Mass Timber High-Rises:

Integrating Form, Structure, and Dwelling Typologies.

by

Oluwatobiloba Oluwaseun Babalola

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

This thesis explores mass timber not only as a sustainable material, but as a spatial and conceptual framework for reimagining vertical urban housing. It treats mass timber as massing, a modular and volumetric system that organizes structure, form, and inhabitation through stacking, subtraction, and spatial play. Moving beyond material or structural efficiency, the project frames mass timber using a grid and modular based kit of parts as both constraints and opportunity as an architectural language for adaptable, community-oriented high-rise housing that responds to the environmental and social challenges of urban living.

Drawing inspiration from Adrian Wong's explorations of modular systems and spatial adaptability [1], the research adopts a process of modular arrangement, like assembling and rearranging blocks where modular volumes are assembled, layered, and reconfigured to generate diverse typologies and shared communal spaces. The project asks: How can the modular logic of mass timber inspire new forms of high-rise housing that balance environmental responsibility with social and spatial richness? The study focuses on how a repetitive volumetric modular unit can be transformed into lively, varied living environments through deliberate acts of aggregation and void-making through subtractive and additive massing.

In addressing Canada's housing crisis and the global demand for low-carbon, rapidly deployable construction, this thesis positions mass timber's prefabricated modularity as a key strategy for delivering affordable, efficient, and low-embodied-carbon housing construction that also inspires diverse spatial possibilities. Its lightweight nature reduces on-site labor, and capacity for off-site fabrication enable faster assembly, minimal waste, and lower emissions compared to conventional concrete or steel systems. Through digital modeling and speculative design studies using Autodesk Revit, the research develops a catalogue of spatial strategies that demonstrate how mass timber's modular volume can act as both structure and medium for spatial play, producing architecture that is sustainable, adaptable, and deeply human, uniting environmental performance with expressive form and social value.

1. Adrian Wong, "Model As Building, Building As Model II — Adrian Wong," accessed November 6, 2025, https://adrian-wong.com/Model-As-Building-Building-As-Model-II.

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Dedication

To God Almighty, the source of my wisdom, strength, and inspiration. Through every challenge and triumph, Your grace has sustained me. This work is a testament to Your guidance, provision, and unwavering love. May it serve as a reflection of the gifts You have bestowed upon me and a means to fulfill the purpose You have set before me. All glory and honor to You.

And to my wife, Boluwatito, my parents, and my family, your belief and support have been the foundation upon which this journey was built.

To every architecture and design enthusiast. This is for you.

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List of Abbreviations

BCH – Build Canada Homes

C40 Cities – A global network of cities working on climate change

FSI – Floor Space Index

FSR – Floor Space Ratio

GHG – Greenhouse Gas

GSI – Ground Space Index

GWP – Global Warming Potential

IPCC – The Intergovernmental Panel on Climate Change

LCA – Life Cycle Assessment

LRT - Light Rail Transit

Mt – Megatonnes

OSR – Open Space Ratio

UNEP – United Nations Environment Programme

UW - University of Waterloo

Chapter 1 | Introduction

Chapter 1 - Introduction

1.1 The State of Housing in Canada

According to Canada's housing plan in solving the housing crisis, it says "We need to build more homes in Canada, and we need to build them by the millions." [2]

1.1.1 The Past

After the Second World War, Canada faced a major housing challenge as returning soldiers and new immigrants increased demand. To respond quickly, the federal government partnered with private industry in a national effort to build homes at an unprecedented pace, creating housing that still shapes Canadian cities today. A generation later, as baby boomers came of age, Canada again experienced housing shortages. Government programs and construction initiatives expanded the housing supply, enabling another generation to access affordable homes.[3]

1.1.2 The Present

In the decades following Canada's postwar housing boom, government investment in housing declined. Successive governments often failed to plan for future housing needs, making it harder to build new homes. Restrictive planning rules limited high-density development near transit and existing infrastructure, municipalities added extra fees, and provincial support for social housing lagged. At the same time, federal involvement decreased. These factors increased costs, caused construction delays, and reduced the availability of affordable housing. [4]

Meanwhile, Canada's population continued to grow. Families expanded and new residents arrived seeking opportunities, contributing to a strong, diverse, and innovative economy. However, housing construction did not keep up with this growth, leaving many Canadians without suitable homes.
In 2017, the federal government renewed investments in housing. Programs were introduced to support low-income and vulnerable Canadians, encourage rental construction, and help first-time buyers. This led to high levels of homebuilding, the fastest in decades.[5]

Still, housing pressures have increased in recent years. The pandemic, followed by rising interest rates, slowed construction, while demand for housing continued to grow. Today, Canada faces a national housing crisis affecting not only large cities but also smaller towns, rural areas, and northern communities.

2. Solving the Housing Crisis : Canada's Housing Plan (Infrastructure Canada, 2024).

3. Solving the Housing Crisis. Canada's Housing Plan (Infrastructure Canada, 2024).
4. Solving the Housing Crisis. Canada's Housing Plan (Infrastructure Canada, 2024).
5. Solving the Housing Crisis. Canada's Housing Plan (Infrastructure Canada, 2024).

Housing affordability challenges now impact both low- and middle-income households, with rising rents and home prices making homeownership increasingly difficult for younger generations. Racialized and newcomer communities are disproportionately affected, and many Canadians face housing instability or even homelessness.[6]

The government emphasizes that these challenges can be addressed with coordinated efforts, aiming to restore access to affordable housing and ensure that today's young Canadians can enjoy opportunities similar to those of previous generations.[7]

1.1.3 The Future

Canada wants to give young people a fair chance to rent or own a home, just like previous generations had. The goal is to make housing affordable so that no one has to spend more than 30% of their income on shelter, and everyone has a safe, stable place to live.
The plan recognizes that different groups of Canadians have different needs, including Indigenous peoples, newcomers, racialized communities, seniors, people with disabilities, and those in rural or remote areas. For many, the housing crisis is long-standing and connected to systemic inequalities.
The government is committed to making sure everyone can have a home.
Canada is currently building homes faster than it has in decades, but more needs to be done to meet growing demand. Solving the housing crisis requires a team effort: federal, provincial, and municipal governments, homebuilders, non-profits, and communities all need to work together.[8]

The plan focuses on three main strategies:

1. **Building more homes:** by lowering construction costs, making it easier to build quickly, improving how homes are made, and growing the workforce.
2. **Making it easier to rent or own a home:** by ensuring people have housing that meets their needs and stability to keep it.
3. **Helping Canadians who can't afford a home:** by creating more affordable housing for students, seniors, people with disabilities, equity-deserving communities, and addressing chronic homelessness.[9]

6. Solving the Housing Crisis. Canada's Housing Plan (Infrastructure Canada, 2024).
7. Solving the Housing Crisis. Canada's Housing Plan (Infrastructure Canada, 2024).
8. Solving the Housing Crisis. Canada's Housing Plan (Infrastructure Canada, 2024).
9. Solving the Housing Crisis. Canada's Housing Plan (Infrastructure Canada, 2024).

10. "CMHC Housing Design Catalogue; Mark Carney's Liberals Unveil Canada's Most Ambitious Housing Plan since the Second World War," n.d.

1.1.4 Building Canada Homes (BCH)

The federal government, under Prime Minister Mark Carney, has launched Build Canada Homes (BCH) to re-engage in housing construction. The program aims to build affordable housing at scale (including on public land), stimulate a new housing industry, and provide financing to support affordable homebuilders.[10]

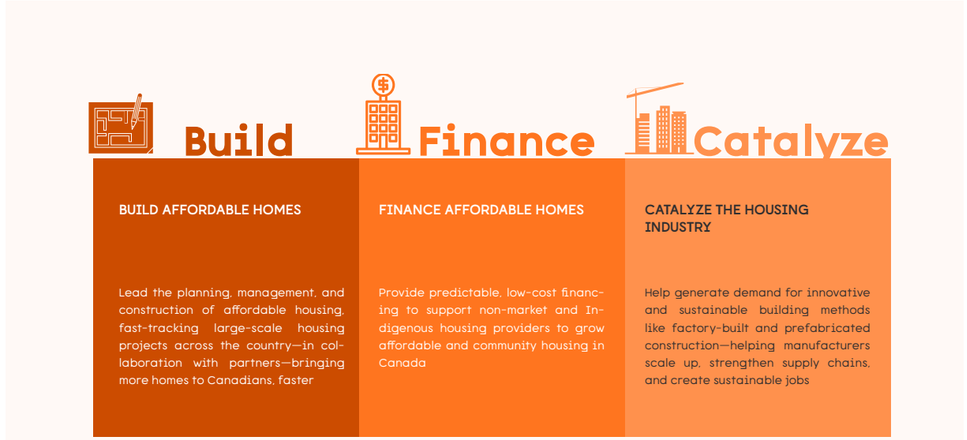


Figure 1: Primary Function of Build Canada Homes. Author's drawing adapted from www.housing-infrastructure.canada.ca.

On September 14, 2025, Prime Minister Mark Carney launched Build Canada Homes (BCH), a federal agency to increase affordable housing and reduce homelessness. BCH will provide transitional and supportive housing, partner with private developers for middle-class homes, and work with governments and Indigenous communities. It will modernize construction, use public lands, attract investment, and prioritize non-market housing as part of a national effort to expand supply, restore affordability, and support all income levels.[11]

The CMHC Design Catalogue supports federal housing initiatives by removing design and approval bottlenecks. By offering standardized, code-compliant housing designs, it enables faster approvals, supports prefabrication, and reduces construction time and cost. This compliments BCH by pairing financial and land-based strategies with repeatable, scalable design solutions using the logic of standardization and modularity. [12]

11. "Prime Minister Carney Launches Build Canada Homes to Supercharge Homebuilding across the Country," Prime Minister of Canada, September 14, 2025, https://www.pm.gc.ca/en/news/news-releases/2025/09/14/prime-minister-carney-launches-build-canada-homes.

12. "Housing Design Catalogue," accessed January 7, 2026, https://www.housingcatalogue.cmhc-schl.gc.ca/.

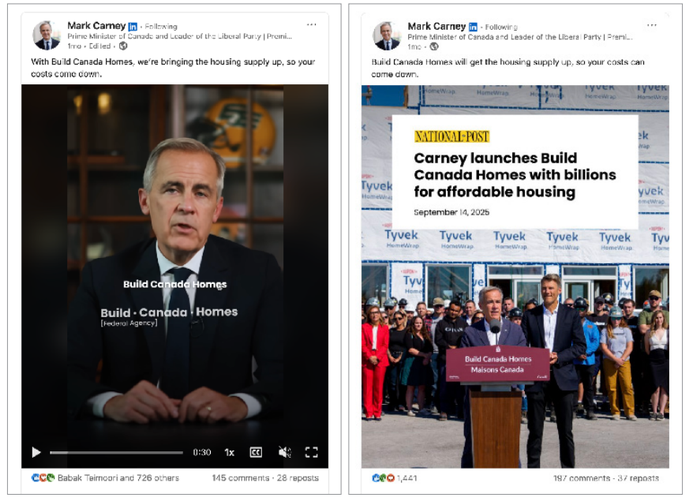


Figure 2: Build Canada Homes - A New Federal Agency. Source: Mark Carney's Linkedin post on september 14th 2025.

Through Build Canada Homes (BCH), the government plans to:

1. Act as a developer by building affordable housing on a large scale, including on public land, and by managing projects in partnership with builders.

2. Build faster, smarter, and more affordable homes by providing over $25 billion to support innovative prefabricated homebuilders in Canada, using Canadian technologies and materials like mass timber and softwood lumber. BCH will also place bulk orders from manufacturers to maintain steady demand, bringing together forestry, engineering, manufacturing, and construction in new ways.

3. Support affordable homebuilders with $10 billion in low-cost financing to create housing for middle- and low-income Canadians, including students, seniors, veterans, people with disabilities, and Indigenous communities, as well as shelters and supportive housing.

4. Focus on sustainability by encouraging the use of sustainably sourced wood, recycled materials, and low-emission construction.

5. Encourage workforce development by requiring companies to hire apprentices and recent graduates on federally supported projects, creating opportunities for young Canadians.[13]

13. "Build | Liberal Party of Canada," accessed November 7, 2025, https://liberal.ca/cstrong/build/.

1.2 Environmental Challenge.

While there is a need to build faster, smarter and more affordable homes, this poses an environmental challenge. Buildings account for 39% of global energy-related carbon emissions worldwide: 28% from operational emissions (from energy needed to heat, cool and power them), and the remaining 11% from materials and construction.[14] (Figure 3).

In Canada, The built environment is still the third largest source of emissions in Canada, with annual GHG emissions accounting for 89 megatonnes (Mt) in 2022, around 13% of direct emissions. [15] (Figure 4).

The built environment contributes to the climate crisis in two major ways: by generating greenhouse gas (GHG) emissions and increasing climate risks. The construction sector is responsible for at least 23% of global CO2 emissions.[16]

14. 2019 Global Status Report for Buildings and Construction, 2019.

15. Natural Resources Canada, "The Canada Green Buildings Strategy: Transforming Canada's Buildings Sector for a Net-Zero and Resilient Future," July 8, 2024, https://natural-resources.canada.ca/energy-efficiency/building-energy-efficiency/canada-green-buildings-strategy-transforming-canada-s-buildings-sector-net-zero-resilient-future.

16. Lizhen Huang et al., Carbon Emission of Global Construction Sector (2017), https://www.sciencedirect.com/science/article/abs/pii/S1364032117309413.

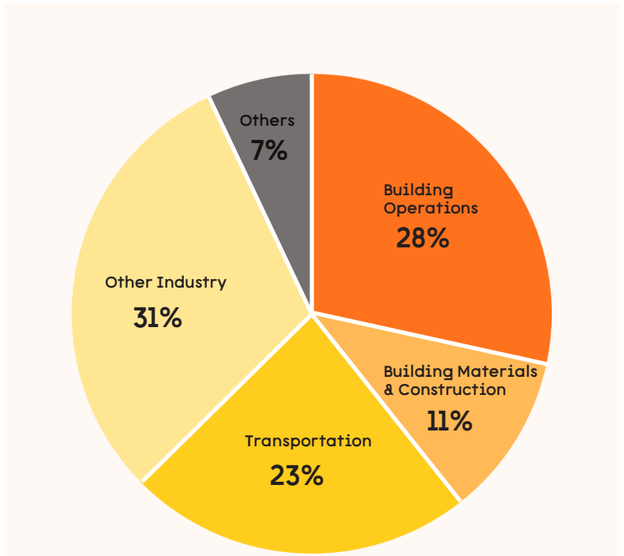


Figure 3: Global CO^2 Emissions by sector (2019)
Author's drawing Adapted from IEA (2019a), Global Status Report for Buildings and Construction.

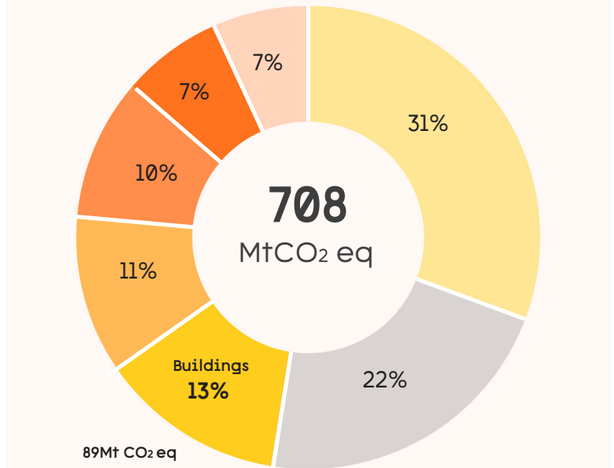


Figure 4: Canada's GHG Emissions by Sector (2022)
Author's drawing Adapted from Natural Resources Canada: The Canada Green Buildings Strategy: Transforming Canada's buildings sector for a net-zero and resilient future



Figure 5: Embodied and Operational Carbon Emissions.
Author's drawing Adapted from Magwood et al. 2021; United Nations Environment Programme (2023). Building Materials and the Climate: Constructing a New Future. Nairobi

A building's carbon footprint over its lifespan is the sum of its embodied plus operational emissions as shown in (figure 5).

