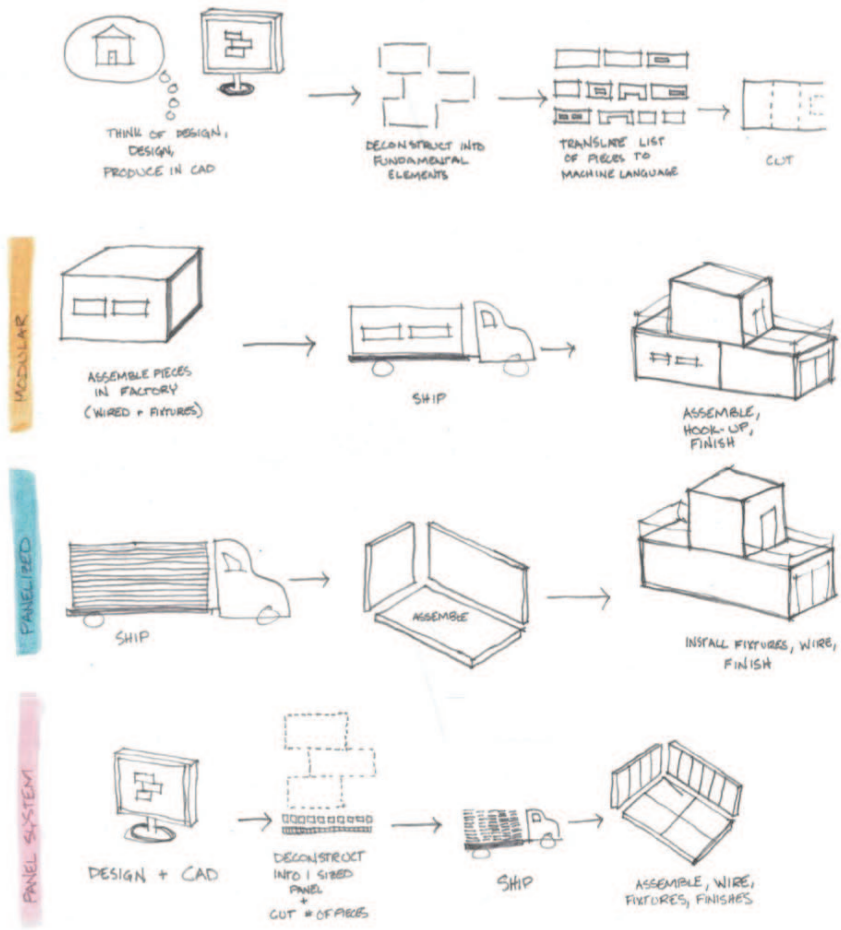

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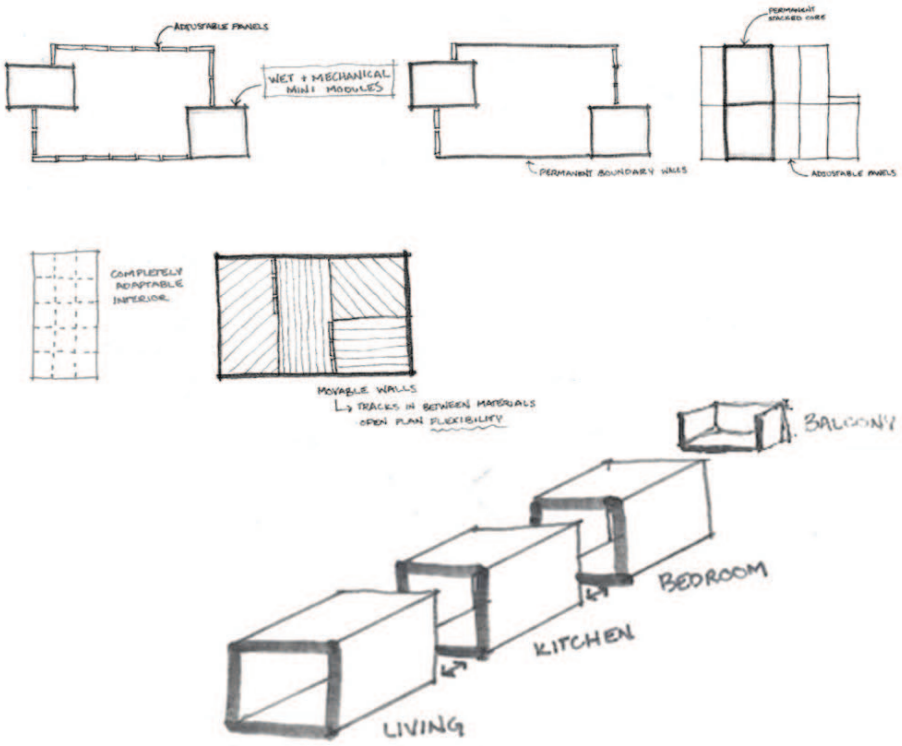

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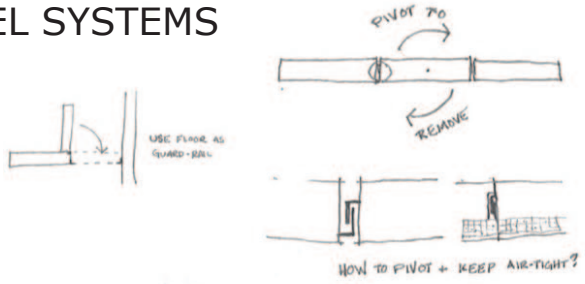
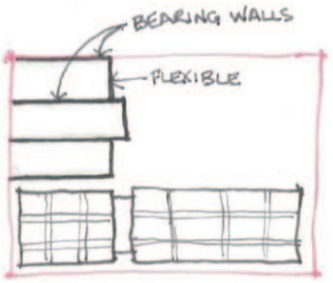
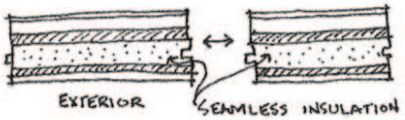
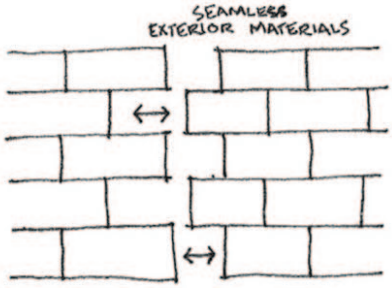
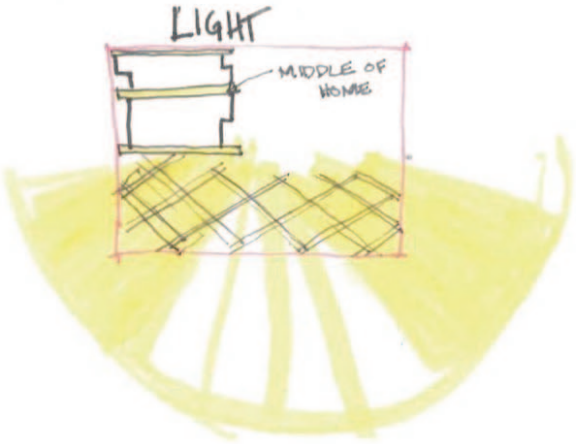


