

HOUSING AND THE CONSTRUCTION LABOR SHORTAGE: DESIGNING FOR JOBS IN
DULUTH MN

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ABSTRACT

This thesis examines the implication of modular timber framing as a design response to the construction labor shortage in Duluth MN. Drawing on the impact of tourism in Duluth and its impact on the housing market, increasing investment in the city is pushing up real estate prices, and in turn changing what buyers are willing to spend on construction labor. Because of this, labor wages remain uncompetitive because of rising real estate and material costs.

This thesis explores the use of modular heavy timber as a local resource with minimal manufacturing expenses, intended to bring more money into the construction labor market. This design response permits a variety of configurations that can fit within a variety of site constraints. Renovation practices for rental properties are also explored to mitigate increasing rent. Modular timber framing is also used in two examples of high-end home designs to show the implication of modular timber in a broader market.

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1. INTRODUCTION

The construction labor shortage in Duluth MN is an issue that has long impacted the cost to build affordable housing. The unpredictable environment surrounding shipment delays and costs for construction materials undermines the ability for employers to give competitive wages to construction laborers while still trying to bid for projects. The high cost of construction and high demand has led to a substantial affordable housing shortage in Duluth. The estimated need for apartments far exceeds the need for single-family homes according to different studies funded by the City of Duluth. The reason for this is apartments are more affordable than single-family homes maintaining a relatively stable rate compared to the demand for single-family homes which has risen dramatically as explored further in this study.

This study explores the ways designers and builders can implement a more efficient means of constructing homes through an in-depth exploration of design practices, construction techniques, and a simplified material palette. The proposed research will explore the broader economics and versatility of heavy timber home construction. The timber industry is prevalent in the surrounding Duluth area, because lumber is a common resource. The research in this proposal explores the economic and environmental impacts of reducing transportation to mitigate shipping delays. The main objective of this proposal is to provide a case study of a common issue in the modern United States economy, by examining the constraints and potential of a common resource and the feasibility of changing practices in architecture firms and the construction industry to make housing more affordable.

2. BACKGROUND

2.1. The Affordable Housing Shortage in Duluth MN

2.1.1. The State of the Housing Market

2.1.1.1. New Construction

According to the Housing Indicator Report of 2022, published by the City of Duluth, the median household income increased 18.21% between 2017 and 2022. The 2018 the median cost for a home as \$173,000 (Housing Indicator Report, 2018), opposed to \$260,000 in 2022 (Housing Indicator Report 2022). This is representative of a 50% increase in the average cost for a home, as opposed to an 18.21% increase in median household income over a longer timeframe. The 2022 Housing Indicator report also indicated the construction of 34 new single-family homes, and a housing unit increase of 176 units in Duluth MN in 2022. 167 multi-family units were also added.

2.1.1.2. Current Housing Stock

A study conducted by Maxfield Research and Consulting for the City of Duluth in 2019, included an estimate for affordable housing demand, excluding market rate, from 2019 to 2024:

- Single-family 126 units
- Owned multifamily 47 units
- Subsidized Rental 2202 units
- Affordable Rental 1010 units
- Active adult (55+) 297 units

This study also made some suggestions for development concepts.

“New housing products are being considered across the country to satisfy at least a portion

of the significant need for affordable housing. Ownership products include homes on small lots with less square feet, pre-manufactured components that are assembled on-site. New concepts for affordable housing also include pre-manufactured components and modules that are shipped and assembled on site” (Maxfield Research 2019). Duluth City’s website referenced this analysis, stating that “Duluth could absorb up to 3,509 additional units of affordable apartment housing and 126 affordable single-family homes by 2024. While progress has been made by the net gain of approximately 1,380 new units from 2015 to 2020, low vacancy rates and increasing costs demonstrate continued demand for housing” (City of Duluth).

During the Covid19 pandemic, the rental vacancy rate jumped to 5% in 2020 according to the Housing Indicator Report of 2022. The report also listed the rental vacancy rate in 2021 at 2% and the rental vacancy rate in 2022 at 3.5%. The Housing Indicator Report of 2022 reported a net gain of 1183 units between 2019 and 2022. This is 34% of the demand predicted by Maxfield Research and Consulting in 2019 of net gained housing by 2024.

2.1.1.3. Residential Rental Market

According to the 2020-2024 Consolidated Plan Housing Market Analysis, “The number of housing units has remained relatively consistent since the 1980’s. While there was a slight dip in the 1990 census of 990 units from the previous decade, there has been a slight increase over the past 20 years. In 2010 there were an estimated 38,990 housing units, up from the 1990 count of 34,646 and 2000 count of 35,500. The increase in units despite the stagnant population is due to the reduction in household size. In 2000, Duluth’s average household size was 2.26 and in 2017 it was estimated at 2.21” (City of Duluth).

2.1.1.4. Single-family Homes

According to the Housing Indicator Report of 2022, 174 single-family homes were built between 2019 and 2022. This is 38% over the anticipated demand that the Maxfield study of 2019 predicted for 2024 as of 2022. However, the Housing Indicator Reports of 2018 and 2022 indicated a 50% increase in the median price for a single-family home between 2018 and 2022. This reflects the low availability of single-family homes in Duluth, turning prospective home buyers to apartments because of cost, even though the demand persists.

2.1.1.5. Gentrification and Ownership

According to National Geographic “Gentrification is a demographic and economic shift that displaces established working-class communities and communities of color in favor of wealthier newcomers and real estate development companies. Heavy private investment in target neighborhoods causes price to rise sharply, and amenities enjoyed by the new residents, such as more expensive shopping and dining, drive out businesses that were supported by the established community” (Brown 20223). To this account, the impacts of gentrification are broad. In the case of the affordable housing shortage in Duluth, gentrification is an important concept to recognize in terms of ownership. For example, the West End neighborhood in Duluth has seen significant change over the last several years due to focused investment in restaurants and breweries. These new, relatively expensive restaurants increased the traffic flow of higher-earning individuals, changing the business landscape in that area with the addition of more expensive retail. Businesses in the West End were built around the way consumers like to spend free time, eating and shopping. This new environment is in stark contrast to what existed prior. The traffic flow of consumers that are willing to spend more provide a business every means to drive up their price, leaving out lower-income consumers in the process. By inhibiting the ability of the residents of

the West End to buy and sell, there is no way for them to become part of the economic shift. This is reminiscent of another large issue in Duluth's economy, and that is the inability of Duluth residents to invest in real-estate as a stable way to store and grow wealth. High rent comes without ownership, and when rent grows it pushes people out of their communities without the ability to profit from the economic benefit of the area. Duluthians aren't benefiting from the growing tourism industry, and it is instead compromising their ability to live comfortably.

2.1.1.6. Impacts of Rental Shortages

According to the Housing Indicator Report of 2022, the average monthly rent was up nine dollars from 2021. Rent averaged \$1,320 in 2021 and \$1,329 in 2022. According to the report, the rental market made up 39.2% of all households in 2022, and the stock of rental units increased from 16,836 units to 17,231 units between 2021 and 2022. During this same timeframe, there was an increase of the average cost for a home, from \$240,000 in 2021 to \$260,000 in 2022.

The Housing Indicator report included the survey results for 3,878 units in 2022. This report indicated the highest vacancy rates at 4.6% were among 2-bedroom units with a median of \$1,025 in monthly rent. This was about the same as 4-bedroom units with a vacancy rate of 4.5% and a median rent of \$1,794 a month. According to the survey, the lowest vacancy rates were among one-bedroom units with a vacancy rate of 1.4% and a median rent of \$834 per month. Total rental vacancy rates were up from 2% in 2021 to 3.5% in 2022. The report also included a housing affordability analysis that compared average rental rates to the number of hours at minimum wage per week to afford these rentals. Additionally, the analysis included the wage rate and annual income to make each rental rate affordable. The number to afford a unit compared to the 40-hour workweek is shown below.

- Studio, $54/40 = 1.35$ times the min or \$14.11 an hour / \$29,360y
- 1 Bedroom $63/40 = 1.575$ times the min or \$16.55 / \$34,440y
- 2 Bedroom $80/40 = 2$ times the min or \$21.13 / \$43,960y
- 3 Bedroom $103/40 = 2.575$ times the min or \$27.15 / \$56,480y
- 4 Bedroom $121/40 = 3.025$ times the min or \$31.98 / \$66,520y
- 5+ Bedroom $153/40 = 3.825$ times the min or \$40.37 / \$83,960y

None of the average rental rates listed above are affordable for a minimum wage job of 40 hours a week. According to the Bureau of Labor Statistics, the median hourly wage in Duluth MN breaks down to \$22.01 per hour, with an annual median wage of \$55,020. To this account, units that have two bedrooms or less are the most affordable units in Duluth, meeting Duluth's average household size of 2.31 listed in the Housing Indicator Report of 2022. However, the expense of more than one child and care for them can quickly discompose a parent's ability to pay rent and find enough space.

2.1.1.7. Impacts of Owned Home Shortages

Inflated prices to buy a home are compromising the ability of workers to invest in property value that could otherwise allow them to keep jobs where wages have been unable to increase, such as construction labor. According to the 2018 housing indicator report published by the City of Duluth, the median cost to buy a home is \$173,000, compared to the median cost of \$260,000 in the 2022 housing indicator report. The 50% increase in the median cost to buy a home is relative to a 23% increase of median annual income shown in the same 2018 and 2022 housing indicator reports.

2.1.2. The Causes of the Affordable Housing Shortage

2.1.2.1. The Tourism Industry

According to an article published by the Bureau of Business and Economic Research, “employment grew from roughly 6,770 in 2011 to 7,200 in 2019. Of course, 2020 experienced a steep decline in employment, due to the COVID-19 pandemic. Annual employment in the leisure and hospitality industry was roughly 5,300, significantly lower than any other year in recent history. While it may take the industry some time to fully recover from the steep decline in 2020, we chose not to include the most recent year in this analysis, as we are assuming the industry will recover” (Haynes 2021). This report covered employment in the leisure and hospitality industry in Duluth. After the COVID-19 pandemic, tourism has recovered in Duluth. The employment of leisure and hospitality workers in Duluth, reflect growing numbers of traffic from all over the world. According to the publication *The Minnesota Visitor Economy 2022* by Tourism Economics, “Among all spending categories, growth in lodging, including short-term rentals and second homes, was especially notable in 2022.” The publication also noted that total visitor spending in Minnesota reached 13.1B in 2022. High visibility from tourists, have changed prices, including the costs of residential real-estate. An anonymous real-estate agent explained the impact of buyers on the residential market that are not from Duluth. They provided an example of an undisclosed buyer from California that bought twenty homes, all about sixty thousand dollars overprice. All this real-estate agent knew about the buyer was that it was a company taking safety measures in case they had to move due to climate-related challenges (Anonymous, Personal Communication, 2024). This highlights a major issue in Duluth’s real-estate economy, and that is the impact of purchases both inside and outside of Duluth, of multiple properties. The 50% increase of the median cost of a single-family home between

reported in the 2018 and 2022 housing indicator reports, showcase the perfect environment for investors to capitalize on both the beauty of the North Shore and extreme property value growth.

2.1.2.2. Competition for Housing and the Construction Labor Shortage

The influx of buyers from outside of Duluth has led to a competitive real-estate market that limits the possibility of Duluth residents to buy an affordable property with little need for repair. High costs for labor due to the construction labor shortage and rising costs of materials has limited the ability of property owners to fix up a lot of the older housing stock in Duluth. For example, to enforce upkeep on the housing stock of rental units, the City of Duluth requires a rental license rewarded after a successful inspection every two years. Even though the efforts by the City of Duluth have had success, upkeep for older single-family homes, and multifamily investment properties is still a problem that persists because of the expense of construction labor. When a property is fixed up to meet current standards, rent is almost always raised to make a return on the expense.

2.1.2.3. Rising Interest Rates

2.1.2.3.1. Buying Power and Loans

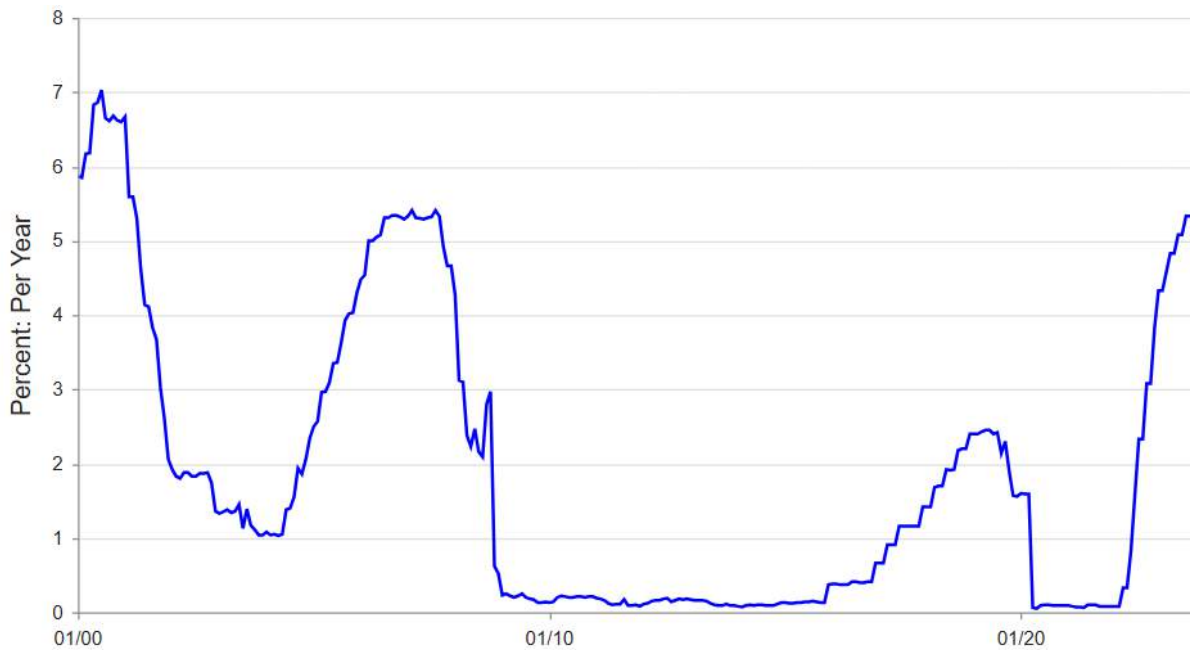


Figure 2.1. Interest Rates in the United States from 2000 – 2023. Federal Reserve Board (2023).

Figure 2.1 above is comprised of data retrieved by the Federal Reserve Board showing US interest rates between 2000 and 2023. Following the 2008 recession, the Federal Reserve lowered interest rates to almost nothing, after a steady rise of interest rates to a high of 2.45% in April of 2019, the recession during the COVID19 pandemic caused interest rates to be lowered by the Federal Reserve again. These low interest rates were followed by a dramatic spike after the pandemic, when the demand for housing soared.

The rise in interest rates was in response to extreme demand, and insufficient supply, stressing supply chains. Real-estate was no exception; the cost of single-family homes rose to unsustainable levels and was mitigated by higher interest rates. However, high interest rates have reduced the US population's buying power, compromising material and labor costs in the construction industry, keeping demand for housing unmet.

2.1.2.3.2. Increased Demand for Rental Units

The short supply of single-family homes, followed by limited buying power has kept apartments full. High interest rates have made buying a home challenging for many entry-level workers because of larger downpayments.

2.2. The Construction Labor Shortage in Duluth MN

2.2.1. The State of the Construction Labor Shortage

According to the Bureau of Labor Statistics, 52.585 jobs of every 100 openings are fulfilled in St. Louis County as of 2022 for construction and extraction occupations, or approximately 53%. This is representative of a major labor shortage in Duluth MN.

Following the pandemic there was a rapid increase in residential construction. According to Dr. Anirban Basu, Marcum's chief construction economist, cited by PR Newswire, the share of residential construction in the construction workforce jumped from 39% before the pandemic to 41.4% after the pandemic (PR Newswire 2023).

2.2.2. The Impact of the Construction Labor Shortage on Affordable Housing

According to Amanda Larson, the general office manager of Heyday Home Solutions in Duluth, "Finding the skilled labor, or finding the lack of skilled labor, definitely changes our business. Instead of being able to have 4 or more projects going at once we are limited to about 3 at a time, which slows down the turnover of money coming in" (A. Larson, Personal Communication, 2023). Larson explained that "We have been fortunate enough to keep some great carpenters on staff due to keeping wages competitive but that also does affect business because you have the higher overhead which in turn projects do cost more, and that can sometimes turn into losing estimates due to our price" (A. Larson, Personal Communication, 2023). In other words, prices are unsustainable for new construction in Duluth, forcing builders

to walk a thin line between competitive wages and competitive bids to stay in business. The lack of skilled labor in the construction industry and the housing market have in turn, had mutual impact on each other. The perceived value of new housing has driven wages down for construction workers, while material prices have risen drastically, limiting the construction industry's ability to meet demand in Duluth.

The cost of construction materials impacts the costs of both large and small projects. Considering Duluth's older housing stock, this makes a difficult environment for investors to convert existing spaces into housing units, and nearly pushes the brand-new construction of affordable units out of the question. The shortage of construction labor expedites this issue when contractors are forced to choose only the highest earning projects, making the repair of these old properties lose their investment potential.

2.2.3. Causes for the Construction Labor Shortage

2.2.3.1. The Education System

2.2.3.1.1. Perception of the Construction Trades in Schools

Justin Scheider is a high school shop teacher for the Esko school system right outside of Duluth. According to Scheider, "One of the reasons that I feel students are less inclined to join the trades is the lack of exposure or encouragement. This lack of exposure might include the fact that their school doesn't have the classes related to the trades, lack of knowledge by counselors or those within the school that help with their future plans, or pressure by others to go to four-year colleges versus smaller schools or the trades" (J. Scheider, Personal Communication, 2024). To encourage students to join the trades, Scheider has taken students to the Construct Tomorrow program.

Construct Tomorrow is an organization that aims to “bring awareness to high school students about the remarkable post-secondary career opportunities in the construction and building trades industries.” According to the organization’s website, “Construct Tomorrow has connected with 70,000 students from more than 400 high schools across the state of Minnesota through experiential, hands-on learning activities that feature the construction trades.” This organization visits Duluth MN every year, hoping to influence a positive perception of the construction trades in schools, and combat Duluth’s severe construction labor shortage.

2.2.3.1.2. Skilled Labor

According to author Tyler Berding “It is well known that construction labor unions have training programs for apprentices that can turn out highly skilled workers in several trades; workers educated in how to follow a manufacturer’s guidelines and architectural details. Sadly, I’ve seen from experience that union-trained labor is often avoided to reduce costs or because union labor is just not available” (Walls and Ceilings 2022).

2.2.3.2. Wages and Retainment

The Arrowhead Builders Association is an organization of builders in Duluth, Heyday Home Solutions is a company that is part of this organization. They are an entity of twelve individuals. Heyday Home Solutions was asked about the relationship between materials prices, shipping predictability, and employee wages. According to Amanda Larson, their general office manager, “materials can definitely affect the cost of the project which affects the amount of projects accepted or denied which then in turn can affect our profits and inhibit us from adding more benefits for the employees or buying new tools, trailers, and vehicles” (A. Larson, Personal Communication, 2023). Larson went on to explain “one of the biggest issues I have with materials are finding items in stock or that I can order and have shipped to me in a reasonable

timeframe” (A. Larson, Personal Communication 2023). According to Larson, “many homeowners don't truly know the cost of materials, especially windows, doors, and lumber” (A. Larson, Personal Communication, 2023). This is because of the recent increase of cost of these construction materials in a very short timeframe. In direct relationship to Heyday Home Solutions Larson explained that “retainment of employees is also a slight problem. We have been fortunate enough to keep some great carpenters on staff due to keeping wages competitive but that also does affect business because you have the higher overhead which in turn projects do cost more, and that can sometimes turn into losing estimates due to our price” (A. Larson, Personal Communication, 2023).

According to PR Newswire “The surplus of open positions has empowered workers to switch jobs, or even industries, in search of higher pay. "The construction industry quit rate, or the share of construction workers who quit their jobs, averaged 2.5% during 2021 and 2022," said Dr. Basu. "Over the previous decade, the construction industry quit rate averaged just 1.8%.” (PR Newswire 2023).”

2.2.3.3. Costs of Construction Materials

2.2.3.3.1. Softwood Lumber Prices

According to Cameron Macht, the Regional Analysis & Outreach Manager for the Labor Market Information Office of the Minnesota Department of Employment and Economic Development, “It is not surprising that almost half of the state's remaining employment in Forestry and Logging is located in the 7-county Northeast Minnesota region, home to most of the state's forest land.”