In recent years, much of the discussion around sustainability in buildings has focused on lowering operational carbon, the emissions produced by heating, cooling, and powering buildings which currently makes up about 75% of total emissions in the construction sector (See Figure 6). However, embodied carbon, which comes from the materials and construction process itself, is expected to rise from 25% to nearly 50% by mid-century (OECD 2019). As energy systems shift toward renewables and building operations become more efficient, operational carbon will decrease while the impact of materials will become a much larger share of total emissions (Architecture 2030 2022).[17]

Under business as usual, embodied emissions will contribute nearly half of all building emissions by mid-century.[18]

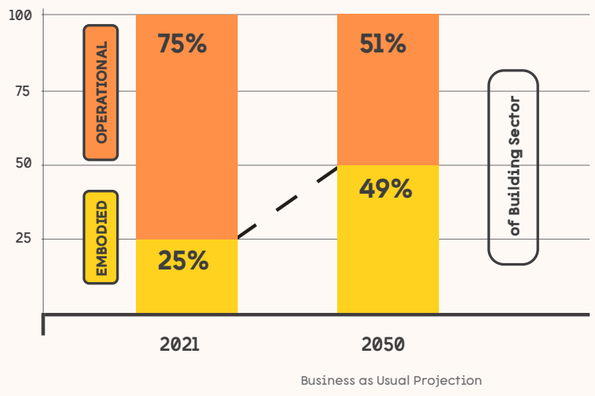


Figure 6: Projected Contributions from Embodied and operational Carbon within the building sector.
Author's drawing Adapted from Architecture 2030 2022. : United Nations Environment Programme (2023). Building Materials and the Climate: Constructing a New Future. Nairobi

Climate change is forcing us to rethink how we design and build. At the same time, the demand for housing and infrastructure is rising faster than ever. One key solution is to turn buildings from a major source of carbon emissions into part of the solution; a carbon sink.

17. United Nations Environment Programme and Yale Center for Ecosystems + Architecture, Building Materials and the Climate: Constructing a New Future (United Nations Environment Programme, 2023), https://wedocs.unep.org/xmlui/handle/20.500.11822/43293.o

18. United Nations Environment Programme and Yale Center for Ecosystems + Architecture, Building Materials and the Climate: Constructing a New Future (United Nations Environment Programme, 2023), https://wedocs.unep.org/xmlui/handle/20.500.11822/43293.o

The construction industry plays a huge role in global emissions. To tackle this problem, designers, architects, engineers, and policymakers must act quickly to lower the carbon impact of both building operations and materials. Delaying action will only worsen the crisis, as greenhouse gas emissions have already increased by 90% since 1970. Even a 1.5°C rise in global temperatures could have devastating effects on ecosystems and communities around the world.[19]

Embodied carbon has become a major focus for many environmental and design organizations, such as C40 Cities, Architecture 2030, the Urban Land Institute, and the World Green Building Council. Experts agree that reducing embodied carbon in buildings and construction materials is essential to meeting global climate goals set by The Intergovernmental Panel on Climate Change and the Paris Climate Agreement (2016). [20]

Embodied carbon is measured through a life cycle assessment (LCA), which examines the total environmental impact of a material or building from production and construction to demolition (See Figure 7). One key result of this analysis is the global warming potential (GWP), which represents the amount of carbon emissions linked to each stage of the material's life. As buildings become more energy-efficient, the carbon emissions from materials, (the upfront embodied carbon) make up an increasingly larger share of a building's total emissions. In the near future, embodied carbon is expected to become the main source of emissions from new buildings.

Different materials have very different levels of embodied carbon. For example, wood products typically require much less energy to produce than steel, concrete, or brick, especially less fossil fuel energy. Because of this, choosing wood and other low-carbon materials can play a key role in designing more sustainable buildings.[21]

19. Hannah Mowrey, "Carbon Source to Carbon Sink: Redesigning the Built Environment for Climate Change," Think Wood, February 2, 2021, https://www.thinkwood.com/blog/carbon-source-to-carbon-sink-redesigning-the-built-environment-for-climate-change.

20. Hannah Mowrey, "Carbon Source to Carbon Sink: Redesigning the Built Environment for Climate Change," Think Wood, February 2, 2021, https://www.thinkwood.com/blog/carbon-source-to-carbon-sink-redesigning-the-built-environment-for-climate-change.

21. Hannah Mowrey, "Carbon Source to Carbon Sink: Redesigning the Built Environment for Climate Change," Think Wood, February 2, 2021, https://www.thinkwood.com/blog/carbon-source-to-carbon-sink-redesigning-the-built-environment-for-climate-change.

Introduction - Environmental Challenge

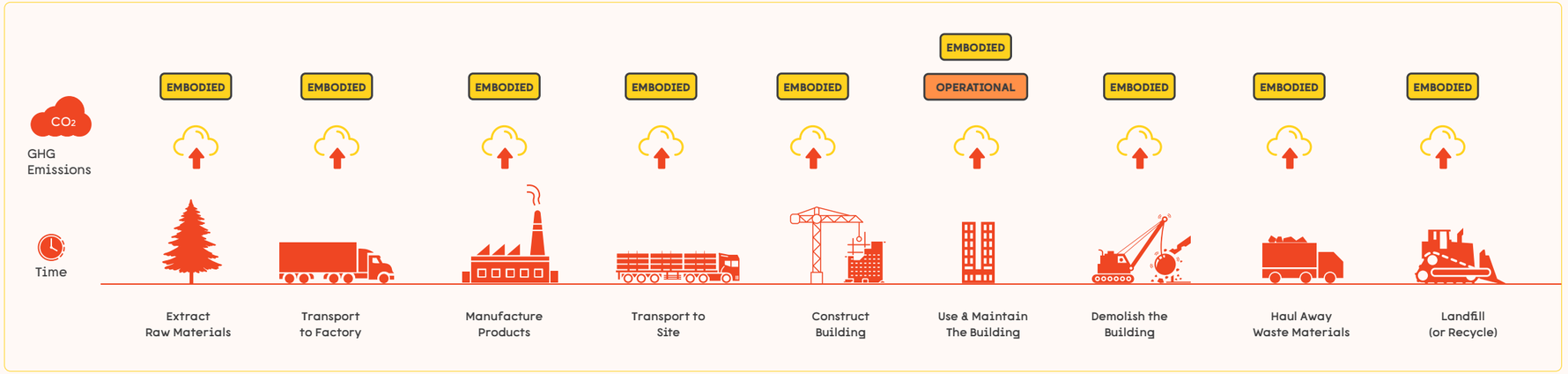


Figure 7: Embodied carbon emissions of New Buildings
Author's drawing adapted from Think Wood https://www.thinkwood.com/blog/carbon-source-to-carbon-sink-redesigning-the-built-environment-for-climate-change

In Canada, between 2023 and 2050, embodied carbon could represent over 90% of a new building's carbon emission.[22]

1.2.1 Building Decarbonization

To decarbonize building materials by 2060 as outlined in the literature, particularly Building material and the climate: constructing a new future, it is necessary to support solutions across all major material types simultaneously. Because there is no single pathway to reducing the carbon impact of building materials, designers and decision-makers must act collectively from the early design stages through the entire life cycle of a building. Collaboration across all stakeholders, designers, scientists, architects, engineers, builders, communities, and waste managers is therefore essential.
The shift to sustainable, low-carbon materials will transform how cities and infrastructure are built. To cut embodied carbon by 40% by 2030 and fully decarbonize materials by 2060, immediate action is needed across all material types. This includes designing buildings for circular use, where components can be disassembled and reused, turning buildings into "material banks." Reducing emissions also means sourcing materials like concrete and steel from recycled sources and increasing the use of renewable, bio-based alternatives.

Overall, decarbonizing construction materials requires two key actions: reducing emissions from conventional materials and expanding the use of renewable ones. These efforts can be guided by the "Avoid–Shift–Improve" framework, which focuses on avoiding unnecessary material use, shifting to low-carbon alternatives, and improving efficiency throughout the building life cycle.[23]



Figure 8: Decarbonizing buildings and construction through the Avoid-Shift-Improve approach. Author's drawing adapted from Think Wood https://www.thinkwood.com/blog/carbon-source-to-carbon-sink-redesigning-the-built-environment-for-climate-change

22. CAGBC Canada Green Building Council, "Decarbonizing Canada's Large Buildings: Summary Report," CAGBC, 2021.

23. United Nations Environment Programme and Yale Center for Ecosystems + Architecture, Building Materials and the Climate: Constructing a New Future (United Nations Environment Programme, 2023), https://wedocs.unep.org/xmlui/handle/20.500.11822/43293.o

According to (figure 8); The Avoid-Shift-Improve approach has the three main strategies to decarbonise building materials. [24]

AVOID: Reduce waste and carbon by designing efficiently, reusing materials, and creating buildings that last longer and can be easily disassembled for reuse.

SHIFT: Use renewable, bio-based materials like sustainably sourced wood and agricultural by-products to cut dependence on new raw materials.

IMPROVE: Make conventional materials like concrete and steel cleaner by using renewable energy, efficient production methods, and better recycling and reuse systems.[25]

1.2.2 Material Efficiency

The United Nations Environment Programme's report Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future examines how improving material efficiency can help meet the 1.5°C climate target. The study finds that emissions from material production more than doubled between 1995 and 2015 from 5 to 11.5 gigatons of CO_2 - equivalent rising from 15 to 23 percent of total global emissions. Most emissions stem from iron and steel, cement, and plastics, with wood products contributing under 1 gigaton as shown in (figure 9). The report argues that resource-efficient design, material reuse, and renewable bio-based materials offer the fastest path toward lowering emissions in construction and manufacturing. [26] This aligns closely with architectural strategies such as mass timber and modular "kit-of-parts" systems that emphasize circularity and low-carbon design.

To reduce emissions, the study identifies two main pathways:

- **Supply-side strategies,** such as cleaner energy sources, low-carbon production technologies, and carbon capture; and

- **Demand-side or material efficiency strategies**, such as designing lighter buildings, reusing and recycling materials, and reducing material demand through shared or smaller living spaces.

The analysis shows that improving material efficiency can deliver significant and faster emission reductions than waiting for large-scale technological shifts, offering a practical route toward meeting the 1.5 °C Paris Agreement goal. [27]

24 United Nations Environment Programme and Yale Center for Ecosystems + Architecture, Building Materials and the Climate: Constructing a New Future (United Nations Environment Programme, 2023), https://wedocs.unep.org/xmlui/handle/20.500.11822/43293.o

25 United Nations Environment Programme and Yale Center for Ecosystems + Architecture, Building Materials and the Climate: Constructing a New Future (United Nations Environment Programme, 2023), https://wedocs.unep.org/xmlui/handle/20.500.11822/43293.o

26 Edgar Hertwich et al., RESOURCE EFFICIENCY AND CLIMATE CHANGE Material Efficiency Strategies for a Low-Carbon Future (UNESCO, 2020).

27 Edgar Hertwich et al., RESOURCE EFFICIENCY AND CLIMATE CHANGE Material Efficiency Strategies for a Low-Carbon Future (UNESCO, 2020).

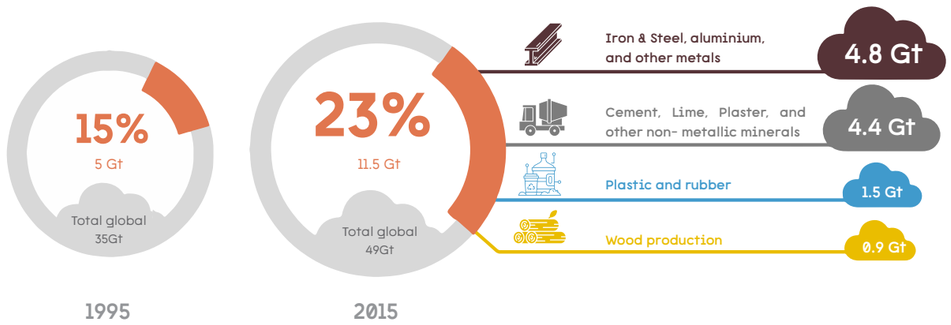


Figure 9: Global emissions from material production, 1995 vs. 2015.
Author's drawing adapted from Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future (Hertwich et al., United Nations Environment Programme, 2020).

The report further highlights how rethinking material use across a building's entire life cycle can significantly reduce global emissions. Using life-cycle assessment and energy modeling, the study analyzed typical housing types built with different materials and energy standards to evaluate how design decisions impact both embodied and operational carbon. It found that strategies such as designing lighter buildings, substituting carbon-intensive materials with sustainably sourced timber, reducing average floor area per person, and improving recycling systems can together lower greenhouse gas emissions from residential construction by up to 40% in developed nations and as much as 70% in rapidly urbanizing regions by 2050. [28]

These findings suggest that decarbonizing the housing sector requires a shift not only in energy performance but also in spatial and material efficiency. Within this framework, mass timber and modular housing systems offer a practical pathway toward lighter, adaptable, and resource-efficient design aligning with broader climate goals while addressing Canada's housing challenges.

28. Edgar Hertwich et al., RESOURCE EFFICIENCY AND CLIMATE CHANGE Material Efficiency Strategies for a Low-Carbon Future (UNESCO, 2020).

1.2.3 Material Comparison

A study by IPCC Sixth Assessment Report Working Group III: Mitigation of Climate Change, as shown in (Figure 10), compares one tonne of three primary structural materials concrete, steel, and timber based on their carbon emissions and carbon storage potential. Concrete and steel are shown to have high embodied carbon emissions while storing very little carbon, whereas timber stores a substantial amount of carbon relative to its low emissions. Figure 10 presents average, minimum, and maximum values for carbon storage, with grey tones representing emissions and green tones indicating storage. Timber's carbon storage is significant because it captures and retains carbon throughout its lifespan, while steel's carbon storage is negligible, and concrete's theoretical maximum storage would take hundreds of years to realize. The comparison also highlights differences in volume-to-weight ratios and material intensity, showing that the choice of material has a major impact on both the environmental footprint and potential carbon mitigation of a building. These differences are important when considering sustainable design strategies for construction and material selection. [29] Although Figure 10 presents a per-tonne comparison, one tonne of concrete, steel and timber produces fundamentally different structural volumes and floor areas, requiring carbon impacts to be understood in relation to built form rather than material weight alone.

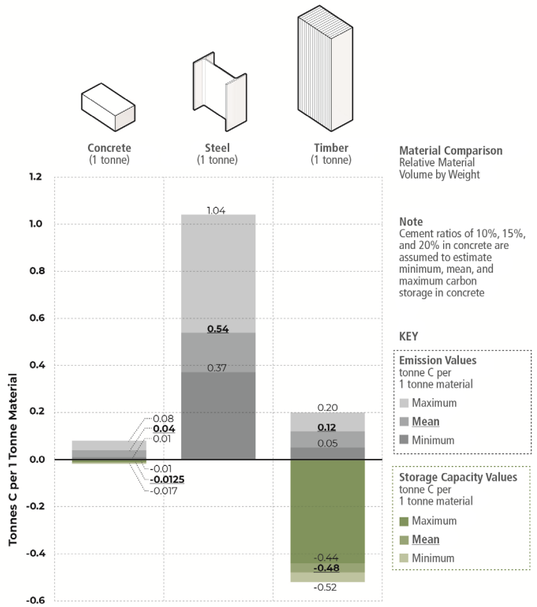


Figure 10: Relative volume, carbon emissions, and carbon storage capacity of primary structural materials (concrete, steel, and timber).
Adapted from Figure 8.17 in Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Birkmann et al. 2022), based on Churkina et al. (2020).