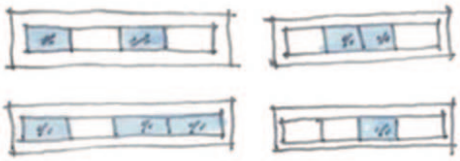


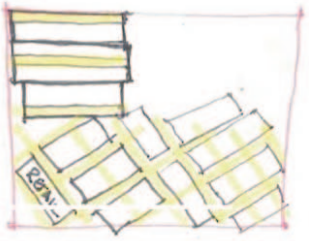


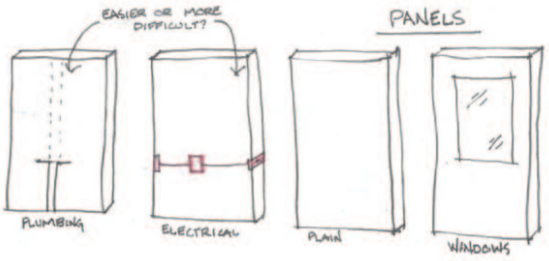


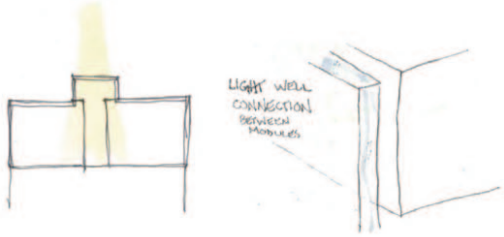


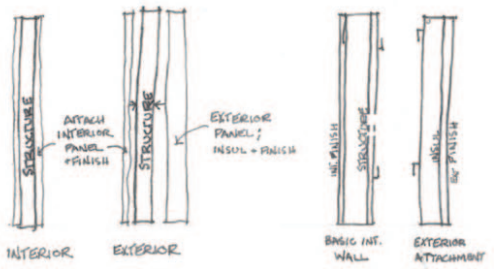


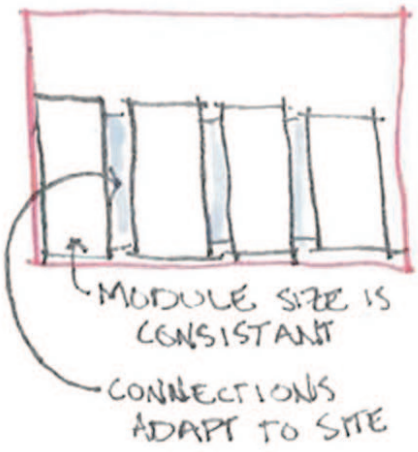


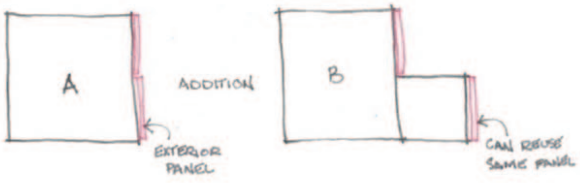












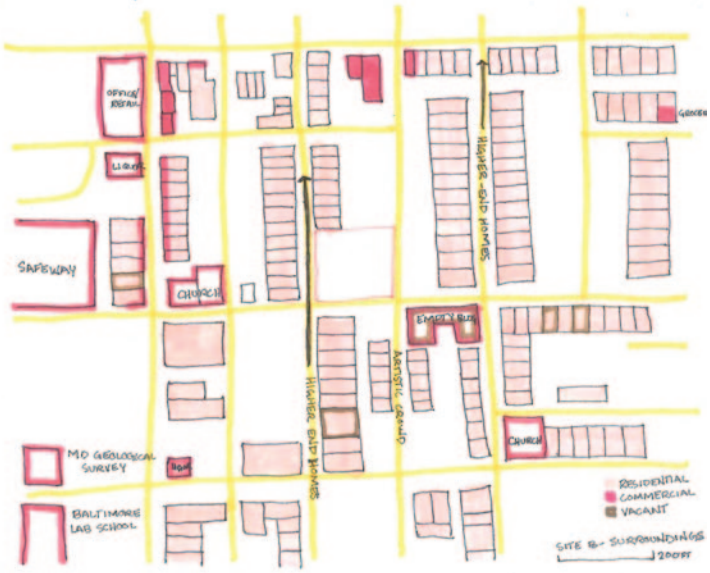
SITE ANALYSIS











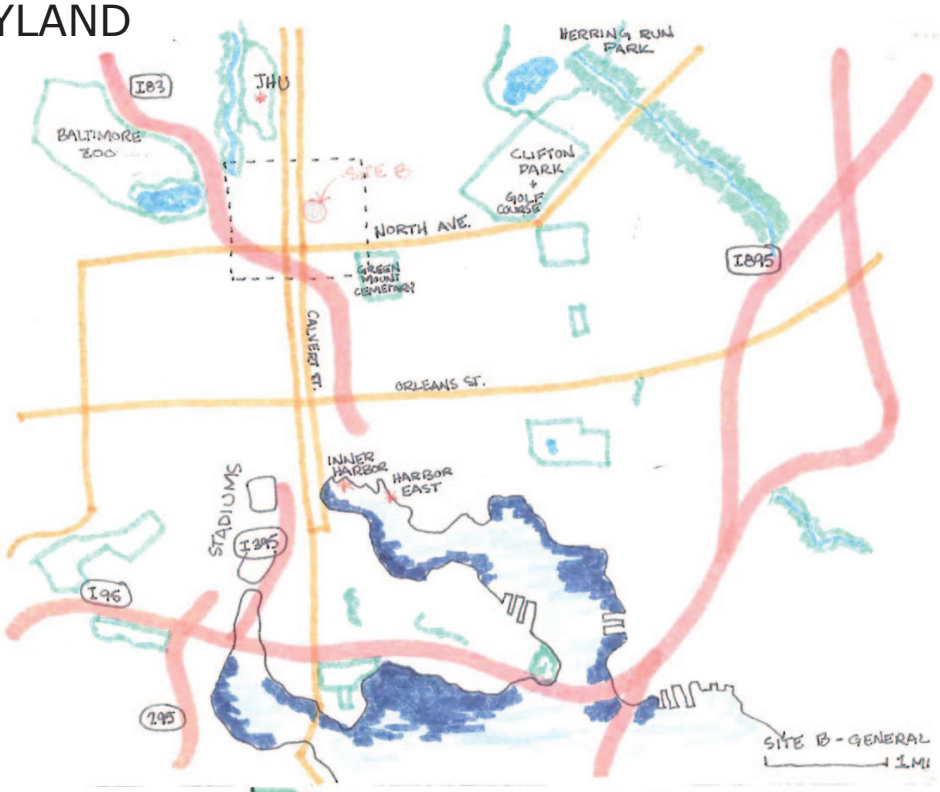


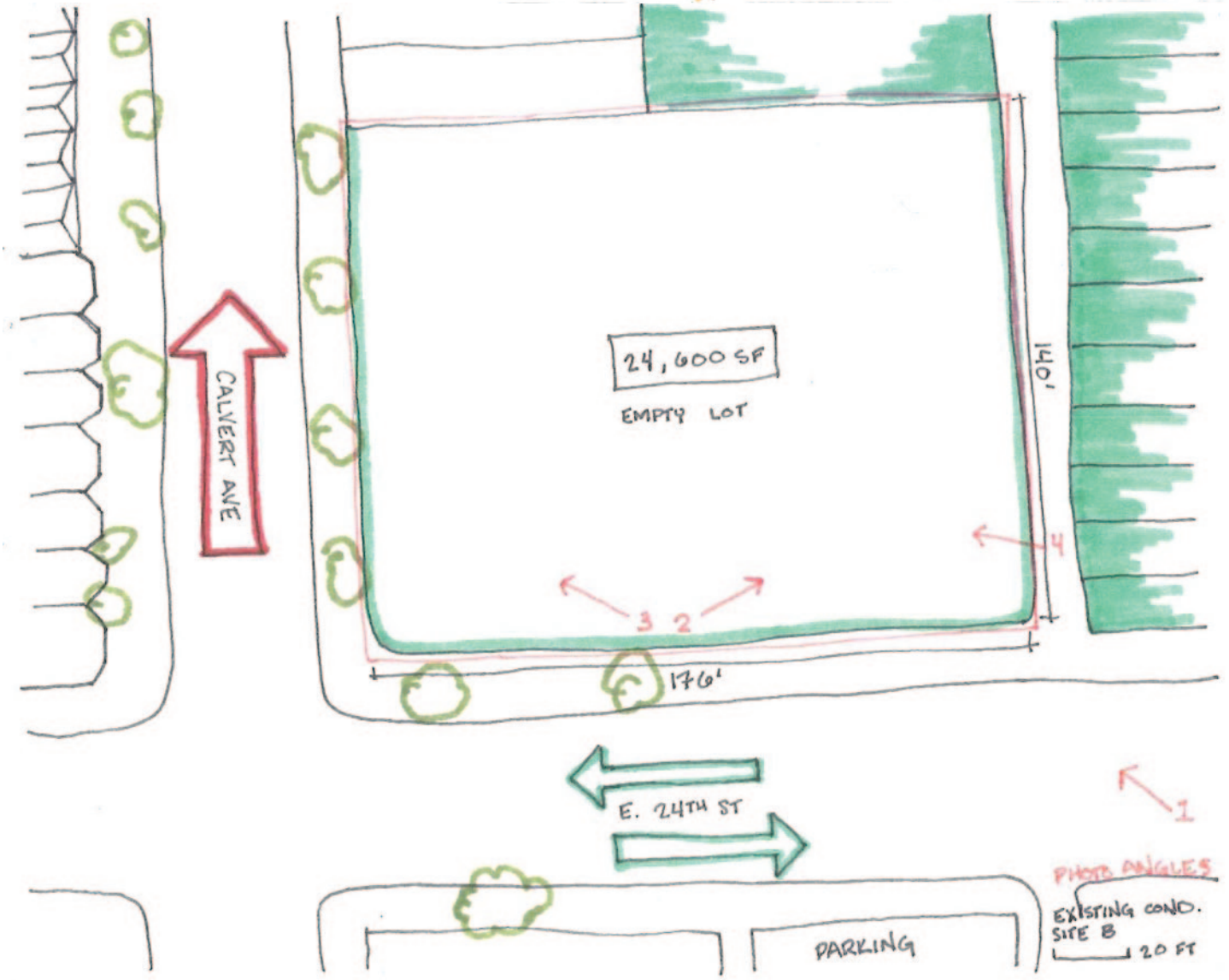


BALTIMORE CITY, MARYLAND

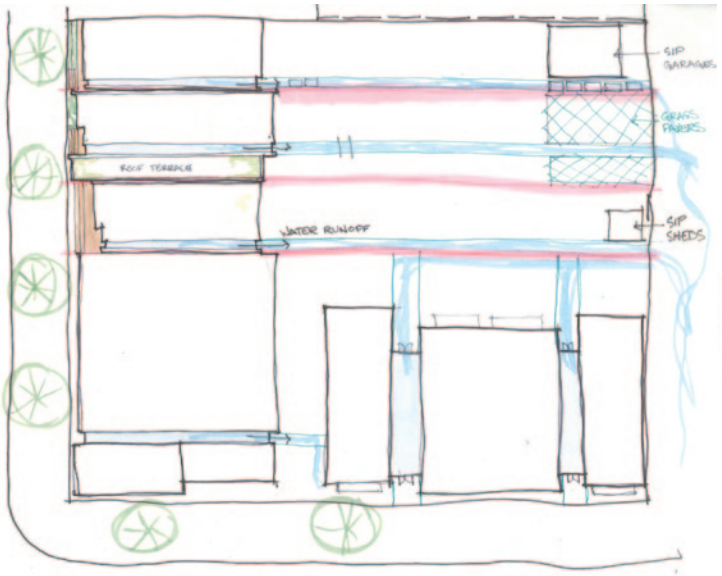


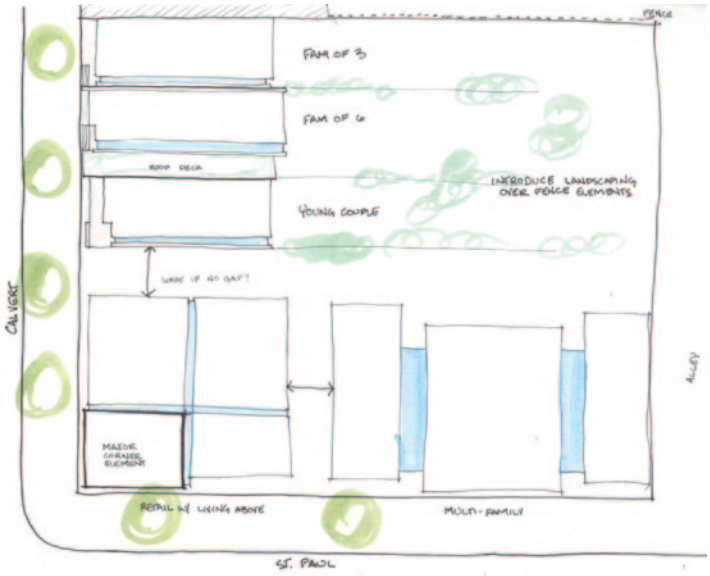


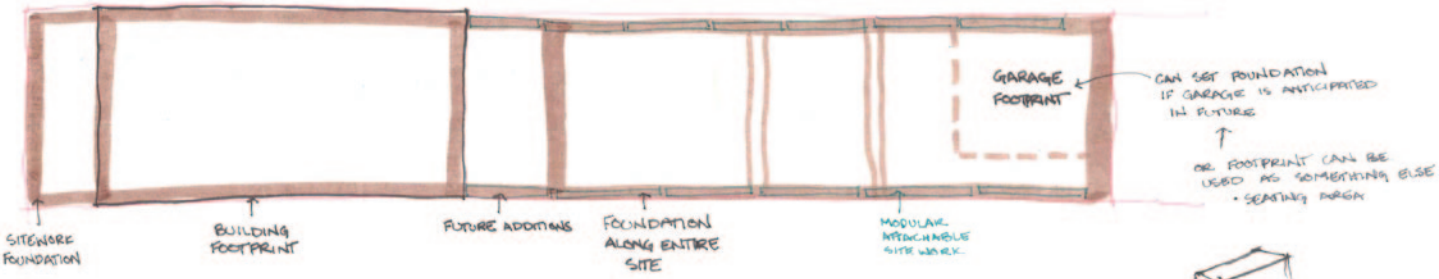


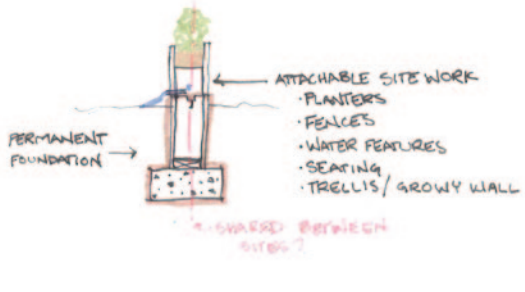


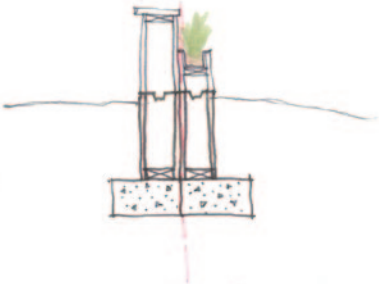
SITEWORK

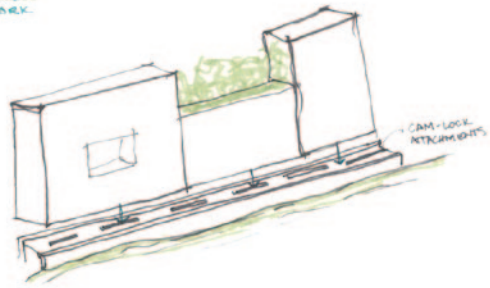










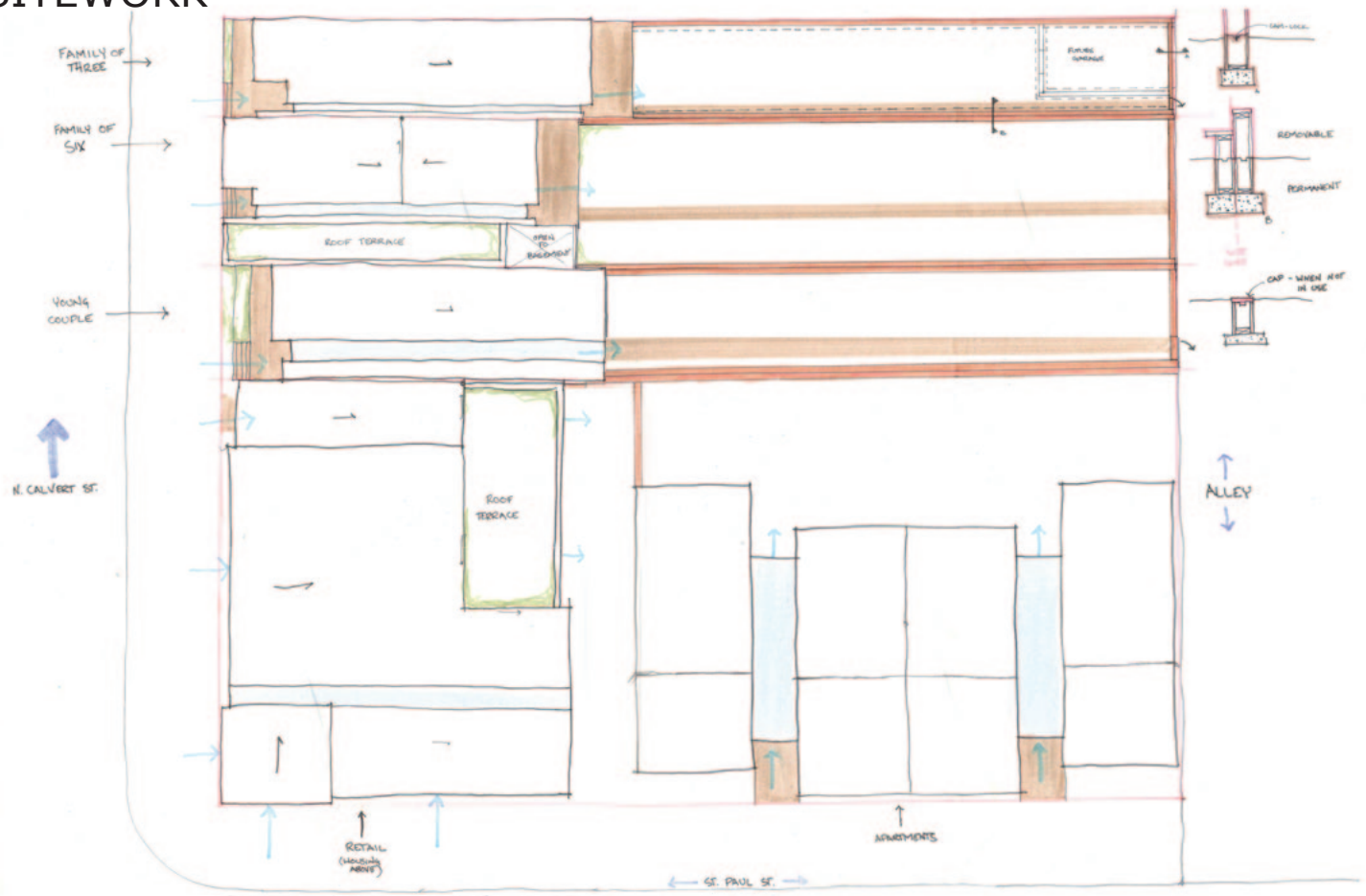


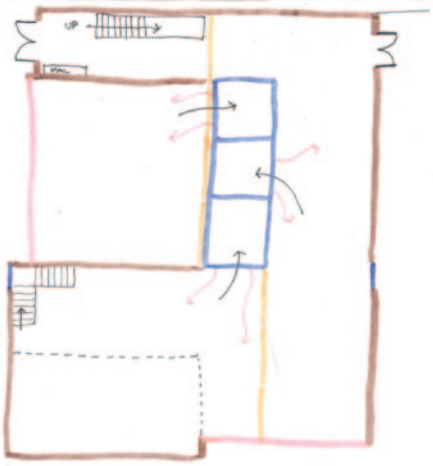




TOWNHOMES

SITEWORK

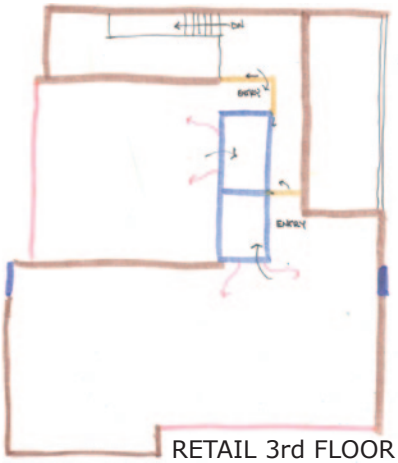




RETAIL 1st FLOOR



APARTMENT 1st FLOOR

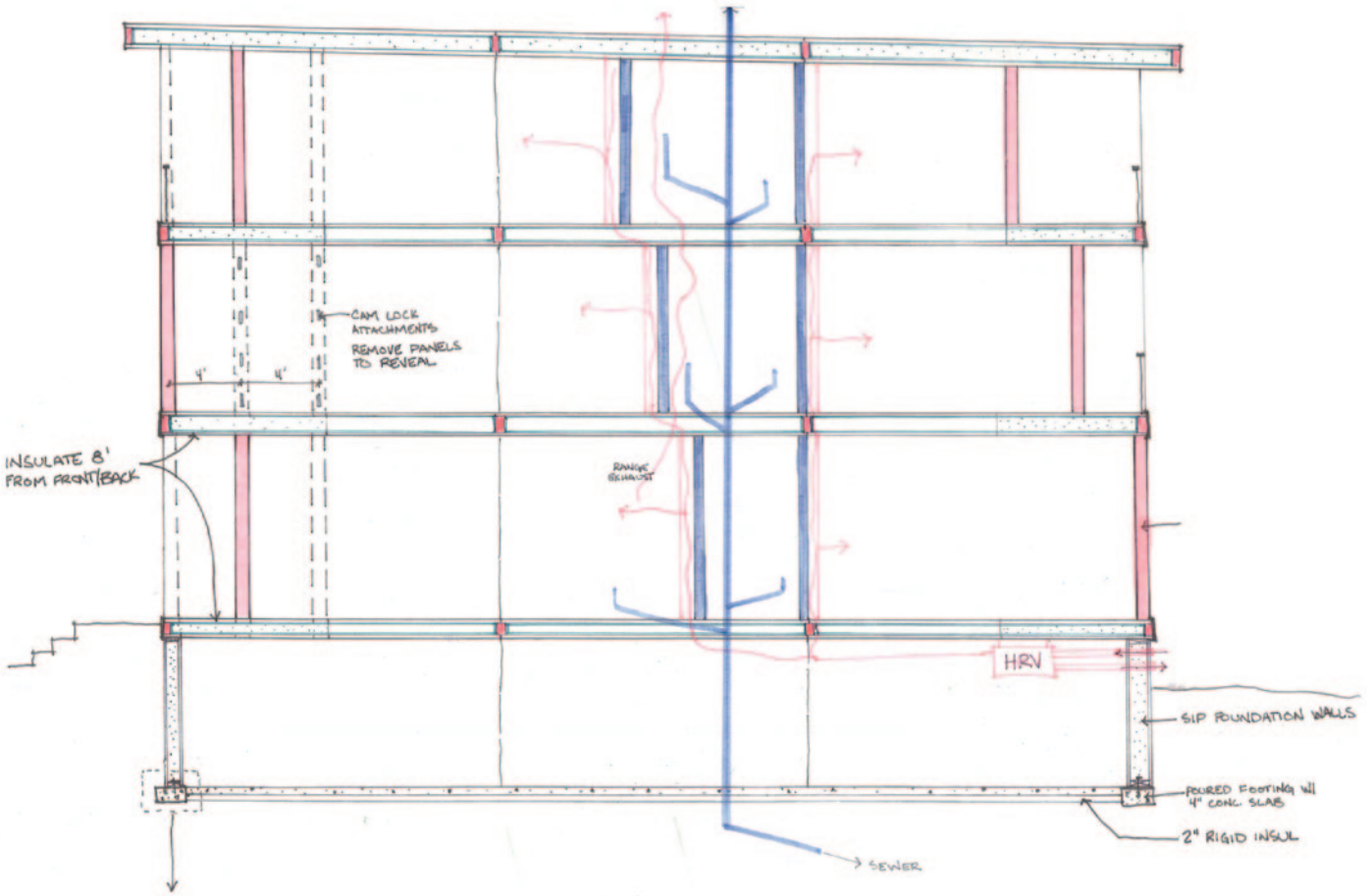


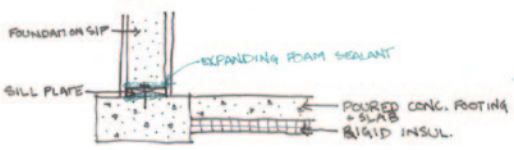
RETAIL 3rd FLOOR



APARTMENT 2nd FLOOR

RETAIL & APARTMENT





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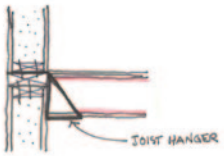

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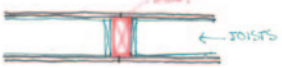