Map 1.
Percent of Forest Land by County, Minnesota, 2014

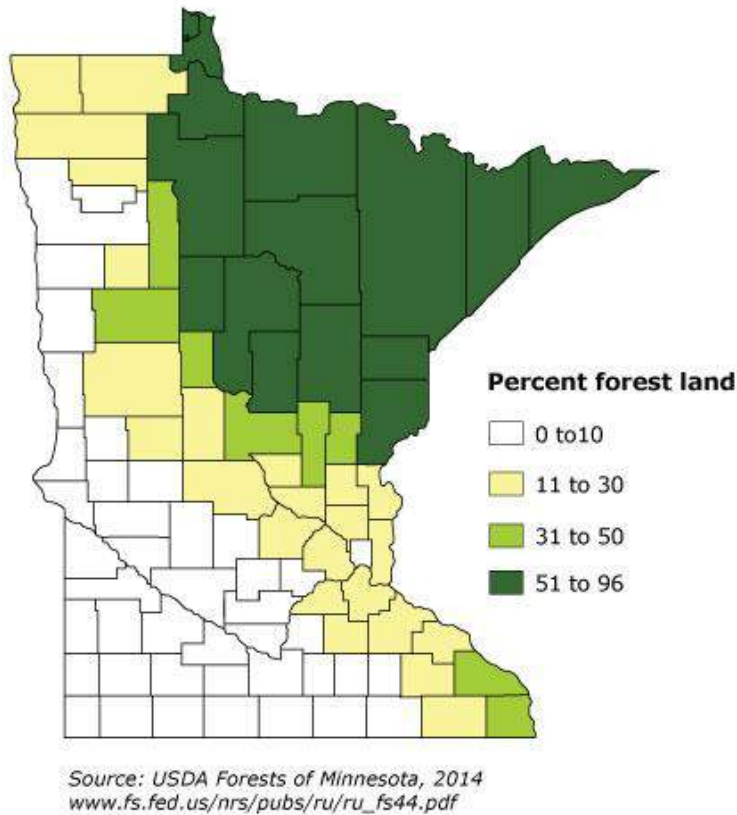


Figure 2.2. Percent of Forest Land by County (Minnesota Department of Employment and Economic Development 2019).

The land with the highest percentage of forest land, ranging from 51% to 96% surrounds the Duluth area. According to Macht, “the Forest Product Industry has endured recessionary shockwaves and employment cutbacks as well as productivity growth and advances in sustainability. Many of these forces have greatly impacted the industry, remolding it into a very different shape (Macht 2023). Macht went on to explain that the wood products industry which includes “Sawmills and Wood Preservation, Other Wood Product Manufacturing, and Veneer, Plywood, and Engineered Wood Product Manufacturing,” has lost 66% of its workforce between 2000 and 2021. According to Macht, “Unlike the other sectors, employment in Forestry and Logging has been relatively stable over time, declining less than 6 percent from 2000 to 2017

and even experiencing hiring growth in the past five years” (Macht 2023). During this period, lumber prices increased by the end of 2017. Interestingly, the forestry and logging sector hasn’t grown as much in profitability as other sectors following the beginning of the COVID19 pandemic. According to the 2021 Minnesota Public Agencies Stumpage Price Review and Price Indices published by the Department of Natural Resources in August of 2022, “In 2021, all species and products stumpage sold by public agencies in Minnesota totaled 1.651 million cord equivalents with a value of \$44.774 million compared to 1.635 million cord equivalents sold with a value of \$40.716 million in 2020. This amounts to a year-over-year volume increase of 15,125 cord equivalents or 0.9 percent and a year-over-year value increase of \$4.057 million or 10 percent” (Department of Natural Resources 2022). However, the sell price per cord equivalent of \$27.12, up 9% from \$24.89 in 2020, was less than the cord equivalent from 2015 to 2017 before the COVID19 pandemic.

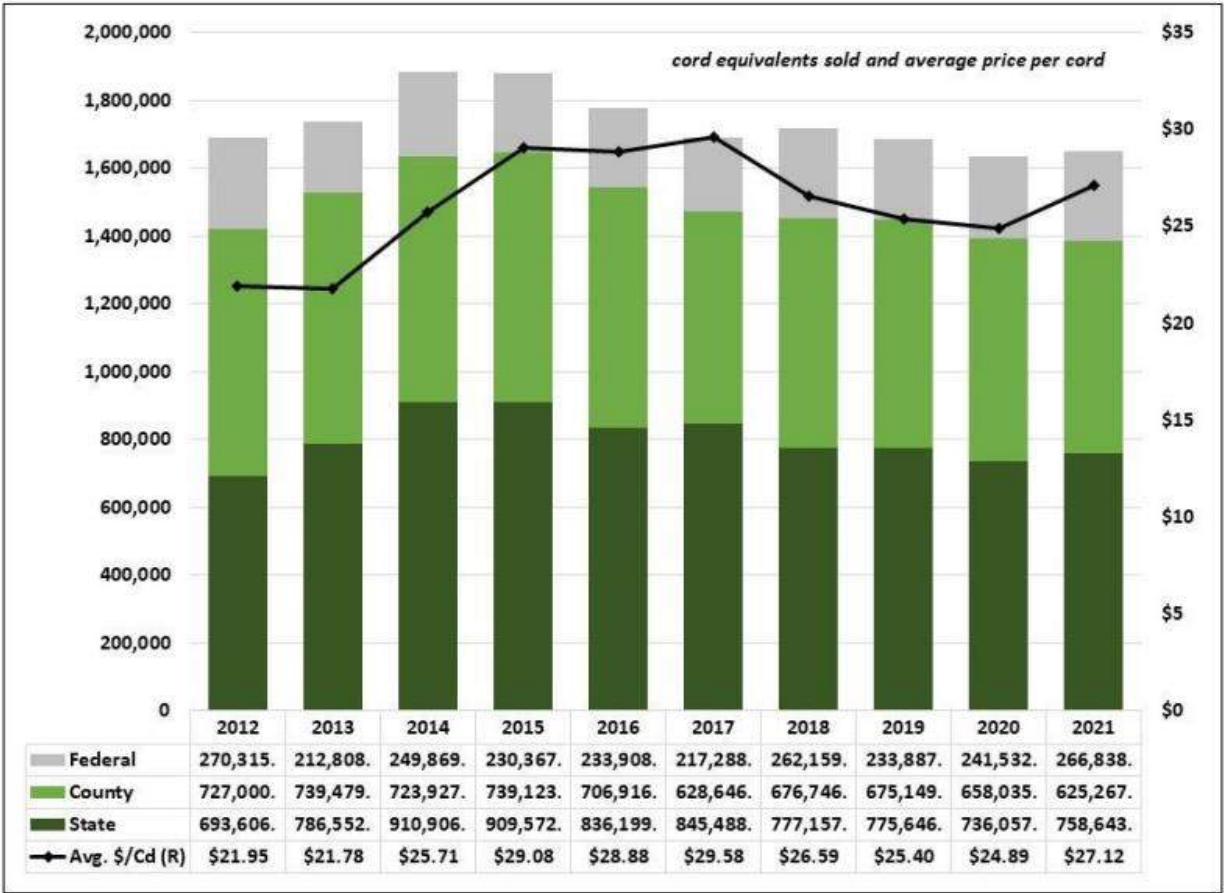


Figure 2.3. Cord Equivalents and Average Price per Cord (Department of Natural Resources 2022).

Red pine as a building material has followed a similar trend but has trended between the \$30 and 40\$ even into the COVID19 pandemic when the Federal Reserve dropped interest rates in early 2020.

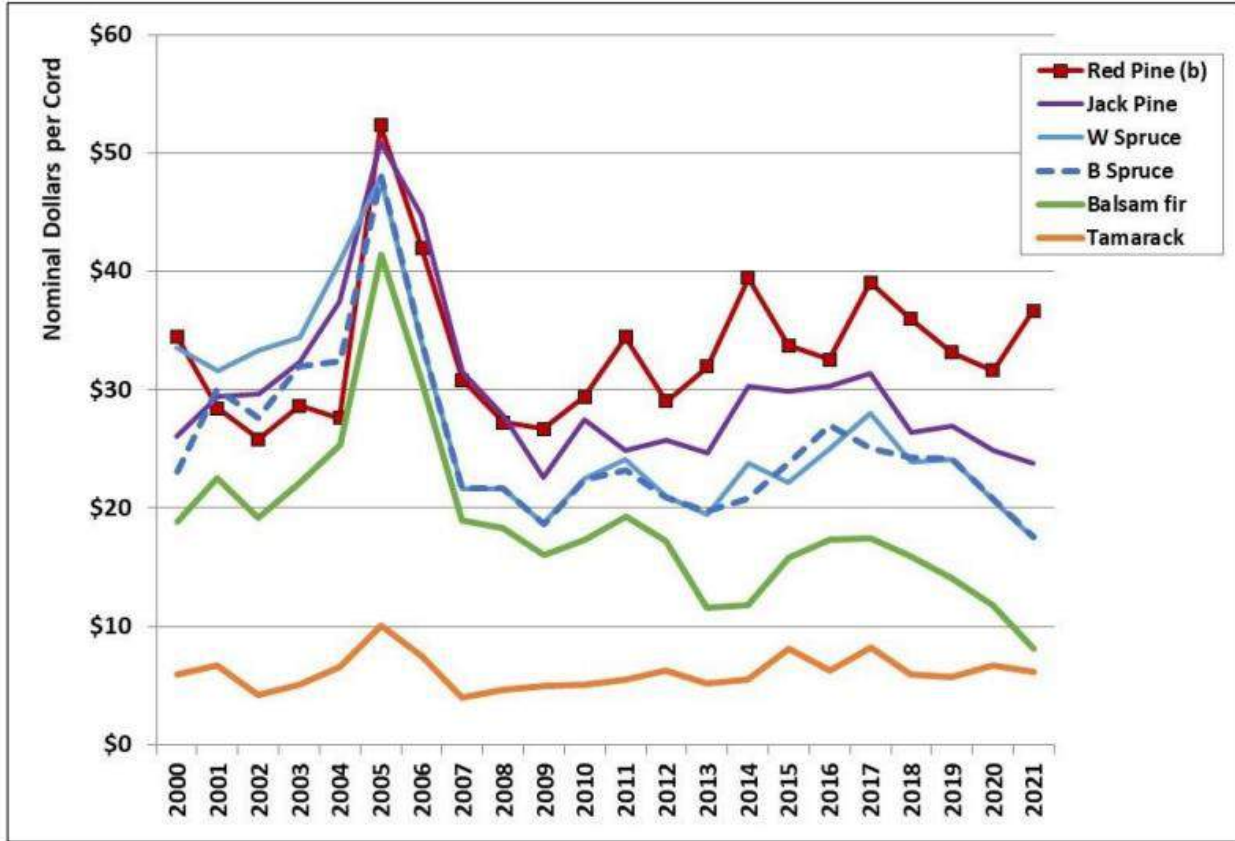


Figure 2.4. Cord Equivalents and Average Price per Cord (Department of Natural Resources 2022).

Even though the price per cord equivalent has remained relatively consistent, this has not been the case for the price of lumber for consumers.

The following tables were published by The National Home Builders Association in 2021.

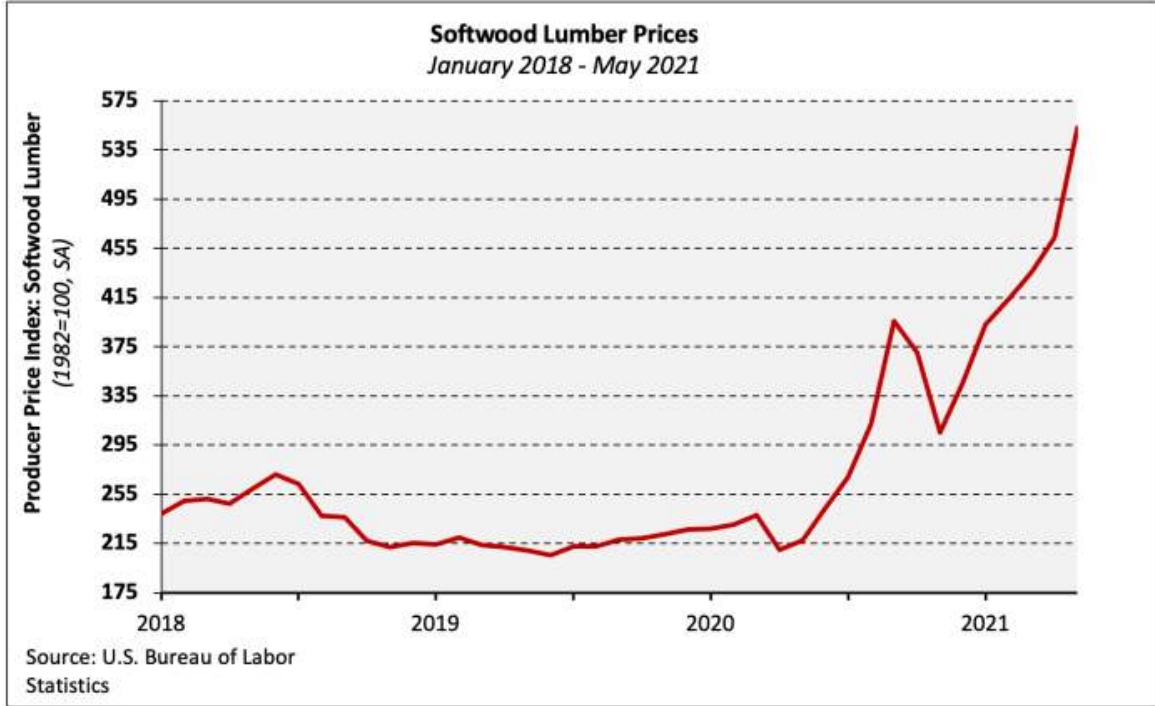


Figure 2.5. Softwood Lumber Prices (National Home Builders Association 2021).

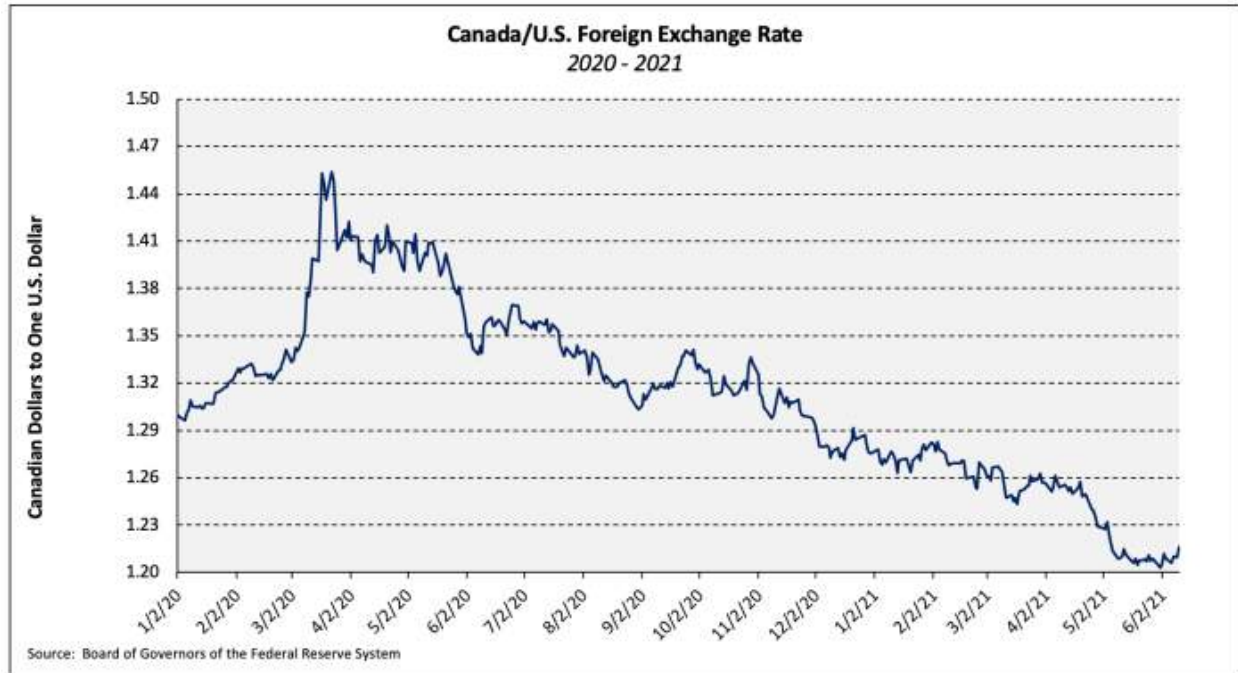


Figure 2.6. Canada/U.S. Foreign Exchange Rate (National Home Builders Association 2021).

2.2.3.3.2. *Steel Mill Products Prices*

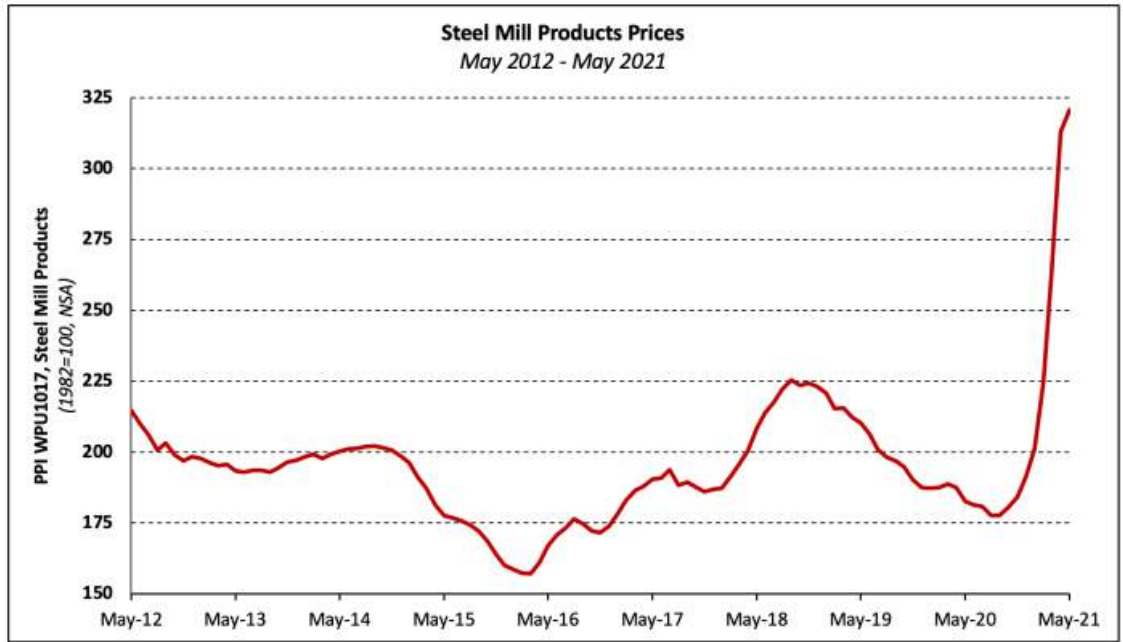


Figure 2.7. Steel Mill Products Prices (National Home Builders Association 2021).

2.2.3.3.3. *Gypsum Products Prices*

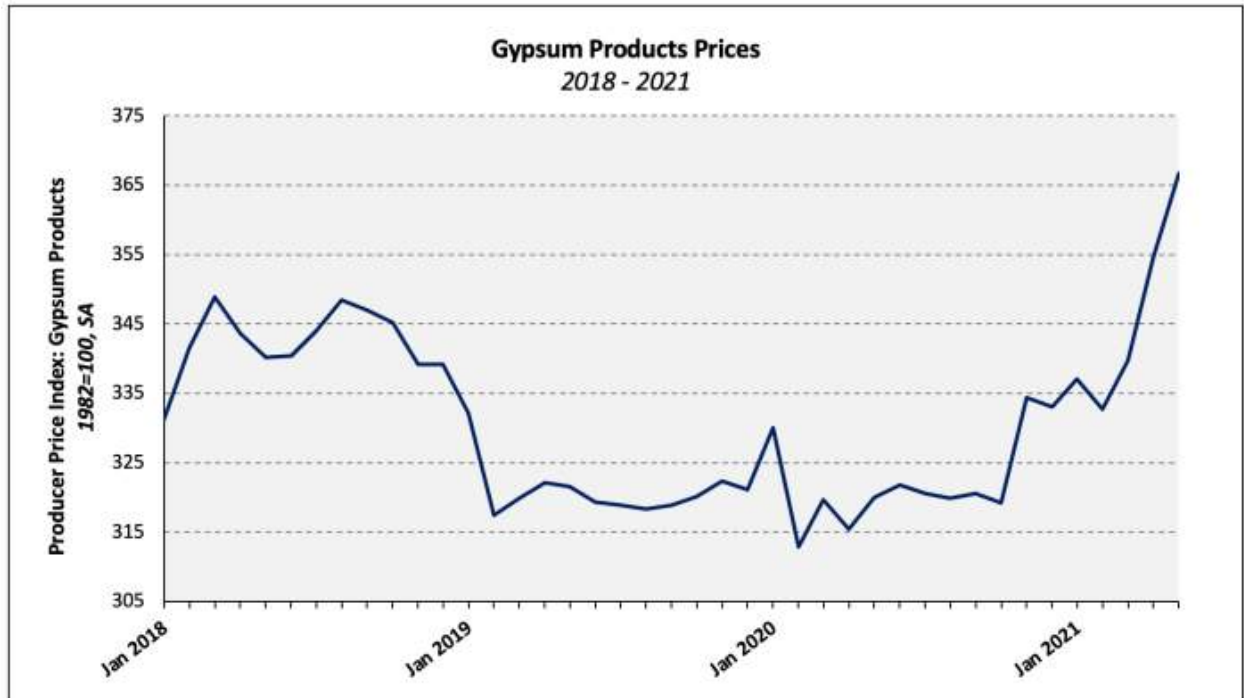


Figure 2.8. Gypsum Products Prices (National Home Builders Association 2021).

3. PROPOSED RESEARCH

3.1. Research Methodology

3.1.1. Research Strategy

The research strategy for this thesis is to explore the labor shortage at a national level and local level. This involves piecing together a chronological plot explaining the existence of the construction labor shortage and consequent housing shortage. Understanding the history of the construction labor shortage and its consequences will allow a more accurate hypothecation of how to combat the labor shortage in the future.