29 "Figure AR6 WG3," accessed November 8, 2025, https://www.ipcc.ch/report/ar6/wg3/figures/chapter-8/figure-8-17.

1.2.3 Mass Timber Potential

The built environment is a major driver of global material consumption, accounting for approximately 38% of the world's wood products. This scale positions construction as a critical leverage point for reducing emobodied carbon, particularly through the strategic substitution of carbon-intensive materials such as concrete and steel with mass timber systems due to its potential for scalability, sustainability, strength and flexibility in mid-rise urban buildings. Mass timber helps to reduce the carbon intensity of construction by eliminating concrete and steel emissions and by providing long-term carbon storage. Using wood products alongside other cost-effective decisions can reduce embodied carbon by as much as 40%. Since embodied carbon in materials represents majority of lifecycle emissions from the construction of buildings, mass timber can have a huge impact. [30]

Mass timber products are large, panelized wood elements made from either solid sawn lumber or engineered structural composite lumber (SCL).

Common types include cross-laminated timber (CLT), nail-laminated timber (NLT), dowel-laminated timber (DLT), and glue-laminated timber (GLT). CLT is usually made from solid sawn lumber but can also use engineered materials such as laminated veneer lumber (LVL). The variety of mass timber products allows architects and engineers flexibility in design, as panels can be combined into customized structural assemblies.

These panels are suitable for walls, floors, and roofs and can be adapted for cantilevered or curved forms or integrated with concrete to form timber-concrete composite (TCC) systems, improving spans, reducing thickness, and controlling vibrations. Mass timber can also be used in hybrid structures alongside light-frame wood construction or other building systems. [31]

30. Bentley Allan and Derek Eaton, "The Mass Timber Roadmap An Integrated Forest-to-Buildings Value Chain," The Transition Accelerator, 2023.

31. Think Wood and Woodworks, "Mass Timber Design Manual, Vol 2," Think Wood, 2022.



Figure 11: Mass Timber Products (Image Credit: Mass Timber Institute, University of Toronto

The diverse types and configurations of mass timber panels not only provide structural flexibility but also create opportunities for architectural experimentation. In the context of this research, mass timber is treated as a modular and spatial medium rather than just a building material. By using the panels to create volumetric building blocks, it becomes possible to explore stacking, shifting, and subtracting volumes to generate varied living typologies and shared social spaces within a unified structural logic. This approach leverages the inherent precision, dimensional stability, and adaptability of mass timber to support both environmental responsibility and innovative high-rise housing design.

1.3.1 Building with Mass Timber

For more than a century, tall buildings around the world have primarily used steel and concrete due to their strength, durability, and suitability for challenging conditions such as earthquakes and high winds. Architects and engineers have refined these materials over time, enabling taller structures and improved fire safety for both buildings and occupants. However, growing concerns about climate change and environmental impact are encouraging a shift toward alternative materials that can reduce the ecological footprint of high-rise construction. Currently, about half of the world's population lives in cities, and this is expected to rise to roughly 70% by 2050. As urban populations grow, the demand for large-scale buildings to accommodate higher densities will increase, making sustainable construction essential for addressing climate change. UN Habitat projects that 3 billion people will need affordable housing in the next 20 years. If built with conventional materials like concrete, which has high carbon emissions, this expansion would worsen environmental impacts. To combat climate change, the world must both reduce greenhouse gas emissions and store carbon effectively. Wood presents a promising solution, as it can lower emissions and store carbon within buildings.[32]

Mass timber construction is often faster than traditional steel or concrete systems, which can reduce project costs and shorten the timeline for occupancy, whether for offices, schools, housing, or hotels. Because panels and components are prefabricated off-site, they are easier to assemble on-site with smaller crews, making them ideal for tight or difficult-to-access locations. The speed of assembly, design efficiency, and flexibility have all contributed to mass timber's growing popularity. Additionally, mass timber supports circular economy approaches by improving resource efficiency and lowering greenhouse gas emissions, helping advance broader environmental and climate goals. [33]

32 "Michael Green Architecture, The Case for Tall Wood Buildings, Second Edition (2020), https://cwc.ca/wp-content/uploads/2020/06/Second-Edition-The-Case-for-Tall-Wood-Buildings.pdf.

33 Natural Resources Canada et al., The State of Mass Timber in Canada 2021 (n.d.), https://ostrnrcan-dostrncan.canada.ca/handle/1845/249560.

1.4 Accelerating the housing development with Mass Timber

Mass timber designs, especially those incorporating prefabrication and modular approaches, offer a promising strategy to accelerate the construction of multi-unit residential structures at greater speeds and lower costs.[34] The recent surge of multi-unit residential building (MURB) developments across many parts of Canada, mostly in the form of condominium or strata projects, is a trend that is forecast to continue well into the foreseeable future. Many cities now seek to intensify development as a strategy in reducing their carbon footprints while capitalizing on existing infrastructure to support growth. [35]
If MURBs are trending to become the dominant form of new housing development in most urban centres across Canada, then it is important that these developments contribute as much to improving the quality of life for their inhabitants as they do for their immediate neighbourhoods and the surrounding city. [36] A worldwide Audit of Mass Timber Construction was carried out by Council on Tall Buildings and Urban Habitat, with (figure 12) below by CTBUH showing the historical evaluation of Mass Timber Buildings.

The rapid growth in the height of timber buildings from 29 meters in 2009 to 85 meters in 2019, as shown in Figure 11 demonstrates the expanding technical feasibility of tall mass timber construction. A nearly 300% increase demonstrates both the expanding potential and the practical limits of building tall with mass timber. [37] However building height alone is not the most meaningful measure of impact. More significant is the parallel growth in total floor area, unit repetition, and the number of mass timber residential projects delivered within the same time frame. In the context of this thesis, height is understood not as an end goal, but as evidence that modular, prefabricated timber systems can be scaled vertically while simultanneously supporting density, repeatability, and efficient housing production in urban contexts.

34. Craig Mitchell and Blackbox offsite solutions ltd., The State of Prefabrication in Canada (2021).

35. Ted Kesik et al., Enhancing the Liveability and Resilience of Multi-Unit Residential Buildings (MURBs); MURB Design Guide (2019).

36. Kesik et al., Enhancing the Liveability and Resilience of Multi-Unit Residential Buildings (MURBs); MURB Design Guide.

37 "Audit of Worldwide Mass Timber Construction – CTBUH," accessed November 8, 2025, https://www.ctbuh.org/audit-of-mass-timber-construction.

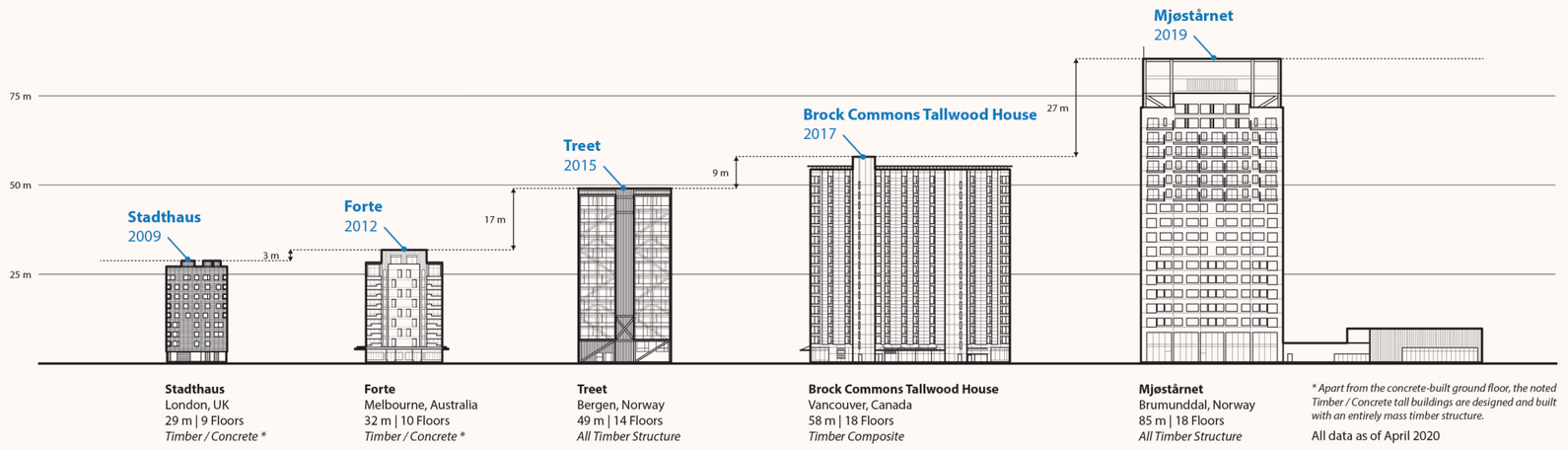


Figure 12: Historical Evaluation of Mass Timber Buildings, Images Source: CTBUH.

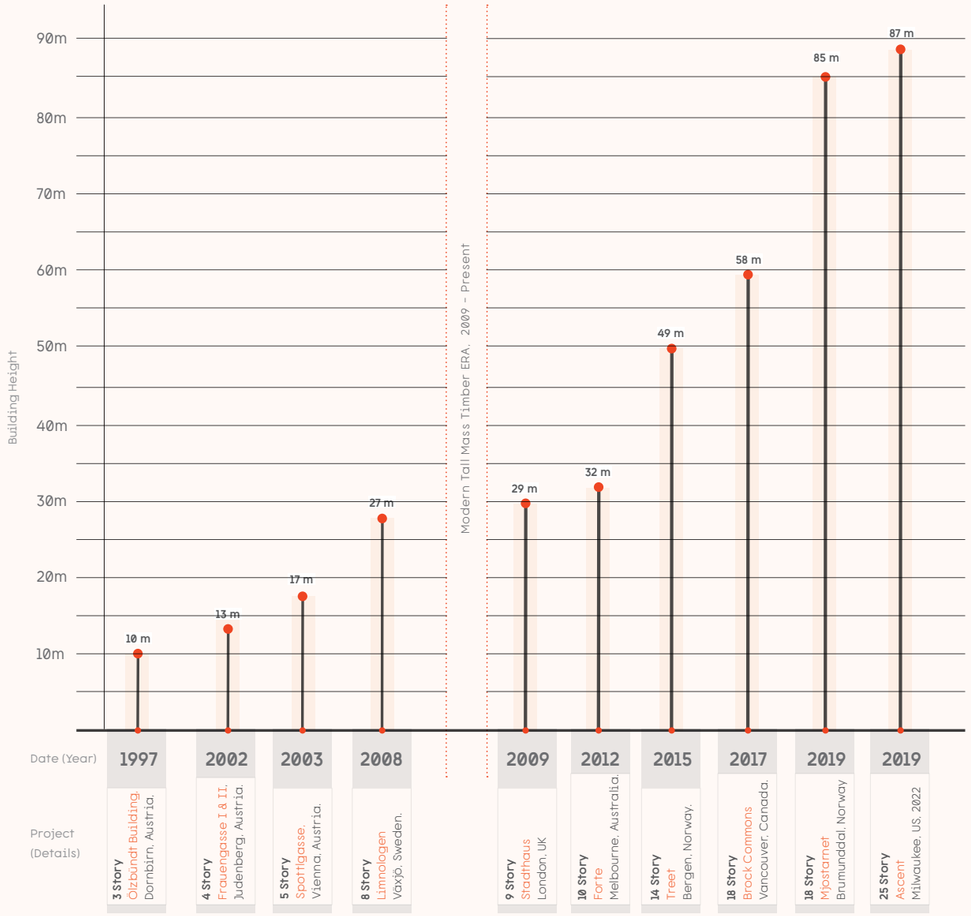


Figure 13: Height Progression of Tall Mass Timber Buildings (1997-2019). Graph illustrating the increase in maximum building height of mass timber projects over timer, highlighting structural and regulatory advancements.

Source: Author's drawing adapted from CTBUH Technical Guides: Tall Timber: Mass Timber for High-Rise Buildings.



Figure 14: Typological Evolution of Tall Mass Timber Buildings. Timeline of representative mass timber projects illustrating changes in building form, program and urban scale alongside increasing height.

Source: Author's collage-adapted from CTBUH Technical Guides: Tall Timber: Mass Timber for High-Rise Buildings.

Figure 13 & Figure 14 illustrate the global evolution of tall mass timber buildings from 1997 to 2019. Starting with low-rise structures like the 3-story Ölzbündt building in Austria, the timeline shows a clear trend of increasing height over time. Key milestones include the 9-story Stadthaus in London (2009), the 14-story Treet in Norway (2015), and culminating in the 18-story Mjøstårnet in Norway (2019) and the 25-story Ascent in the US (2019), demonstrating the advancing potential of mass timber construction for high-rises.

1.4.1 Understanding Mass Timber's Structural Logic & Design Constraints

A clear overview of mass timber's structural logic and material constraints is essential for designing high-rise housing. Mass timber panels, whether cross-laminated (CLT), nail-laminated (NLT), dowel-laminated (DLT), or glue-laminated (GLT), come in large, prefabricated units that define both possibilities and limitations in construction. Their dimensional properties, load-bearing capacity, and connection methods influence how volumes can be stacked, subtracted, or cantilevered. Understanding these constraints allows designers to leverage mass timber not only as a structural solution but as a spatial framework, where modularity and repeatable units guide creative manipulation of form, shared spaces, and adaptable layouts.

By treating mass timber as a kit-of-parts, the design process integrates the material's technical boundaries into the generation of flexible, high-rise typologies, ensuring that structural efficiency, constructability, and environmental performance are embedded from the outset. This foundational understanding informs the thesis' experimental approach, linking material logic with volumetric massing, social program, and spatial diversity.

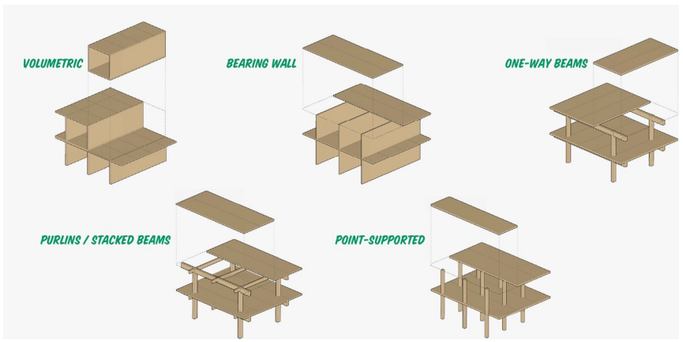


Figure 15: Structural Applications for Mass Timber (Image Credit: W.E. O'Neil Construction, DLR Group)

Mass timber products can be used in a variety of structural assemblies: CLT volumetric, CLT bearing wall, one-way beam, purlins/stacked beams, and point supported CLT as shown in (Figure 15) [38]

1.4.2 Mass Timber Systems (Volumetric Modular Timber Construction)

Timber components can be assembled into a range of structural systems, and the choice of system depends on factors such as the building's function, height, and spatial organization, as well as practical constraints like load-bearing demands, site conditions, cost and time limits, transportation logistics, and the desired level of prefabrication. Lightweight timber systems rely on small, closely spaced sawn wood members nailed together to form a structural "skeleton," often delivered as prefabricated open or closed panels, making them an efficient, safe, and sustainable option for low-rise buildings.

Mass timber systems, by contrast, use larger engineered wood elements manufactured off-site to create the primary load-bearing structure; under appropriate design conditions, these componets can achieve structural performance comparable to steel and concrete for mid-rise building application, while remaining lighter and more environmentally responsible.