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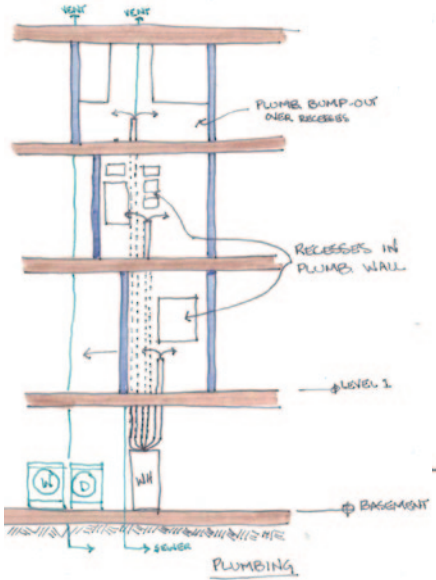
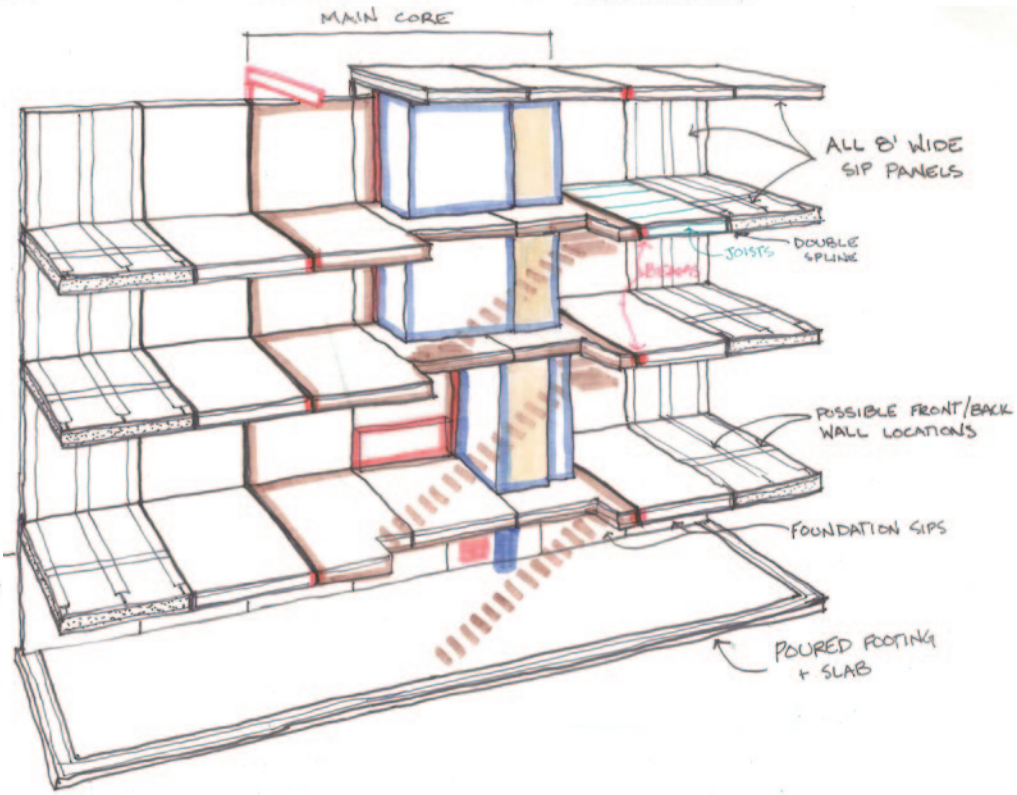
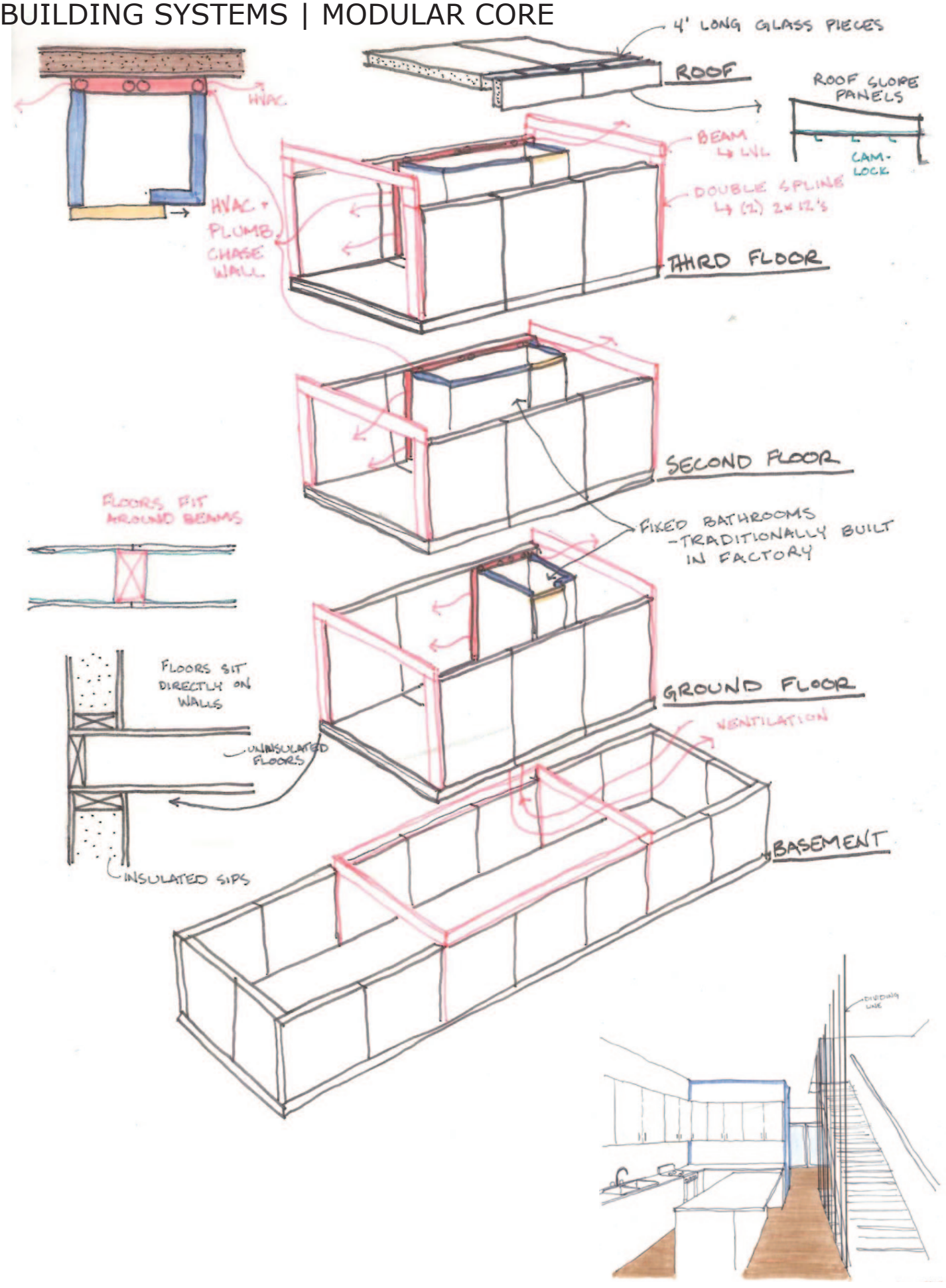