3.1.2. Project Timeline

1.	3.	5.	7.	9.
Housing shortage research	Methodology: How do we change practice?	Case study research: What has been done?	Contextual analysis	Presentation development
	Construction labor shortage research	Project Implementation in Duluth MN begins	Develop business model example	Project design: provides a broad set of implications
2.	4.	6.	8.	

3.2. Project Implementation

3.2.1. Project Goals

3.2.1.1. Material Economy

The use of local resources is both more affordable and sustainable, permitting a larger budget allocation for construction. Jack pine and red pine are both local to the Duluth area, fitting this requirement.

3.2.1.2. Reduced Manufacturing

By minimizing manufacturing, more of the building expense can go to construction workers. The use of heavy timber building components limits the number of cutting required to create pieces of lumber that currently have more demand.

3.2.1.3. Easy Constructability

Simple construction can increase pay for construction workers and reduce the overall expense of a project. This is done by the simplified material palette that is permitted using timber. Easy constructability and the use of a simplified material palette also counters the shortage of skilled labor directly, eliminating expenses.

3.2.1.4. Reusability and Sustainability

Designing for adaptive reuse of space and materials can help northern cities meet environmental goals. This is accomplished using modular heavy timber components that can be taken apart and reconfigured. The heavy timber superstructure implemented in the design of the modular system also permits adaptive reuse within the space because of wider, modular spans between supporting elements.

3.2.2. Case Studies

3.2.2.1. Popular Case Studies

3.2.2.1.1. The Eames House



Figure 3.1. Eames House (Eames Foundation 2020).

According to the Eames Foundation, the Eames House was built in 1949 by Charles and Ray Eames. “The Eames House consists of two glass and steel rectangular boxes: one is a residence; one, a working studio. They are nestled into a hillside, backed by an eight-foot tall by 200’ long concrete retaining wall” (Eames Foundation 2020).

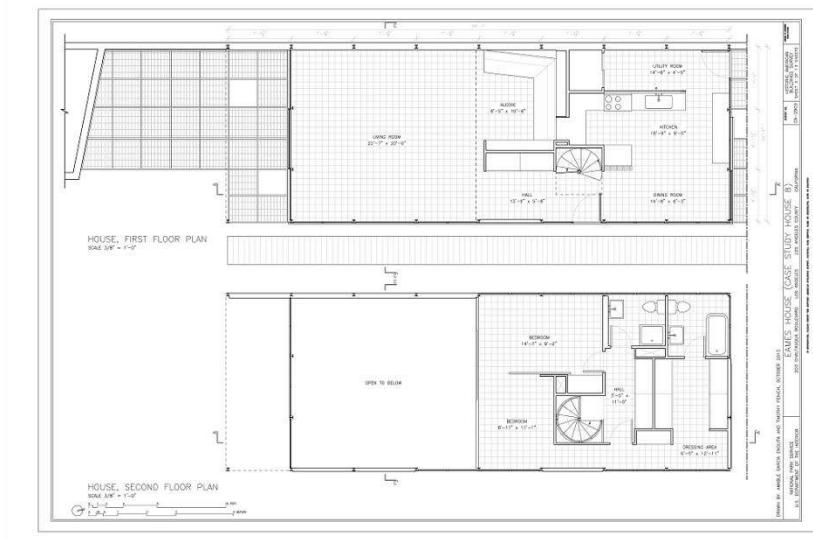


Figure 3.2. Eames House First Floor Plan (Library of Congress 2015).

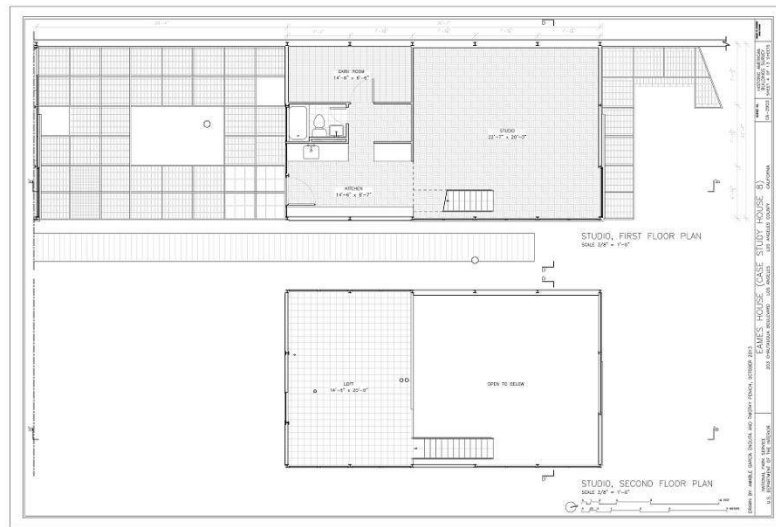


Figure 3.3. Eames House Second Floor Plan (Library of Congress 2015).

In the drawings above, the 200' retaining wall is visible on the back side of the building. The rest of the structure consists of glass and steel. The columns that support the structure can be seen in these plans. As seen in drawing below, these columns support web trusses that span between the columns and a wall that sits on top of the 200' retaining wall.



Figure 3.4. Eames House Elevations and Section (Library of Congress 2015).

The use of modular and prefabricated elements, in addition to the simple geometry of the Eames House contributed significantly to its short construction period. According to an Art In Context publication by Kylie Deyzel, “The foundation for the house and the steel frame was completed in a mere 16 hours by a total of five workers, and the rest of the house was finalized within a short eleven months” (Deyzel 2023). According to Deyzel, “The Eames House was part of the Los Angeles Arts and Architecture Magazine Case Study Program when it was designed in 1945. The goal of these case study homes was for them to prioritize the use of modern technology and materials that were invented during World War II” (Deyzel 2023). This reflects the mass industrialist era after World War II and the heavy emphasis on manufacturing. Because of the economy shift, manufacturing proved to be a cheap and efficient way to produce goods. Charles and Ray Eames used the state of the economy to their advantage implementing the simple design and construction of the Eames House. The Eames House is a perfect example of celebrating the economy of material choices by emphasizing their relationship to the broader economy, and by celebrating their efficiency.

3.2.2.1.2. *Le Corbusier*



Figure 3.5. La Tourette (Arch Daily 2010).

Le Corbusier was a prominent leader of the Modernist Movement. He developed a modular design approach based on a set of principles he found in nature and in people. In the case of Le Corbusier, modular construction existed mostly in a set of ideas that governed a universal order, shaping the modernist movement. Although Le Corbusier found economy in a cheap material, using repetitive molding strategies and the materials versatility, Le Corbusier's spaces are not user oriented. Le Corbusier's use of the modular system compartmentalizes the heavily diverse and expressive human existence.

3.2.2.1.3. *Ludwig Mies van der Rohe*



Figure 3.6. Federal Building (Arch Daily 2023).

The architecture of Mies van der Rohe has significant focus on the modular use of materials and their relationship to one another. In terms of construction labor, the limited

altercation of building materials can save construction labor costs for the client, but perfecting the relationship of certain materials with one another can contradict this logic, with the tiny margin of error in the construction process.



Figure 3.7. Federal Building (Arch Daily 2023).

The extent of the coordination between design elements can be examined at the base of the Federal Building. Upon close examination, the pavers that make up the sidewalk cannot be broken, and they are lines up with the columns and base of the building. Any discrepancy between the exact location of the building, the pavers, and positioning of the columns, can result in expensive fixes.

3.2.2.1.4. *Rem Koolhaas*



Figure 3.8. IIT McCormick Tribune Campus Center (OMA).

In the McCormick Tribune Campus Center, the architect Rem Koolhaas used a notable variety of materials. In this building, the variety of materials were applied in a way that would almost appear unfinished in many circumstances, but little alteration to building materials, and a larger margin of error can save costs considerably when it looks nice.

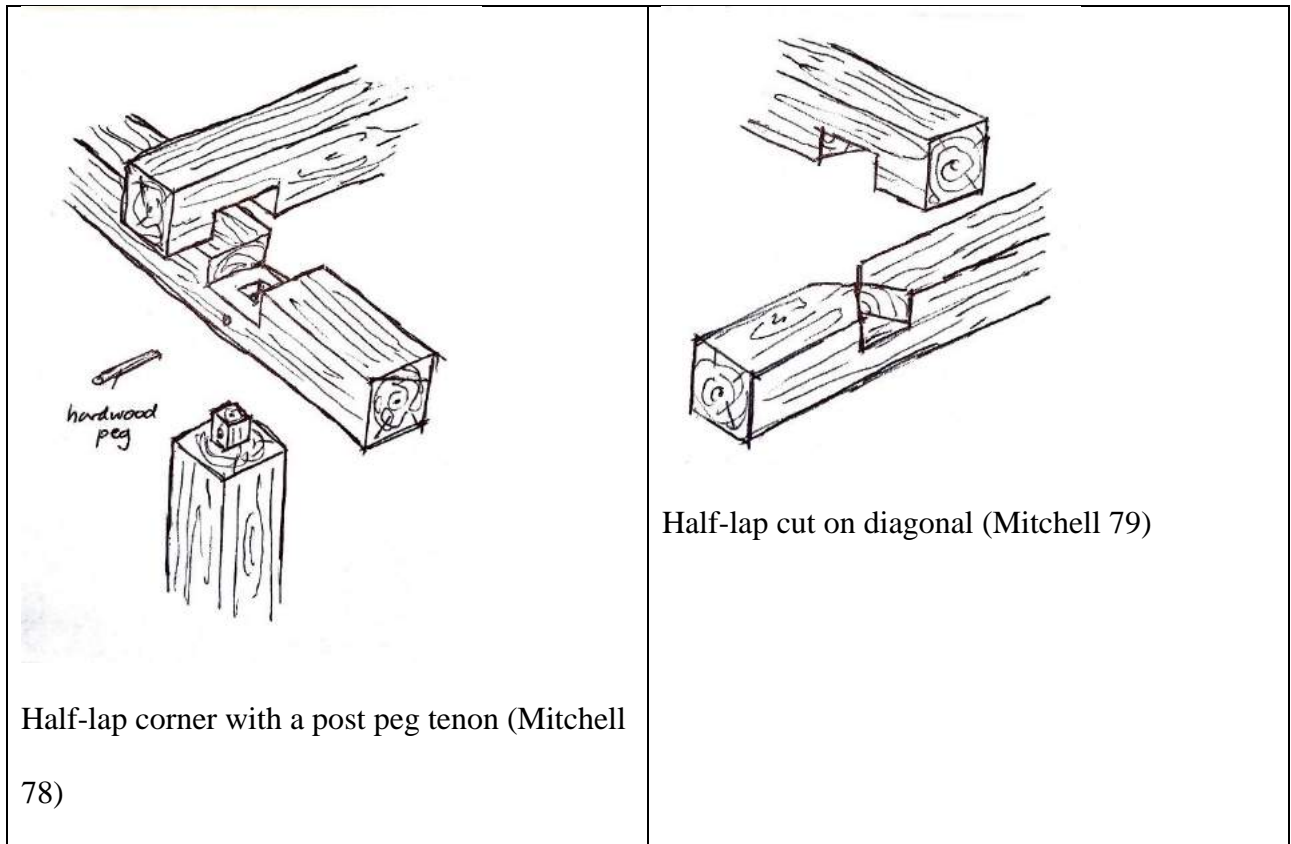


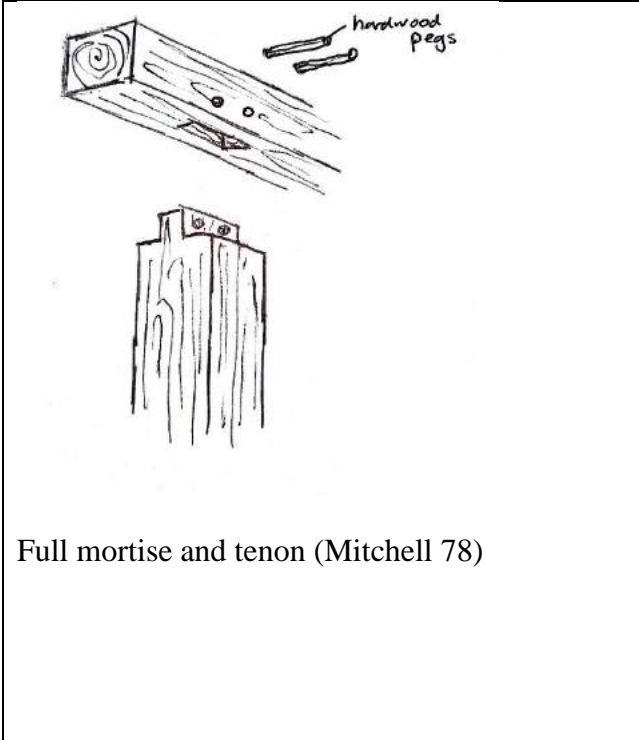
Figure 3.9. IIT McCormick Tribune Campus Center Interior (Behance 2013).

The photograph above showcases the expressive nature of the large material palette. Repetitive design components in the McCormick Tribune Campus Center are only used when necessary. The playful composition of this building allow the repetitive nature of design elements to be broken, which doesn't work against the workflow of the construction team. The whimsical nature of this design create a larger margin of error, where discrepancies between the design and construction of the building are not noticeable.

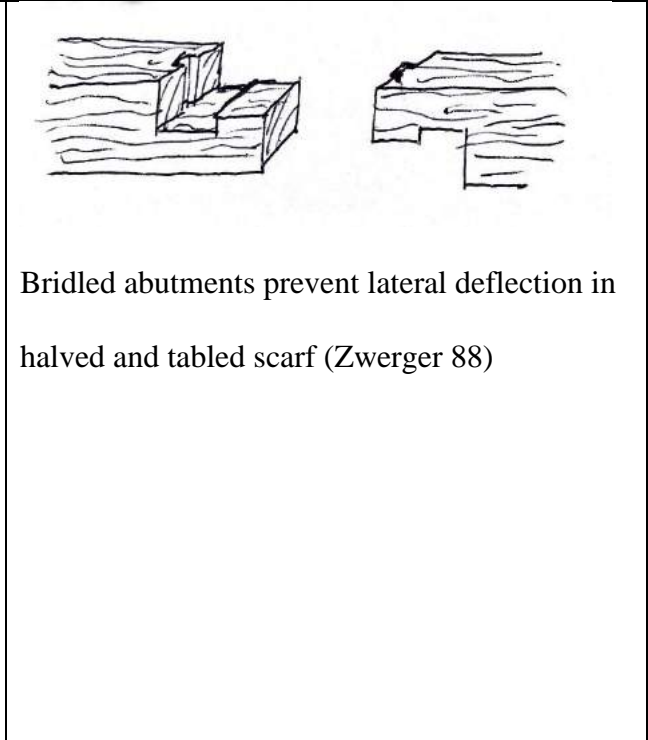
3.2.2.2. Construction Methods

3.2.2.2.1. Common Modular Post and Beam Construction Methods

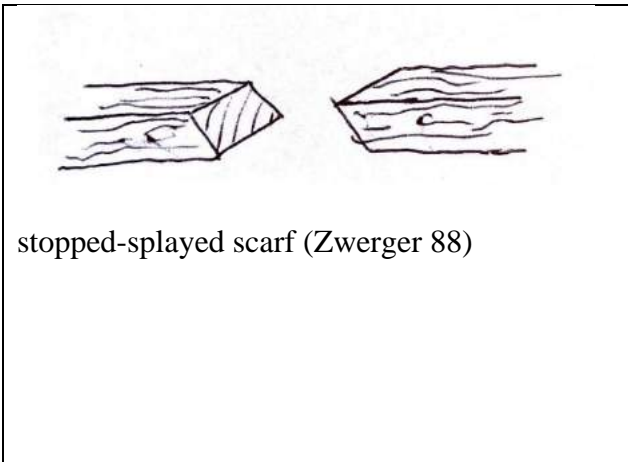




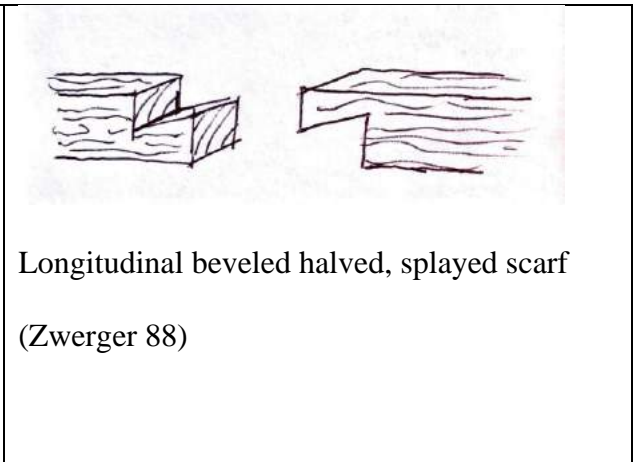
Full mortise and tenon (Mitchell 78)



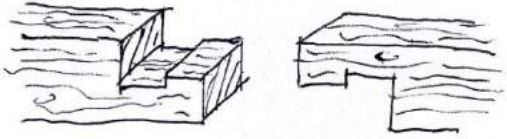
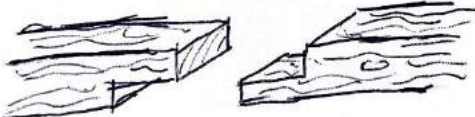
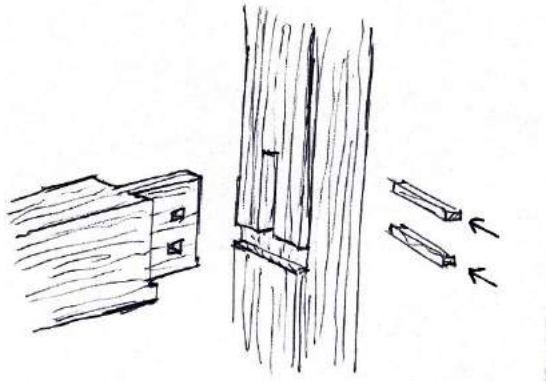
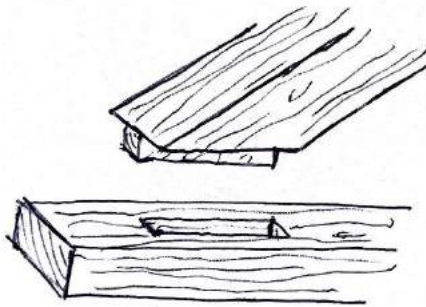
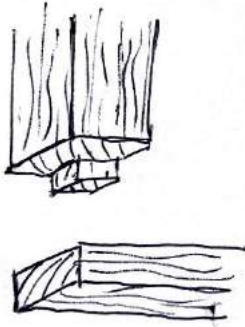
Bridled abutments prevent lateral deflection in halved and tabled scarf (Zwerger 88)

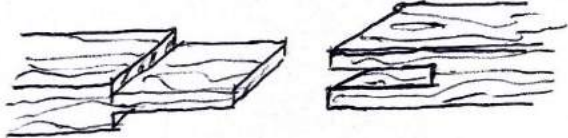
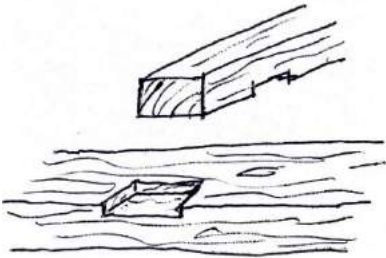
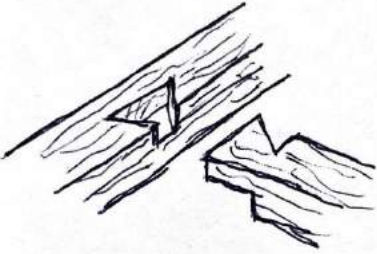


stopped-splayed scarf (Zwerger 88)

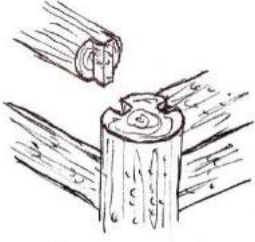
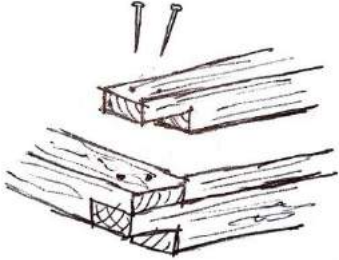


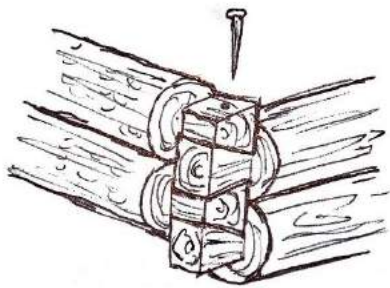
Longitudinal beveled halved, splayed scarf (Zwerger 88)

 <p>Halved and tabled scarf (Zwerger 88)</p>	 <p>Edged halved scarf (Zwerger 88)</p>
 <p>Oblique tenon joint (Zwerger 103)</p>	 <p>Tenon hole (Zwerger 89)</p>
 <p>Beveled corner (Zwerger 89)</p>	

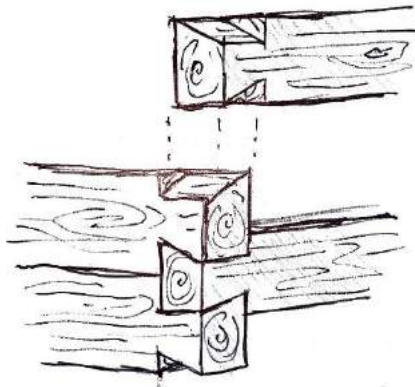
 <p>Tenon placed in an open mortise (Zwerger 88)</p>	 <p>A notched joint as a special variation of a halved joint that is not recessed as deeply (Zwerger 88)</p>
 <p>The end of collar beam lap-joined into a housing recess in the spar (Zwerger 88)</p>	