Among the various mass timber approaches, this study highlights the three most common for mid-rise construction; as shown in (figure 16) panelized systems, volumetric modular units, and post-and-beam structures with particular emphasis and adoption on volumetric and panelised modular units, while briefly addressing other timber systems to provide broader context.[39]

Panelised & Volumetric modular timber systems are prioritized in this study because they offer the greatest potential for high-rise application, faster construction time, repetitive vertical stacking, efficient load transfer, integration with service cores, and controlled prefabrication-key requirements for tall residential buildings. While post and beam systems can achieve heights, they typically rely on larger spans and bespoke connections, making them less efficient for repetitive high-rise housing compared to panelised and volumetric systems. [40]



Figure 16: Mass Timber Systems (Image Source: Timber Typologies: Timber Development UK) page 35. figure used with permissions from Timber Development UK..

38 "Mass Timber Part I: The Fundamentals," CBT, accessed November 10, 2025, https://www.cbtarchitects.com/news-ideas/mass-timber-part-i-fundamentals.

39 Timber Development UK Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction," November 20, 2024, https://timberdevelopment.uk/resources/timber-typologies/.

40 Timber Development UK Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction," November 20, 2024, https://timberdevelopment.uk/resources/timber-typologies/.

1. Lightweight Timber Frame: Emerging in the early 19th century, lightweight timber framing became a widely used method for low-rise residential buildings. It supports standardized components and some prefabrication while still allowing flexibility in the overall architectural design. The materials are easy to source, with many suppliers offering items such as locally grown timber studs, joists, and OSB panels.[41]

41 Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction."

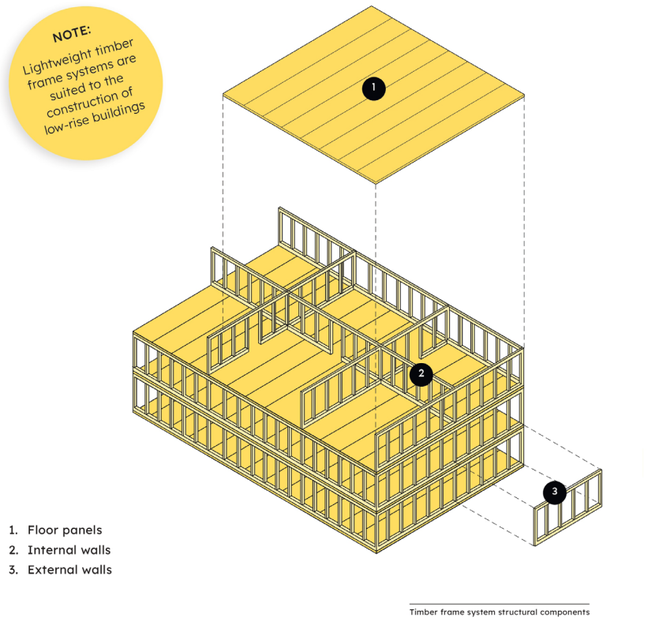


Figure 17: Lightweight Timber Frame (Image Source: Timber Typologies: Timber Development UK) Page 36, figure used with permissions from Timber Development UK..

2. Panelised Mass Timber Construction uses prefabricated timber panels typically CLT or NLT manufactured off-site and assembled on-site. These panels can span in two directions, creating a honeycomb-like structural system that distributes vertical and lateral loads. Floor and wall panels work together structurally, with the wall panels increasing load-bearing capacity and improving airtightness. In low- and mid-rise buildings, panelized systems can also replace concrete in forming the building core.[42]

42 Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction."

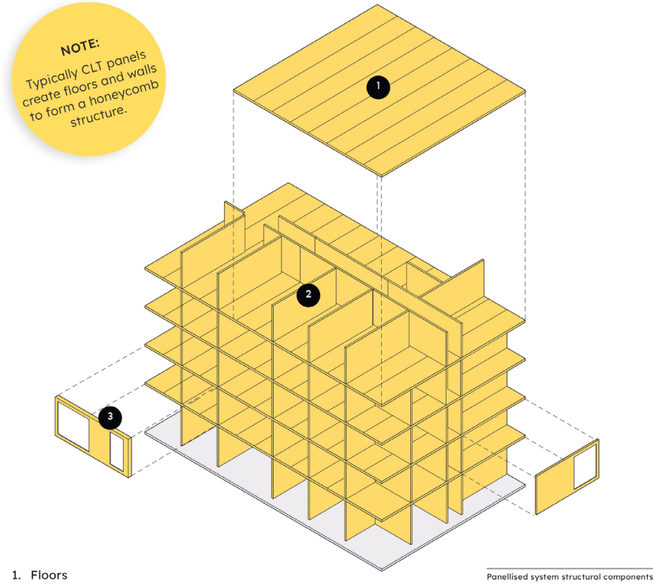


Figure 18: Panelised mass timber construction (Image Source: Timber Typologies: Timber Development UK) Page 44, figure used with permissions from Timber Development UK..

3. Post & Beam Timber Construction

Post-and-beam timber construction builds on the principles of lightweight framing but replaces small members with stronger mass timber elements to create a load-bearing structural skeleton of beams, columns, and floor slabs. This system supports taller buildings and longer spans by using engineered products such as glued laminated timber (glulam) and laminated veneer lumber (LVL) for the vertical posts and horizontal beams, while solid CLT panels are typically used for the floor slabs. Connections between beams and columns are commonly made with concealed steel hardware, though exposed bolts, screws, or even timber connectors may also be used. The overall structure is completed with secondary components such as façade panels and internal walls. As building height increases, structural efficiency is acieved through regular column grids, load sharing across repetitive bays, and optimized member sizing, allowing mass timber post-and-beam systems to remain materially efficient despite increasing cumulative gravity loads. [43]

43 Timber Development UK Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction," November 20, 2024, https://timberdevelopment.uk/resources/timber-typologies/.

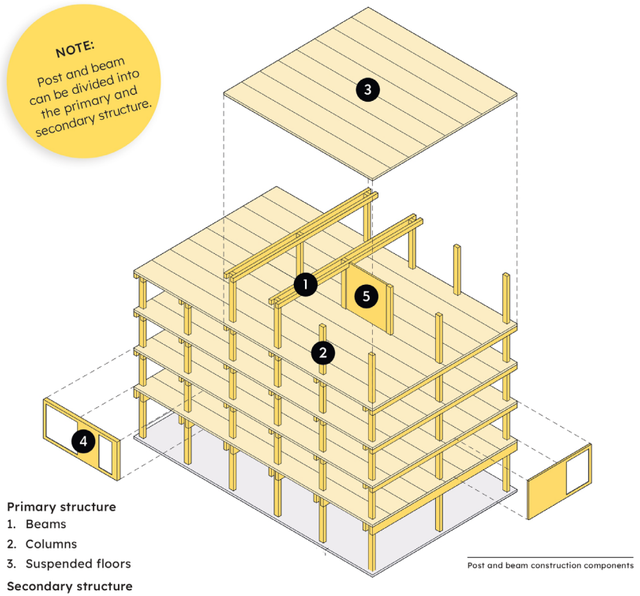


Figure 19: Post & Beam Mass Timber Construction (Image Source: Timber Typologies; Timber Development UK) Page 48, figure used with permissions from Timber Development UK..

4. Volumetric Modular Timber Construction

Volumetric modular timber construction uses fully prefabricated three-dimensional modules to achieve high levels of accuracy, quality, and speed on site. These modules are typically built using CLT panels, glulam beams, or closed timber panels for the walls, floors, and ceilings, which helps reduce the number of joints and potential defects while improving overall building performance. Modules can also be combined with steel to form hybrid systems. Because they arrive largely complete, including finishes, services, and sometimes exterior elements like membranes, cladding, or windows, volumetric units are well suited to large projects where repetition, structural performance, acoustics, airtightness, and moisture control are critical. Careful detailing is required to prevent fire spread and moisture issues between modules. Although the supply chain for fully modular timber systems is still developing, turnkey volumetric solutions offer opportunities for client customization and can significantly accelerate construction. [44]

44 Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction."

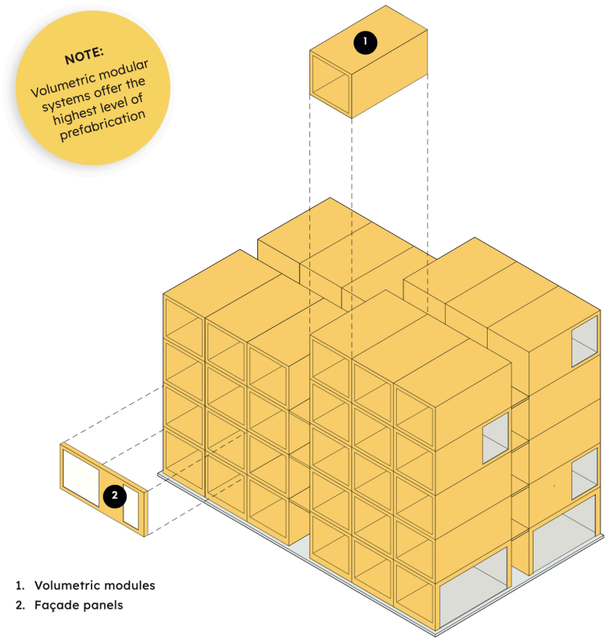


Figure 20: Volumetric Modular Mass Timber Construction (Image Source: Timber Typologies; Timber Development UK) Page 40, figure used with permissions from Timber Development UK.



Volumetric modular factory showing the timber based units being finished with external membranes and windows

Figure 21: CLT modular units in a factory environment, showing units being finished with external membranes and windows. (Image Source: Timber Typologies; Timber Development UK) Page 40, figure used with permissions from Timber Development UK.

4b. Structural Systems of Volumetric Modular Mass Timber Construction.
Volumetric timber modules are governed by strict dimensional limits, since their size must accommodate the capacity of transport vehicles and the physical constraints of the delivery route, including road widths, turning radii, and overhead clearances. When modules exceed these optimal dimensions, transportation becomes more complex and significantly more expensive. Even though timber is comparatively lightweight, completed modules can weigh as much as 20 tonnes, meaning both transport and on-site lifting strategies require careful coordination. In the UK context, road infrastructure sets typical maximums of approximately 15–20 metres in length, up to 3 metres in width (with 2.5 metres preferred to fit comfortably within a standard 3.65-metre single traffic lane), and around 3.45–4.05 metres in height to remain within the 5-metre clearance provided by motorway bridges. These dimensional constraints influence how modules are designed, especially with respect to how they will be stacked, lifted, and connected once on site, as these decisions shape the structural layout of each unit, its junctions, and the wider construction sequence.[45]

The highly repetitive and standardised nature of volumetric construction makes it particularly well suited for building types such as student residences, hotels, and multi-unit residential developments, where consistent room layouts and repeated modules are an advantage rather than a limitation. However, for projects exceeding five storeys, additional stabilizing elements such as solid internal walls, braced frames, or a concrete core are required to meet structural and lateral stability demands, which can increase both material use and overall project cost. Despite these considerations, volumetric timber construction remains an efficient and high-performance method for projects that benefit from precision manufacturing, speed of assembly, and predictable structural behaviour. [46]

45 Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction."

46 Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction."

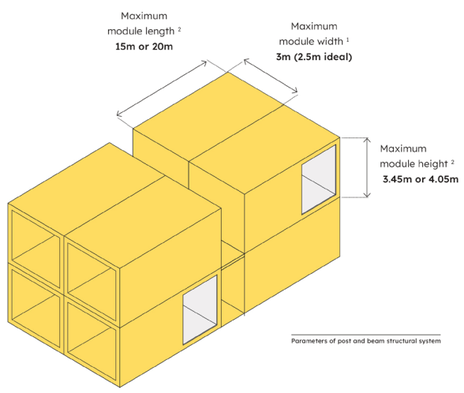


Figure 22: Parameters of Volumetric Modular Mass Timber Construction (Image Source: Timber Typologies: Timber Development UK) Page 42, figure used with permissions from Timber Development UK.

Volumetric modular timber construction uses factory-built three-dimensional units made from engineered wood components such as LVL and glulam for beams and columns, and CLT for floors and some walls. These modules can be delivered either fully finished or as structural shells requiring on-site completion. The system is most effective for low- and mid-rise residential projects, offering major reductions in construction time since on-site work is limited to foundations, placement, and connections. Module dimensions must be planned carefully to meet transportation and highway constraints, and layouts offer flexibility especially when CLT allows non–load-bearing internal walls though alignment limitations can affect stacking. While individual modules could technically be reused elsewhere, the practical demountability of full buildings is limited by the modular configuration and connection strategies. [47]

1.4.3 Advantages & Disadvantages of Mass Timber's Volumetric Modular off-site construction

Cross-laminated timber (CLT) volumetric systems form a natural extension of the thesis' exploration of mass timber as both material and spatial framework. CLT volumetric modules integrate structure, enclosure, and spatial organization into prefabricated units that can be stacked, and combined in multiple configurations, aligning directly with the thesis' focus on modularity, massing, and spatial play. By embedding structural integrity within volumetric units, CLT volumetric construction allows designers to treat each module as both a building block and a spatial container, enabling rapid assembly while maintaining flexibility for diverse typologies and communal spaces.

Recent applications demonstrate the versatility of this approach. For example, CBT Architects discuss the fundamentals of mass timber and the use of prefabricated volumetric units to accelerate construction while reducing waste and embodied carbon. [48]

Ergodomus' Heimdalsporten, a project located in Trondheim Norway, Europe is a Hybrid Modular completed project that exemplifies how modular CLT units can be used to create adaptable high-density housing by combining modular units with hybrid construction techniques, producing both efficiency and spatial richness. [49]

Similarly, the Tuinfluiter Building project located in Heerhugowaard, Holland, Europe is a completed Volumetric Modular project that illustrates how volumetric modules can be deployed in a flexible, repetitive logic that supports rapid construction while allowing for varied interior layouts and social spaces.[50]

The disadvantage includes shipping a lot of air, double elements of floors and ceiling on each level, and double wall between each unit.

47 Timber Development UK Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction," November 20, 2024, https://timberdevelopment.uk/resources/timber-typologies/.

48 "Mass Timber Part I: The Fundamentals," CBT, accessed November 10, 2025, https://www.cbtarchitects.com/news-ideas/mass-timber-part-i-fundamentals.

49 "Heimdalsporten Hybrid Volumetric Modular Building - Trondheim, Norway | Projects," Ergodomus, n.d., accessed November 10, 2025, https://www.ergodomus.it/projects/heimdalsporten-hybrid-modular/.

50 "Tuinfluiter Volumetric Modular Building - Heerhugowaard, Holland | Projects," Ergodomus, n.d., accessed November 10, 2025, https://www.ergodomus.it/projects/tuinfluiter-modular/.

These projects underscore that volumetric CLT modules are not solely a structural solution; they are a medium for architectural experimentation. Their integration into the thesis' iterative design methodology enables exploration of additive and subtractive massing strategies, communal interstitial spaces, and modular stacking systems, while also addressing urgent environmental imperatives through low-carbon, prefabricated construction. By situating the research within the context of contemporary CLT volumetric applications, the study demonstrates both the practical feasibility and the spatial potential of mass timber as a generator of socially and environmentally responsive high-rise housing. Mass timber's modular off-site construction offers a great potential for reduced material waste, lower carbon emissions, minimized site disruption, and scalable solutions for both urban mass housing and rural or remote communities.