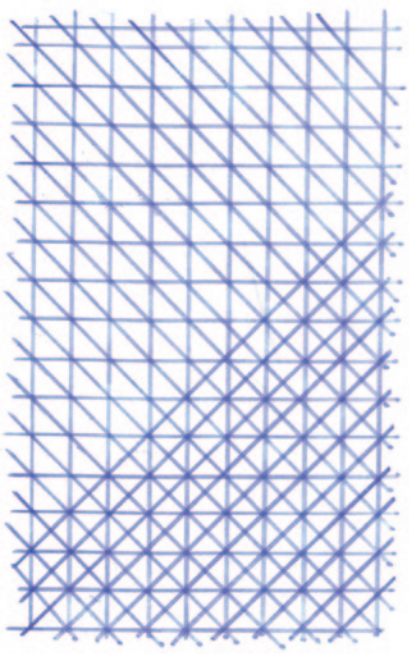
PLUMBING

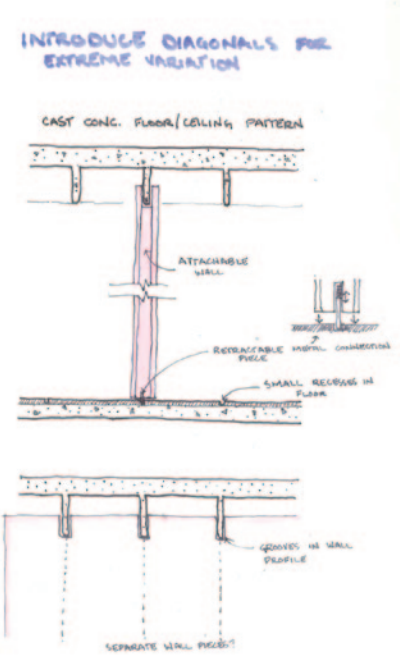


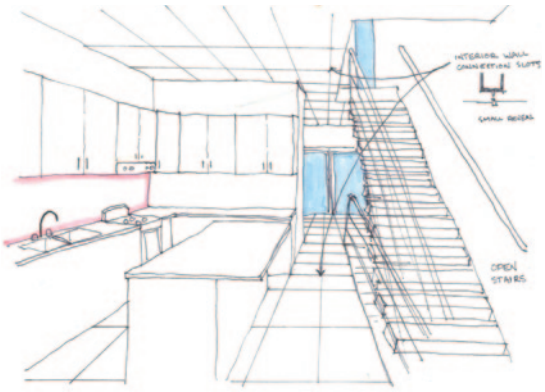
BUILDING SYSTEMS | MODULAR CORE

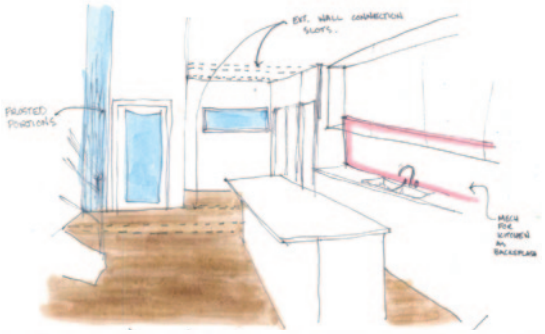


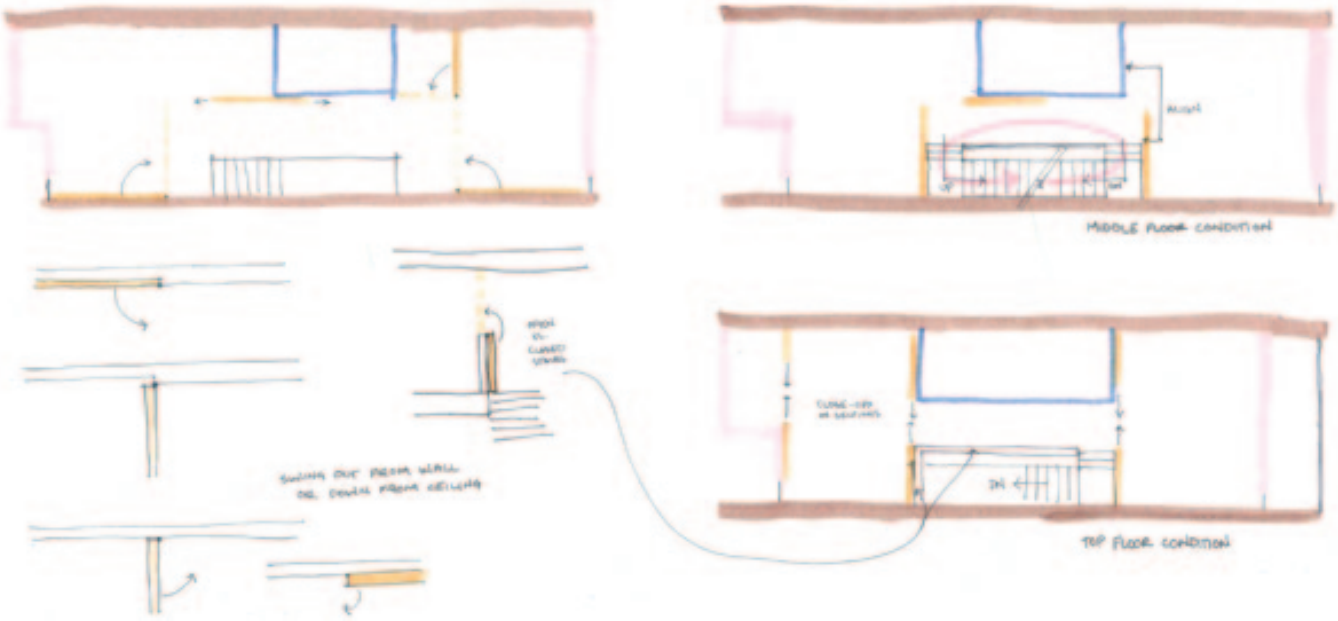
ADAPTABLE INTERIOR IDEATION

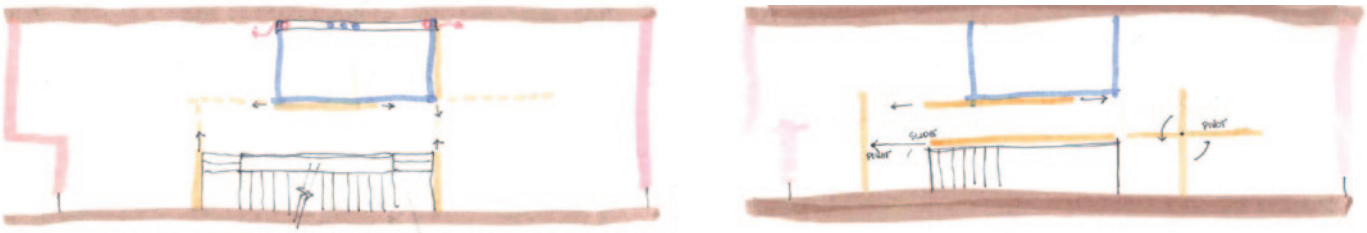


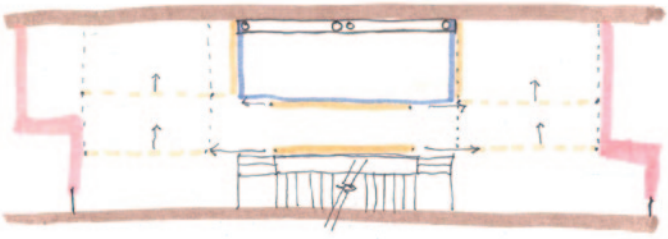


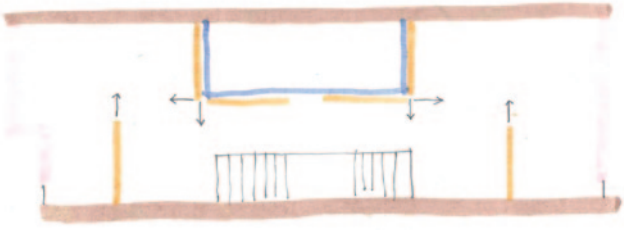




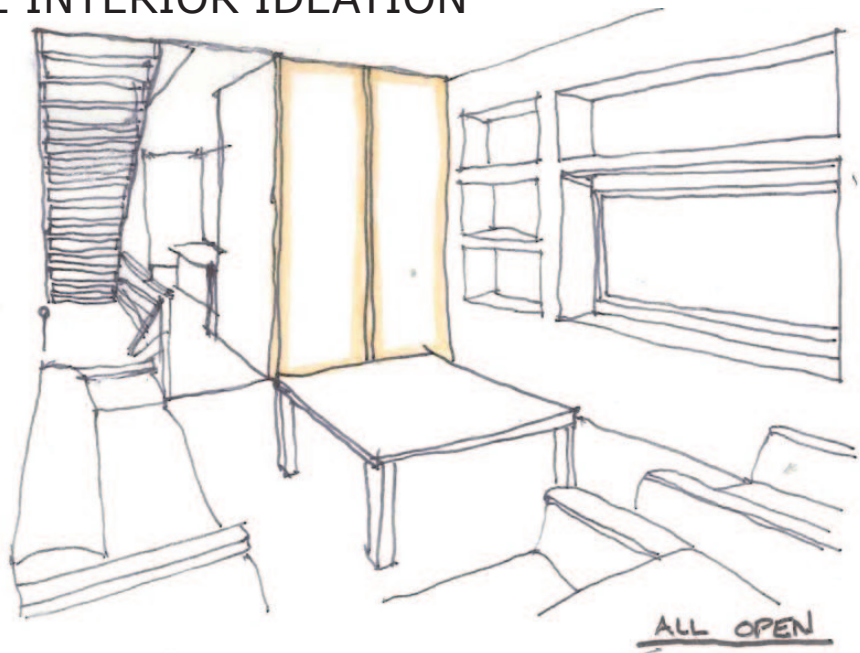




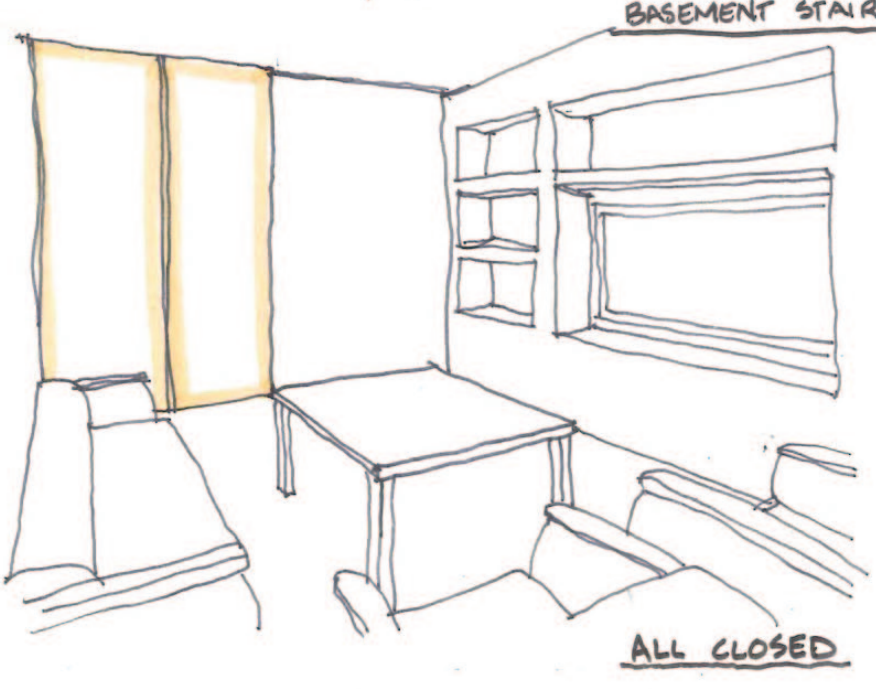




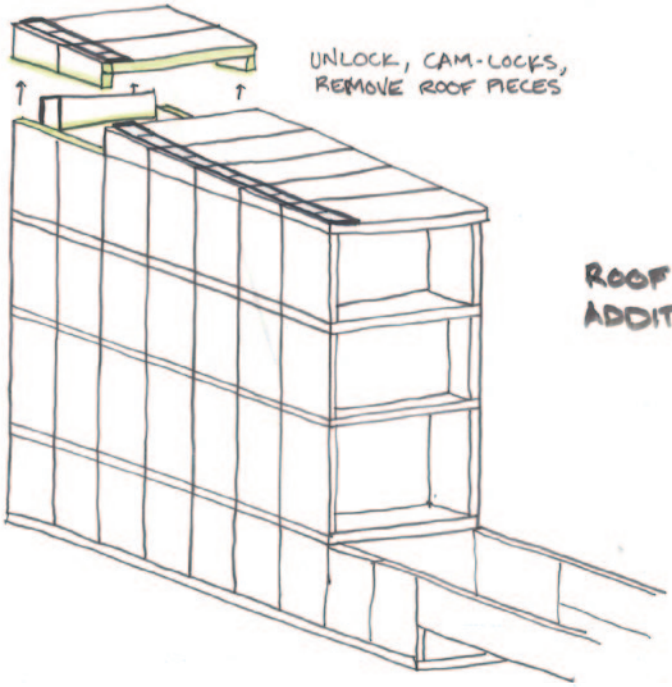
ADAPTABLE INTERIOR IDEATION

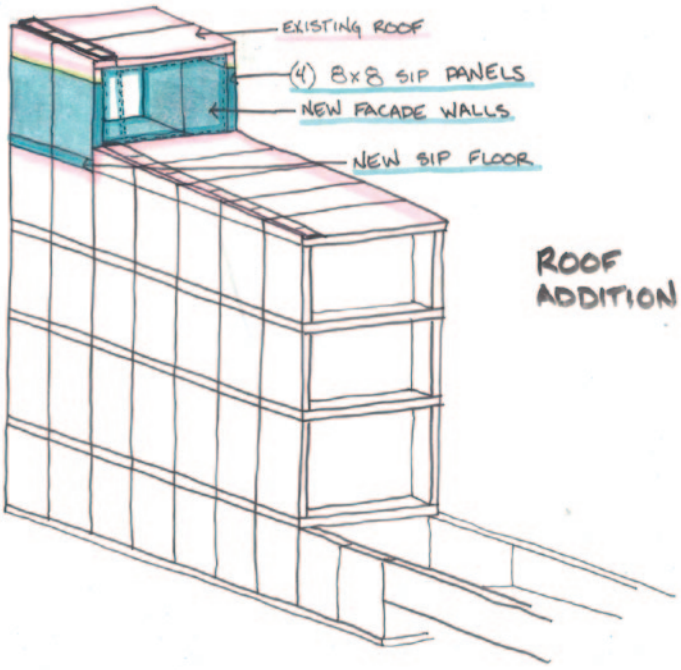


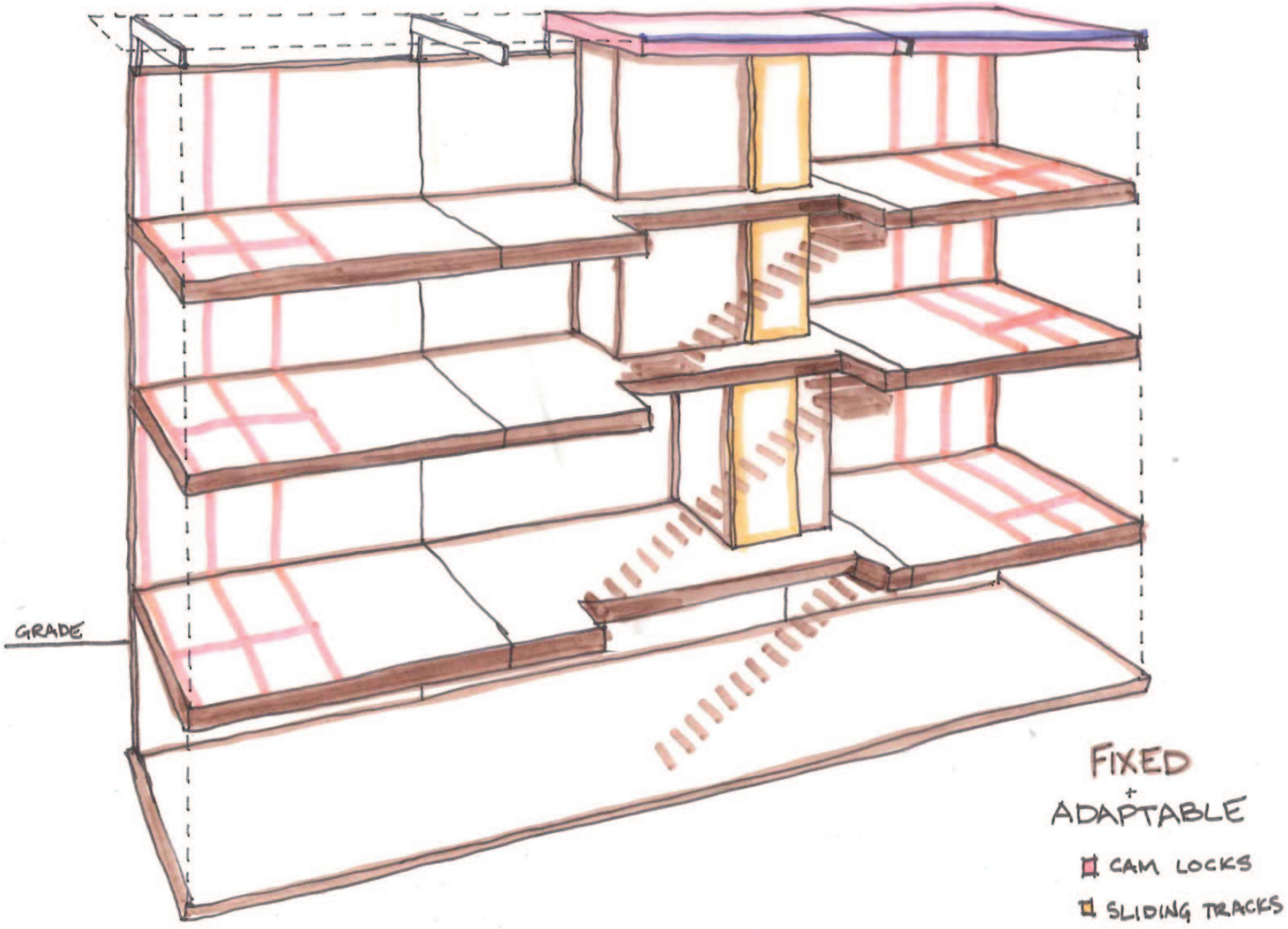




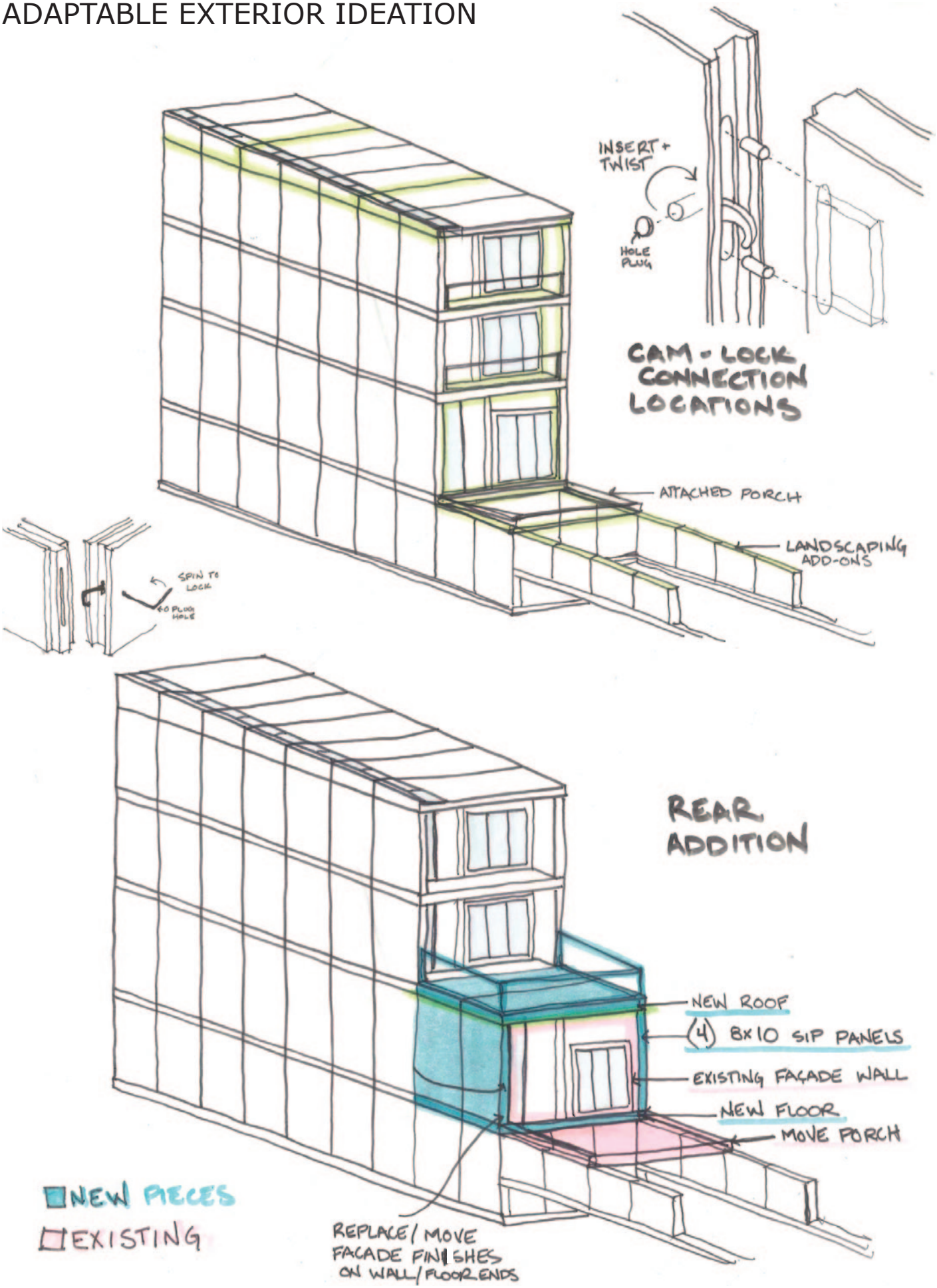
ADAPTABLE EXTERIOR IDEATION



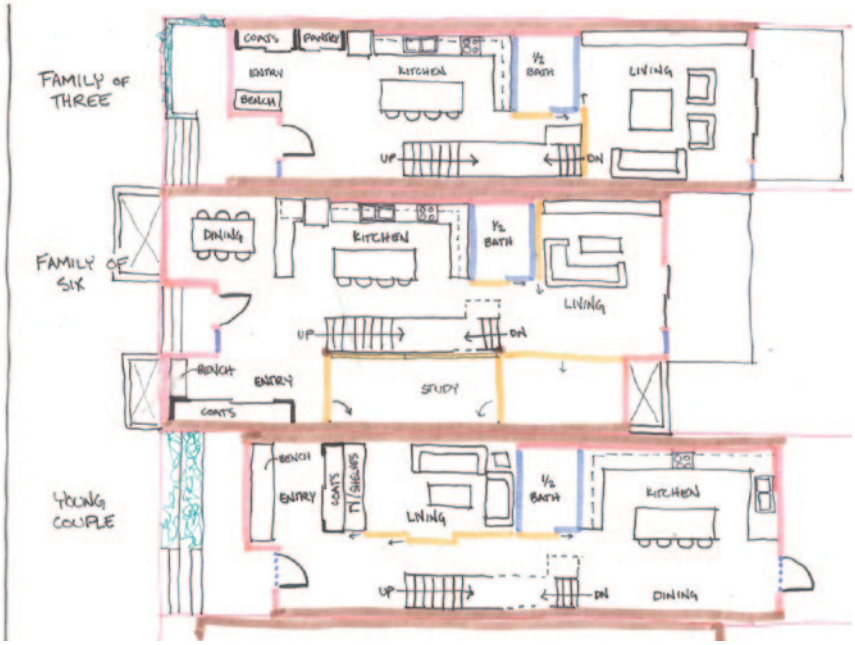




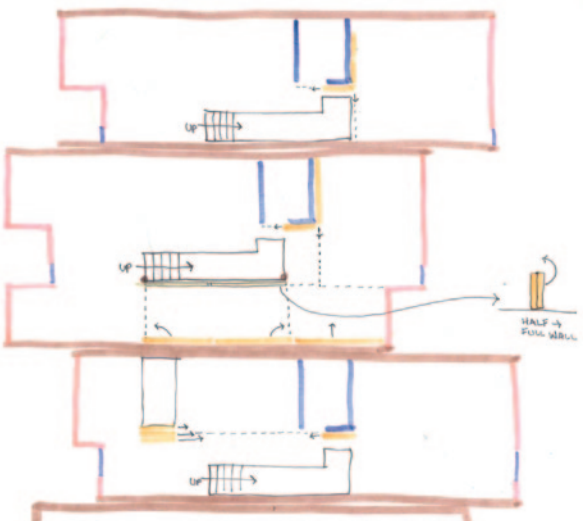
ADAPTABLE EXTERIOR IDEATION



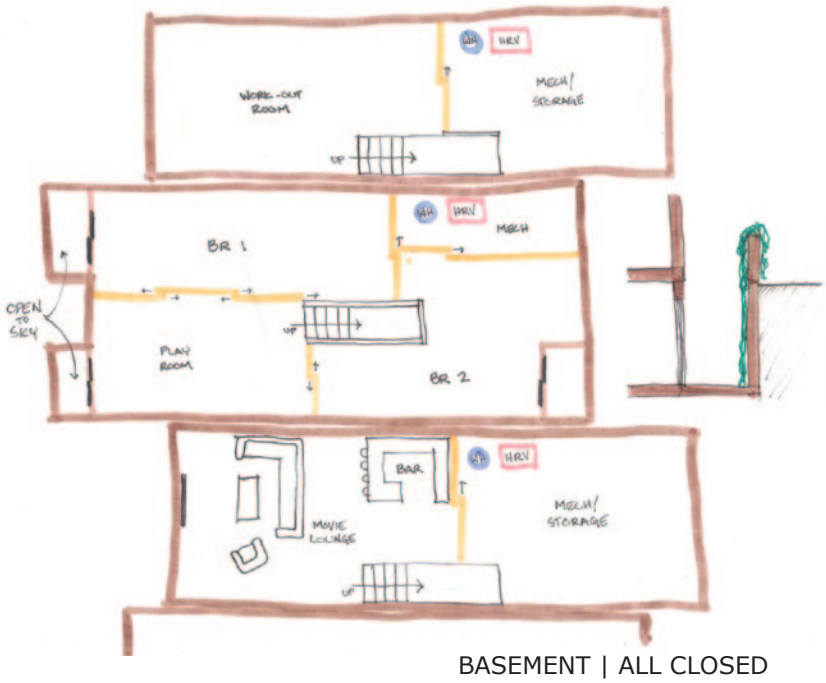
ADAPTABLE & CUSTOMIZED TOWNHOUSE PLANS



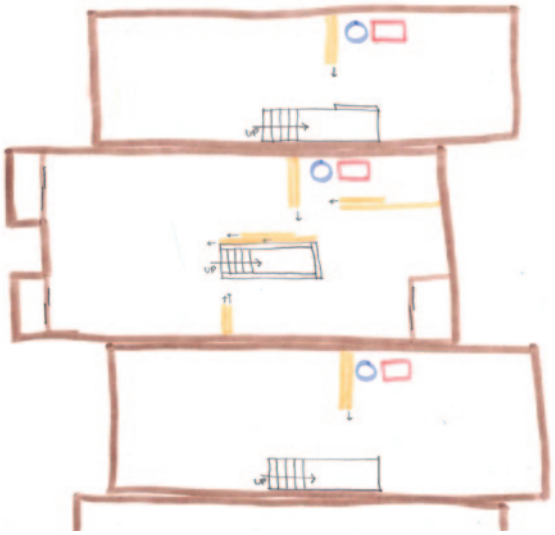
FIRST FLOOR | ALL CLOSED



FIRST FLOOR | ALL OPEN

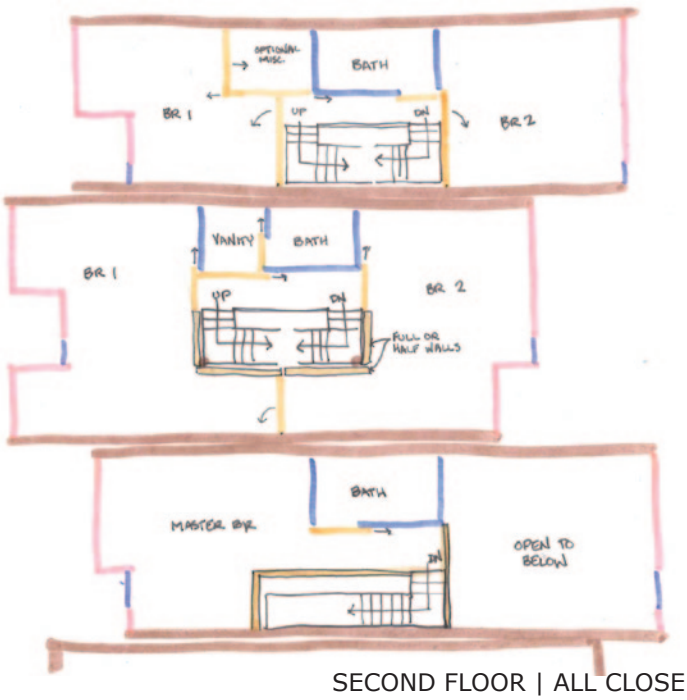


BASEMENT | ALL CLOSED

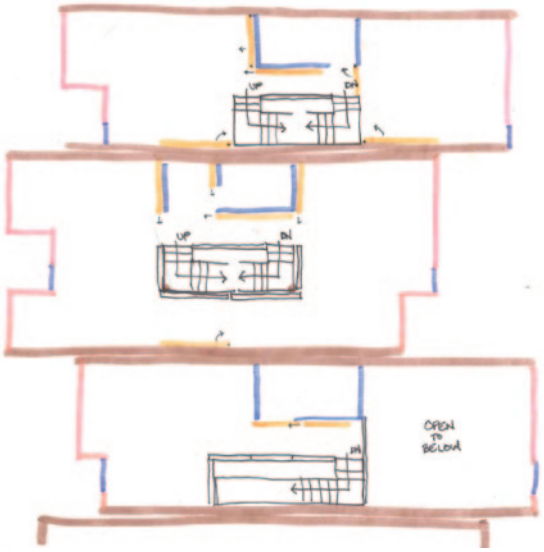


BASEMENT | ALL OPEN