3.2.2.2.2. American Log Home Construction Methods

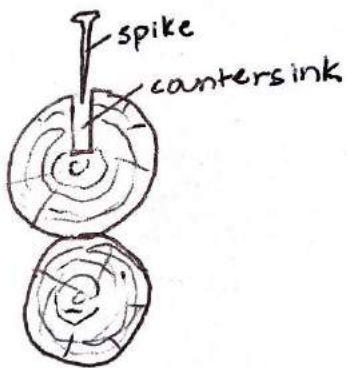
 <p>Tenon end with corner post (Hard 62)</p>	 <p>Half-lap (Hard 62)</p>
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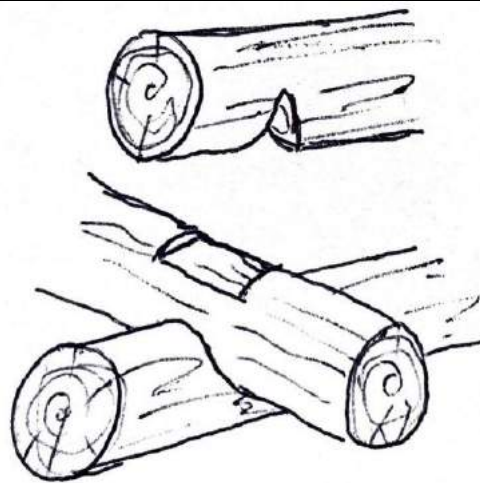
Common dovetail (Hard 62)



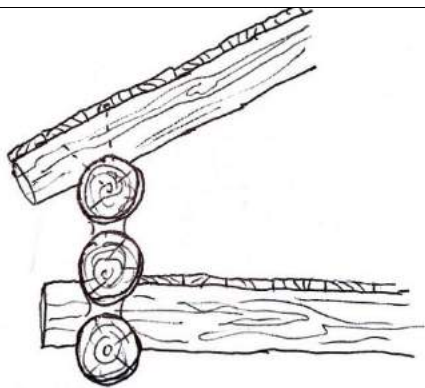
Compound dovetail joint (Hard 63)



Round log construction (Hard 53)

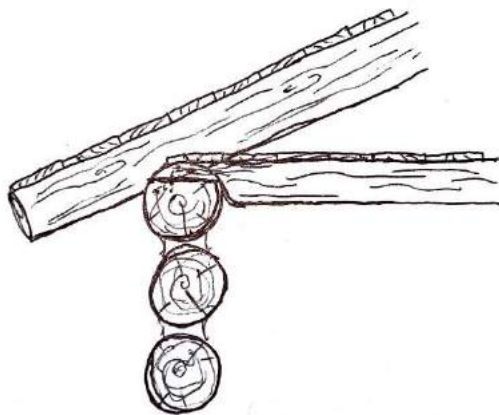


A-and-V joint (Hunt 29)



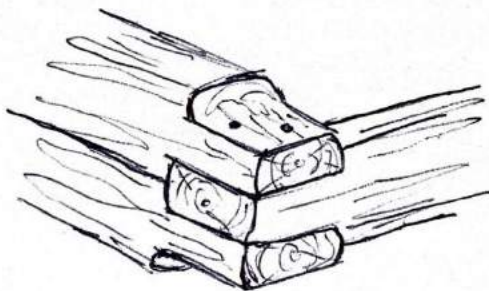
Construction of ceiling for second floor

(Hunt 40)

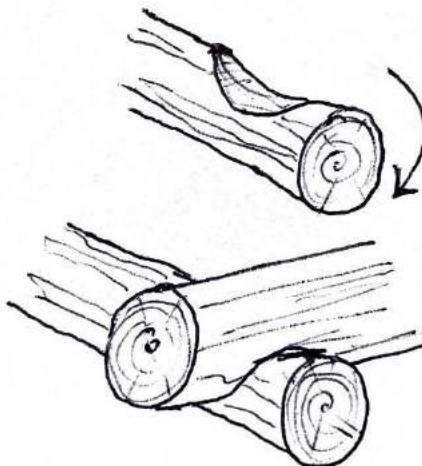


Construction of ceiling for no second floor

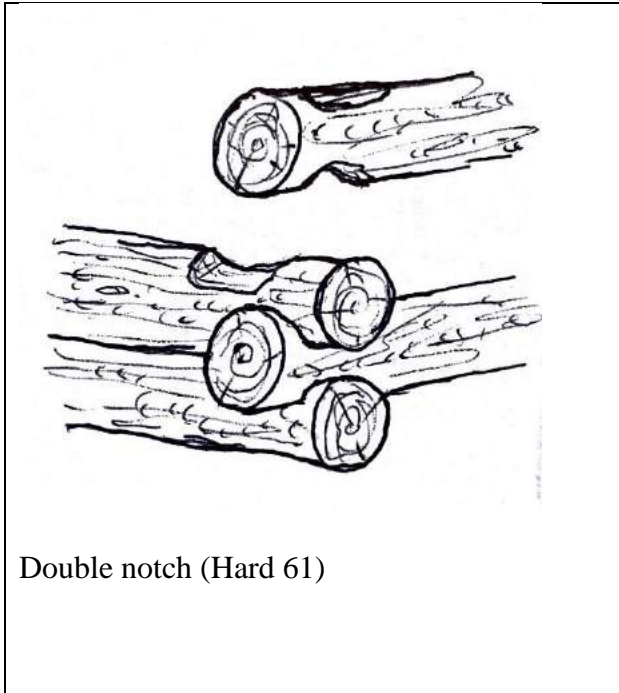
(Hunt 40)



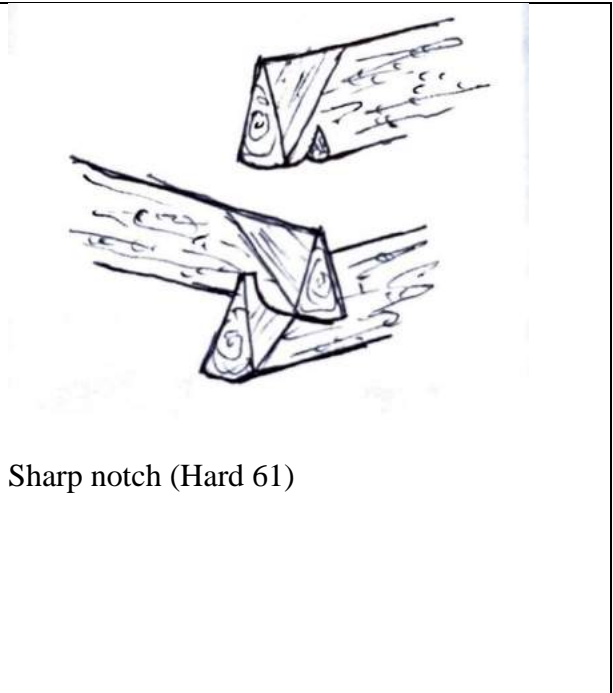
Dovetail joint (Hunt 32)



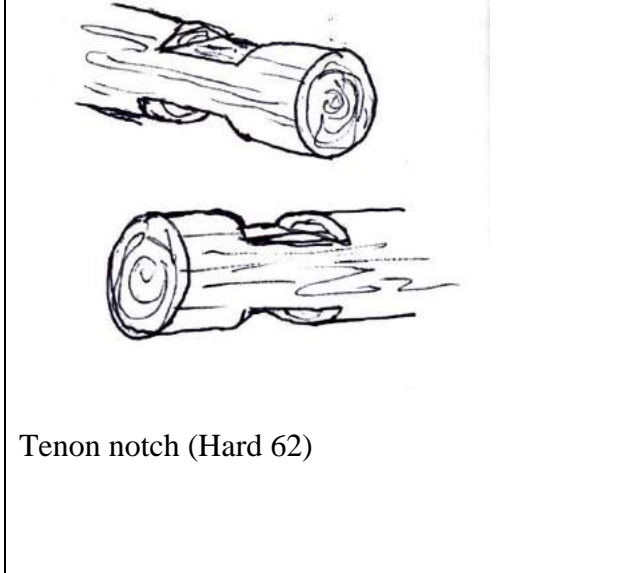
Common joint (Hunt 29)



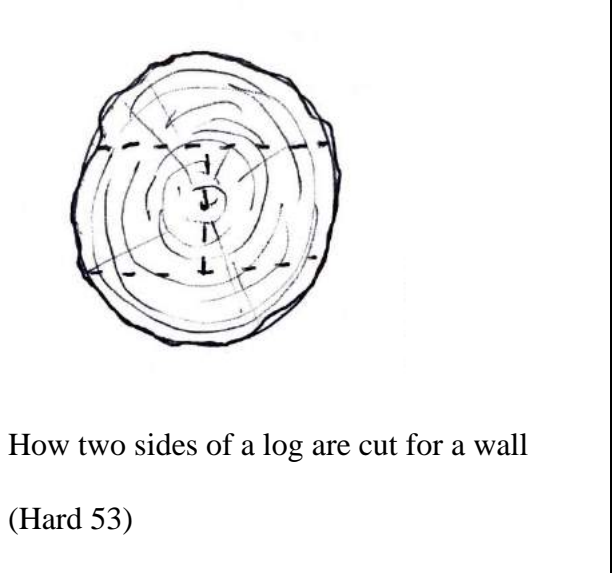
Double notch (Hard 61)



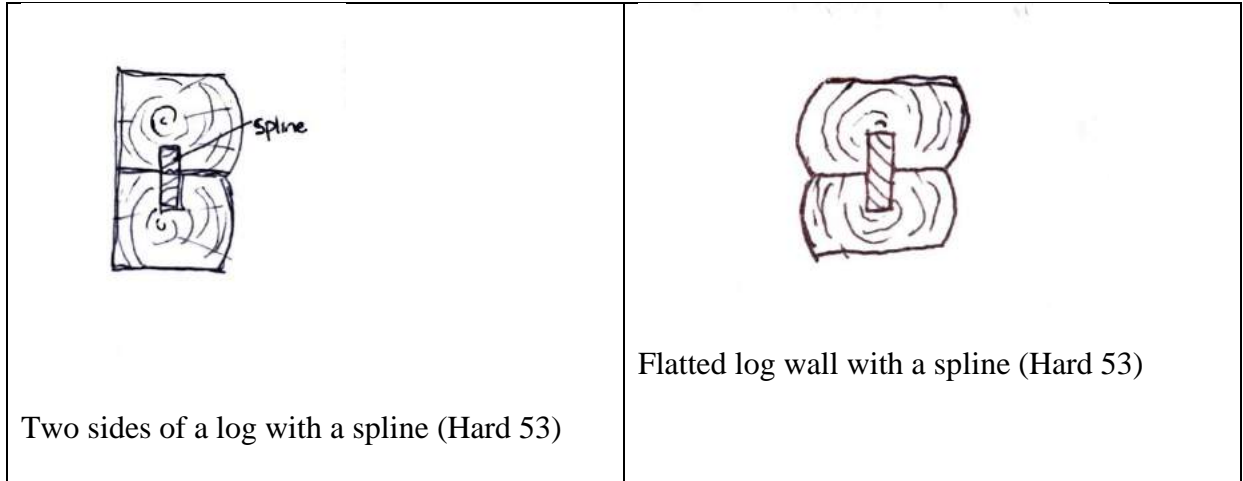
Sharp notch (Hard 61)



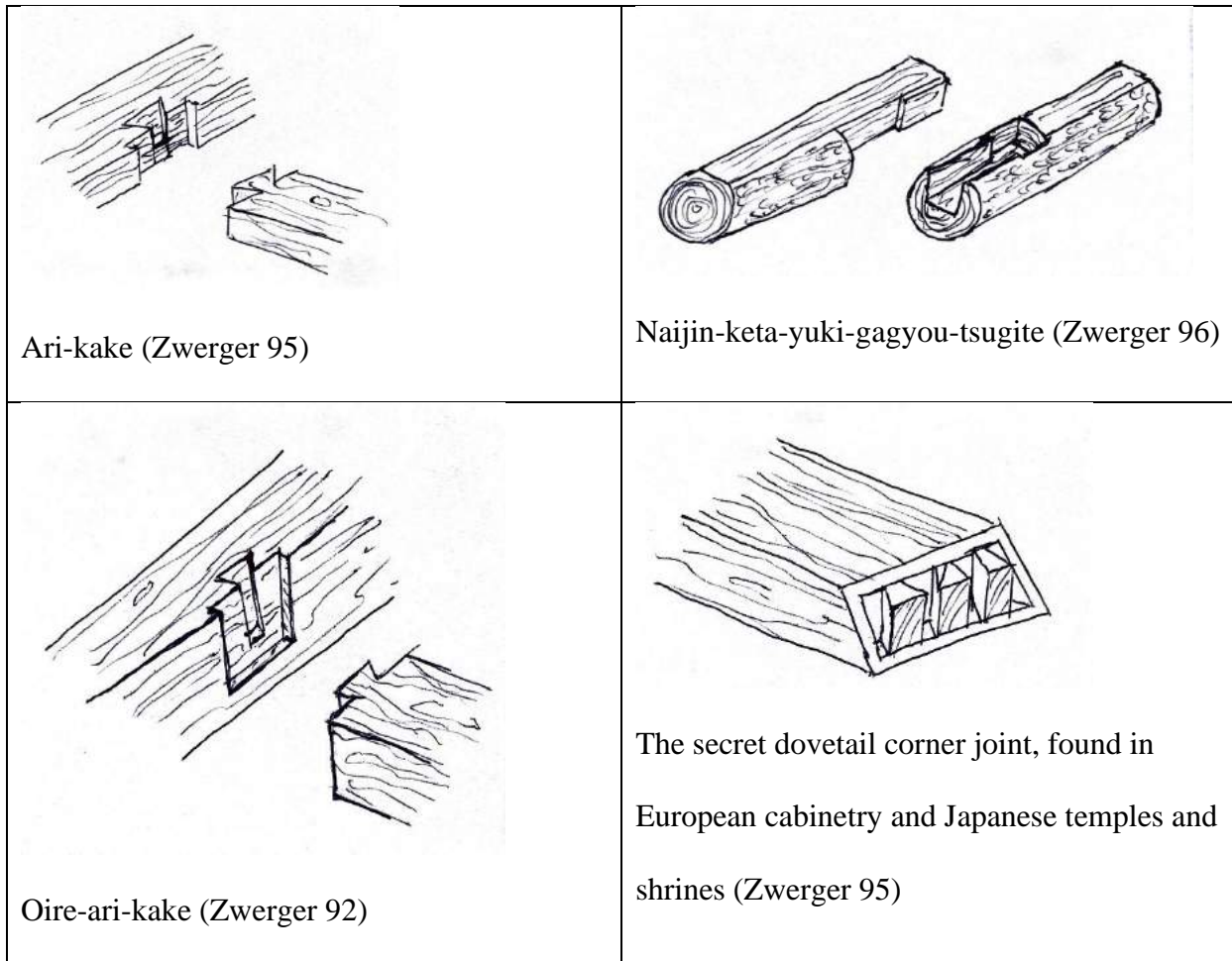
Tenon notch (Hard 62)

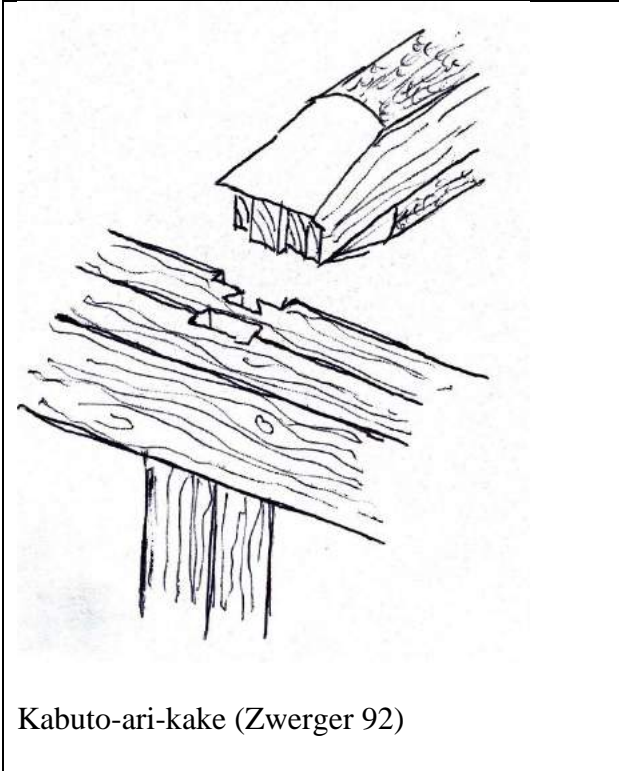


How two sides of a log are cut for a wall (Hard 53)

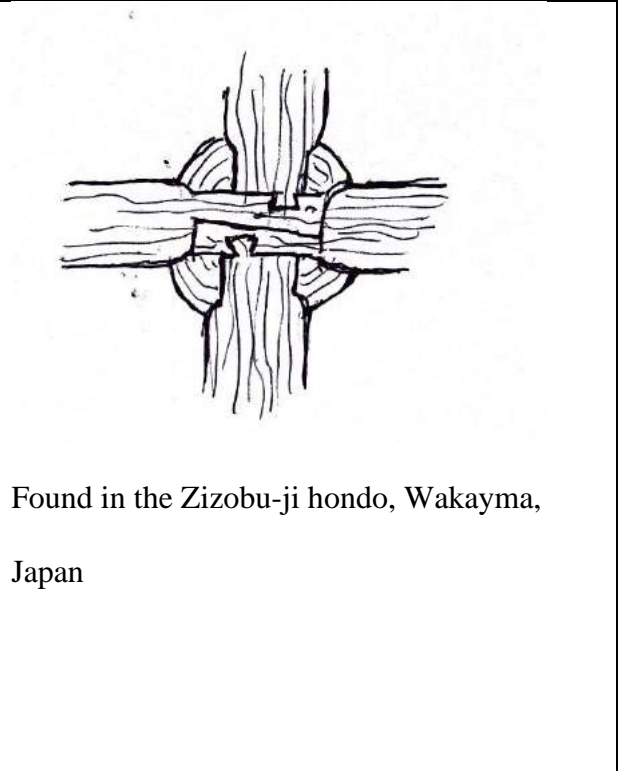


3.2.2.2.3. Japanese Construction Methods

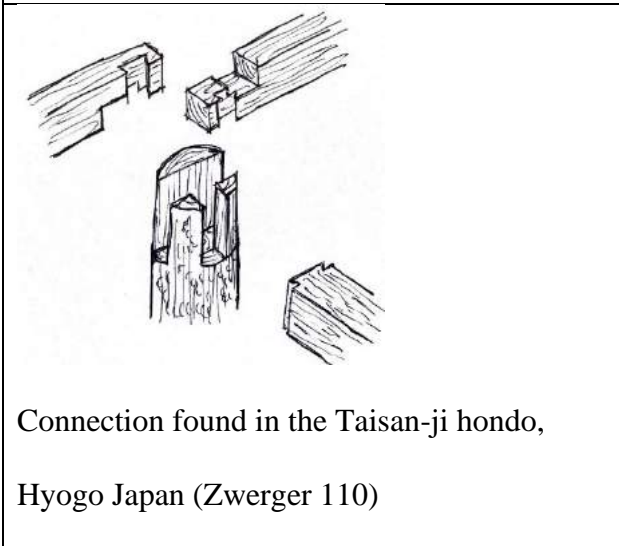




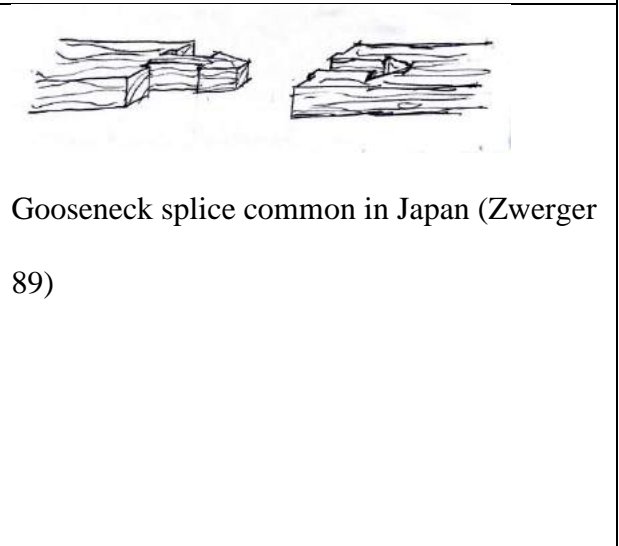
Kabuto-ari-kake (Zwerger 92)



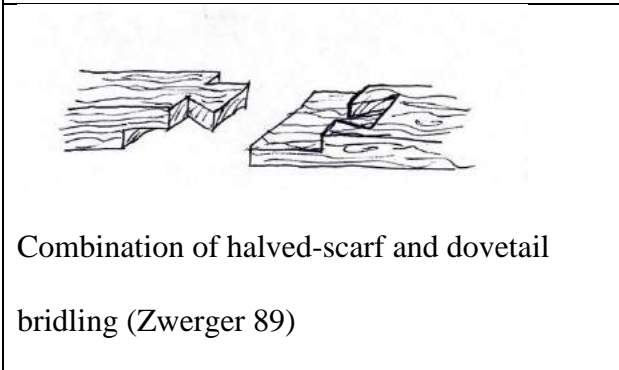
Found in the Zizobu-ji hondo, Wakayma,
Japan



Connection found in the Taisan-ji hondo,
Hyogo Japan (Zwerger 110)



Gooseneck splice common in Japan (Zwerger
89)



Combination of halved-scarf and dovetail
bridling (Zwerger 89)

3.2.2.3. Local Case Studies

3.2.2.3.1. Morgan Park

Morgan Park in Duluth MN was historically a company town for U.S. Steel. This town was built to make jobs at the steel plant convenient through the implementation of cost-effective housing.