1.4.4 Hybrid Systems of Mass Timber Construction.

Hybrid mass timber systems combine timber with materials such as steel or concrete to take advantage of the strengths of each, improving structural efficiency, reducing material use, and lowering costs. These systems can range from mostly timber mixing lightweight framing with mass timber elements to timber–steel or timber–concrete combinations and may also include concrete cores when additional lateral stability or non-combustible exits is required. Because hybrid buildings rely on components from multiple suppliers, coordination and procurement can be more complex, but the benefits of prefabrication precision, high quality, and faster construction remain. Since floor slabs typically use the most material in a building, placing timber in these horizontal elements helps significantly reduce embodied carbon, especially when compared with steel or concrete, which have higher carbon footprints. Structurally, steel and concrete are often used for beams and columns in hybrid systems, with steel such as
castellated beams providing long spans and space for building services, and precast concrete offering similar advantages or improved performance in flood-prone ground-level areas. Although hybrids are heavier than all-timber systems, they still reduce foundation loads and can be advantageous on sites with difficult soil conditions, restrictive easements, or close proximity to existing structures, while maintaining material efficiency and lowering overall carbon impacts.[51]

The Council on Tall Buildings and Urban Habitat identifies four primary structural categories for mass timber buildings: All-Timber, Concrete-Timber Hybrid, Steel-Timber Hybrid, and Concrete-Steel-Timber Hybrid.

51 Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction."

1. All Timber Structures

An "all-timber" building is one where the main structural components above ground such as the vertical supports, floor-spanning systems, and lateral load-resisting elements are made entirely from timber. Small non-timber connectors can still be used where needed to join timber elements without disqualifying the system. A structure can also be classified as "all-timber" even if its timber floor panels are topped with concrete, if the concrete does not carry structural loads and is used only for added mass, acoustic performance, or vibration control (2022). As of 2022, the tallest building constructed entirely from timber is Mjösa¬tårnet in Brumunddal, Norway, reaching 85 metres.[52]

2. Concrete-Timber Hybrid Structures

In hybrid concrete-timber buildings, the primary above-ground structural elements including vertical supports, floor systems, and lateral load-resisting components are constructed from timber, concrete, or a combination of the two. A common strategy employs a concrete core to stabilize an encompassing timber frame. Some designs use concrete beams and columns for structural support, with timber forming the floor decking. Prefabricated solutions are also prevalent, combining concrete frames with timber wall or floor panels, or integrating timber modules atop concrete floors. Notably, the tallest example of this hybrid typology is the Ascent building in Milwaukee, USA, which reaches a height of 87 meters. [53]

3. Steel-Timber Hybrid Structures

Steel-timber hybrid structures combine timber and steel in all primary above-ground elements, including vertical supports, floors, and lateral-force-resisting components. These buildings often use steel cores, braces, or frames for lateral stability, alongside timber-based gravity systems for floors and walls, representing a greater integration of steel than typical timber construction. The tallest example of this typology is the Sara Kulturhus in Skellefteå, Sweden, at 73 meters. [54]

4. Concrete-Steel-Timber Hybrid Structures

Concrete-steel-timber hybrid structures integrate timber, steel, and concrete in all primary above-ground elements, including vertical supports, floors, and lateral-force-resisting components. A typical approach uses a concrete core with steel beams and columns, while timber forms floors and interior walls, though multiple combinations are possible. The tallest example of this typology is De Karel Doorman in Rotterdam, Netherlands, at 71 meters. [55]

52 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings., CTBUH Technical Guides. (Council on Tall Buildings and Urban Habitat., 2023).

53 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings., CTBUH Technical Guides. (Council on Tall Buildings and Urban Habitat., 2023).

54 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings., CTBUH Technical Guides. (Council on Tall Buildings and Urban Habitat., 2023).

55 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings., CTBUH Technical Guides. (Council on Tall Buildings and Urban Habitat., 2023).

1.5 State of Tall Timber Buildings – Global Audit

Recent data indicates that the global mass timber movement has gained significant traction, with 139 high-rise mass timber buildings, eight stories or taller, either completed, under construction, or proposed. This dataset has been compiled over nearly a decade through a combination of CTBUH Journal publications, conference presentations, volunteer research efforts, and a dedicated "tall timber" audit conducted in February 2022. More recently, the Council on Tall Buildings and Urban Habitat (CTBUH) has sponsored research projects examining the technical, structural, and architectural applications of mass timber in high-rise construction. According to CTBUH, a "proposed" building is defined as one with a specific site under development, a professional design team engaged beyond the conceptual stage, formal planning consent in progress, and an explicit intention to construct and complete the building.[56]

1.5.1 Tall Mass Timber Buildings by Functions

Globally, the majority of high-rise mass timber buildings over eight stories that have been completed to date are residential, accounting for 63 of 99 buildings, or approximately 64 percent. Office buildings make up 23 percent (23 buildings), mixed-use developments represent 11 percent (11 buildings), and institutional projects comprise only 2 percent (2 buildings) (see Figure 23). This distribution reinforces the benefits and potential of mass timber outlined in Chapter 1.3.1, particularly its appeal for residential applications. Many developers are drawn to mass timber for its aesthetic qualities, with exposed structural panels and wood finishes enhancing the character of individual units and communal spaces. [57]

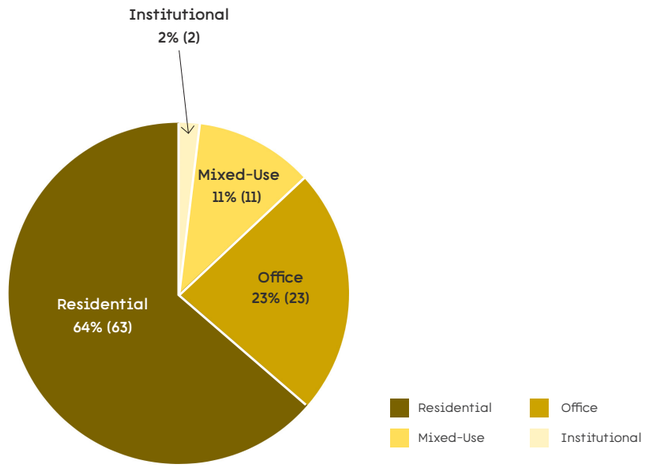


Figure 23: Tall Mass Timber Buildings by Function by CTBUH. Author's drawing adapted from Tall Timber: Mass Timber for High-Rise Buildings., CTBUH Technical Guides. (Council on Tall Buildings and Urban Habitat., 2023).

56 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

57 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

This predominance of residential use underscores why this thesis focuses primarily on advancing mass timber for housing. By leveraging mass timber's prefabricated modularity, environmental performance, and expressive spatial possibilities, the research aims to expand its potential beyond conventional applications, exploring how volumetric mass timber systems can generate adaptable, socially rich, and environmentally responsible high-rise residential buildings. The thesis builds on existing practice while pushing the boundaries of mass timber's spatial and structural versatility in residential contexts.

1.5.2 Tall Mass Timber Buildings by Structural Systems

The CTBUH audit and technical guide categorize structural systems for high-rise mass timber buildings into four main types: all-timber, concrete-timber hybrid, steel-timber hybrid, and concrete-steel-timber hybrid. The Pie chart in (Figure 24) shows that among buildings eight stories and taller, nearly half (46 of 99, or 46 percent) utilize an all-timber structural system, while concrete-timber hybrids account for 31 percent, steel-timber hybrids 12 percent, and concrete-steel-timber hybrids 10 percent. [58]

This distribution reveals an interesting trend. Despite common assumptions that timber's relative lightness and flexural properties would limit building height, many projects have successfully employed purely timber structures without hybridization. This demonstrates the evolving confidence in mass timber as a primary structural material for high-rise construction and supports the thesis' focus on exploring volumetric mass timber systems as both a structural and spatial strategy for residential buildings.

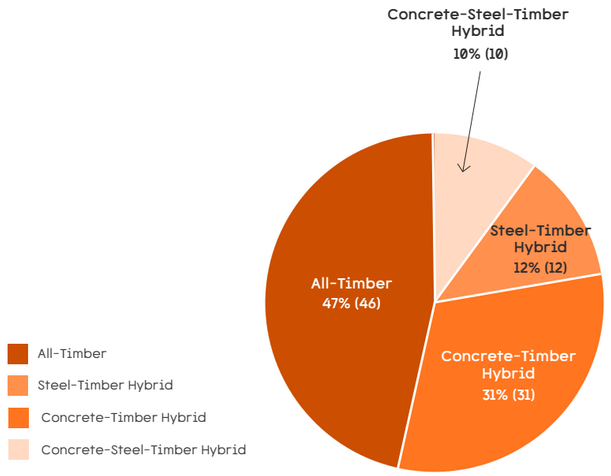


Figure 24: Tall Mass Timber Buildings by Structural System- by CTBUH. Author's drawing adapted from Tall Timber: Mass Timber for High-Rise Buildings., CTBUH Technical Guides. (Council on Tall Buildings and Urban Habitat., 2023).

58 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings., CTBUH Technical Guides. (Council on Tall Buildings and Urban Habitat., 2023).

1.5.3 Tall Mass Timber Buildings by Region

Europe leads the world in high-rise mass timber construction, accounting for 67 percent of completed buildings, a position supported by its origins in mass timber technology, well-managed forests, and strict environmental regulations (CTBUH 2023, Figure 25). North America follows with 20 percent, benefiting from extensive forests and a long tradition of wood construction, though not historically in mass timber. Oceania contributes 11 percent of the total, notable for early high-rise mass timber projects such as Forte in Melbourne and 25 King in Brisbane, despite a comparatively small domestic timber industry that relies heavily on imports from Europe. Asia currently has only two high-rise mass timber buildings (2 percent), though this region is expected to experience significant growth in the coming years.[59]

59 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

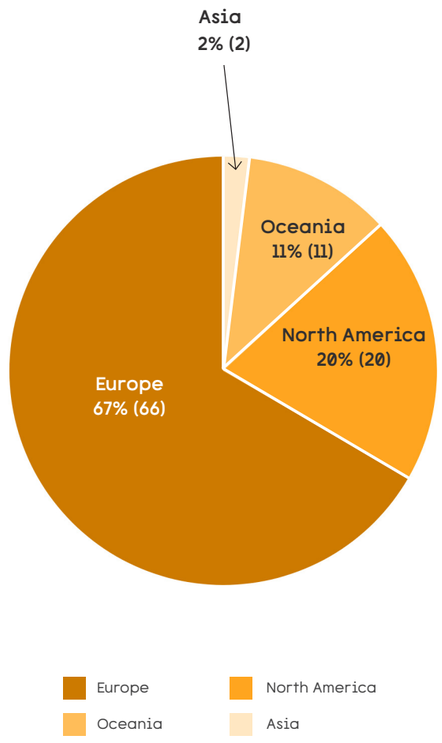


Figure 25: Tall Mass Timber Buildings by Region by CTBUH. Author's drawing adapted from Tall Timber: Mass Timber for High-Rise Buildings., CTBUH Technical Guides. (Council on Tall Buildings and Urban Habitat., 2023).

1.6 The Design Gap

Much of the contemporary discourse on mass timber positions it primarily as a technical and environmental solution, emphasizing structural performance, prefabrication efficiency, embodied carbon reduction, and construction speed. While these attributes have been instrumental in advancing the adoption of mass timber in mid- and high-rise construction, they have also contributed to a narrow framing of the material one that prioritizes technical feasibility over architectural exploration. As a result, mass timber is frequently discussed as a means of optimizing building performance rather than as a medium capable of shaping spatial experience, form, and modes of inhabitation. Its potential as a volumetric, modular, and spatial system one that can actively influence dwelling typologies, social interaction, and architectural expression remains comparatively underexplored within both academic and professional practice.

This imbalance reveals a critical design gap: the limited investigation of mass timber as a driver of architectural form and spatial richness in high-rise housing.[60]

Evidence of this tendency is reflected in influential studies examining the barriers to mass timber adoption. For example, the Architecture 2030 Pilot Study on Mass Timber in North America identifies challenges related to cost uncertainty, lack of contractor expertise to regulatory inconsistencies, building code limitations, and supply chain constraints. While these factors are essential to understanding the practical realities of mass timber construction, they also reinforce a broader professional focus on technical, regulatory, and logistical concerns, often at the expense of architectural creativity, spatial innovation, and inhabitation strategies.[61]

This thesis responds directly to this design gap by reframing mass timber not only as a construction material, but as a modular and volumetric architectural system. By treating mass timber assemblies as both structure and space-making elements, the research explores how repetition, aggregation, and selective subtraction can generate diverse dwelling typologies and shared social spaces within high-rise residential buildings. In doing so, the study positions mass timber as a catalyst for adaptable, expressive, and socially engaging housing environments, demonstrating that architectural richness and spatial innovation can coexist with the technical and environmental demands of contemporary urban construction.

60 Steffen Lehmann and Paul D. Kremer, "Filling the Knowledge Gaps in Mass Timber Construction.," Mass Timber Construction Journal 6, no. 1 (2023): 1–10.

61 Scott Francisco et al., "MASS TIMBER TIPPING POINT: A Study of Mass Timber Uptake Through the Experiences of North America's Leading Architects and Engineers," Final Report, n.d.

Current research on mass timber frequently emphasizes modularity, structural efficiency, and circular economy principles, including grid optimization, material reduction, zero-waste construction, and hybrid construction strategies. Studies highlight approaches such as volumetric modules, modular systems, retrofitting, and end-of-life planning to achieve lighter buildings, reduced material use, and faster construction (Journal of Mass Timber Construction 2022).[62]

While these studies provide important insights for sustainable and efficient mass timber construction, they largely measure success through structural performance, carbon storage, or economic metrics, rather than the spatial, social, and creative possibilities of mass timber.

This observation reinforces the design gap identified in this thesis: mass timber is often treated primarily as a technical or logistical solution, leaving its potential as a medium for spatial experimentation, volumetric play, and adaptive high-rise housing underexplored. By focusing on repeatable, modular volumetric units as both structural elements and generators of inhabitable space, this research aims to bridge that gap, demonstrating how mass timber can create socially rich, flexible, and environmentally responsible residential environments, particularly in the high-rise multi-unit residential building housing sector. [63]

62 Lehmann and Kremer, "Filling the Knowledge Gaps in Mass Timber Construction."

63 Lehmann and Kremer, "Filling the Knowledge Gaps in Mass Timber Construction."

Research Goal

1.7 Research Goal

To explore how modular mass timber volumetric and panelized units can be combined and arranged to create flexible, livable, and socially engaging high-rise housing that is environmentally friendly, architecturally expressive, and adaptable to different site contexts and programmatic requirements.

1.8 Research Objectives

- Develop a Case Study Analysis: Conduct an in-depth examination of five high-rise mass timber buildings to understand existing modular and spatial arrangements, structural strategies, and design patterns.

- Establish Pattern Recognition: Identify recurring volumetric and spatial patterns in the case studies that influence livability, flexibility, and social engagement.

- Iterate Design Configurations: Test and refine modular arrangements through digital modeling and speculative design studies to explore spatial possibilities and variations.

- Create Design Rules/Logic: Formulate a set of guidelines for arranging mass timber volumetric units to generate adaptable, socially rich, and environmentally responsive high-rise housing.

- Adapt to Context: Apply the proposed modular strategies to chosen site conditions, programmatic requirements, and urban contexts.

1.9 Research Scope

This research explores modular mass timber volumetric and panelized systems as a tool for spatial, creative, and social experimentation in high-rise urban housing. Focusing on residential buildings from 12 to 25 stories, it investigates how modular units can be arranged, aggregated, or manipulated to create flexible, livable, socially engaging, and environmentally responsible spaces.
Emphasizing architectural creativity and expression alongside sustainability, low embodied carbon construction, and affordability, the study uses case studies, pattern analysis, and iterative digital modeling to develop adaptable design strategies that can be applied to diverse urban contexts, programmatic needs, and environmental conditions.