ADAPTABLE & CUSTOMIZED TOWNHOUSE PLANS



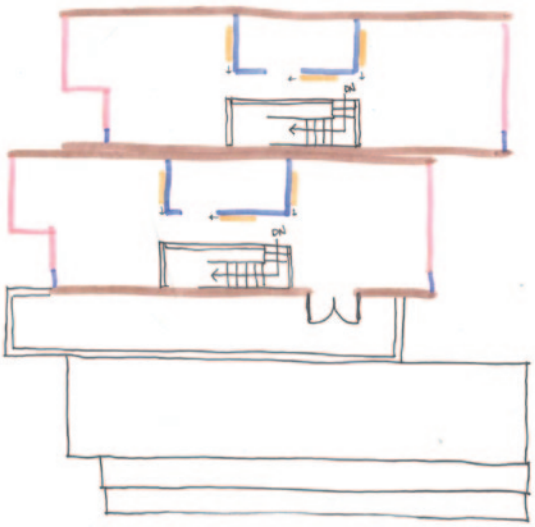
SECOND FLOOR | ALL CLOSED



SECOND FLOOR | ALL OPEN



THIRD FLOOR | ALL CLOSED

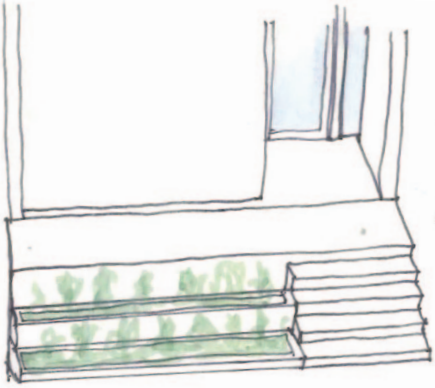


THIRD FLOOR | ALL OPEN

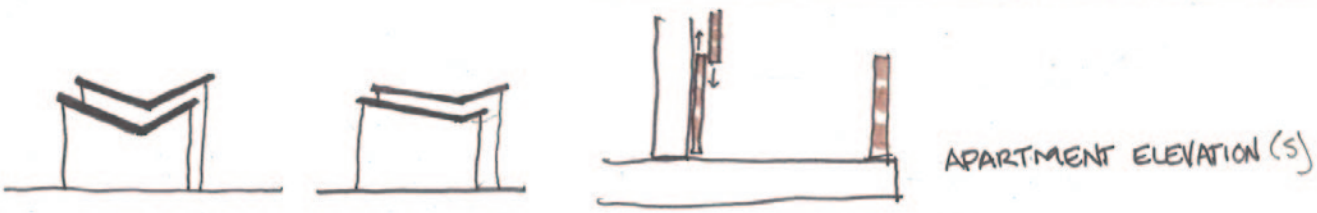
CUSTOMIZED EXTERIOR IDEATION











CUSTOMIZED EXTERIOR IDEATION





STANDARD W/ SLIDING PANELS

TRADITIONAL

MODERN

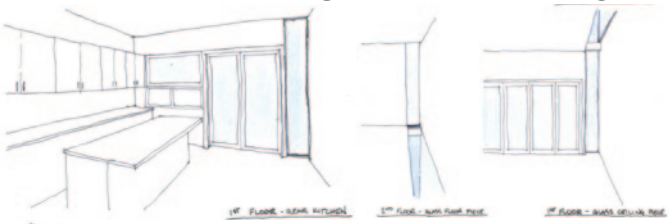
RESIDENCE ENTRANCE



CUSTOMIZED TOWNHOMES



BACKYARD ELEVATION





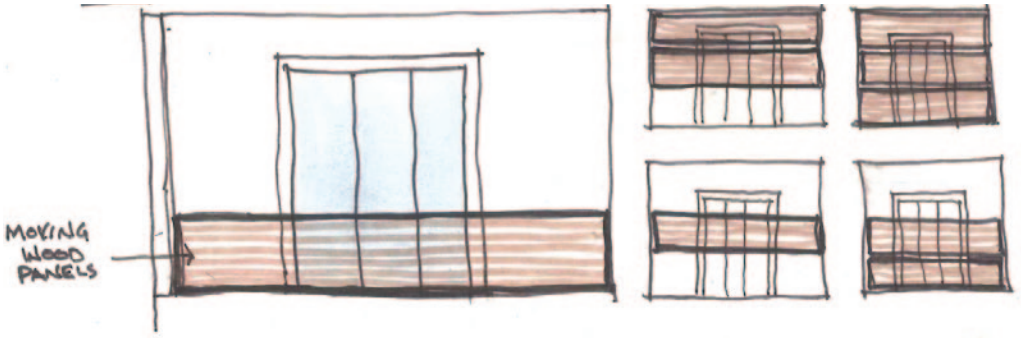


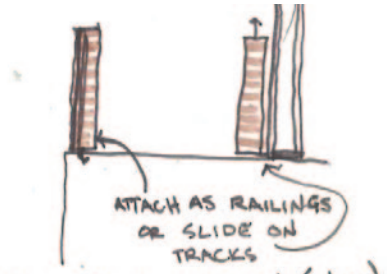
TOWNHOME C

CUSTOMIZED TOWNHOMES

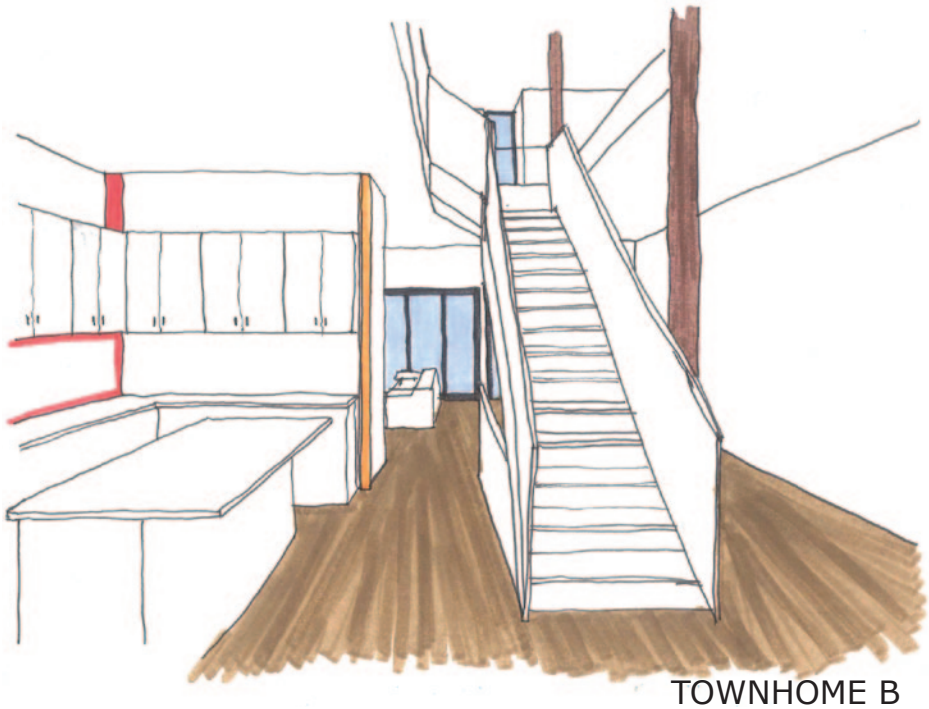


TOWNHOME A TOWNHOME B TOWNHOME C STREET ELEVATION

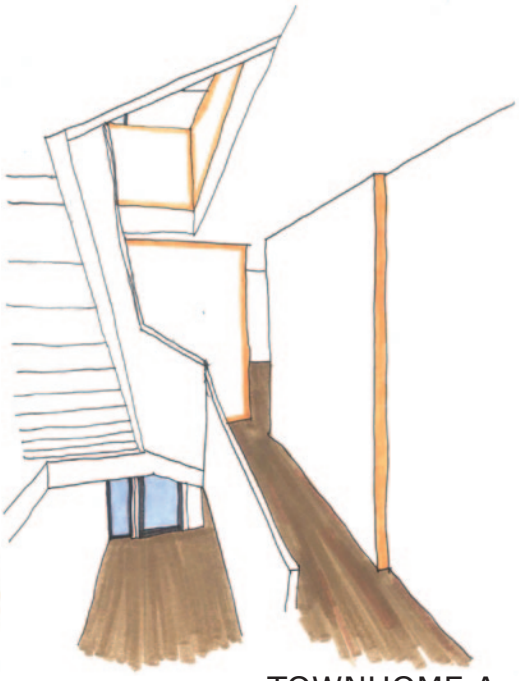




FRONT ELEVATION (WEST)



TOWNHOME B



TOWNHOME A

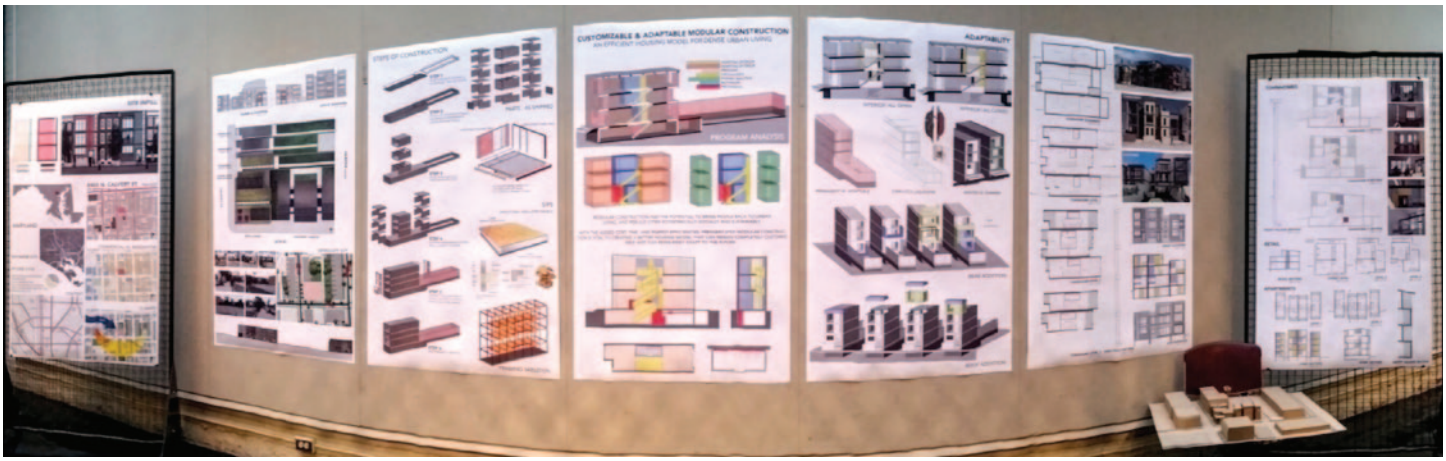
FINAL PRESENTATION

CUSTOMIZABLE & ADAPTABLE
MODULAR CONSTRUCTION

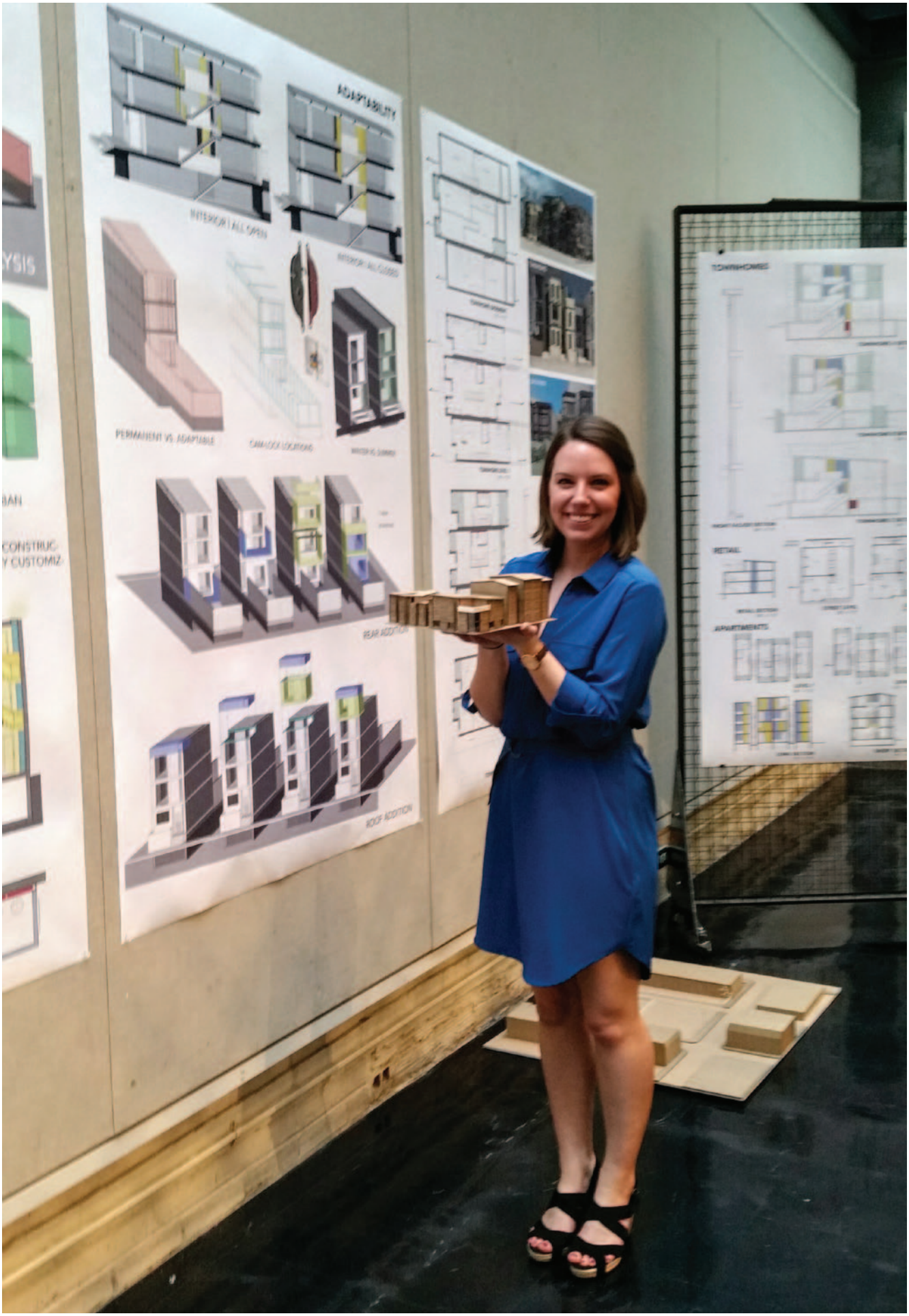


AN EFFICIENT HOUSING MODEL FOR DENSE URBAN LIVING


SITE INFILL
2403 N. CALVERT ST.
MARYLAND
BALTIMORE CITY
ZIP CODE: 21218
STEPS OF CONSTRUCTION
CUSTOMIZABLE & ADAPTABLE MODULAR CONSTRUCTION
ADAPTABILITY