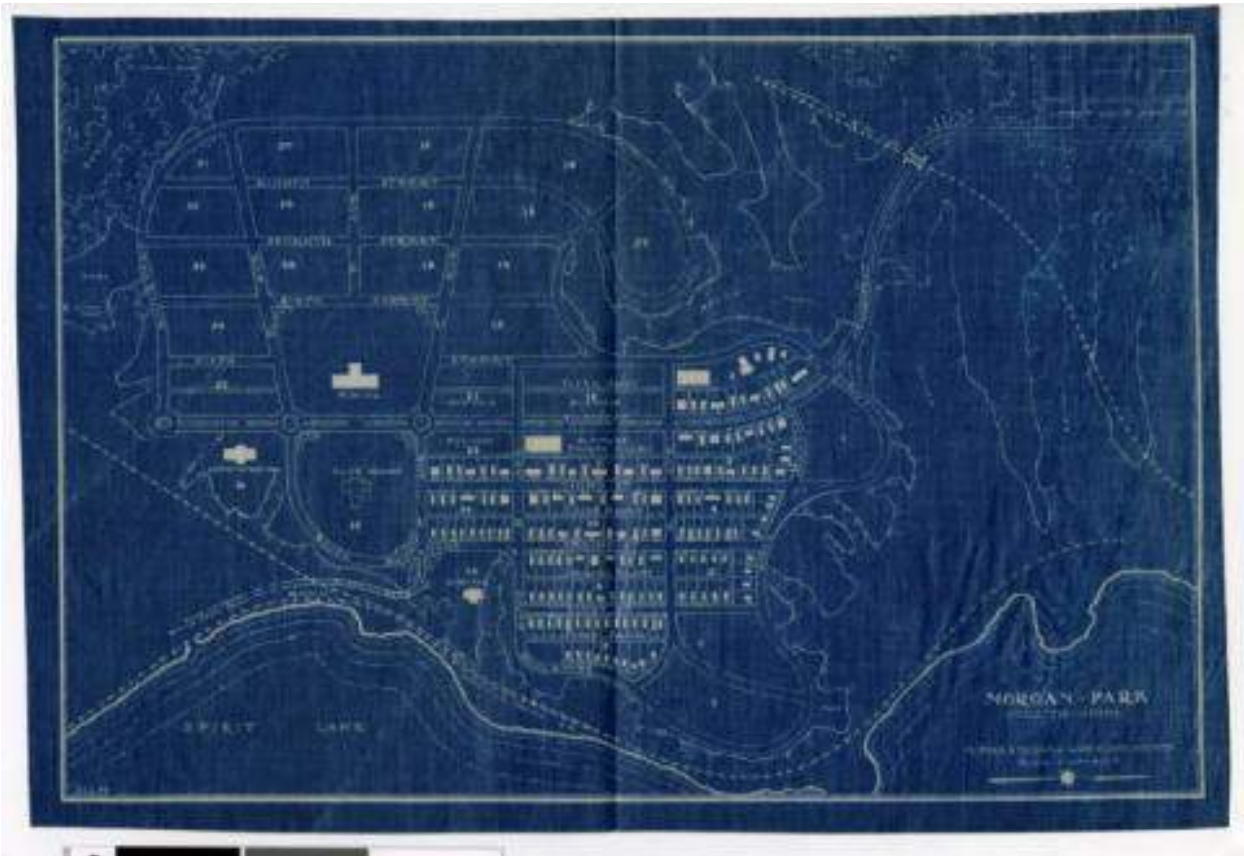
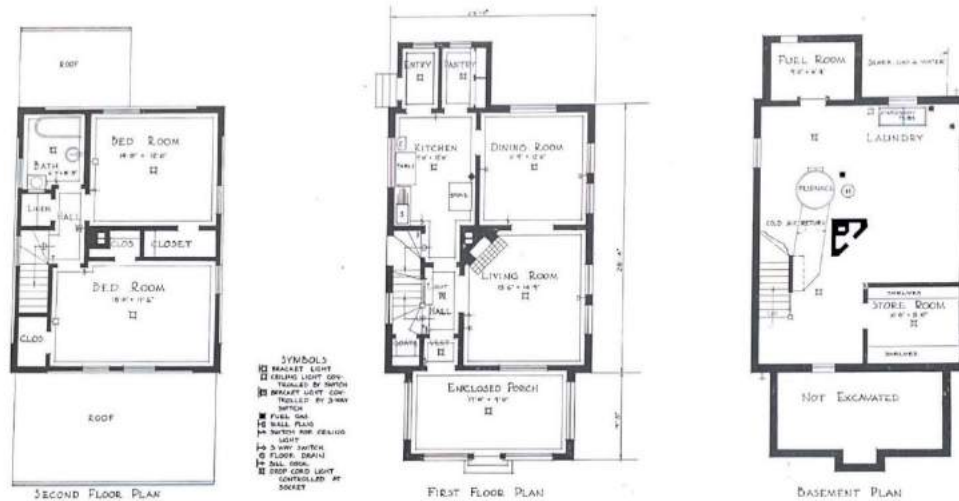


Figure 3.10. Proposed Plan of Morgan Park (Minnesota Digital Library).



Figure 3.11. Old Photograph of Morgan Park (Minnesota Digital Library).

The historic photograph above showcases a street of CMU residences in Morgan Park. Below are the plans from a publication on “Information regarding the forty-six new dwellings located on Blocks One and Six,” this historic publication is in courtesy of Bob Berg, a historian that currently lives in Morgan Park. Figure 3.7 shows the plans for the house pictured second from the left in figure 3.6.



PLANS FOR
 FIVE ROOM HOUSE
 MORGAN PARK CO. DULUTH MINN.
 DEAN & DEAN ARCHITECTS
 SCALE 1/8" = 1'-0" FEET
 15-F

DESCRIPTION OF TYPE 15-F

Type 15-F are five-room houses.

FIRST FLOOR. Full enclosed porch. Small reception hall, or stair hall with a coat closet off the stairs. Large open arches connect hall and living room, and living room and dining room. A fireplace in the living room. Door from kitchen into the dining room; large pantry adjoining kitchen, and rear porch with space for a refrigerator.

SECOND FLOOR. Two large bedrooms, a linen closet in hall, and a bath room. Each bedroom has a large closet.

Figure 3.12. House Type 15-F Plans for Morgan Park (Courtesy of Bob Berg).

According to Author Arnold R. Alanen “the mass production of concrete blocks in North America began in 1900, the year that Harmon Palmer received a patent for a cast-iron machine for fabricating the blocks. Prior to this time masonry blocks were touted as a building material that might allow everyone to live in a masonry residence.” Alanen went on to explain that the concrete blocks were formed on site in Morgan Park with a hand-operated machine marketed by the Hydro-Stone Company based in Chicago. According to Alanen “Hydro-Stone blocks were T-shaped, which meant that they could be used to construct either ‘one-piece’ or ‘two-piece’ walls. When used in a one-piece wall, the single projecting interior ‘lug’ on each block acted like a concrete stud, to which furring and lath could be attached, followed by the application of fiber plaster” (Alanen 88).



Figure 3.13. Original CMUs for a Morgan Park Residence (Courtesy of Bob Berg).

3.2.2.3.2. Steve O'Neil Apartments in Duluth MN



Figure 3.14. Steve O'Neil Apartments in Duluth MN (Affordable Housing Online 2023).

According to Affordable Housing Online, “The Steve O’Neil Apartments are 44 one, two and three bedroom apartments for homeless families with children. Supportive services are provided for families. Features include: secured building, furnished apartments, 24 Hour Front Desk Staff, laundry facilities, community room with kitchen.” The funding of this project was made possible by different funding programs for low income housing. According to Affordable Housing Online, this project has received funding from the Low-Income Housing Tax Credit, the HOME Investment Partnerships Program, and a Section 8 Project-Based Voucher. Affordable Housing Online explained these projects in more detail, “Since this property has received funding in part through the Low Income Housing Tax Credit (LIHTC) program, a certain number of units are set aside for lower income households. Households must earn either less than

50% or 60% of the area median income (depending on the set-aside option chosen by the property owner) to qualify for these units. Rents in these units are capped at a maximum of 30% of the set-aside area median income (adjusted for unit size). Some rental units in this property may not be subject to LIHTC and therefore have higher rents and no maximum household income requirement.” Affordable Housing Online also explained the HOME Investment Partnership Program, “This project has received some funding from a participating jurisdiction (local or state government agency) through the HUD HOME Investments Partnerships Program (HOME). In projects with five or more HOME-assisted units, at least 20% of these units must be occupied by families earning 50% or less of area median income (AMI). All other HOME-assisted units must be occupied by families earning 80% or less of AMI, but in practice most are reserved for families earning 60% or less AMI. Maximum monthly rent is capped with a Low HOME Rent for <50% AMI units and a High HOME Rent for the remaining HOME-assisted units. Contact the property directly for the specific dollar amount of these rent caps.”

3.2.2.4. Voyageur Log Homes and Log Construction Methods

Voyageur Log Homes is a manufacturer and construction company that builds log homes throughout the Midwest region of the United States; this includes many projects in northern Minnesota and up the north shore. At VLH, trees run through a mill to be cut into the pieces needed for a construction project. VLH can work with existing home plans or can develop custom plans fitting a client’s needs. After the pieces are cut, VLH can build the project with a crew that specializes in log construction.

When logs are first brought into the VLH mill, they are checked for quality. According to Shawn Halvorson, who operates VLH, logs are checked for large cracks, warps, or large blemishes on the sides of the trees. Checking the quality of the wood determines how the wood is

used. Certain logs work for walls and structural components, while others are used for smaller wood members and interior finishes. For logs that are used structurally, the most important indicator of use is the heartwood in the center.



Figure 3.15. Logs After Harvesting.

The heartwood at the center of each tree can be seen in the photograph below. Shawn Halverson explained that to reduce shrinkage in the logs after construction, the logs are milled

down to the heartwood. Halverson explained that using the whole log for building walls had less embodied energy but took more time from a construction standpoint because they would have to wait about a year to resume construction. This is because the sapwood part of the log will shrink about an inch during that time (S. Halverson, Personal Communication 2023).



Figure 3.16. Logs Organized For Use.

After the logs are sorted, they are cut and dried. To only extract the heartwood before the drying process, the logs are milled to large square-cut members.



Figure 3.17. Square-cut Heartwood Logs.

After the logs dry, they are milled to 8” or 10” rounded logs based on the size of the extracted heartwood or milled to square-cut logs for construction based on the project.



Figure 3.18. Round-cut Heartwood Logs.

After the logs are cut to the desired size, they are cut to interlock at corners and with each other for a waterproof seal. Every log is numbered and organized depending on the project. According to Halverson, the streamlined milling process saves a lot of time on site, and the preparedness

before construction is what allows him to bid competitively even for projects that are 100 miles away. The logs leave the mill with 1-3 cranes and are assembled on site (S. Halvorson, Personal Communication 2023).



Figure 3.19. Inside Log Cabin Looking Outside.

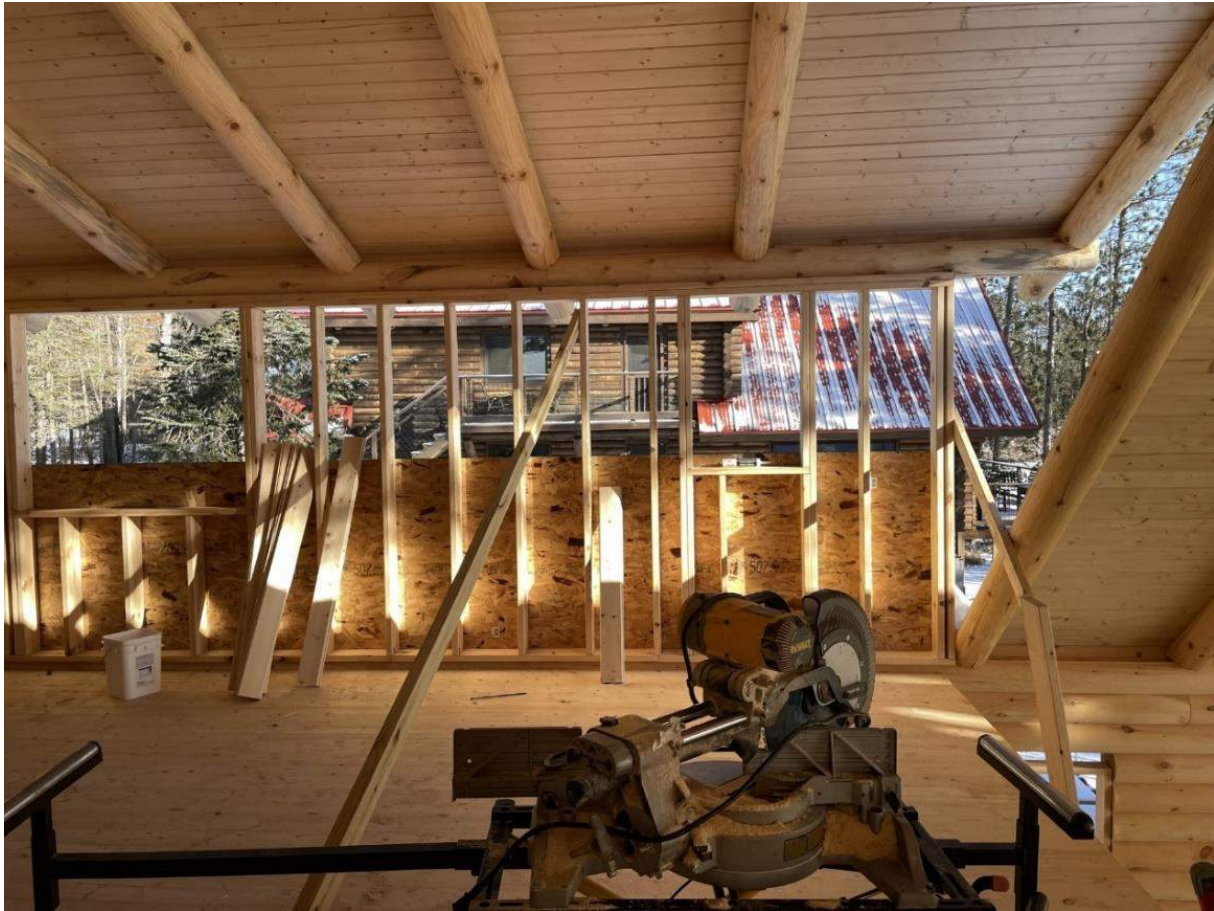


Figure 3.20. Shed Dormer Inside Log Cabin.



Figure 3.21. Full Loft Inside Cabin



Figure 3.22. Loft Inside Log Cabin



Figure 3.23. Outside of log Cabin.

4. PROPOSAL

4.1.1. Proposed Solution

The proposed solution consists of three parts, intended to complete the cycle of a healthy housing market. The first part is the design of a modular heavy timber system that can be used to build entry level housing within a variety of site constraints. This system is explored in its application to housing for construction workers. The second part is the design of two high-end custom homes with a material palette restrained to the primary use of timber, and the economy of modular structural components. The third part is the reconfiguration of rental properties, intended to grow property value for the investor without the need to raise rent. These three parts complete the cycle, from entry level rentals to entry level houses, to high-end real estate.

4.1.1.1. *Housing for Construction Workers*

This project explores modular heavy timber construction to create a variety of entry level homes for construction workers. The shortage of entry level housing in the Duluth area can push out individuals hoping to enter the workforce. This system allows entry level buyers to build a cost-effective home that can be added to or embellished over time to grow its value. This can be done by replacing the simple material palette on the inside, reconfiguring the structure, or adding more modules to the structure.

4.1.1.1.1. *Site Analysis of Proposed Site: 34xx Trinity Rd, Duluth MN*

This site had a convenient location with high accessibility to the interstate for project delivery and highway 53 which leads to most logging sites. This five-acre site is on the market for \$179,900. The proposed entry level housing development is designed to fit within 30'

setbacks on the north and south sides of the site, in addition to 10' setbacks on the east and west sides. These setbacks are also imposed on each individual structure. The dwellings are configured to fit the topography and optimize views and sunlight.



Figure 4.1. Birdseye View 34xx Trinity Rd, Duluth MN (Trulia 2023).

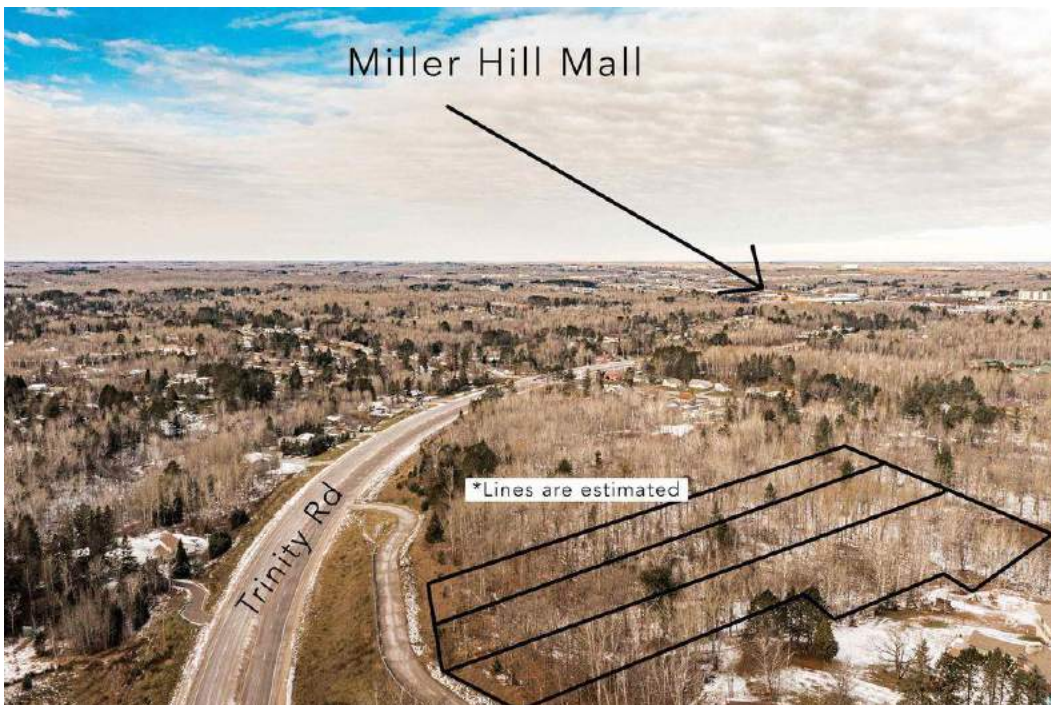


Figure 4.2. Birdseye View with Trinity Road (Trulia 2023).



Figure 4.3. Property Lines 34xx Trinity Rd, Duluth MN (Trulia 2023).

4.1.1.1.2. Proposed Site Plan

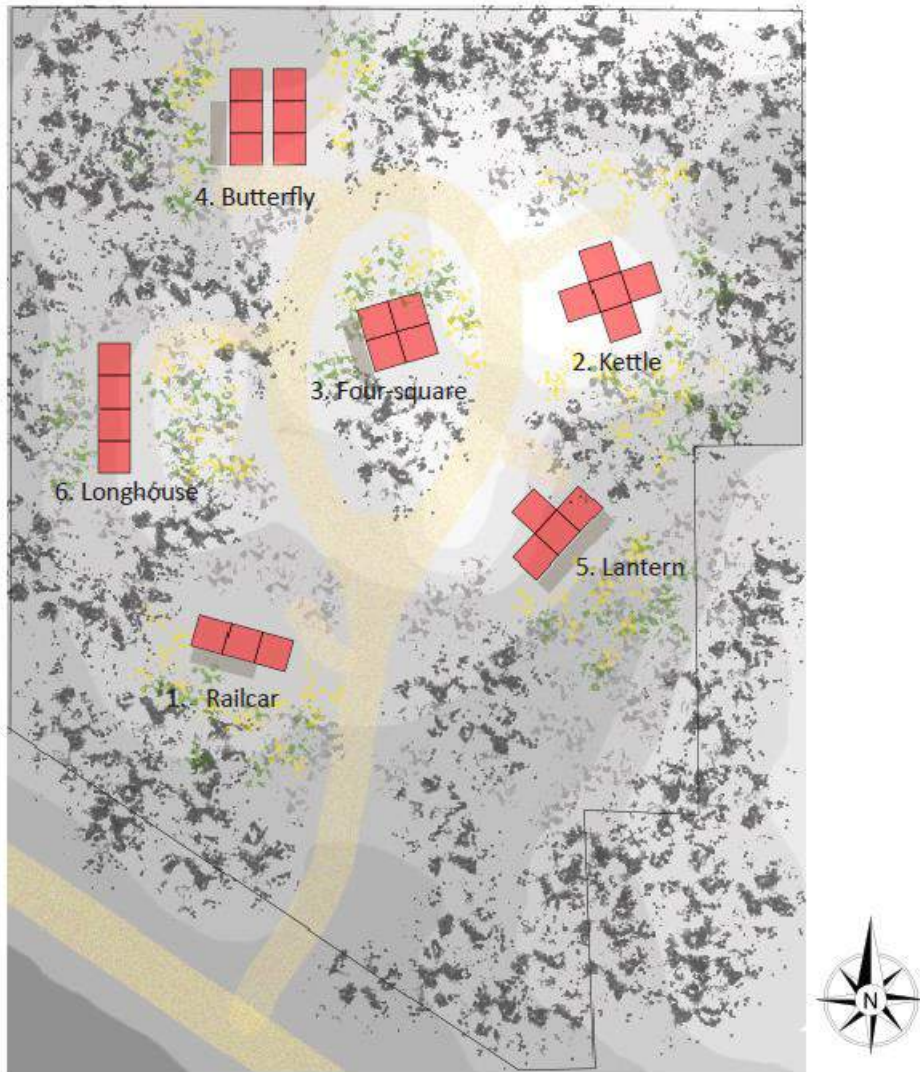


Figure 4.4. Site Plan for Modular Homes.