1.10 Research Questions

1. How can modular mass timber volumetric & panelized units be arranged and configured to create high-rise housing that is flexible, socially engaging, environmentally responsible, and architecturally expressive?

2. What recurring spatial and modular patterns can be observed in existing high-rise mass timber buildings, and how can they inform adaptable and livable design strategies?

3. What design rules or logics can guide the configuration of modular mass timber units for diverse programmatic and site contexts?

4. How can iterative digital modeling and speculative design be used to test, refine, and balance architectural creativity, social engagement, and environmental performance in volumetric arrangements?

Chapter 2 | Literature Review

Chapter 2 - Literature Review

2.1 Introduction

Globally, designers, architects, and engineers are increasingly exploring the potential of mass timber for mid- to high-rise construction. Conceptual proposals are testing the structural, material, and regulatory boundaries of timber construction at extreme heights. Notable examples such as the Oakwood Tower in London (80 storeys, PLP Architecture), the River Beech Tower in Chicago (80 storeys, Perkins+Will and Thornton Tomasetti), and other visionary studies illustrated in Figure 19 demonstrate the growing ambition and confidence in mass timber's potential for tall building construction. These projects have expanded the global discourse on timber architecture, proving its technical feasibility and inspiring continued innovation at urban scales.

Building on this momentum, this thesis explores the architectural and spatial potential of mass timber within a feasible range of 12–25 storeys. It investigates how modular volumetric timber systems can produce flexible, communal, and environmentally responsive high-rise housing typologies that enhance the quality of urban living advancing mass timber design beyond questions of height and structure toward new forms of spatial and social innovation.

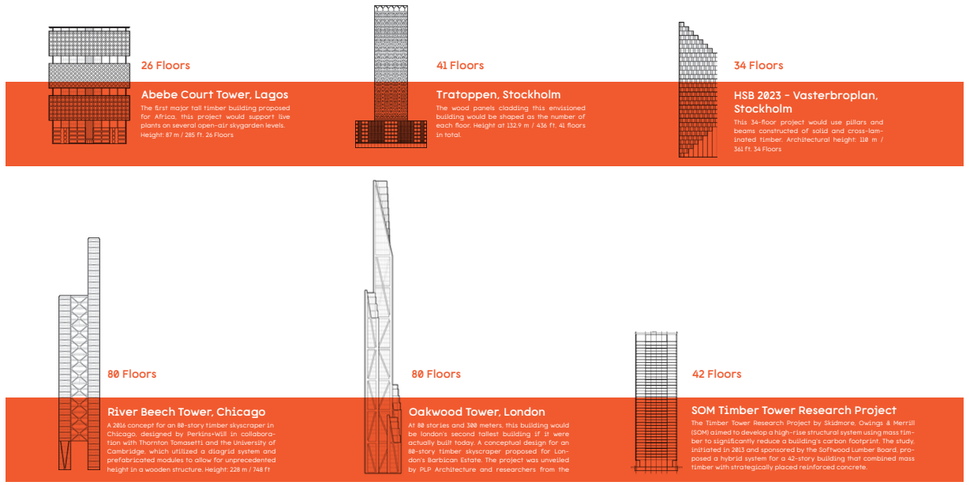


Figure 26: Conceptual Proposal of timber construction methods at "extreme heights".
Source: CTBUH.

This chapter presents a comparative analysis of five pioneering high-rise mass timber buildings, **Brock Commons Tallwood House (Vancouver)**, L**ighthouse Joensuu (Finland), Mjøstårnet (Norway), Ascent (Milwaukee, USA), and Treet (Bergen, Norway)** to identify patterns of modular organization, structural logic, and spatial aggregation that inform the architectural framework of this thesis. Each case exemplifies the potential of mass timber as massing: a material system that operates simultaneously as structure, space, and expressive form.

By analyzing the modular grids, vertical cores, communal interventions, and volumetric aggregations of these case studies, this chapter distills recurring architectural logics that guide the development of the design strategies explored in later chapters. These precedents collectively demonstrate how modular timber systems can support both technical efficiency and social engagement, while maintaining expressive architectural identity.

2.2 Case Study Selection Criteria

This research analyzes five high-rise (12–25 storey) mass timber multi-unit residential buildings (MURBs) completed after 2012 in cold climates (ASHRAE Zones 5–7). The selection prioritizes projects that explore modular and compact massing strategies such as stacking, interlocking, carving, or aggregating that contribute to creative spatial organization, social interaction, and livable vertical communities.

While an initial survey considered approximately 25 global mass timber projects, five were selected through the following criteria to enable focused analysis of architectural, spatial, and social patterns (see Table 1). The five selected case studies vary in geographic context, structural system, and programmatic composition, representing diverse approaches to integrating modular timber in tall building design.

2.2.1 Selection Criteria

1. Completion Year: Completed post-2012 to reflect contemporary mass timber technologies, modular construction, and housing design practices.

2. Building Function: Primarily residential or mixed-use projects with a housing component that fosters community and shared living conditions.

3. Building Height: Between 12 and 25 storeys, representing the emerging scale of mid- to high-rise mass timber applications.

4. Structural System: Predominantly mass timber (CLT, glulam, or hybrid timber systems) with a clear modular or grid-based structural logic.

5. Architectural Documentation: Availability of detailed design information plans, sections, elevations, grid spacing, gross floor area, building footprint, and floor-to-floor heights to support spatial and massing analysis.

6. Compact Massing and Modularity: Demonstrates distinct modular, volumetric, or compositional strategies (e.g., stacking, interlocking, aggregation, or carved volumes) that enable spatial variation and architectural expression within structural limits.

7. Social and Communal Quality: Prioritizes projects that integrate shared or collective spaces, fostering interaction and a sense of community within vertical housing environments.

8. Data Accessibility: Supported by credible, publicly available documentation from architectural firms, publications, or research databases.

2.2.2 Overview of Case Study Projects

The Table 1 shows the selected 5 case studies highlighted in orange.
Summary of Selected Mass Timber Case Studies:

1. **Brock Commons Tallwood House (Vancouver, Canada)**
   Stories: 18
   Height: 58 meters
   Completion: 2017

2. **Lighthouse (Joensuu, Finland)**
   Stories: 14
   Height: 48 meters
   Completion: 2019

3. **Mjöstårnet (Brumunddal, Norway)**
   Stories: 18
   Height: 85.4 meters
   Completion: 2019

4. **Ascent (Milwaukee, USA)**
   Stories: 25
   Height: 86.6 meters
   Completion: 2022

5. **Treet (Bergen, Norway)**
   Stories: 14
   Height: 49 meters
   Completion: 2015

Case Studies & Pattern Recognition

	s/n	Building Name	City, Country	Height	Floor Count	Structural System	Function	Completion Year
NORTH AMERICA	1	Ascent	Milwaukee, USA	86.6m	25	Concrete-Timber Hybrid	Residential	2022
	2	Brock Commons Tallwood	Vancouver, Canada	57.9m	18	Timber-Concrete Hybrid	Residential	2017
	3	Origine	Quebec, Canada	40.9m	13	All-Timber	Residential	2017
	4	INTRO Residential Tower	Cleveland, USA	39.6m	9	Timber-Concrete Hybrid	Mixed-Use	2022
	5	2150 Keith Drive	Vancouver, Canada	45m	10	Timber-Concrete Hybrid	Office	2022
	6	T3 Bayside	Toronto, Canada	42m	25	All-Timber	Office	2023
	7	Tallwood 1 (District 56)	Victoria, Canada	41m	12	Timber-Steel Hybrid	Office	2022
EUROPE	8	Mjøstarnet	Brumunddal, Norway	85.4m	18	All-Timber	Mixed-Use	2019
	9	Hoho	Vienna, Austria	84m	24	Timber-Concrete Hybrid	Mixed-Use	2020
	10	Sara Kulturhus	Skellefteå, Sweden	72.8m	19	Timber-Steel Hy-	Mixed-Use	2021
	11	HAUT	Amsterdam, Netherlands	73m	22	Timber-Concrete Hybrid	Residential	2022
	12	De Karel Doorman	Rotterdam, Netherlands	70.5m	22	Timber-Concrete-Steel Hybrid	Mixed-Use	2012
	13	Roots Tower	Hamburg Germany	65m	19	Timber-Concrete Hybrid	Residential	2024
	14	Hyperion	Bordeaux, France	55m	16	Timber-Concrete-Steel Hybrid	Residential	2021
	15	Albizzia	Lyon, France	53m	17	Timber-Concrete Hybrid	Mixed-Use	2023
	16	Lighthouse Joensuu	Joensuu, Finland	48m	14	Timber-Steel Hybrid	Residential	2019
	17	Cederhusen	Stockholm, Sweden	44m*	13	All-Timber	Residential	2023
	18	SKAIO	Heilbronn, Germany	34m	10	Timber-Concrete Hybrid	Residential	2019
	19	Puukuokka Housing Block	Jyvaskyla, Finland	27m*	8	All-Timber	Residential	2018
	20	Treet	Bergen, Norway	49m	14	All-Timber	Residential	2015
	21	Dalston Works	London, UK	33.8m	10	All-Timber	Residential	2017
	22	Rundeskogen Hus B	Sandnes, Norway	34m	10	Timber-Concrete Hybrid	Residential	2012
AUSTRALIA	23	25 King	Brisbane, Australia	46.8m	11	All-Timber	Office	2018
	24	55 Southbank	Melbourne, Australia	69.7m	19	Timber-Concrete-Steel Hybrid	Mixed-Use	2020
	25	Forte	Melbourne, Australia	32.2m	10	All-Timber	Residential	2012

SELECTION CRITERIA

Completed after 2012	Cold Climate	Residential or Mixed use	Avalaible Informations	12 - 50 storeys	Compact Massing	Operative Verb Alignment	Overall Selection
●	●	●	●	●	●	●	●
●	●	●	●	●	●	●	●
●	●	●	●	●		●	
●	●	●	●			●	
●	●		●			●	
●	●		●	●		●	
●	●		●	●		●	
●	●	●	●	●	●	●	●
●	●	●	●			●	
●	●	●	●	●	●	●	
●	●	●	●	●	●	●	
●		●	●	●		●	
●	●	●	●	●		●	
●	●	●	●	●	●	●	●
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●	●	●	●		●	●	
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●	●	●	●	●	●	●	●
●	●	●	●			●	
	●	●	●			●	
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Table 1: Case Study Selection Table.

Case Studies & Pattern Recognition

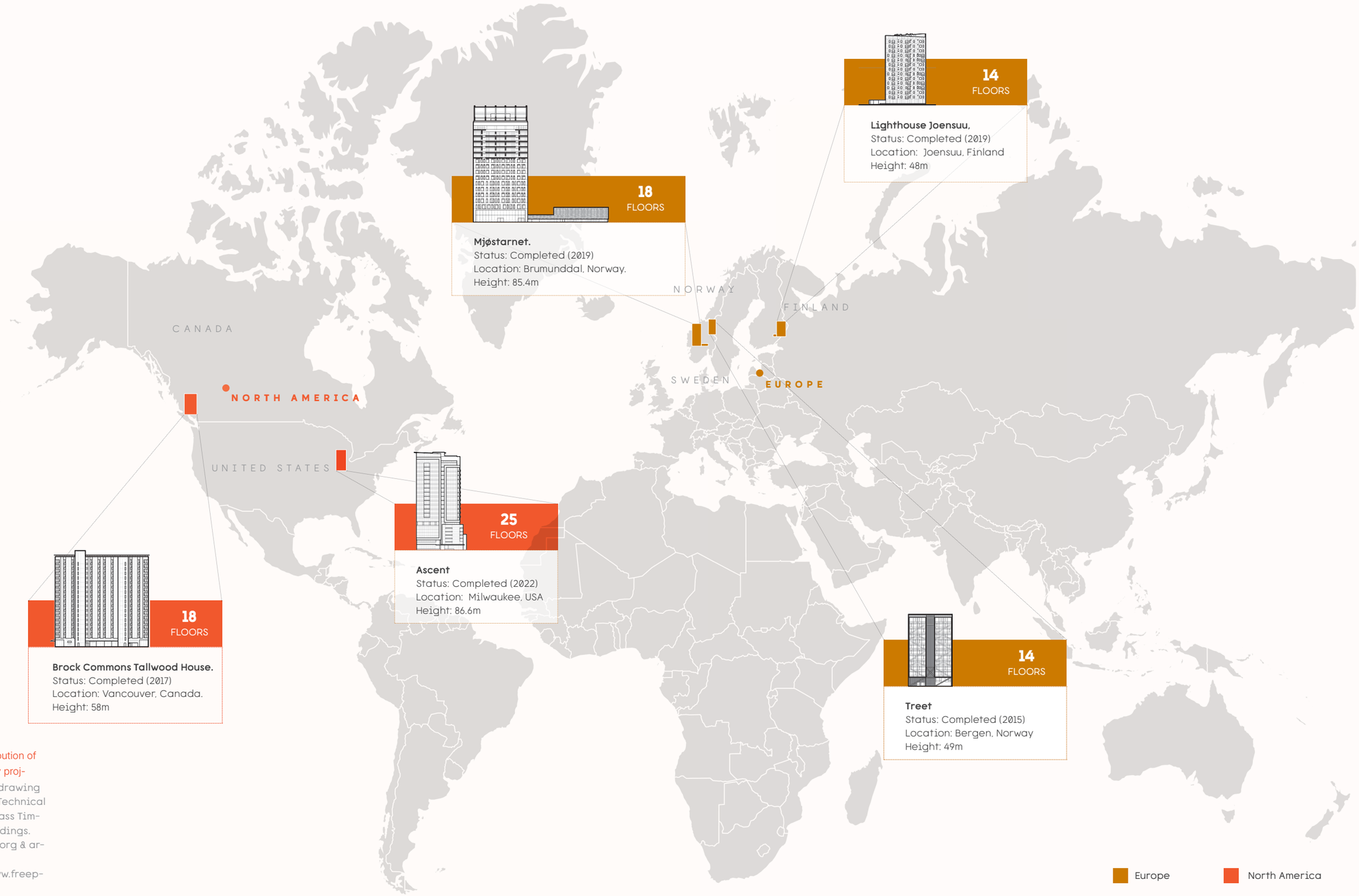


Figure 27: Global Distribution of the Selected case study projects. Source: Author's drawing adapted from CTBUH Technical Guides: Tall Timber: Mass Timber for High-Rise Buildings. Image Source: CTBUH.org & architectureprize.com
World Map Source. www.freepik.com

Case Studies - Quantitative Case Study Extractions

SELECTED CASE STUDY

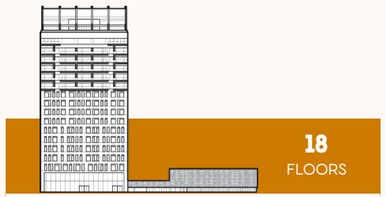
Table 2: Key Building Geometry information of selected case study projects. Source: Author's drawing adapted from CTBUH Technical Guides: Tall Timber: Mass Timber for High-Rise Buildings. Image Source: CTBUH.org.