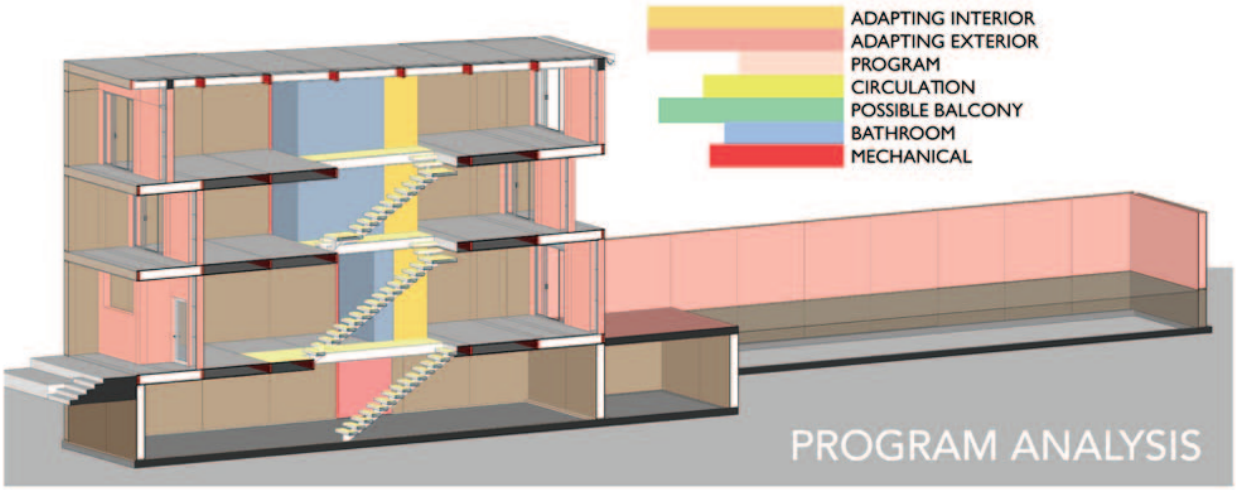

CUSTOMIZABLE & ADAPTABLE MODULAR CONSTRUCTION
ADAPTABILITY

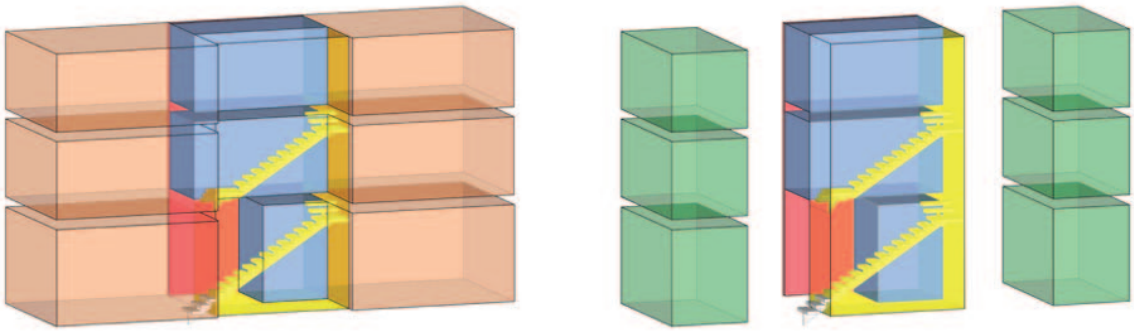

ADAPTABILITY


ADAPTABILITY
INTERIOR | ALL OPEN
PERMANENT VS. ADAPTABLE
REAR ADDITION
ROOF ADDITION
TOWNHOMES
RETAIL
APARTMENTS

CUSTOMIZABLE & ADAPTABLE MODULAR CONSTRUCTION

AN EFFICIENT HOUSING MODEL FOR DENSE URBAN LIVING

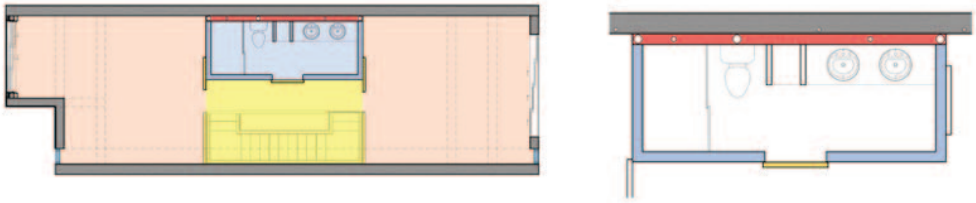




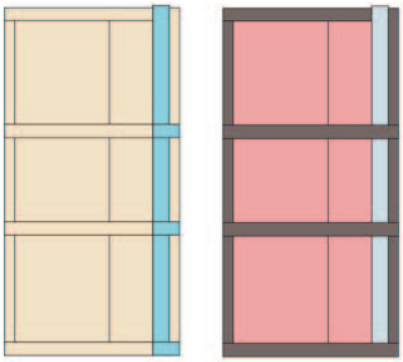
MODULAR CONSTRUCTION HAS THE POTENTIAL TO BRING PEOPLE BACK TO URBAN LIVING, AND REBUILD CITIES ECONOMICALLY, SOCIALLY, AND SUSTAINABLY.

WITH THE ADDED COST, TIME, AND ENERGY EFFICIENCIES, PREFABRICATED MODULAR CONSTRUCTION IS VITAL TO CREATING A BETTER HOUSING MODEL THAT CAN REMAIN COMPLETELY CUSTOMIZABLE AND CAN SEAMLESSLY ADAPT TO THE FUTURE.





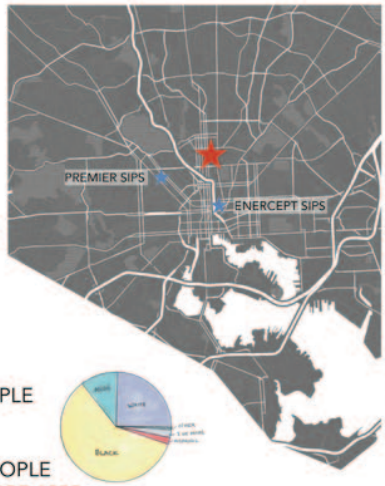
SITE INFILL







MARYLAND



BALTIMORE CITY

ZIP CODE: 21218

POPULATION: 49,552 PEOPLE
53% RENTERS
12.6% UNEMPLOYED
AVG. HOUSEHOLD: 2.3 PEOPLE
MOST HOMES BUILT BEFORE 1939
MEDIAN AGE: 33.5

CONTEXT



2403 N. CALVERT ST.

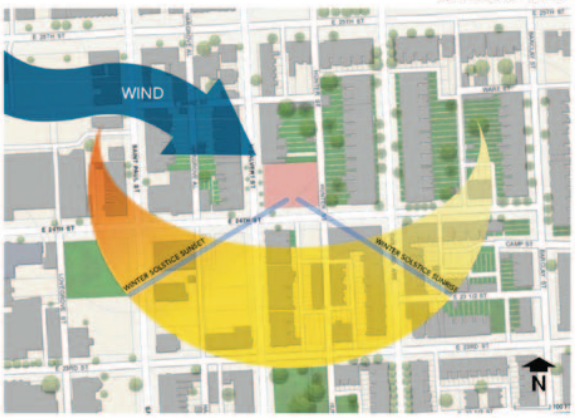
TRANSIT

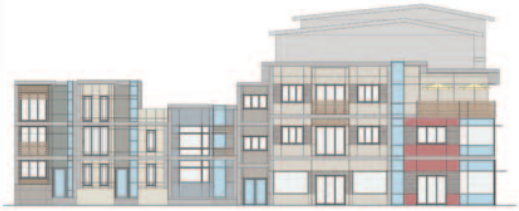


COMMERCIAL VS. RESIDENTIAL



CLIMATE

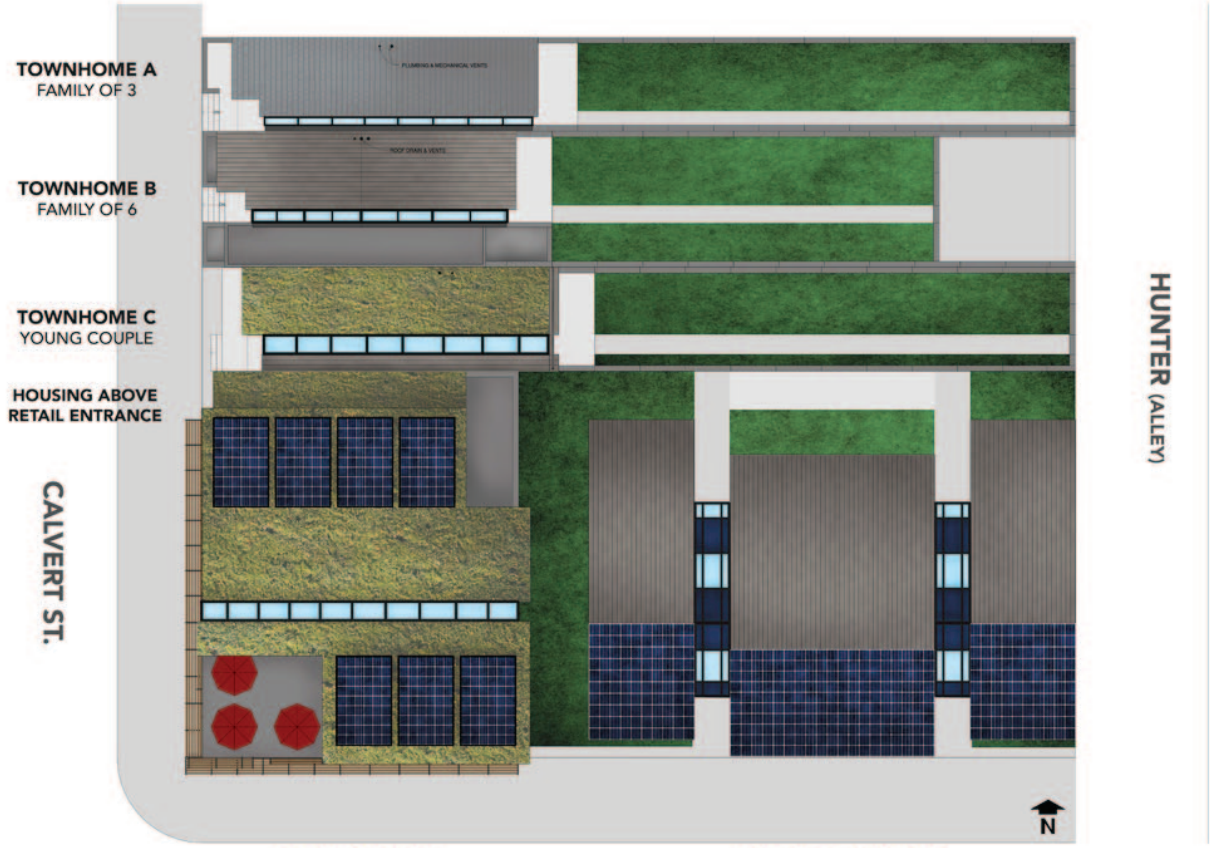




CALVERT ST. ELEVATION
1/8" = 1'-0"

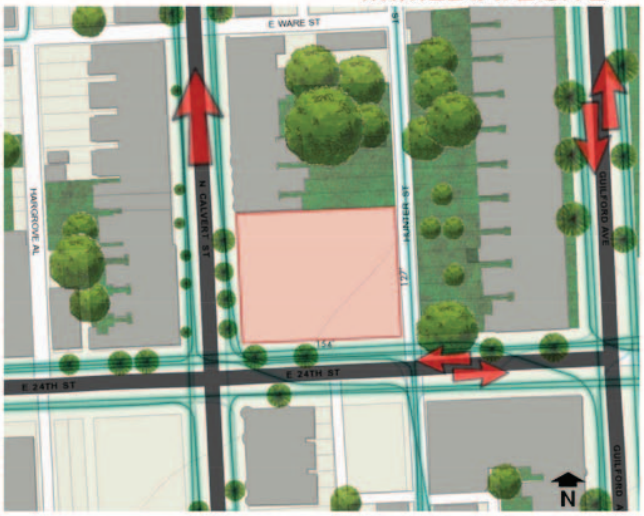


24TH ST. ELEVATION
1/8" = 1'-0"



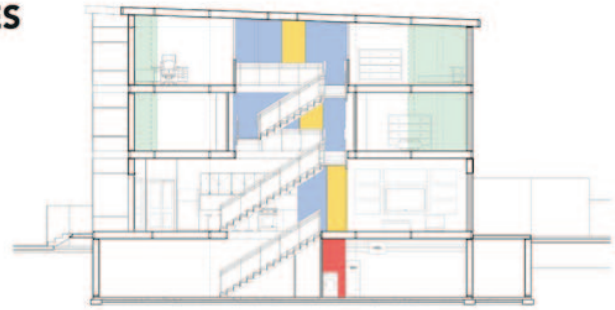
IMMEDIATE SITE



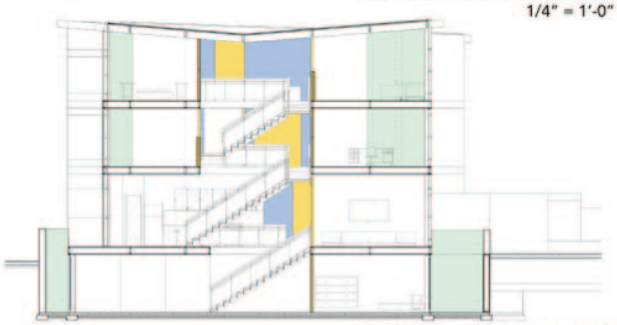




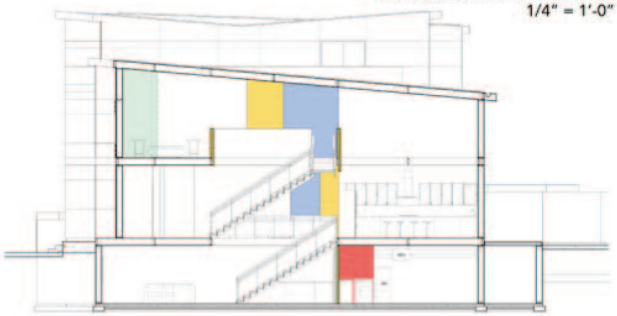
TOWNHOMES



TOWNHOME A SECTION
1/4" = 1'-0"



TOWNHOME B SECTION
1/4" = 1'-0"



TOWNHOME C SECTION
1/4" = 1'-0"



FRONT FACADE SECTION
3/4" = 1'-0"





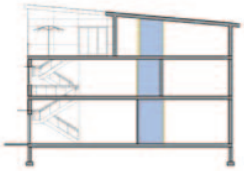








RETAIL



RETAIL SECTION
1/8" = 1'-0"



STREET LEVEL
1/8" = 1'-0"



LEVEL 2
1/8" = 1'-0"

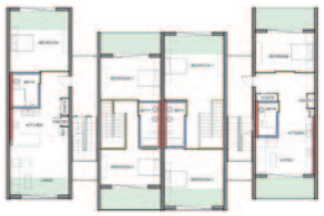


LEVEL 3
1/8" = 1'-0"

APARTMENTS



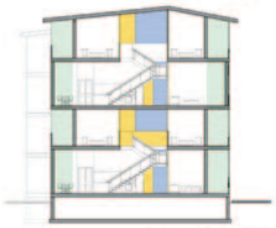
LEVEL 1
1/8" = 1'-0"



LEVEL 2
1/8" = 1'-0"



LONG SECTION
1/8" = 1'-0"



SHORT SECTION
1/8" = 1'-0"



FRONT FACADE SECTION



TOWNHOME BASEMENT
1/4" = 1'-0"







TOWNHOME LEVEL 1
1/4" = 1'-0"



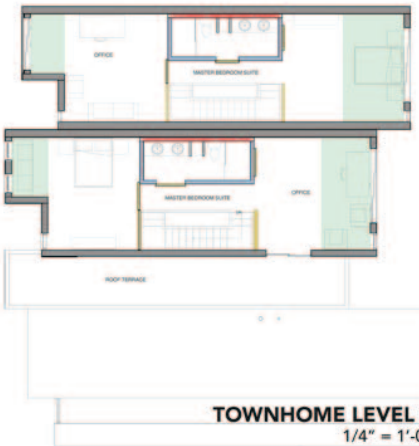


TOWNHOME LEVEL 2
1/4" = 1'-0"



FRONT ELEVATION
1/4" = 1'-0"





TOWNHOME LEVEL 3
1/4" = 1'-0"

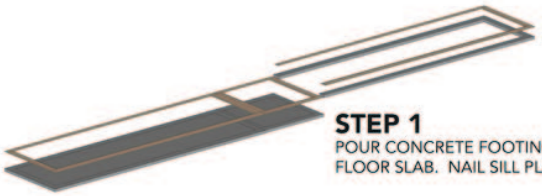


SIDE WALL SECTION
3/4" = 1'-0"

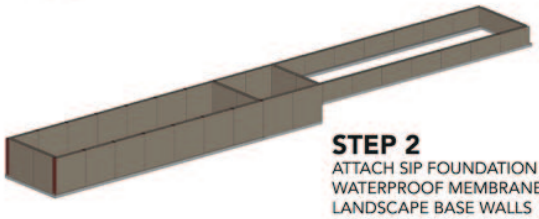


REAR ELEVATION
1/4" = 1'-0"

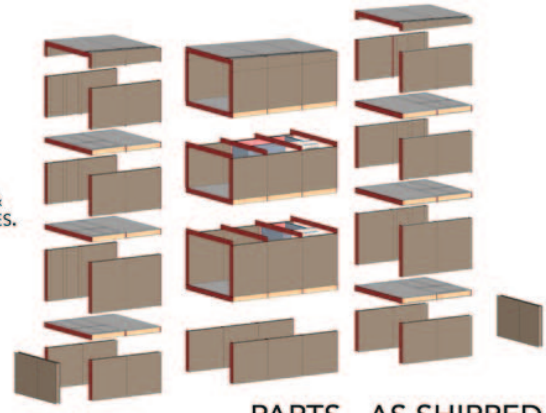
STEPS OF CONSTRUCTION



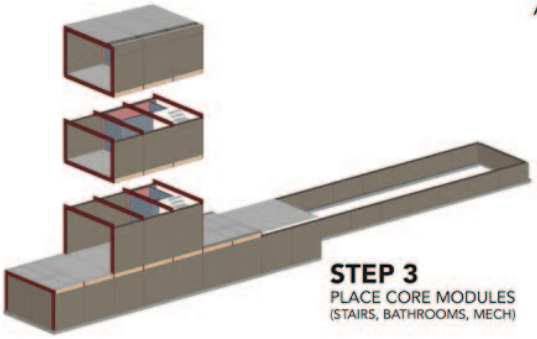
STEP 1
POUR CONCRETE FOOTING &
FLOOR SLAB. NAIL SILL PLATES.