4.1.1.1.3. Modular System Design

- A. 5/8" sheathing and roof material
- B. Truss with 16" energy heels
- C. 8" x 8" square-cut log structure
- D. Wooden weather barrier and siding, interior wood finish
- E. Joist structure and wood flooring
- F. Insulated and customizable CMU foundation

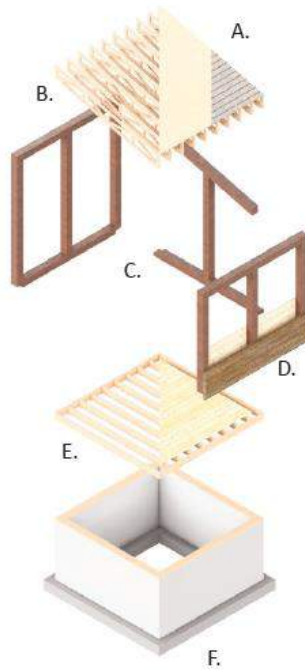


Figure 4.5. Module Construction.

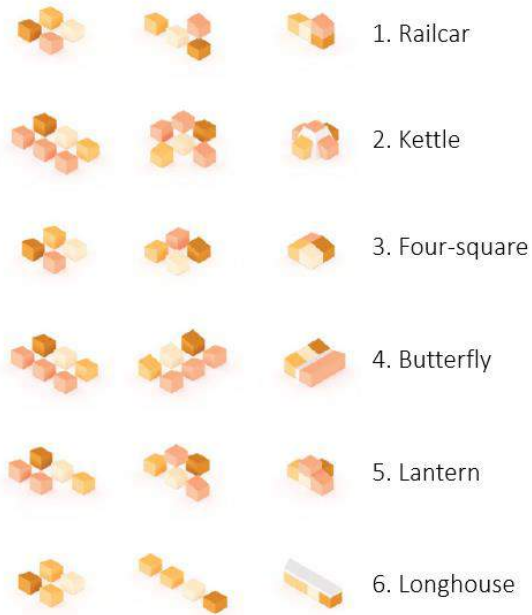


Figure 4.6. Modular Home Configurations.

- 1. Kitchen module
- 2. Entry or bedroom storage module
- 3. Laundry and bathroom sink module

- A. Lookouts extend over wall framing
- B. Customizable eave extension
- C. Customizable CMU foundation
- D. Joists and belt joists start at the same length
- E. Wooden weather barrier is attached to log structure

- a. Columns are attached with steel strapping
- b. Extensions are accomplished by rotating the joist configuration for support

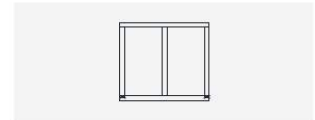
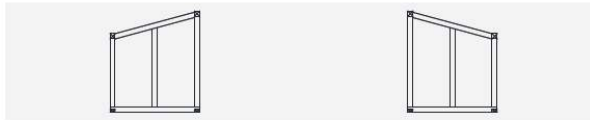
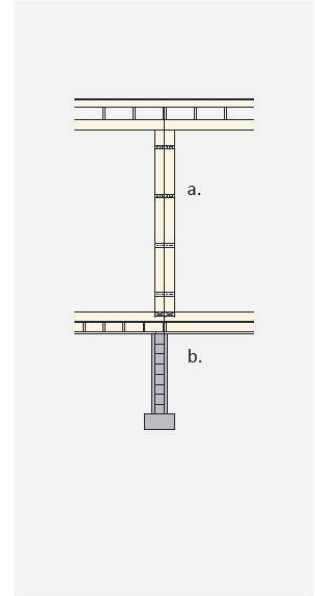
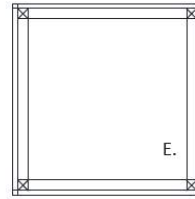
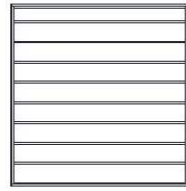
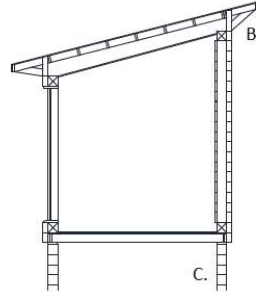
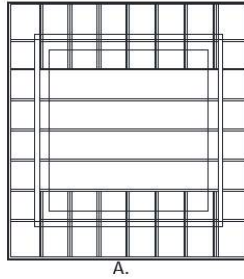
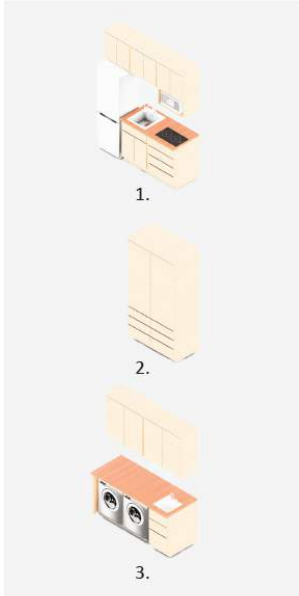


Figure 4.7. Modular Home Details.

4.1.1.1.4. Railcar



Figure 4.8. Railcar Exterior View.

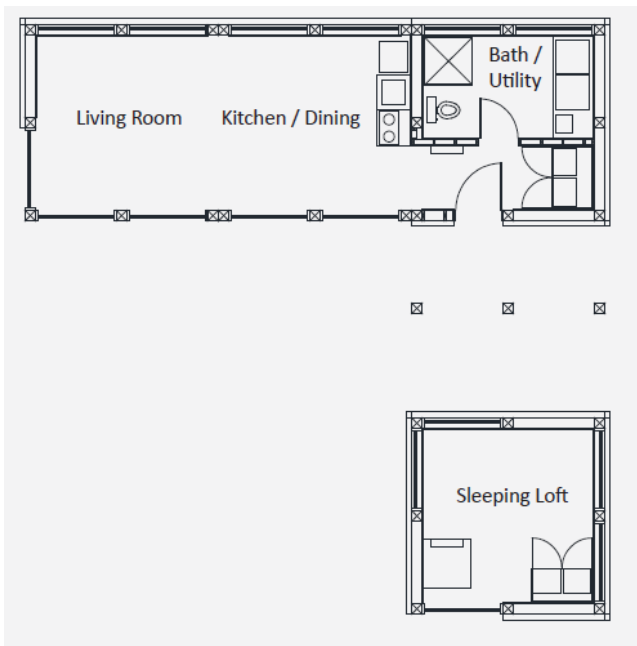


Figure 4.9. Railcar Floorplans.



Figure 4.10. Railcar Interior View.

4.1.1.1.5. Kettle



Figure 4.11. Kettle Exterior View.

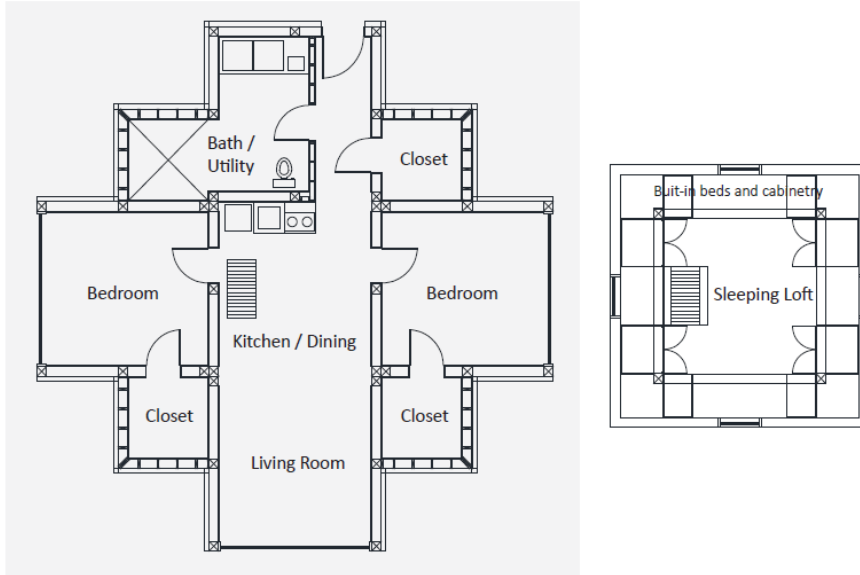


Figure 4.11. Kettle Floorplans.

Figure 4.12. Outside of log Cabin.



Figure 4.13. Kettle Interior View.

4.1.1.1.6. *Four-Square*



Figure 4.14. Four-Square Exterior View.

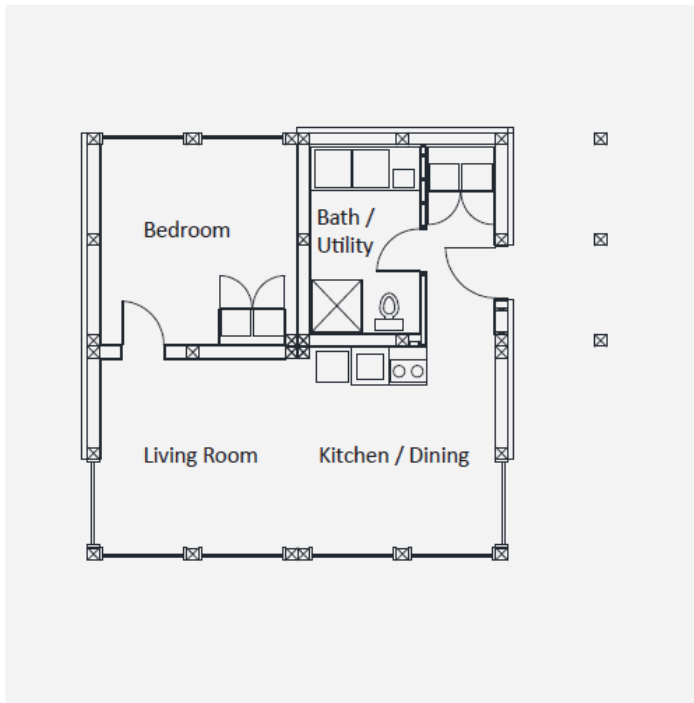


Figure 4.15. Four-Square Floorplan.



Figure 4.16. Four-Square Interior View.

4.1.1.1.7. Butterfly



Figure 4.16. Butterfly Exterior View.

Figure 4.17. Outside of log Cabin.

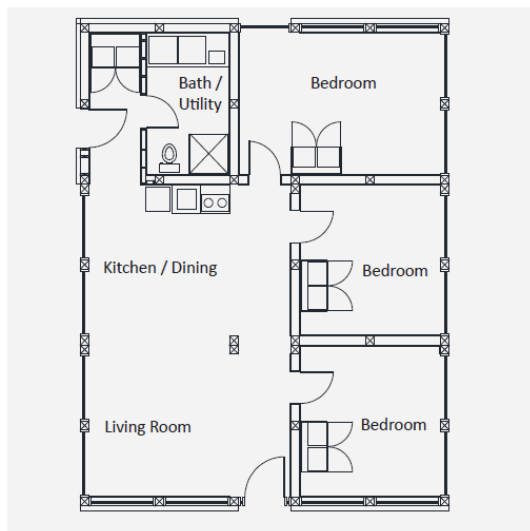


Figure 4.18. Butterfly Floorplan.



Figure 4.19. Butterfly Interior View.

4.1.1.1.8. *Lantern*



Figure 4.20. Lantern Exterior View.

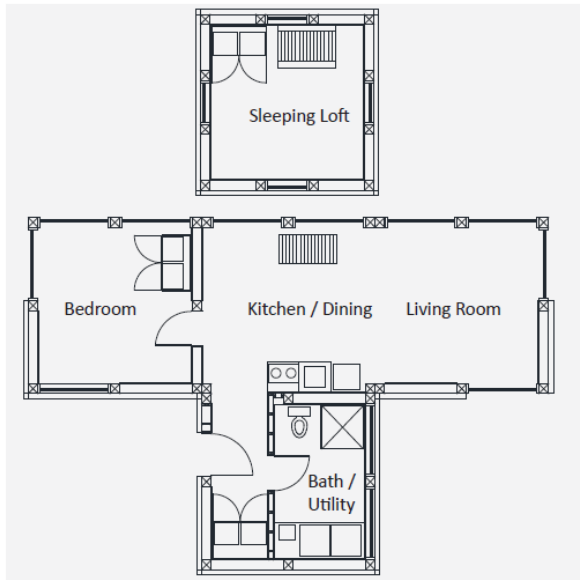


Figure 4.21. Lantern Floorplans.

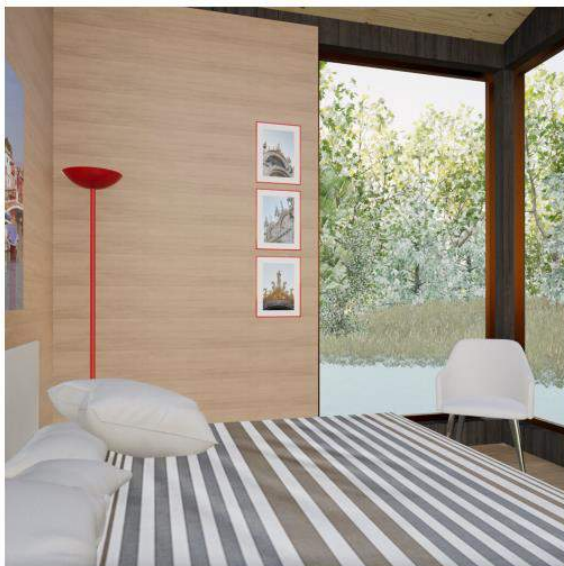


Figure 4.22. Lantern Interior View.

4.1.1.1.9. Longhouse



Figure 4.23. Longhouse Exterior View.

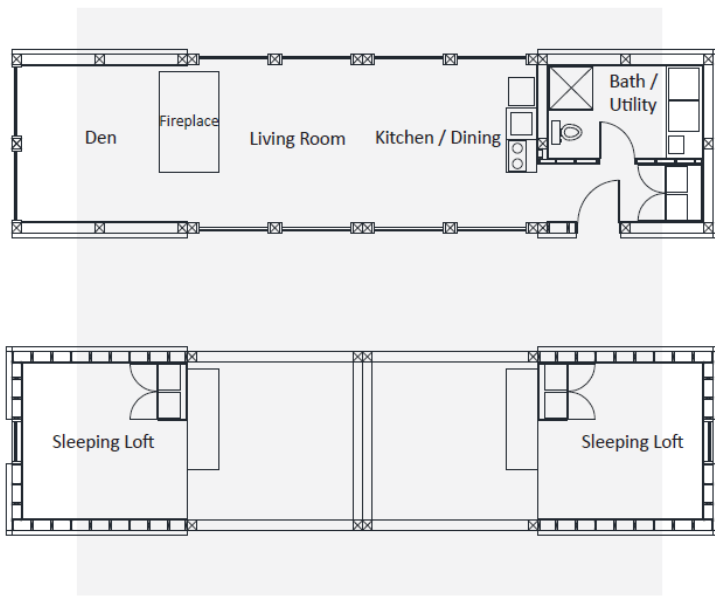


Figure 4.24. Longhouse Floorplans.



Figure 4.25. Longhouse Interior.

4.1.1.2. Custom Homes

The second part of this proposal explores material economy in high-end custom homes through the use of repetition and modular timber components. This is implemented in the design of two custom homes.

4.1.1.2.1. Site One: 15xx Minnesota Ave W, Duluth MN



Figure 4.26. Site Nuvole (Trulia 2023).

This site is located on the lake side of Park Point, which is oriented towards Duluth and the North Shore. The design of the design proposal for this site draws inspiration from the translation of rolling waves, to rolling grass, and rolling dunes of beach sand. This project explores the use of modular timber construction, and uses repetition not only for economy, but as a parti.



Figure 4.27. Park Point Beach.

4.1.1.2.2. Plans

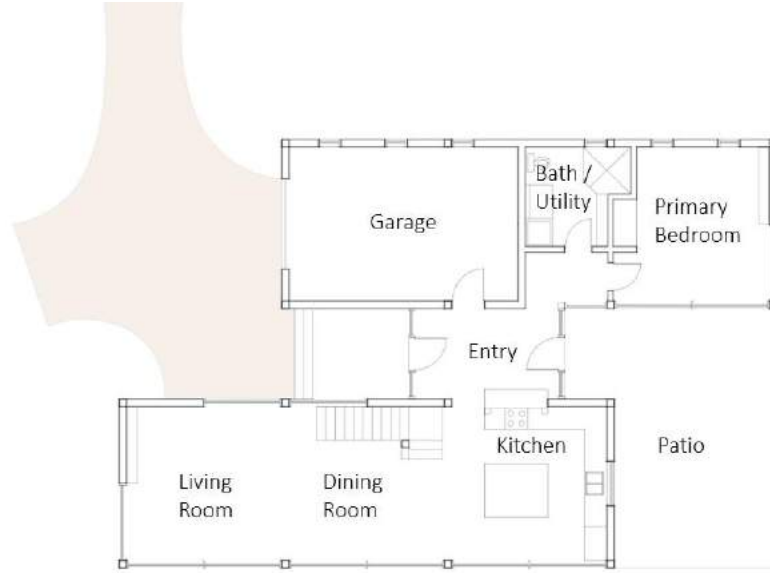


Figure 4.28. First Level Nuvole.

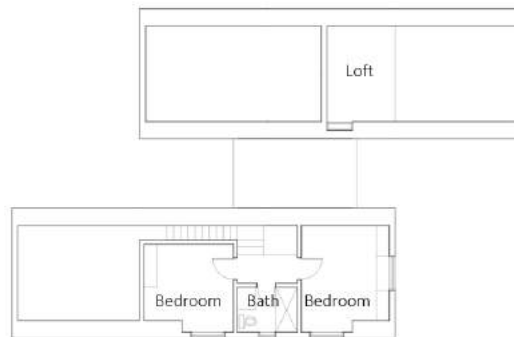


Figure 4.29. Second Level Nuvole.

4.1.1.2.3. Structure

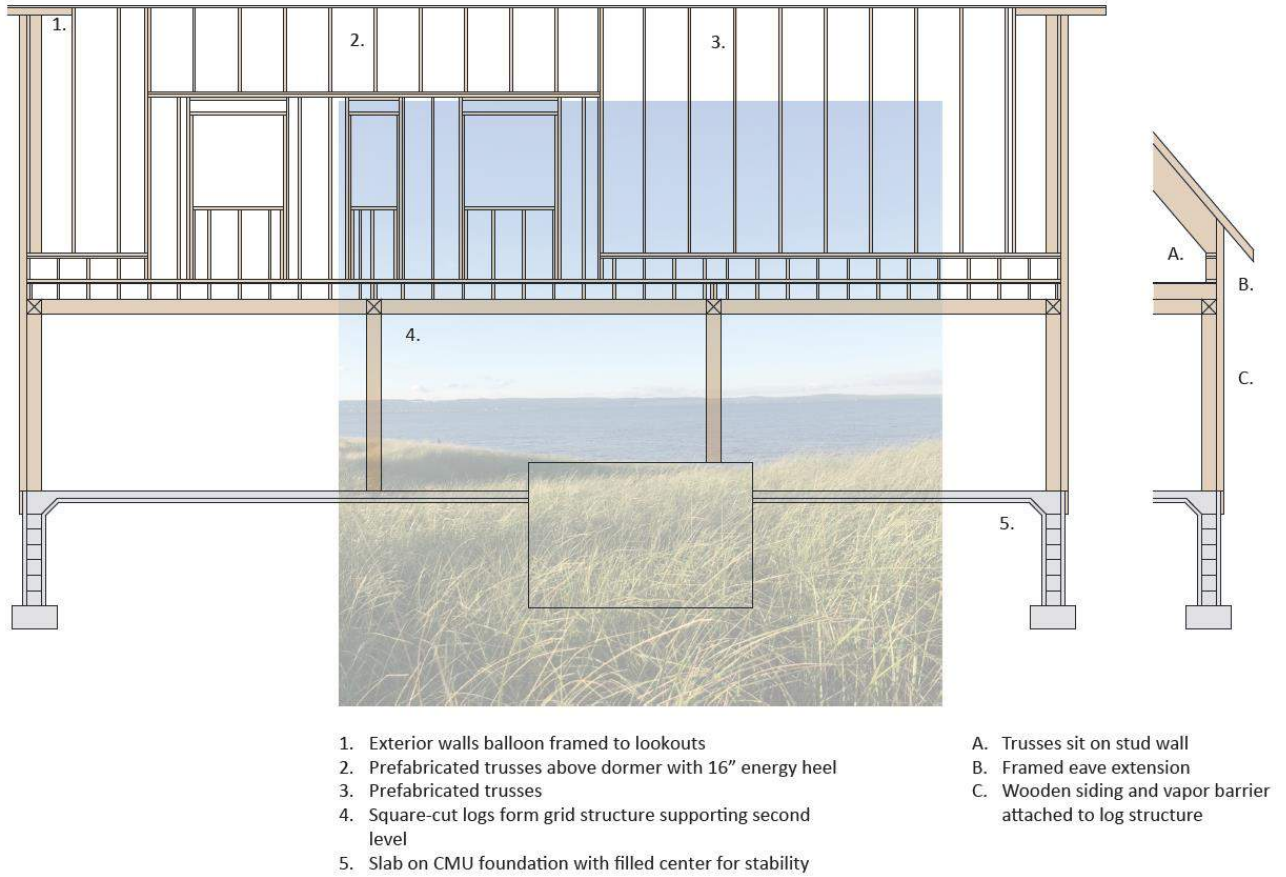


Figure 4.30. Structure Nuvole.