Brock Commons Tallwood House.
Status: Completed (2017)
Location: Vancouver, Canada.
Height: 58m



Lighthouse Joensuu,
Status: Completed (2019)
Location: Joensuu, Finland
Height: 48m



Mjøstarnet.
Status: Completed (2019)
Location: Brumunddal, Norway.
Height: 85.4m

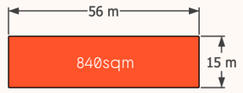
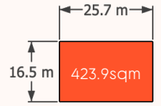
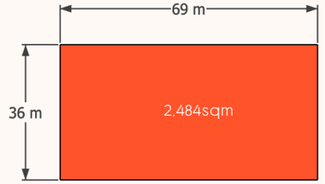
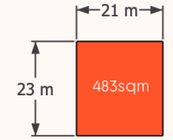
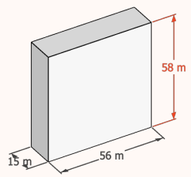
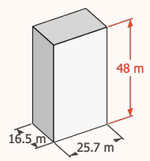
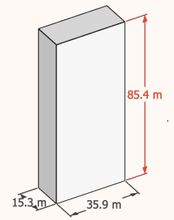
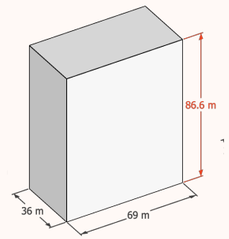
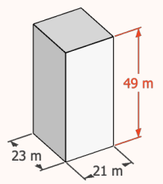


Ascent
Status: Completed (2022)
Location: Milwaukee, USA
Height: 86.6m



Treet
Status: Completed (2015)
Location: Bergen, Norway
Height: 49m

KEY BUILDING GEOMETRY DRIVERS

Building Footprint (Tower) (m)					
Plan Aspect Ratio (Length/Width)	56m/15m = 3.73 : 1	25.7m/16.48m = 1.56 : 1	35.9m/15.3m = 2.35 : 1	69m/36m = 1.92 : 1	23m/21m = 1.10 : 1
Height (m)	58m 	48m 	85.4m 	86.6m 	49m 
Total Gross Floor Area (GFA)	15,120 sqm	5,935 sqm	11,480 sqm	47,909 sqm	8,080 sqm
Building Envelope Area (BEA)	9,916 sqm	4,896 sqm	6,006 sqm	23,154 sqm	4,891 sqm
Compartment Index = (BEA/GFA)	9,916 sqm/15,120 sqm = 0.60	4,896 sqm/5,935 sqm = 0.82	6,006 sqm/11,480 sqm = 0.52	23,154 sqm/47,909 sqm = 0.48	4,891 sqm/8,080 sqm = 0.61

The five selected case studies represent a global snapshot of mid-to-high-rise mass timber construction, featuring projects from Norway, Finland, Canada, and the USA, with completion dates ranging from 2015 to 2022. The buildings, namely Brock Commons Tallwood House, Lighthouse Joensuu, Mjøstårnet, Ascent, and Treet, vary in height from 48 meters to 86.6 meters, 14 to 25 floors, demonstrating the scalability of the technology. The quantitative analysis reveals key metrics for each project, including their gross floor area, building footprint, building envelope area and the calculated ratio of footprint to total area, in Table 2 which provides insight into their respective massing and efficiency. This data forms a basis for comparative analysis of architectural scale and form in modern timber engineering.

2.2.3 Quantifying Urban Building Form: The Spacematrix as a case study lens While the architectural potential of mass timber lies in its modular assembly and volumetric flexibility, its broader importance is measured by how it performs within the dense fabric of the city. To move beyond looking only at the form of individual buildings, this study uses the Spacematrix framework, developed by Meta Berghauser Pont and Per Haupt, as a way to understand how mass timber buildings contribute to urban density, livability, and spatial quality.

The research began with a comparative survey of 40 mass timber residential and mixed-use buildings from around the world (Table 3). This initial study examined their height, density, and site relationships to identify common patterns and strategies. From this larger set, the same five representative high-rise projects were selected for deeper analysis. Key building data; gross floor area, site area, and building footprint, were collected to calculate the core spatial indices that structure the Spacematrix framework: the Floor Space Index (FSI), Ground Space Index (GSI), and Open Space Ratio (OSR). [64]

The Spacematrix offers a simple but powerful way to describe how buildings relate to their surroundings. Instead of relying on general measures like dwellings per hectare, it uses three key indicators that together describe the "spatial DNA" of urban form:

1. Floor Space Index (FSI) – measures the total built floor area relative to the site area, showing how dense or intense the development is.

2. Ground Space Index (GSI) – shows how much of the ground is covered by the building, revealing massing strategies and how the project sits on the site.

3. Open Space Ratio (OSR) – measures the amount of unbuilt or open space, giving insight into the spatial relief, light, and potential for shared outdoor areas. [65]

64. Meta Berghauser Pont and Per Haupt, Spacematrix: Space, Density and Urban Form - Revised Edition, in TU Delft OPEN Books (TU Delft OPEN Books, 2023), https://doi.org/10.59490/mg.38.

65. Pont and Haupt, Spacematrix.

Applied to the selected case studies, these three measures help reveal the unique characteristics of each project. The FSI shows how each contributes to compact, efficient development; the GSI explains whether the buildings are low and broad or tall and slender; and the OSR highlights how the design creates openness and livable communal spaces.

Building Intensity (FSI)

(Floor Space Index) FSI reflects the building intensity independently of the programmatic composition. FSI = Gross Floor Area (F) / Site Area (A)

Coverage (GSI)

GSI, or coverage, demonstrates the relationship between built and non-built space. GSI = Building Footprint (B) / Site Area (A)

Spaciousness (OSR)

The variable OSR, or spaciousness, is a measure of the amount of non-built space at ground level per square meter of gross floor area.

OSR = (1 - GSI) / FSI

In this way, the Spacematrix bridges the gap between architecture and urban design. It provides a clear foundation for understanding how design choices at the building scale influence the experience and performance of the city around them. This analysis also sets the stage for the next phase of the research, which looks more closely at the architectural logic inside these buildings their structural grids, modular units, and spatial configurations to connect measurable urban performance with lived spatial experience. [66]

2.3 Case Study Observation & Analysis

The Table 3 & Table 4 presents a comparative overview of 40 mass timber residential and mixed-use projects, including Gross Floor Area (GFA), Site Area, and Building Footprint to calculate the FSI, GSI and OSR. Data were collected primarily from official project websites, where available. In cases where information was not publicly accessible, Autodesk Forma, Google Maps, and OpenStreetMap were used to estimate site dimensions and building footprints. This dataset provides the foundation for calculating key urban metrics such as the Floor Space Index (FSI), Ground Space Index (GSI), and Open Space Ratio (OSR), which are used to analyze and compare the density and spatial configuration of mass timber projects at a global scale.

66 Meta Berghauser Pont and Per Haupt, Spacematrix: Space, Density and Urban Form - Revised Edition, in TU Delft OPEN Books (TU Delft OPEN Books, 2023), https://doi.org/10.59490/mg.38.

Case Study of 40 Mass Timber Projects

s/n	Building Name	Location	Height	Floor Count (L)	Function	GFA	Site Area	Building Footprint	FSI	GSI	OSR
1	HAUT	Amsterdam, Netherlands	73m	21	Residential	14,500 sqm	3,769 sqm	1100 sqm	3.85	0.29	0.18
2	Roots Tower	Hamburg Germany	65m	19	Residential	20,600 sqm	5,827 sqm	2,823 sqm	3.54	0.48	0.15
3	Hyperion	Bordeaux, France	55.5m	16	Residential	17,000 sqm	4,211 sqm	2,340 sqm	4.04	0.56	0.11
4	Rundeskogen Hus B	Sandnes, Norway	54m	16	Residential	11,480 sqm	14,250 sqm	1,463 sqm	0.80	0.1	1.13
5	Cederhusen	Stockholm, Sweden	44m	13	Residential	22,000 sqm	4,541 sqm	2,291 sqm	4.84	0.50	0.10
6	Hoas Tuulonitty	Espoo, Finland	44m	13	Residential	7,584 sqm	3,701 sqm	1,326 sqm	2.05	0.36	0.31
7	Tallwood 1 (District 56)	Langford Canada	41.7m	12	Residential	15,977 sqm	2,422 sqm	1,175 sqm	6.60	0.49	0.08
8	Origine	Quebec, Canada	40.9m	13	Residential	11,547 sqm	2,025 sqm	1,686 sqm	5.70	0.83	0.03
9	Dalston Works	London, UK	33.8m	10	Residential	12,103 sqm	4,091 sqm	1,283 sqm	2.96	0.31	0.23
10	De Karel Doorman	Rotterdam, Netherlands	70.5m	22	Mixed-Use	22,950 sqm	3,120 sqm	3,500 sqm	7.36	0.89	0.01
11	Monterey	Brisbane, Australia	37m	11	Residential	6,810 sqm	1,169 sqm	524 sqm	5.83	0.45	0.09
12	Hoho Wien	Vienna, Austria	84m	24	Mixed-Use	25,000 sqm	3,920 sqm	1,372 sqm	6.38	0.35	0.10
13	Trafalgar Place	London, UK	36.3m	10	Residential	16,660 sqm	11,300 sqm	3,608 sqm	1.47	0.32	0.46
14	Sara Kulturhus	Skellefteå, Sweden	72.8m	20	Mixed-Use	28,000 sqm	7,100 sqm	5,957 sqm	3.94	0.84	0.04
15	Stadhaus	Hackney, Lodon, UK	29m	9	Mixed-Use	2,750 sqm	860 sqm	280 sqm	3.20	0.03	0.30
16	Heartwood	Washington, USA	25.5m	8	Residential	6,123 sqm	1,574.9	781 sqm	3.89	0.50	0.13
17	Forte	Melbourne, Australia	32.2m	10	Residential	2,890 sqm	768 sqm	442 sqm	3.76	0.58	0.11
18	Sensations	Strasbourg, France	38m	11	Residential	9,533 sqm	4,321 sqm	1,764 sqm	2.2	0.41	0.27
19	AVEO Bella Vista	Sydney, Australia	36m	11	Residential	19,866 sqm	59,413 sqm	8,800 sqm	0.33	0.15	2.58
20	SKAIO	Heilbronn, Germany	34m	10	Residential	5,685 sqm	750 sqm	730 sqm	7.58	0.97	0.004
21	The Cube Building	London, UK	33m	10	Residential	6,750 sqm	1,400 sqm	1,200 sqm	4.82	0.86	0.03
22	Cenni di Cambiamento	Mmilan, Italy	31m	9	Residential	9,300 sqm	22,000 sqm	1,026 sqm	0.42	0.05	2.26
23	ANDYS at 1510 Webster st	Oakland, California, USA	65m	19	Residential	17,956 sqm	16,632 sqm	1,394 sqm	1.08	0.08	0.85
24	Carbon 12	Portland, USA	29m	8	Residential	3,530 sqm	1,078 sqm	372 sqm	3.27	0.34	0.20
25	Botanikern	Uppsala, Sweden	31m	9	Residential	13,400 sqm	2,950 sqm	1,827 sqm	4.54	0.62	0.08

Table 3: Case Study of 40 Mass Timber Projects.

s/n	Building Name	Location	Height	Floor Count (L)	Function	GFA	Site Area	Building Footprint	FSI	GSI	OSR
26	Kajstaden	Västerås, Sweden	31m	9	Residential	7,500 sqm	5,183 sqm	2,146 sqm	1.45	0.41	0.41
27	DAS Kelo	Rovaniemi, Finland	27m	8	Residential	4,600 sqm	3,186 sqm	581 sqm	1.44	0.18	0.57
28	Portvakten Housing Block	Jyvaskyla, Finland	27m	8	Residential	5,953 sqm	6,289 sqm	862 sqm	0.95	0.14	0.91
29	Strandparken	Stockholm, Sweden	27m	8	Residential	3,892 sqm	1,598 sqm	540 sqm	2.44	0.34	0.27
30	Emmons on 3rd	Seattle, United States	26.3	8	Residential	3,309 sqm	850 sqm	713.5 sqm	3.89	0.84	0.04
31	Limnologen	Vaxjo, Sweden	27m	8	Residential	10,700 sqm	13,514 sqm	4,438 sqm	0.79	0.33	0.85
32	Hotel Jakarta	Amsterdam, Netherlands	34m	9	Mixed-Use	16,500 sqm	987 sqm	422 sqm	16.7	0.43	0.03
33	Wood City Residential Building	Helsinki, Finland	27m	8	Residential	11,000 sqm	13,000 sqm	1,680 sqm	0.85	0.13	1.02
34	Trummens Strand	Vaxjo, Sweden	27m	8	Mixed-Use	22,200 sqm	13,363 sqm	3,717 sqm	1.67	0.28	0.43
35	Arbora Condominium	Montreal, Canada	27m	8	Mixed-Use	55,515 sqm	9,631 sqm	5,639 sqm	5.76	0.59	0.07
36	Ascent	Milwaukee, USA	86.6m	25	Residential	47,900 sqm	2,650 sqm	2,484 sqm	18	0.94	0.003
37	Brock Commons Tallwood	Vancouver, Canada	57.9m	18	Residential	15,120 sqm	2,315 sqm	840 sqm	6.53	0.36	0.098
38	Mjøstarnet	Brumunddal, Norway	85.4m	18	Mixed-Use Residential	16,000 sqm	12,925 sqm	629 sqm	1.23	0.29	0.58
39	Lighthouse Joensuu	Joensuu, Finland	48m	14	Residential	5,935 sqm	2,360 sqm	424 sqm	2.42	0.27	0.30
40	Treet	Bergen, Norway	49m	14	Residential	8,080 sqm	2,600 sqm	483 sqm	3.1	0.19	0.26

Table 4: Case Study of 40 Mass Timber Projects.

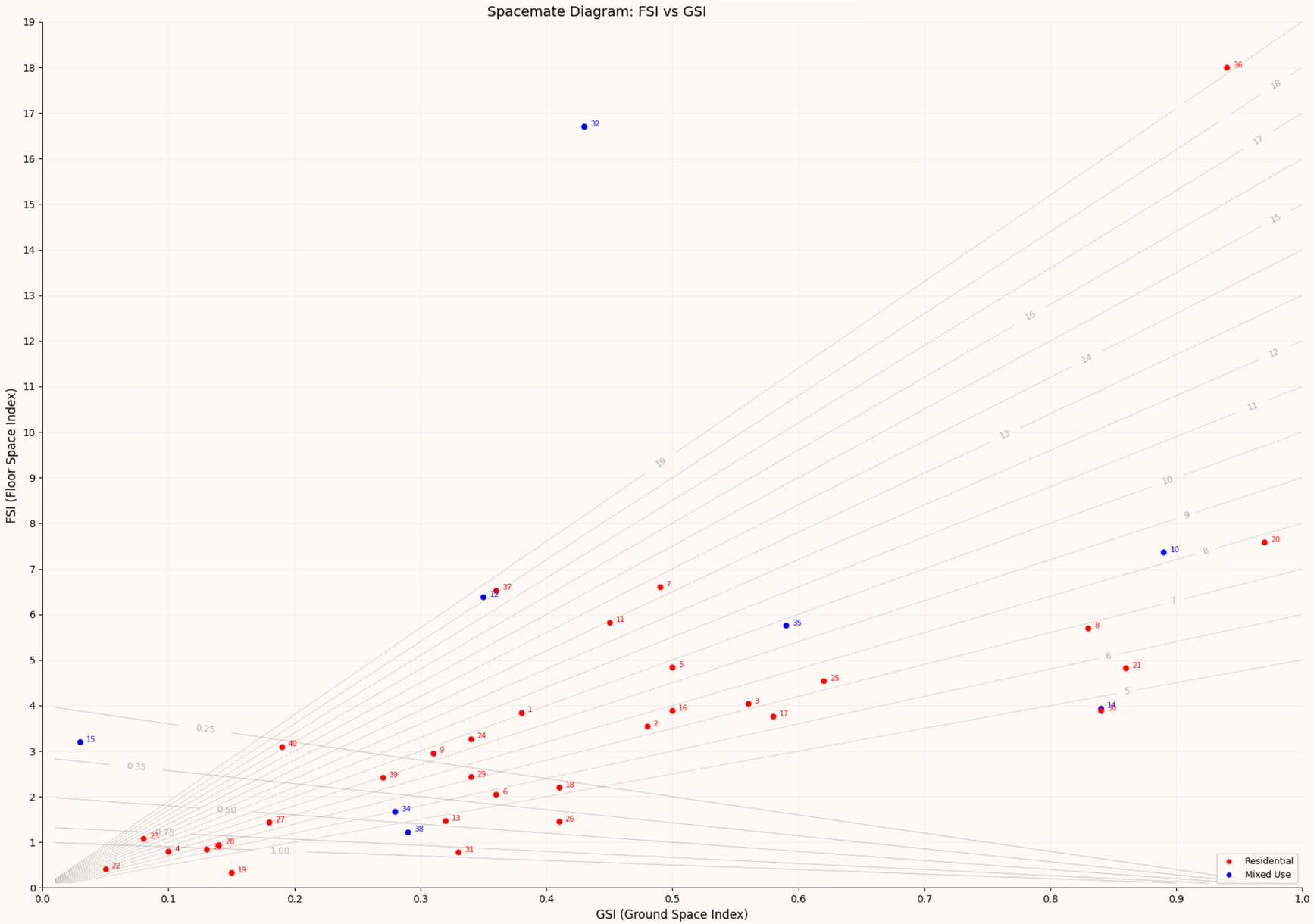
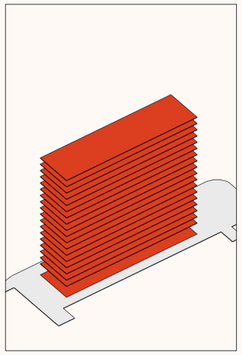