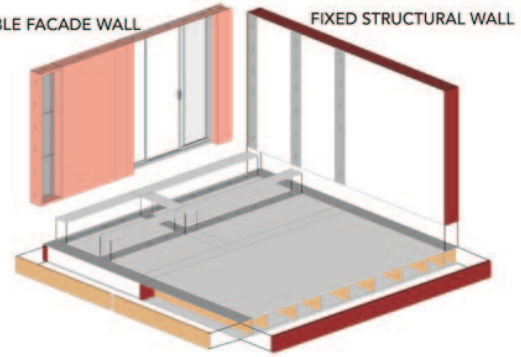
STEP 2
ATTACH SIP FOUNDATION WALLS,
WATERPROOF MEMBRANE &
LANDSCAPE BASE WALLS



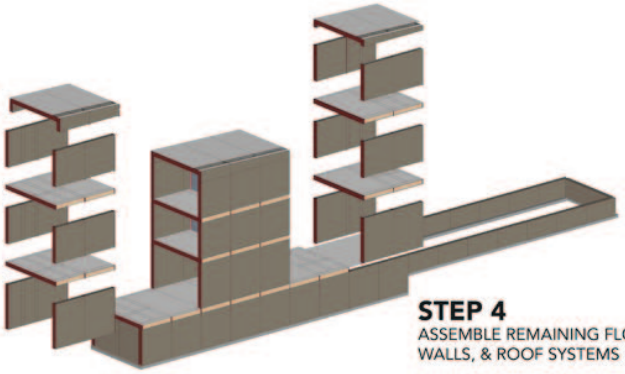
PARTS - AS SHIPPED



STEP 3
PLACE CORE MODULES
(STAIRS, BATHROOMS, MECH)



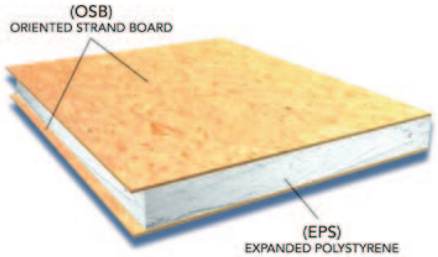
16' FLOOR PANEL MADE OF:
(1) 8' INSULATED SIP PANEL
(1) 8' TYPICALLY FRAMED FLOOR

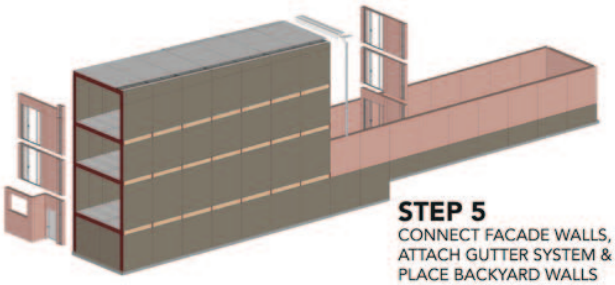


STEP 4
ASSEMBLE REMAINING FLOORS,
WALLS, & ROOF SYSTEMS

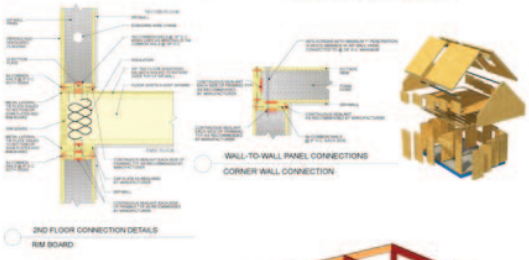
SIPS

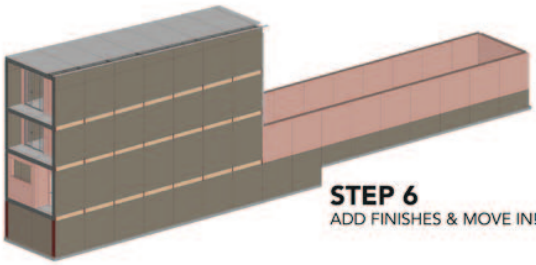
STRUCTURAL INSULATED PANELS



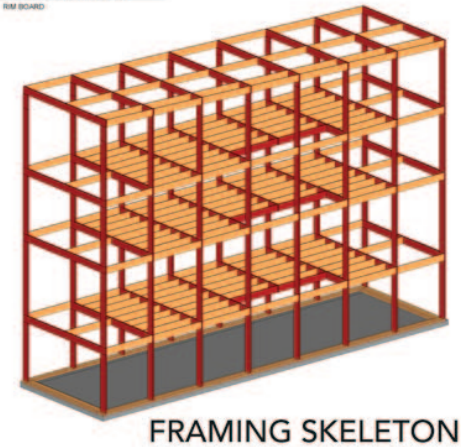


STEP 5
CONNECT FACADE WALLS,
ATTACH GUTTER SYSTEM &
PLACE BACKYARD WALLS



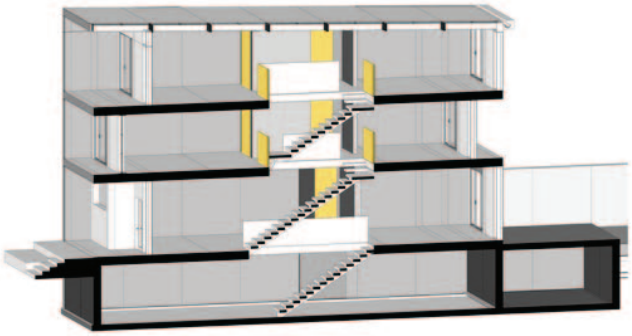


STEP 6
ADD FINISHES & MOVE IN!

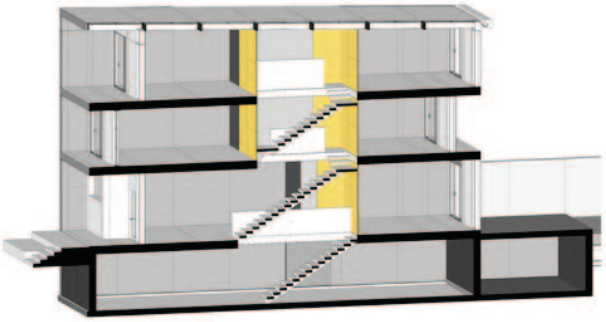


FRAMING SKELETON

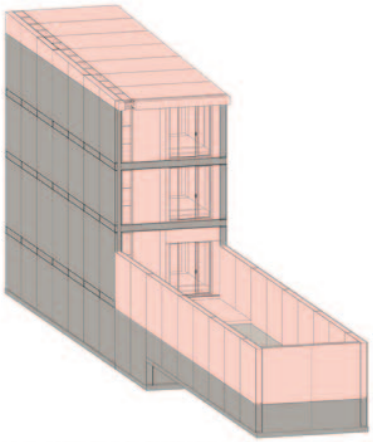
ADAPTABILITY



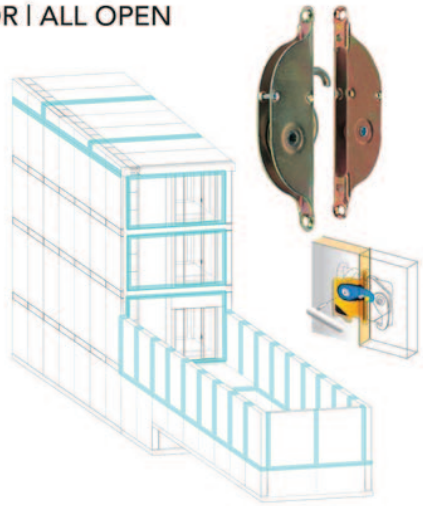
INTERIOR | ALL OPEN



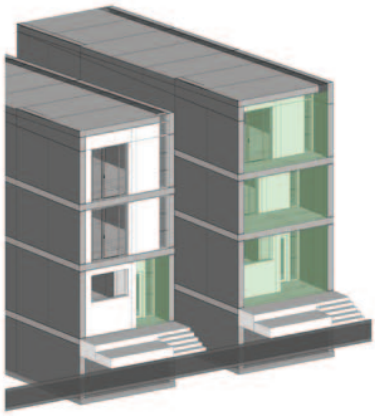
INTERIOR | ALL CLOSED



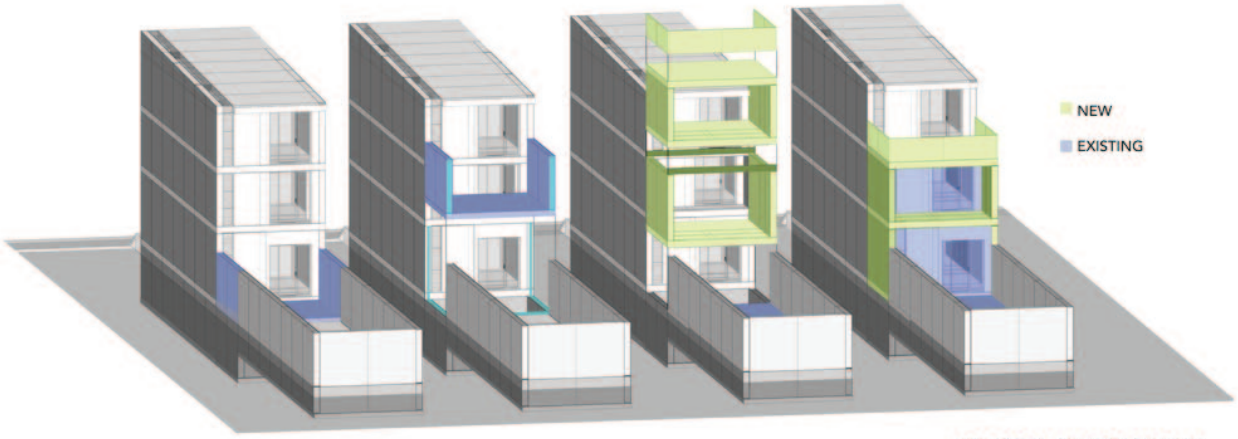
PERMANENT VS. ADAPTABLE



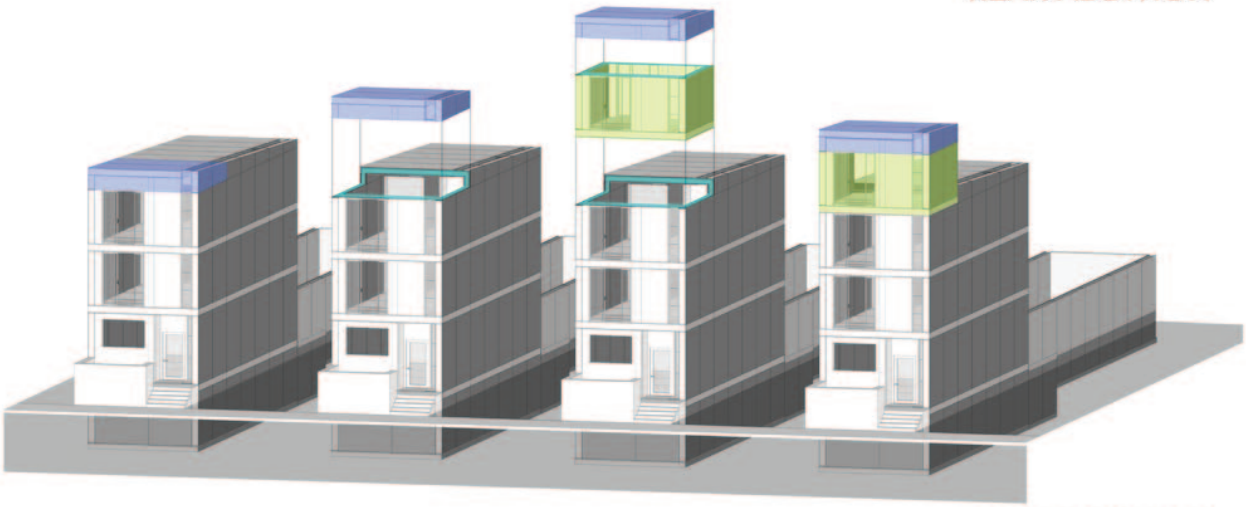
CAM-LOCK LOCATIONS



WINTER VS. SUMMER



REAR ADDITION

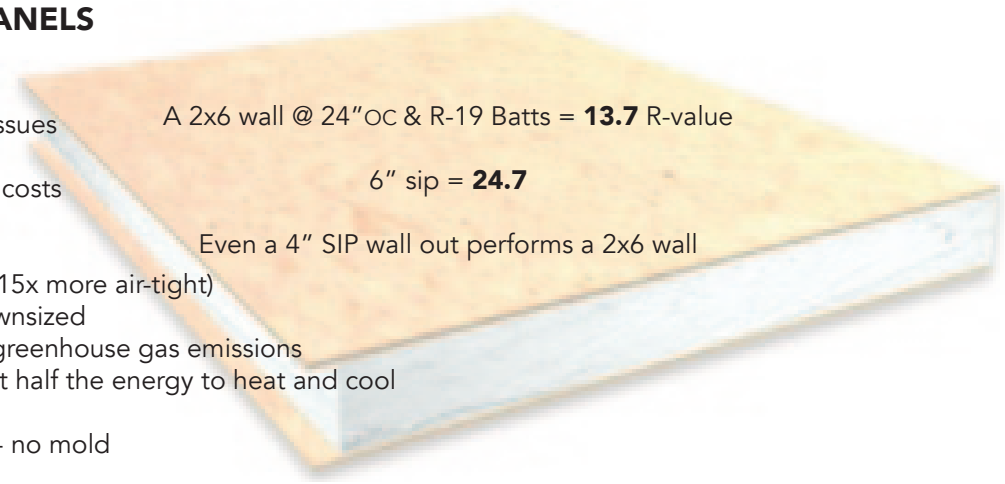


ROOF ADDITION

STRUCTURAL INSULATED PANELS

Efficiency

55% faster to build- labor reduction
Eliminates trade conflicts & timing issues
Reduction of construction waste
-Decrease of waste disposal costs
Continuous insulation
Sound & air insulation
Less air and moisture penetrations (15x more air-tight)
Hvac equipment can be majorly downsized
-Reduce of energy use and greenhouse gas emissions
-Mostly for ventilation- about half the energy to heat and cool
-Allergens are filtered
-Humidity can be controlled- no mold



A 2x6 wall @ 24"OC & R-19 Batts = **13.7** R-value

6" sip = **24.7**

Even a 4" SIP wall out performs a 2x6 wall

Factory precision

-Perfectly straight walls
-Stronger
-As large as 8'x24' panels

Structure

Can span up to 12' unsupported
Seamlessly compatible with typical stick framing
Continuous surface to nail anything to
(finishes, cabinetry, picture frames
without searching for studs)

PBS Panel R-Values

Type I modified EPS core

Core Thickness	R-Value at 75°	R-Value at 40°	R-Value at 25°
3-1/2"	15	16	17
5-1/2"	23	25	26
7-1/4"	29	32	33
9-1/4"	37	40	42
11-1/4"	45	49	51

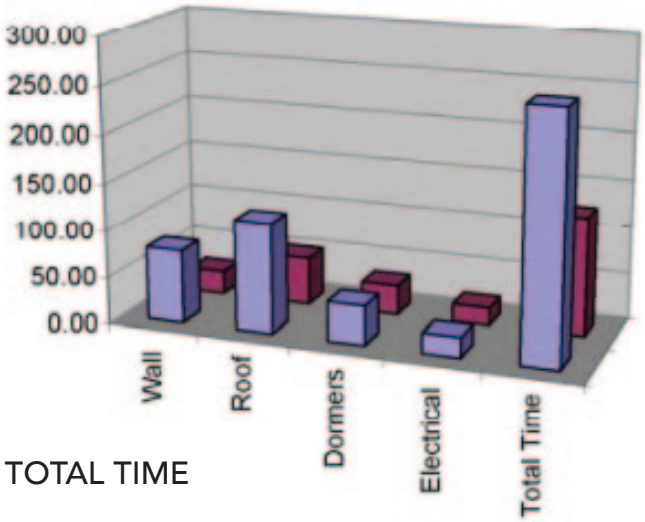
PBS Panel Weights

Type I modified EPS core

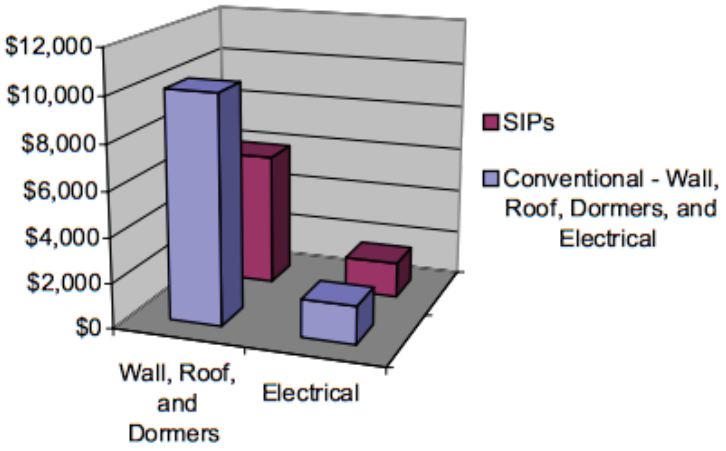
Core Thickness	OSB Skin Thickness		
	7/16"	5/8"	3/4"
3-1/2"	3.3	4.6	5.5
5-1/2"	3.5	4.8	5.7
7-1/4"	3.7	5.0	5.9
9-1/4"	3.9	5.2	6.1
11-1/4"	4.0	5.4	6.2