4.1.1.2.4. *Design*



Figure 3.31. Exterior View Nuvole.



Figure 4.31. Living Room and Shifting Stairway Nuvole.

4.1.1.2.5. Site Two: 11xx W 8th St, Duluth MN



Figure 3.32. Site Weird Machine (Trulia 2023).

This site is located near the top of Observation Hill in Duluth, where their vast views of the lake and city landscape. This project draws inspiration from the red radio tower lights that surround the site, floating in the sky like red stars, each blinking with a pulse of their own. This design response draws on the mystique and subtle nature of these lights in an industrial and natural design statement.

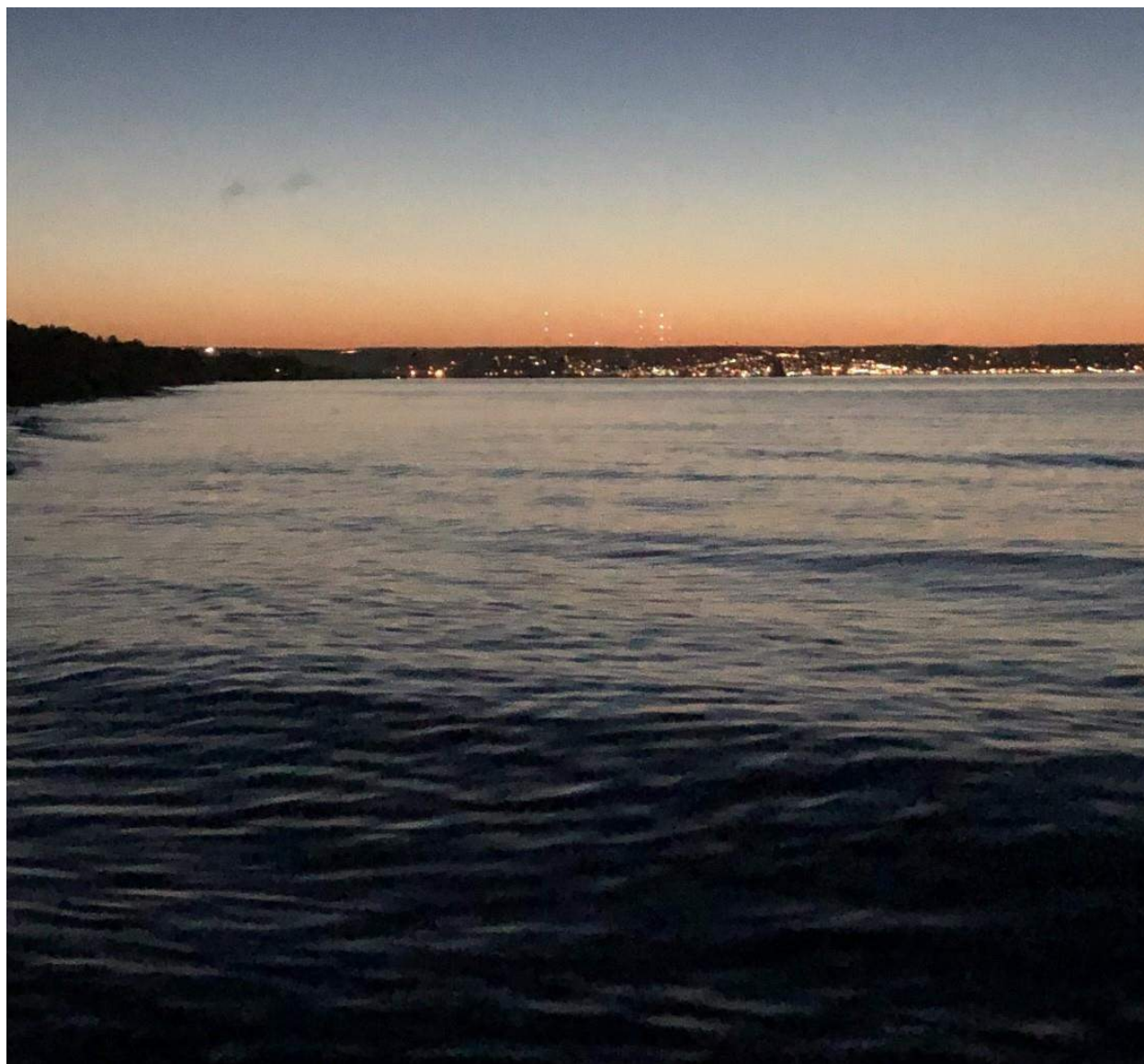


Figure 4.33. Radio Tower Lights Seen Over Duluth.

4.1.1.2.6. Plans

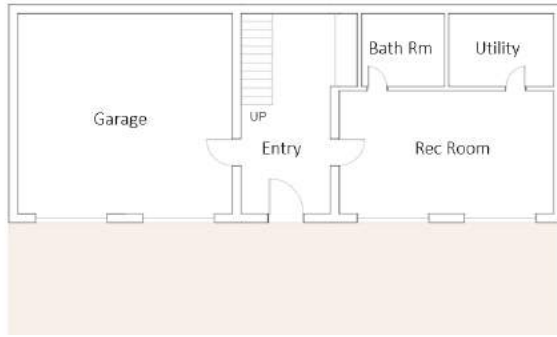


Figure 4.34. First Floor Weird Machine.

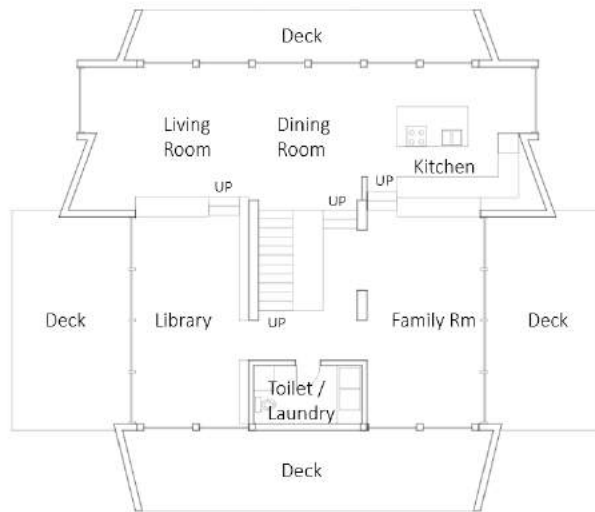


Figure 4.35. Second Floor Weird Machine.

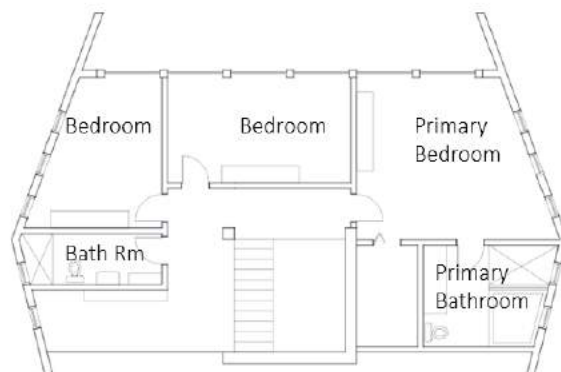


Figure 4.36. Third Floor Weird Machine.

4.1.1.2.7. Structure

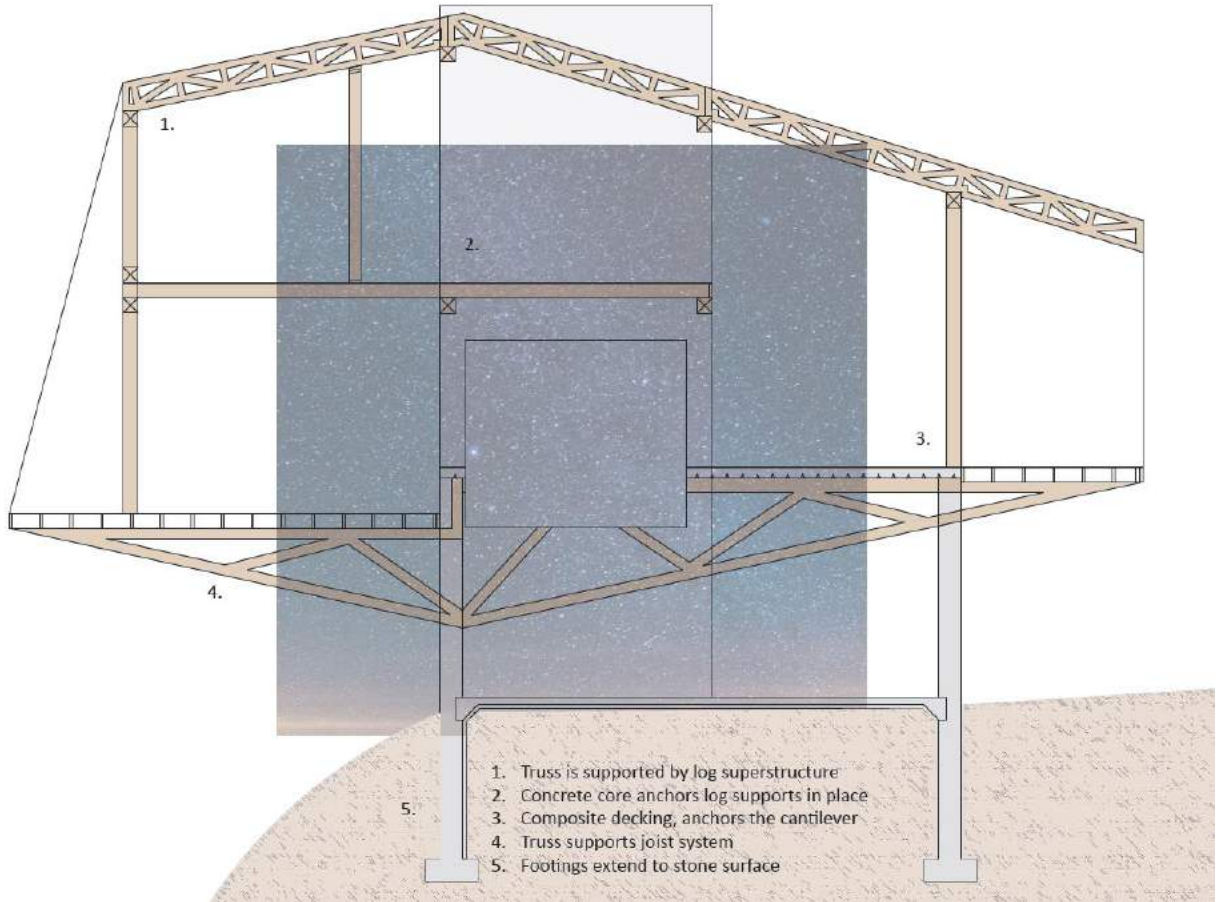


Figure 4.37. Structure Weird Machine.

4.1.1.2.8. *Design*



Figure 4.38. Exterior View Weird Machine.



Figure 4.39. Living Space Weird Machine.

4.1.1.3. Renovations

The third part of this proposal is the renovation of three buildings all in places that are still affordable areas around and inside Duluth. The intent of these design responses are to explore ways investors can increase the value of a property without compromising affordable rent. This is done by talking older investment properties and finding ways to add units to them.

4.1.1.3.1. Site One: 18 W 1st St, Duluth MN



Figure 4.40. Street View 18W 1st St, Duluth MN.

This site is located in Downtown Duluth, where retail and office space have lost significant value due to the growth of Canal Park and the Miller Hill area. This building is currently unused for investment purposes. This project seeks ways to transform the vacant retail and office space in this building to investments with less overhead. This is done with the addition of two apartment units, replacing office space, and cutting down the size of the retail space.

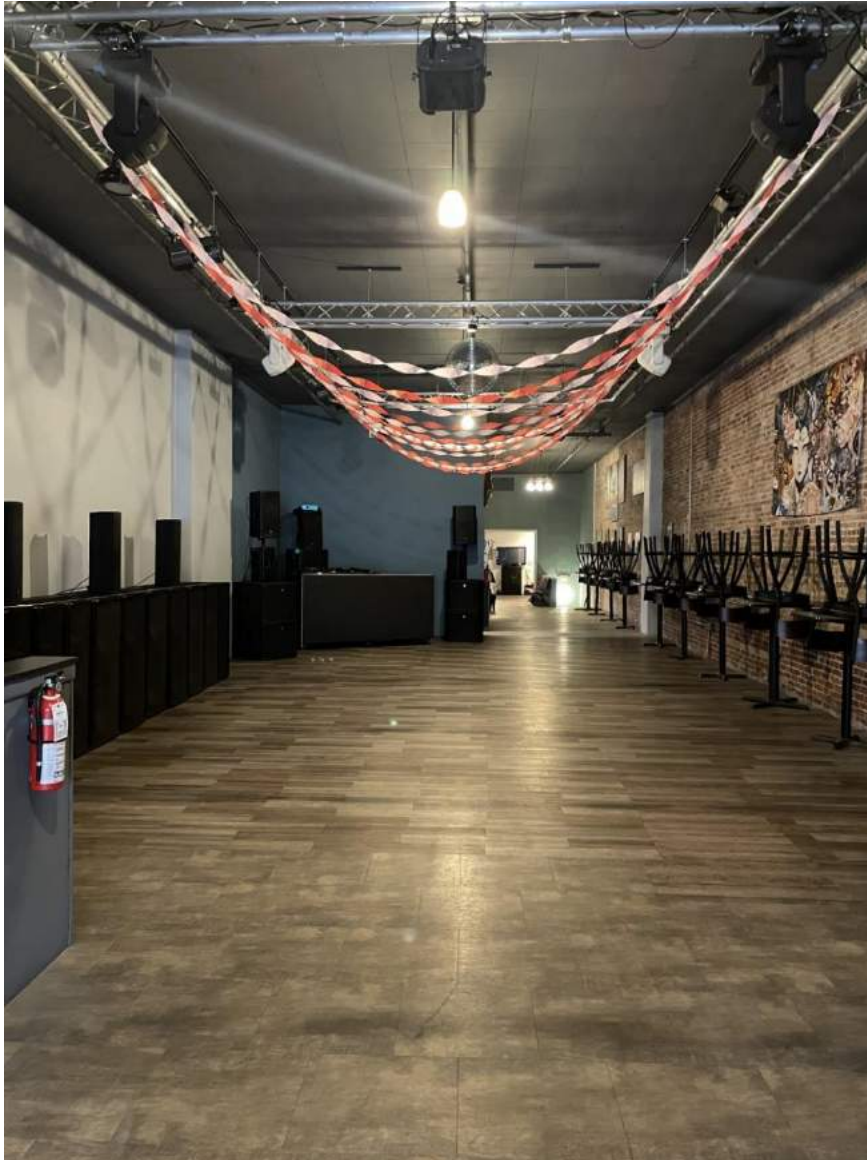


Figure 4.41. Retail Space 18W 1st St, Duluth MN.



Figure 4.42. Lower Level Office 18W 1st St, Duluth MN.



Figure 4.43. Lower Level Office 18W 1st St, Duluth MN.



Figure 4.44. Lower Level Old Safe 18W 1st St, Duluth MN.

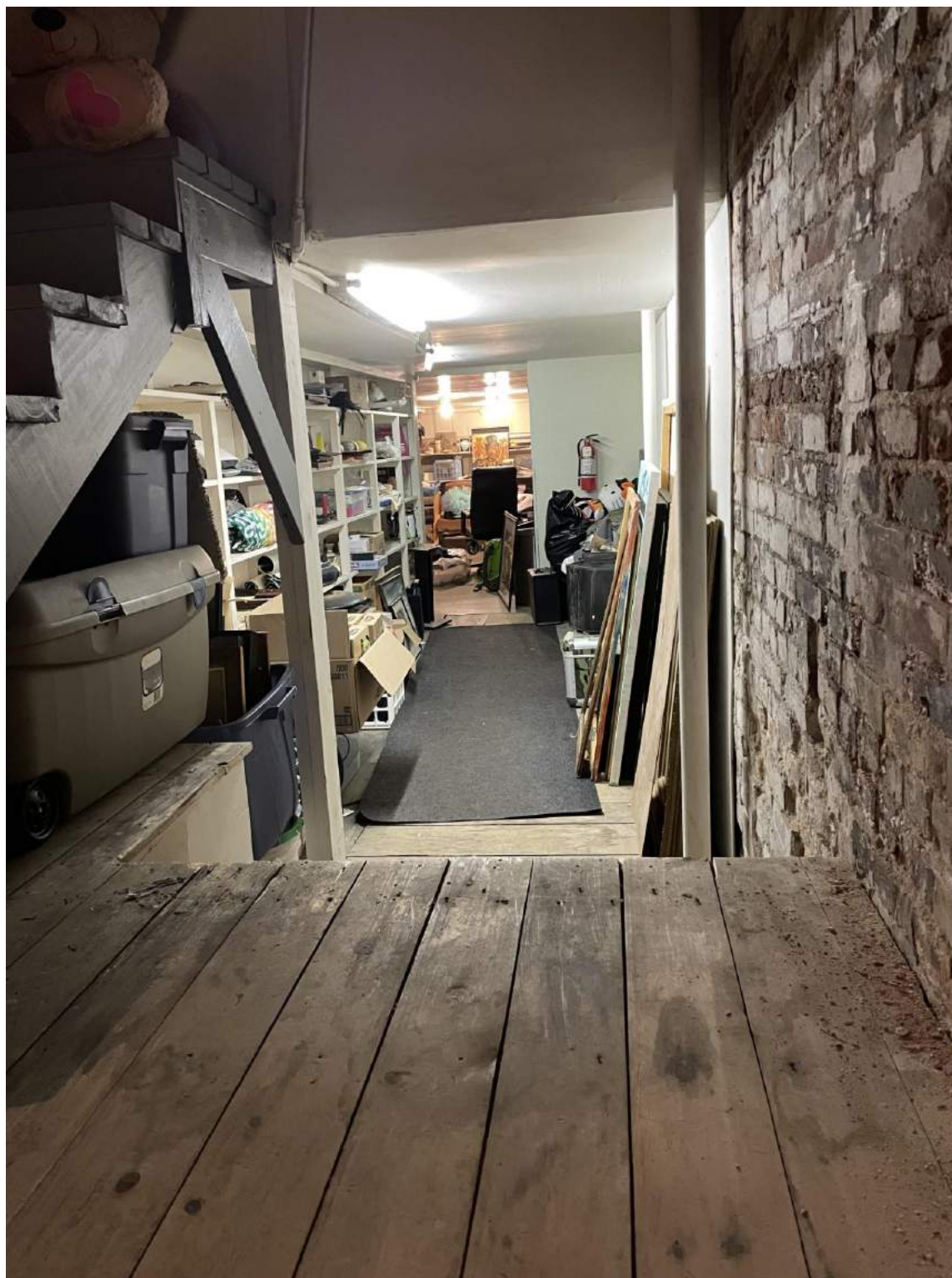


Figure 4.45. Upper Level Hallway and Storage 18W 1st St, Duluth MN.



Figure 4.46. Upper Level Storage Room 18W 1st St, Duluth MN.



Figure 4.47. Roof Access 18W 1st St, Duluth MN.