SPECIFIC *PREMIER SIPs* DATA

Higher material cost + Lower labor & construction costs =
Better quality, healthier, stronger house and much lower energy costs



TOTAL TIME



TOTAL COST

INSTALLED COST COMPARISON

Application	Column A Wall Labor Cost	Column B Roof Labor Cost	Column C Dormers Labor Cost	Column E Subtotal Cost	Column F Delta % for Column E
Conventional - wall, roof, and dormers	$3,331	$4,998	$1,765	$10,094	
SIPs - wall, roof, and dormers	$1,372	$2,816	$1,735	$5,923	-41%

Application	Column A Electrical Labor Cost		Column C Subtotal Cost	Column D Delta % for Column C
Conventional - Electrical rough-in	$979		$979	
SIPs - Electrical rough-in	$870		$870	-11%

Note: For Delta % by using Conventional time as denominator

FIGURES FROM RS MEANS BUSINESS SOLUTIONS
REED CONSTRUCTION DATA

PRESENTATION HANDOUT

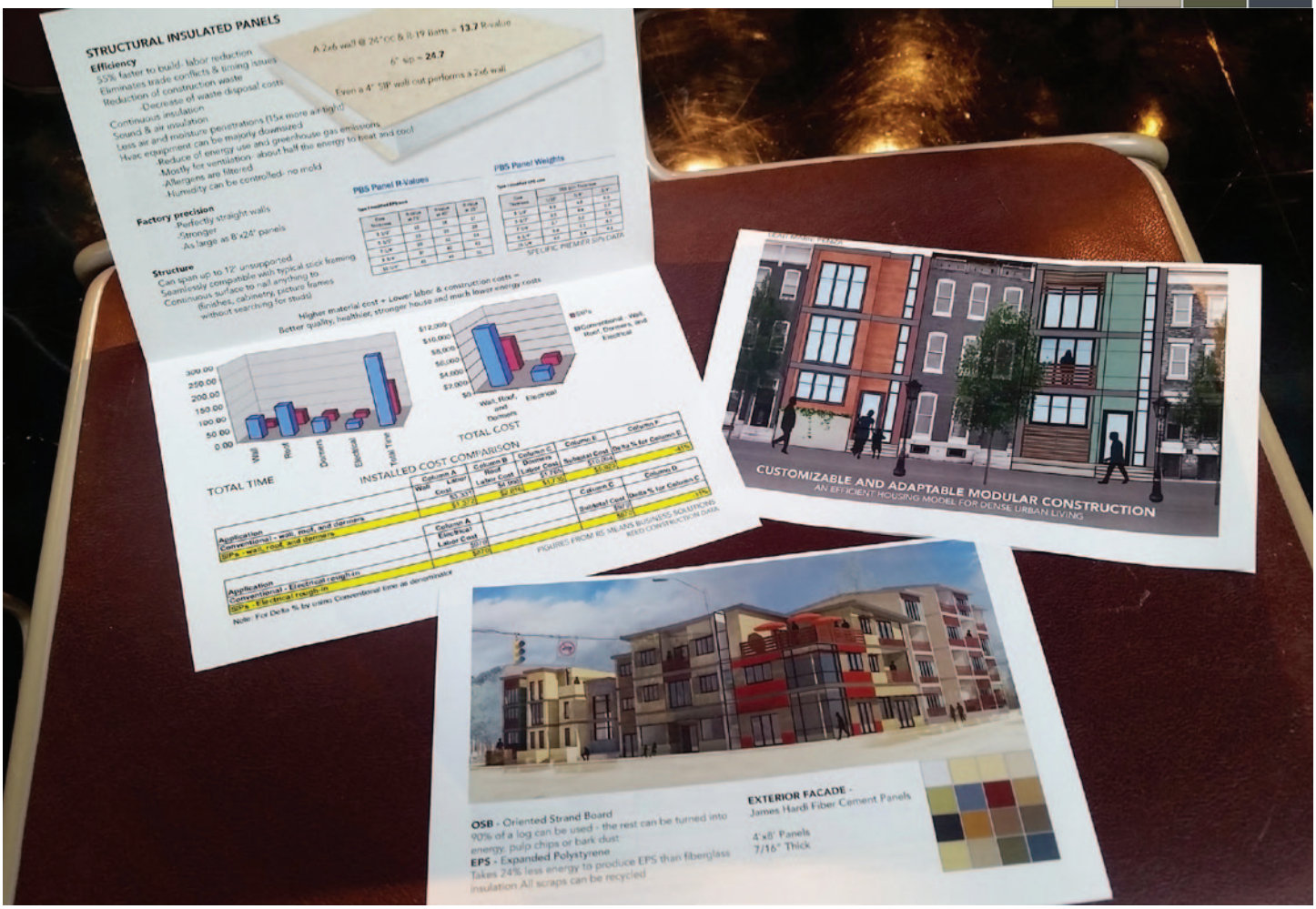


OSB - Oriented Strand Board
90% of a log can be used - the rest can be turned into energy, pulp chips or bark dust
EPS - Expanded Polystyrene
Takes 24% less energy to produce EPS than fiberglass insulation All scraps can be recycled

EXTERIOR FACADE -
James Hardi Fiber Cement Panels

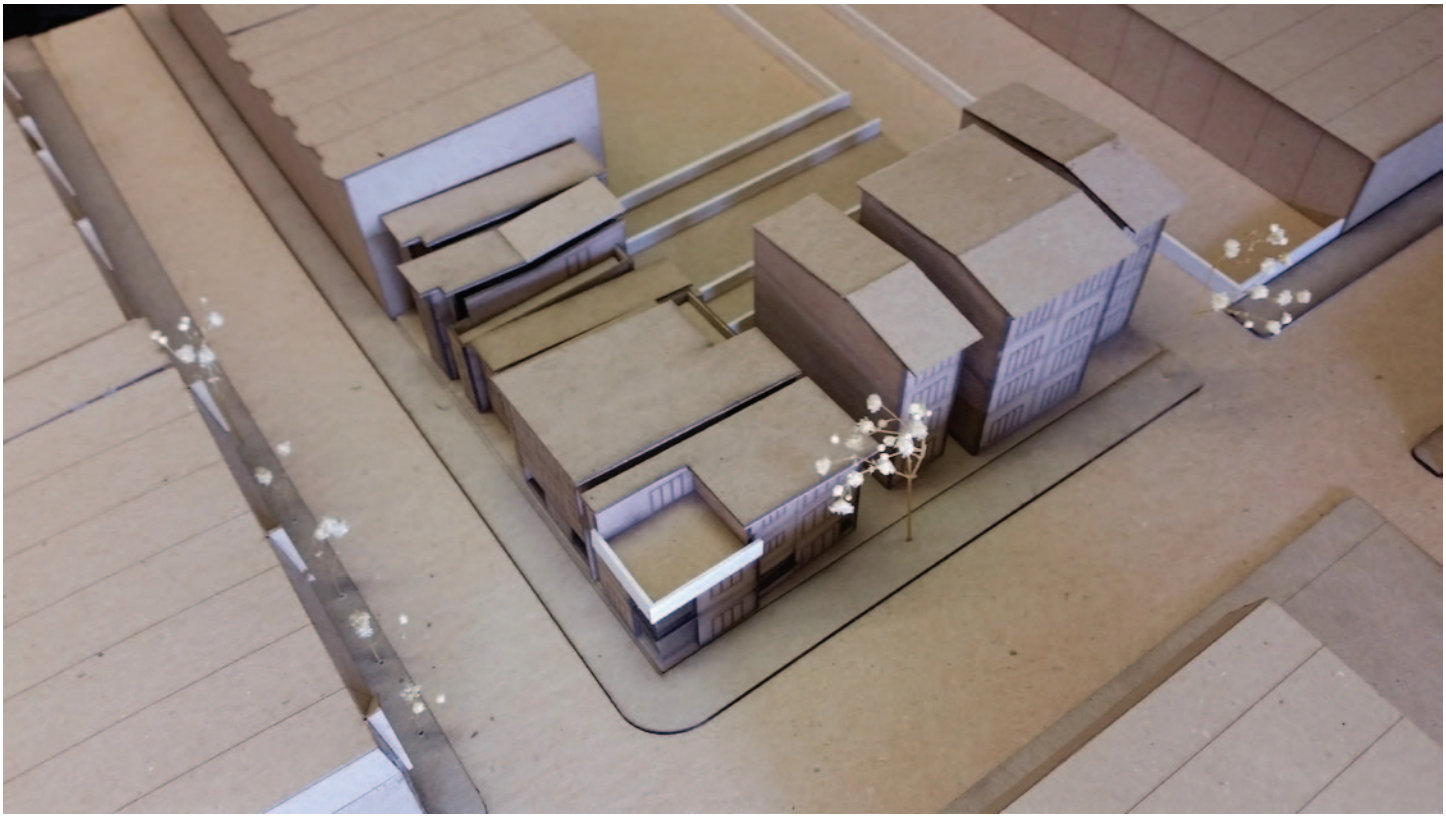
4'x8' Panels
7/16" Thick





MODEL





MODEL





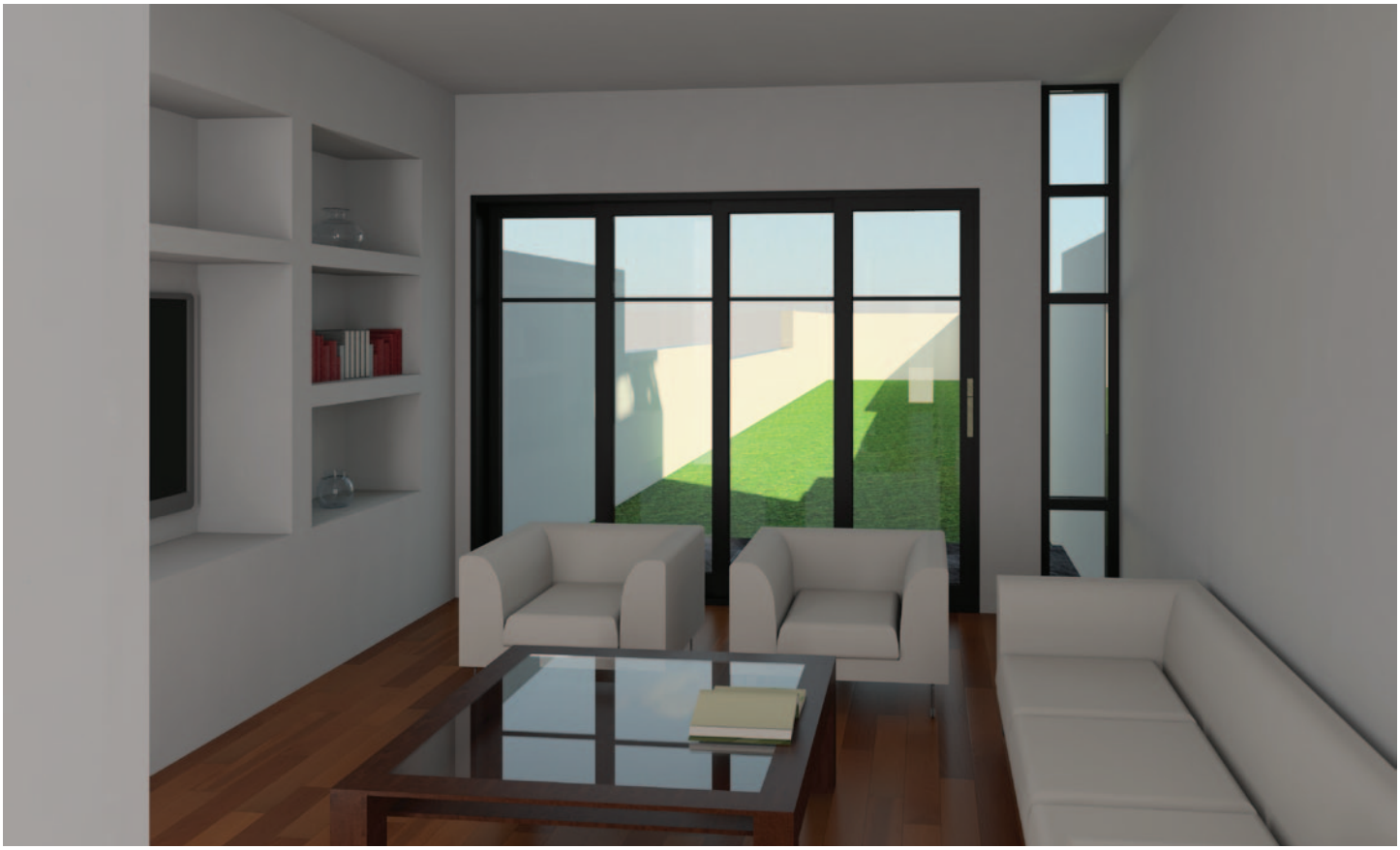
RENDERINGS | EXTERIOR



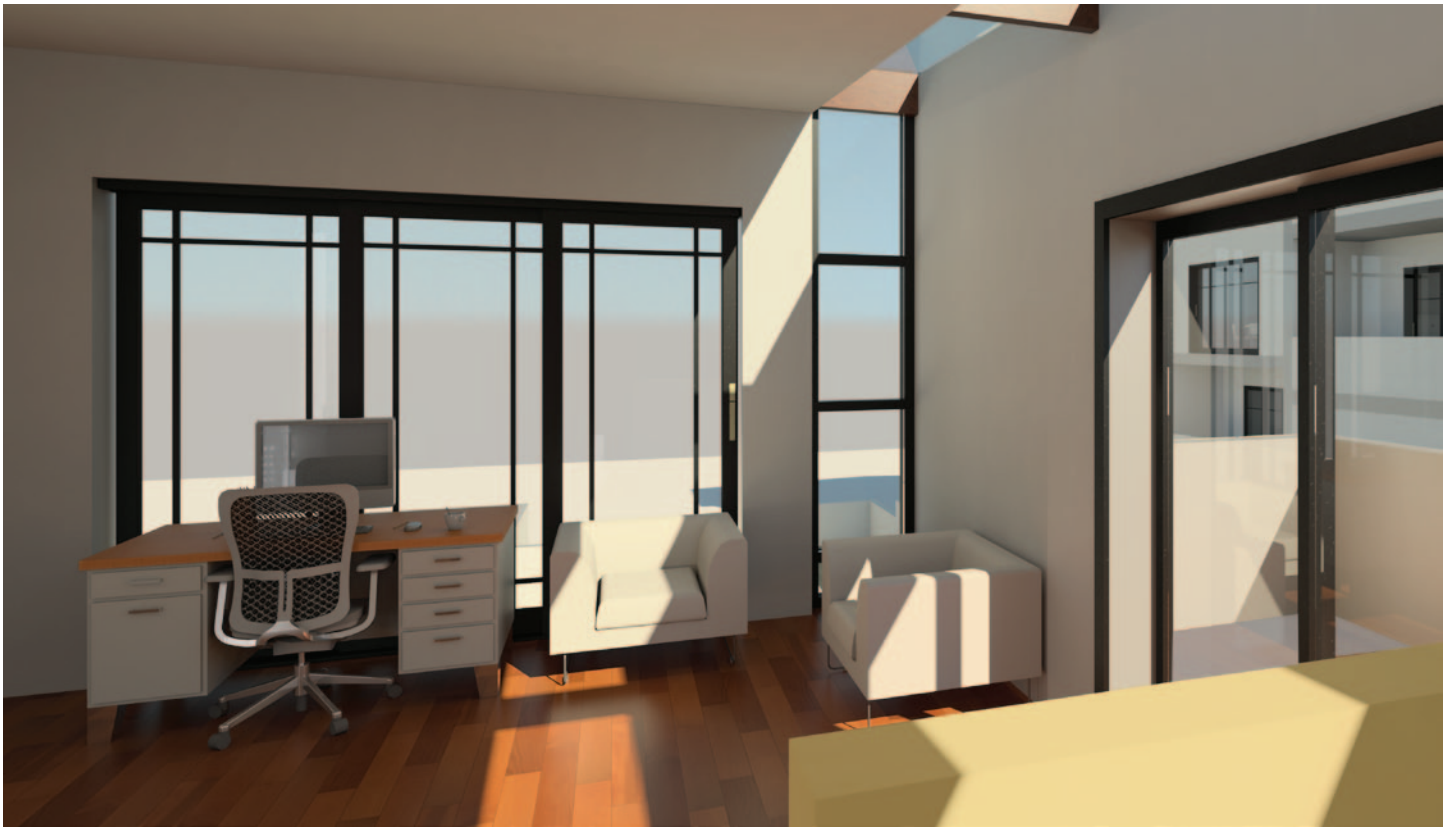


RENDERINGS | TOWNHOME A





RENDERINGS | TOWNHOME B





RENDERINGS | TOWNHOME C





THANK YOU!

I would like to offer a huge thank you to everyone who helped and pushed me during this long proccess, including my proffessors, committee members, peers, and parents.