4.1.1.3.2. Context

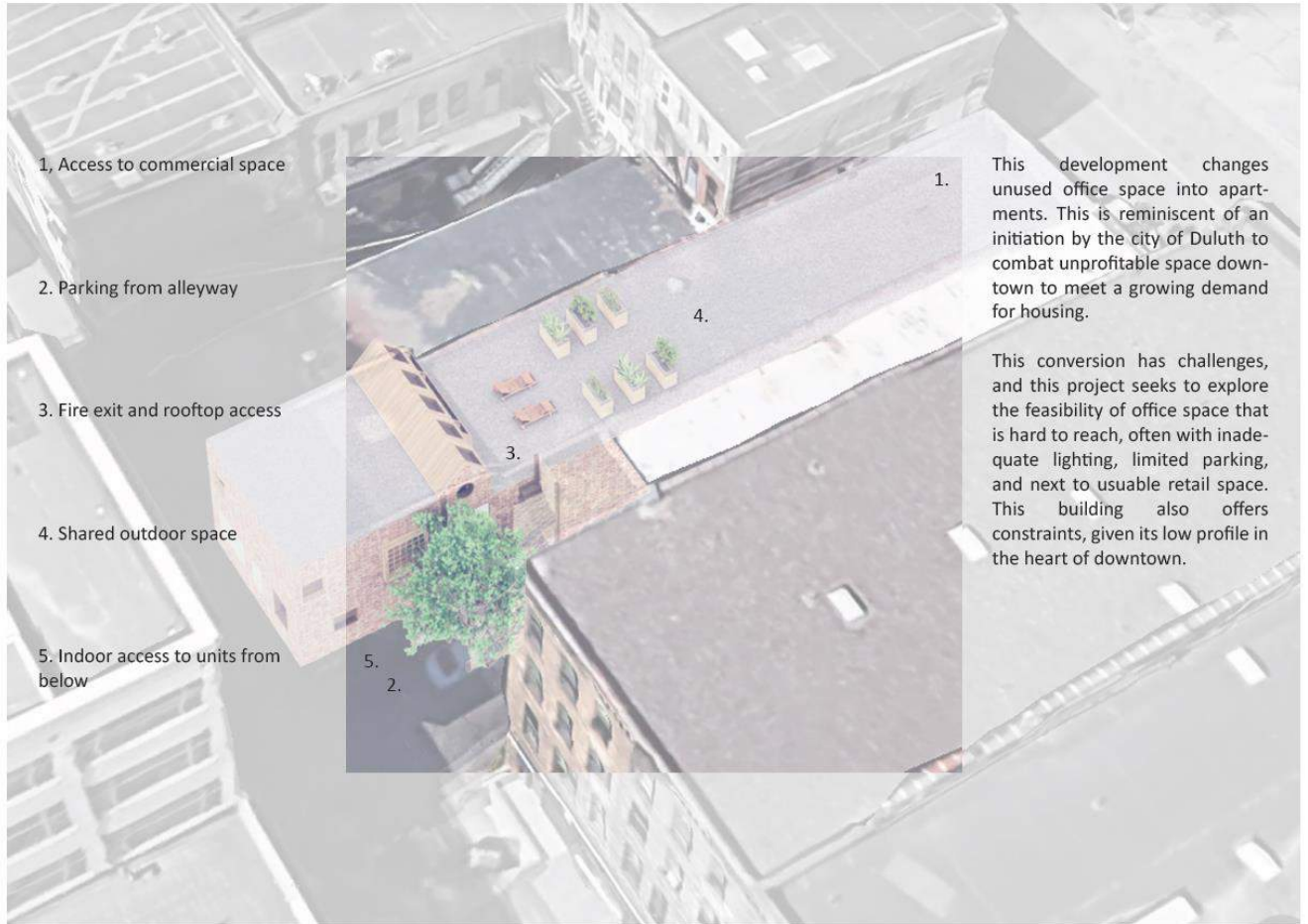


Figure 4.48. Context Diagram 18W 1st St, Duluth MN.

4.1.1.3.3. Renovation Plans

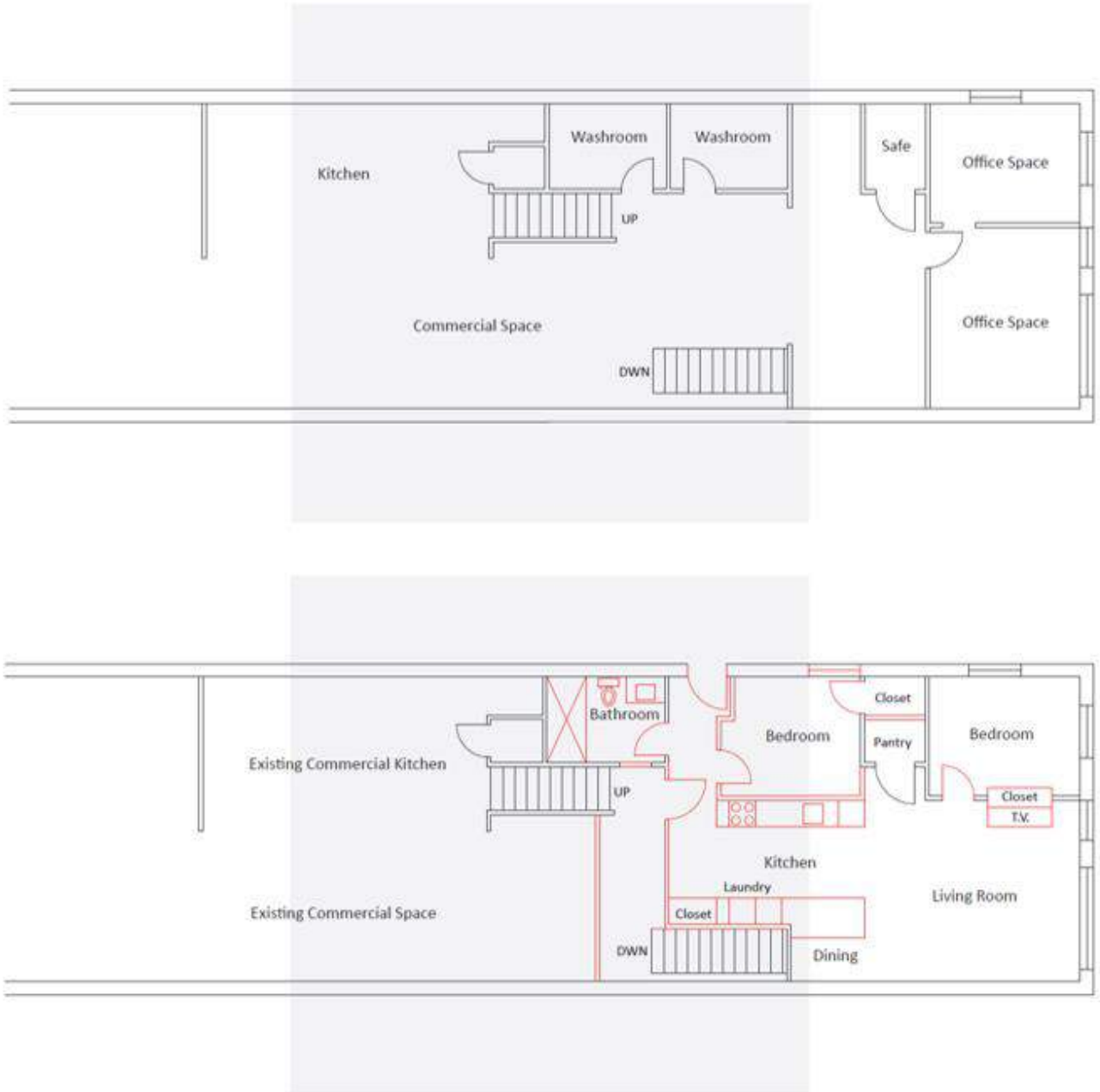


Figure 4.49. Existing and Renovation Plans of Lower Floor 18W 1st St, Duluth MN.

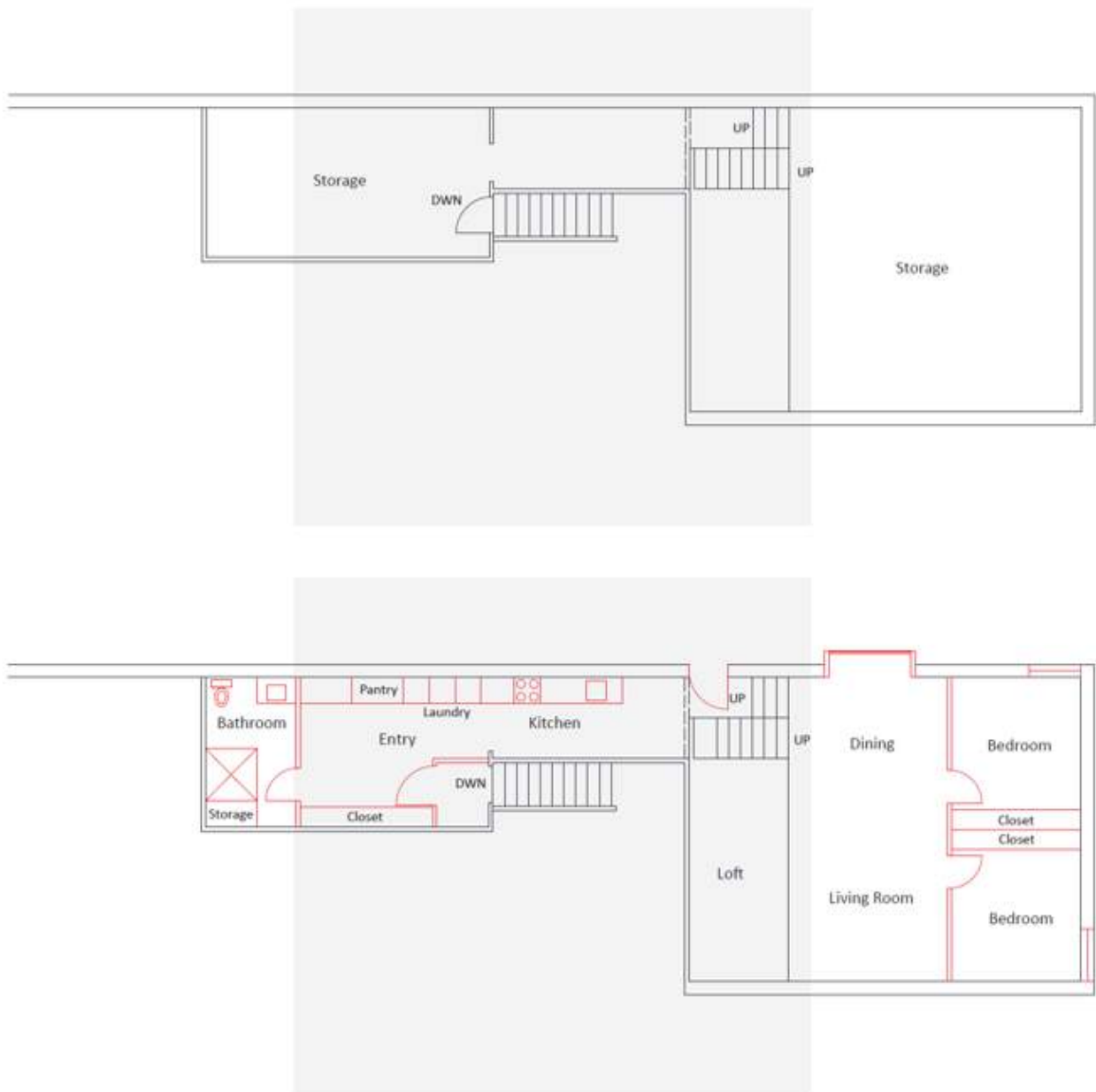


Figure 4.50. Existing and Renovation Plans of Upper Floor 18W 1st St, Duluth MN.

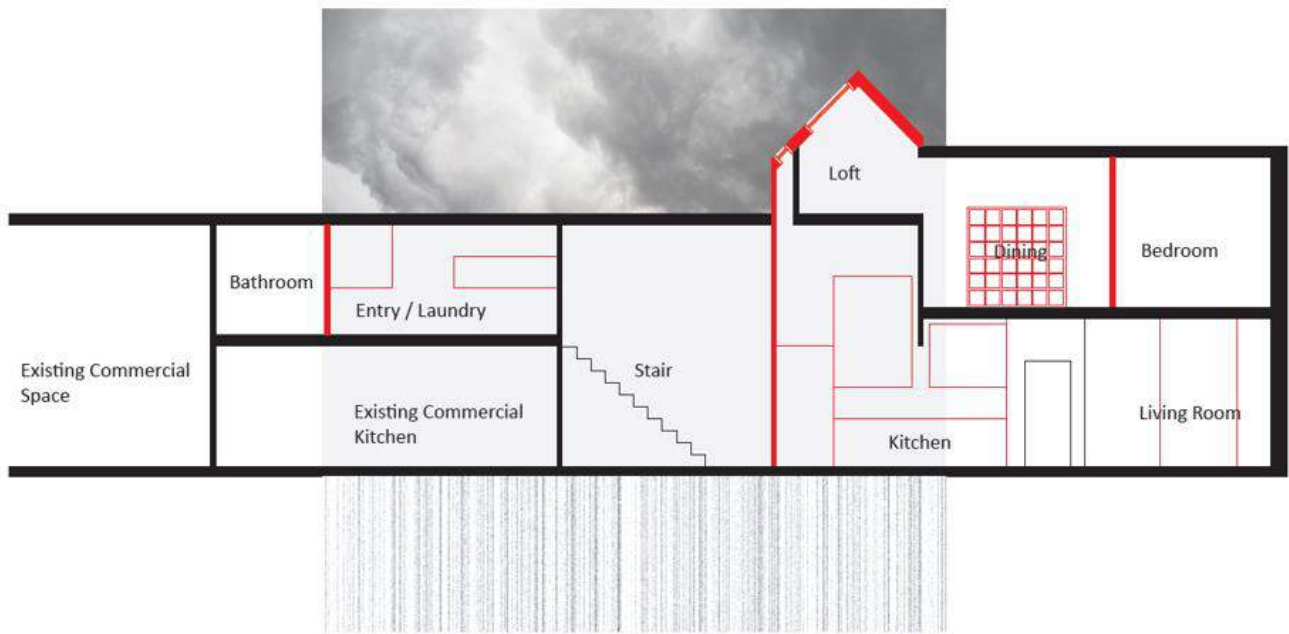


Figure 4.51. Section of Proposed Design 18W 1st St, Duluth MN.

4.1.1.3.4. Design



Figure 4.52. Roof Deck View 18W 1st St, Duluth MN.



Figure 4.53. Interior View of Lower Unit 18W 1st St, Duluth MN.

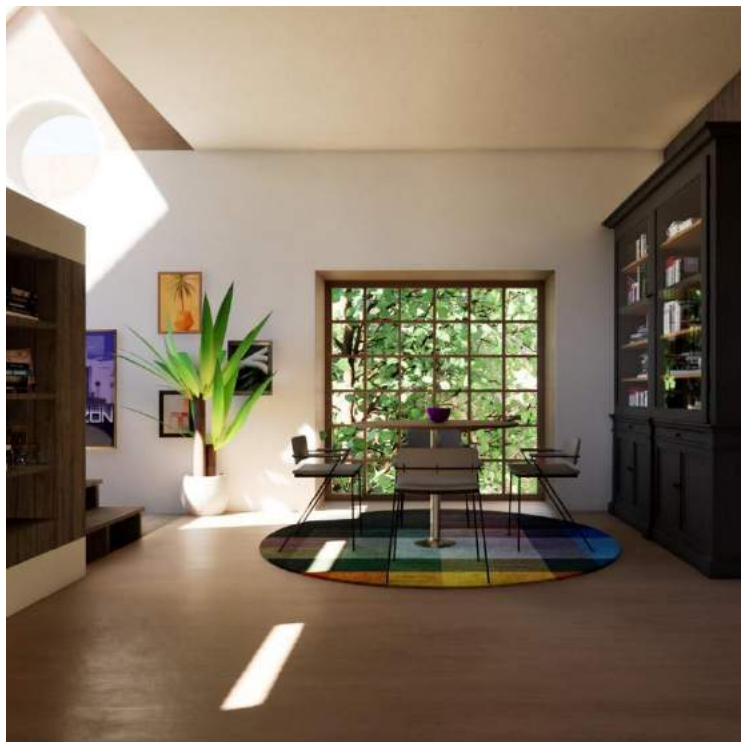


Figure 4.54. Interior View of Upper Unit 18W 1st St, Duluth MN.

4.1.1.3.5. Site Two: 513 N Second Ave E, Duluth MN



Figure 4.55. Exterior View 513 N 2nd Ave E, Duluth MN.

This site is a triplex located in Central Hillside next to Downtown Duluth. This design response repurposes a second floor storage room that is separated from the three units by a shared hallway. The design intent of this project is to convert the storage room into a studio apartment, increasing the investment potential of the building, while stabilizing the rent for the tenants.

4.1.1.3.6. *Renovation Plans*

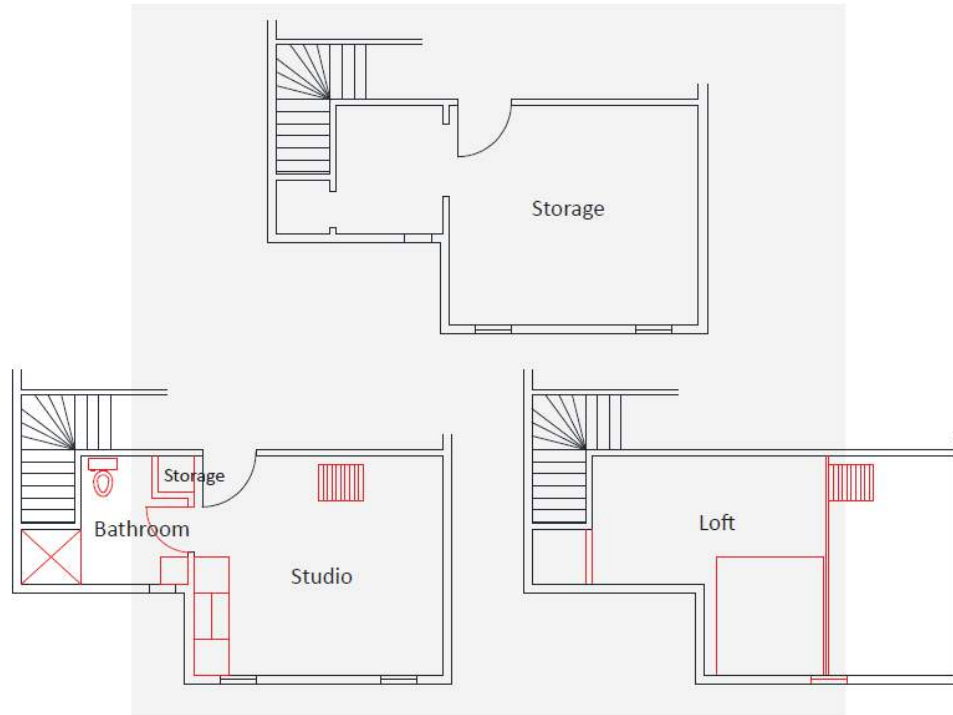


Figure 4.56. Existing and Renovation Plans 513 N 2nd Ave E, Duluth MN.

4.1.1.3.7. *Design*



Figure 4.57. Apartment Addition 513 N 2nd Ave E, Duluth MN.



Figure 4.58. Interior View 513 N 2nd Ave E, Duluth MN.

4.1.1.3.8. Site Three: 1214 N 12th St, Superior WI



Figure 4.59. Exterior View 1214 N 12th St, Superior WI.

This site is a duplex located in Superior WI, next to Duluth. The design response is the conversion of an attic space that is currently accessible through the second floor bathroom to a third unit with the addition of a stairway.

4.1.1.3.9. Renovation Plans

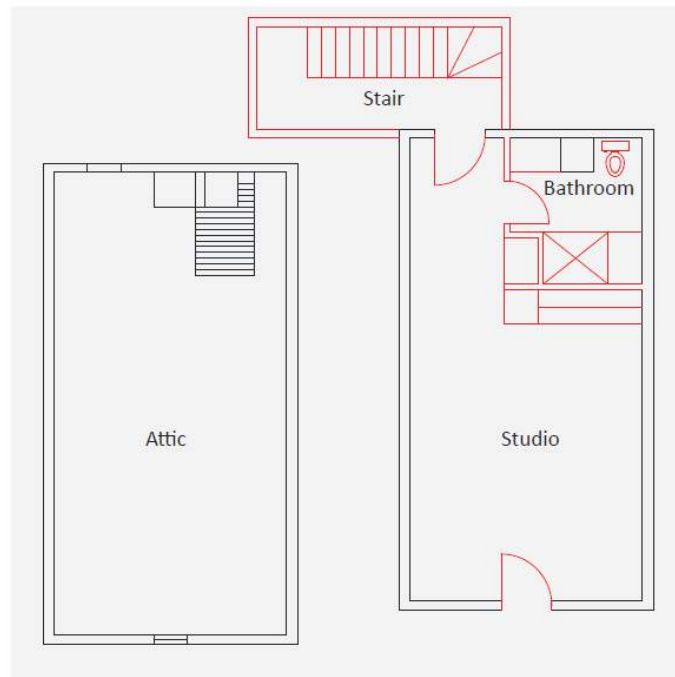


Figure 4.60. Existing and Renovation Plans 1214 N 12th St, Superior WI.

4.1.1.3.10. *Design*



Figure 4.61. Apartment Addition 1214 N 12th St, Superior WI.

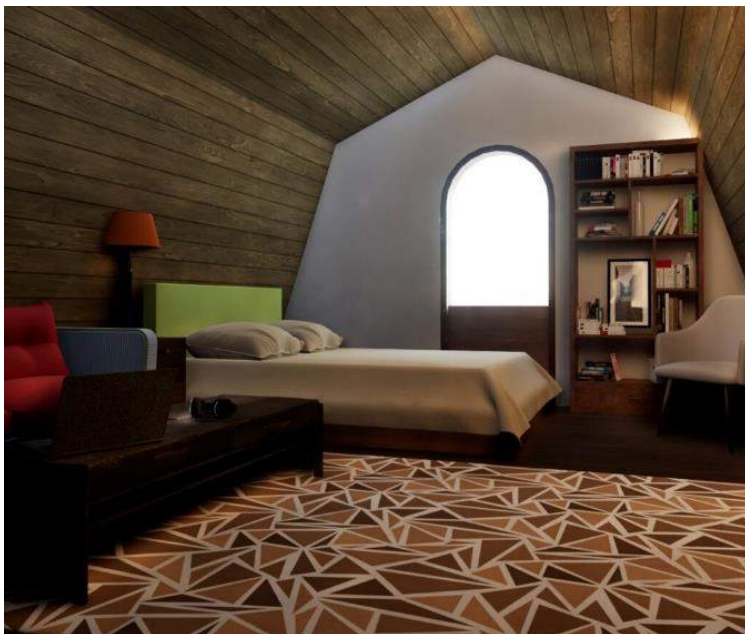


Figure 4.62. Interior View 1214 N 12th St, Superior WI

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