Figure 28: Spacemate diagram of 40 mass timber projects showing the FSI in relation to the GSI



18
FLOORS

Brock Commons Tallwood House.
Status: Completed (2017)
Location: Vancouver, Canada.
Height: 58m





Basic Density Indicators

FSI = 15,120sqm/2,315sqm = 6.53
GSI = 840sqm/2,315sqm = 0.36
OSR = (1-0.36)/6.53 = 0.098
L = 18

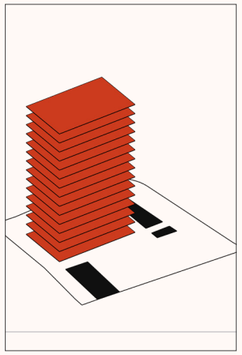
Density Variables

Site Area (A) = 2,315 sqm
Gross floor area (F) = 15,120 sqm
Building footprint (B) = 15×56 m = 840 sqm
Building height/No of Storeys or layers (L): 18
Site Coverage: 36%



14
FLOORS

Lighthouse Joensuu,
Status: Completed (2019)
Location: Joensuu, Finland
Height: 48m



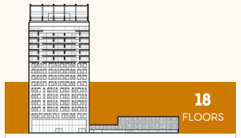


Basic Density Indicators

FSI = (5,935sqm + 222.25sqm) /2,360sqm = 2.42
GSI = (423.9sqm + 222.25sqm) /2,360sqm = 0.27
OSR = (1-0.27)/2.42 = 0.30
L = 14

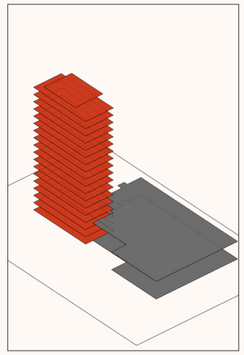
Density Variables

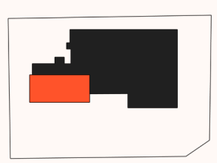
Site Area (A) = 2,360 sqm
Gross floor area (F) = 5,935 sqm
Building footprint (B) = 25.7m x 16.48m = 423.9 sqm
Ancilliary Building footprint = 222.25sqm
Building height/No of Storeys or layers (L): 14
Site Coverage: 27.4%



18
FLOORS

Mjøstarnet.
Status: Completed (2019)
Location: Brumunddal, Norway.
Height: 85.4m





Basic Density Indicators

FSI = 16,000sqm/12,965 sqm = 1.23
GSI = 3,752sqm/12,965 sqm = 0.29
OSR = (1-0.29)/1.23 = 0.58
L = 18

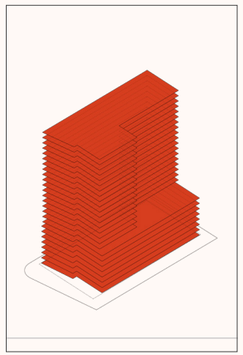
Density Variables

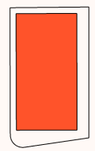
Site Area (A) = 12,965 sqm
Gross floor area (F) = 16,000 sqm
Building Tower footprint (B) = 37m x 17m = 629 sqm
Building footprint - Tower and Bath house (B') = 3,752 sqm
Building height/No of Storeys or layers (L): 18
Site Coverage: 36.9%



25
FLOORS

Ascent
Status: Completed (2022)
Location: Milwaukee, USA
Height: 86.6m





Basic Density Indicators

FSI = 47,909sqm/2,650 sqm = 18
GSI = 2,484sqm/2,650 sqm = 0.94
OSR = (1-0.35)/1.09 = 0.003
L = 25

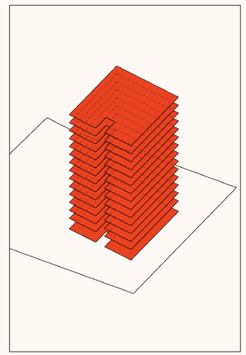
Density Variables

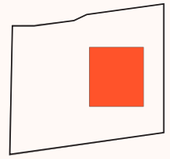
Site Area (A) = 2,650 sqm
Gross floor area (F) = 47,909 sqm
Building Tower footprint (B) = 36m x 69m = 2,484 sqm
Building height/No of Storeys or layers (L): 25
Site Coverage: 94%



14
FLOORS

Treet
Status: Completed (2015)
Location: Bergen, Norway
Height: 49m





Basic Density Indicators

FSI = 8,080 sqm/2,600 sqm = 3.1
GSI = 483 sqm/2,600 sqm = 0.19
OSR = (1-0.19)/3.1 = 0.26
L = 14

Density Variables

Site Area (A) = 2,600 sqm
Gross floor area (F) = 8,080 sqm
Building Tower footprint (B) = 23m x 21m = 483 sqm
Building height/No of Storeys or layers (L) = 14
Site Coverage = 19%

Figure 29: Density indicator summary of 5 selected case study projects. Source: Author's drawings adapted from CTBUH Technical Guides.

Case Studies & Pattern Recognition

Density Indicators	Brock Commons	Lighthouse Joensuu	Mjostarnet	Ascent	Treet
FSI - (Bulding Intensity)	6.53	2.42	1.23	18	3.1
GSI - (Coverage)	0.36	0.27	0.29	0.94	0.19
OSR - (Spaciousness)	0.098	0.30	0.58	0.003	0.26
L - (No of Floors)	18	14	18	25	14
GFA (Gross Floor Area)	15,120 sqm	5,935 sqm	16,000 sqm	47,909 sqm	8,080 sqm
A - (Site Area)	2,315 sqm	2,360 sqm	12695.04 sqm	2,650 sqm	2,610 sqm
B - (Building FootPrint)	840 sqm	646.15 sqm	3,752 sqm	2,484 sqm	483 sqm

TABLE 5: Density indicator summary of 5 selected case study projects. Source: Author's drawings adapted from CTBUH Technical Guides.

2.3.1 Density Analysis of Selected Case Study

The quantitative analysis of the five case studies shown in table 5, is summarized as a bar chart in Figure 30 and Figure 31, reveals distinct density profiles and spatial strategies, moving from hyper-dense urban forms to more spatially generous configurations.

1. Ascent: Ascent represents the extreme of urban intensity. With an exceptionally high FSI of 18 and a GSI of 0.94, it achieves its density through a combination of a large footprint that covers almost the entire site and significant height (25 floors). The consequent very low OSR (0.003) indicates minimal open space per unit of floor area, a trade-off for maximizing housing yield on a constrained urban site. This profile is characteristic of a high-density podium-and-tower typology.

2. Brock Commons Tallwood House: Brock Commons employs a different strategy for high density. With a high FSI of 6.53 but a moderate GSI of 0.36, it achieves its intensity through verticality rather than a sprawling footprint. This results in a slender point tower. Its low OSR (0.098) is similar to Ascent's, confirming a focus on interior program over expansive external open space, but its lower GSI makes it a more permeable and less imposing presence at the street level.

3. Treet: Treet presents a balanced, moderate-density profile. Its FSI of 3.1 and low GSI of 0.19 suggest a mid-rise building that does not dominate its site. The moderate OSR of 0.26 indicates a more generous provision of open space compared to the previous two cases, pointing towards a residential typology that values a balance between built form and spatial quality.

4. Lighthouse Joensuu: This project occupies a low-density position with an FSI of 2.42 and a low-to-moderate GSI of 0.27. Crucially, it has the highest OSR (0.30) among the cases, indicating a significant allocation of open space relative to its built volume. This profile suggests a low-rise or mid-rise block that prioritizes a spacious, campus-like environment and community-oriented outdoor areas over sheer density.

5. Mjøstårnet: Mjøstårnet stands out with a uniquely low FSI (1.23) for its height (18 floors), coupled with a low GSI (0.29). This results in the project's most defining metric: an exceptionally high OSR of 0.58. This data describes a slender, freestanding tower that occupies a small portion of a large site, preserving vast amounts of surrounding public space. This strategy prioritizes landmark status and spatial generosity over high density.

Synthesis: Collectively, the case studies demonstrate that mass timber is adaptable to a wide spectrum of urban density strategies. The FSI/GSI/OSR profiles show a clear inverse relationship between density (FSI) and spaciousness (OSR). Projects like Ascent and Brock Commons showcase mass timber's role in high-density urban solutions, while Mjøstårnet and Lighthouse Joensuu illustrate its use in creating more spatially dominant, landmark, or community-focused buildings. Treet occupies a middle ground, demonstrating a balanced approach to mid-rise living. This range validates mass timber as a versatile system capable of meeting diverse urban and architectural goals.

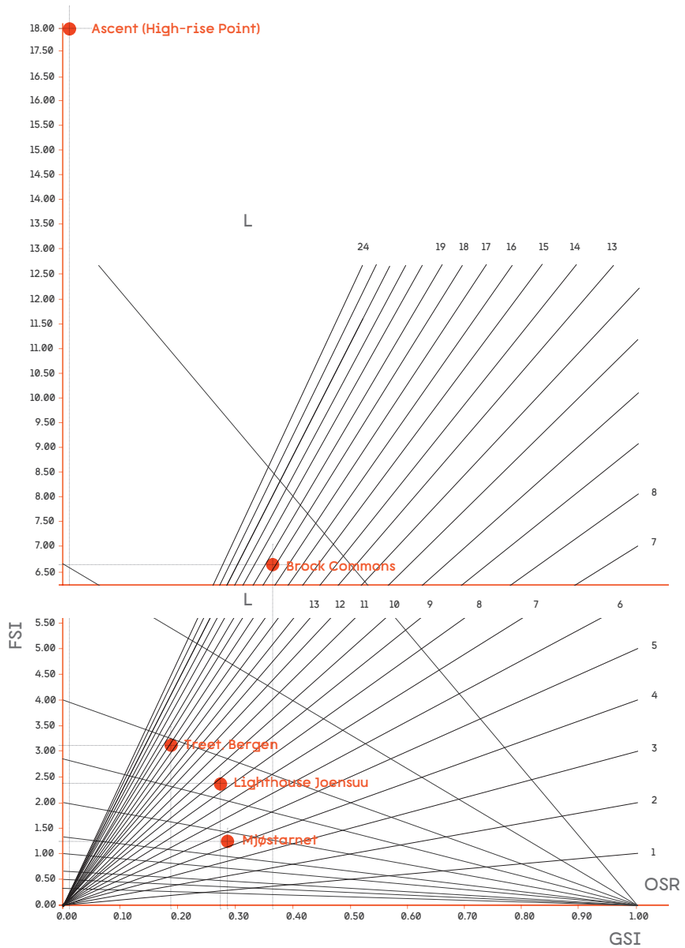


FIGURE 30: Spacemate diagram of 5 selected case study projects. Source: As designed by Berghauser pont and Haupt (2010).



2.4 Spatial and Volumetric Observation of Mass Timber Building Case Studies

This section analyzes mass timber building case studies through a modular perspective, examining each unit as a discrete module and investigating how these modules are repeated, stacked, and arranged around central lift cores and stairwells. Attention is given to the spatial connections between modules and the integration of communal spaces, highlighting how modular organization shapes circulation, social interaction, and the overall spatial logic and adaptability of mass timber buildings.

2.4.1 Brock Commons Tallwood House, Vancouver



Image * UBC Brock Commons Tallwood House | Acton Ostry Architects

Level 1: Lobby, Administration, food services, social and study spaces for sudents, mechanical electrical and other service rooms.
Level 2-17: Residential Units (16 single units and 2 Quad units per floor.)
Level 18: Student Lounge

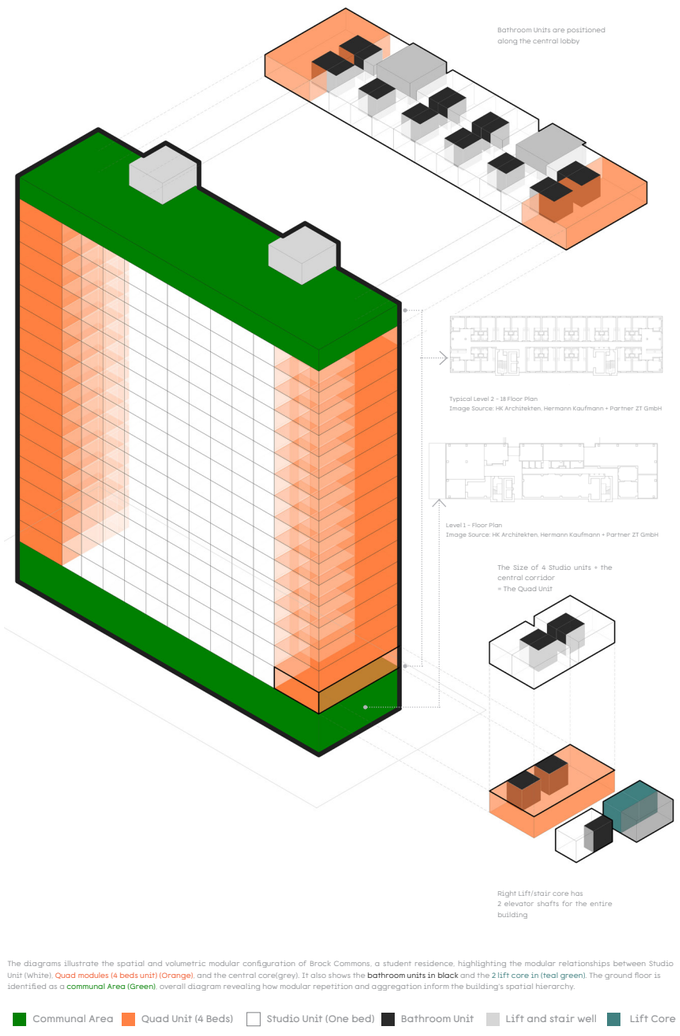


FIGURE 32: Spatial and Volumetric Modular Configuration of Brock Commons Tallwood House. Author's drawing adapted from "UBC Brock Commons Tallwood House & Acton Ostry Architect"

Brock Commons operates on a tightly disciplined modular system defined by its structural grid of 4 m × 2.9 m, as identified in the CTBUH Tall Timber technical guide. [67]

This grid underpins the repetitive CLT floor plates and organizes the building into a series of studio units aggregated into "quad modules" 16 (one-bedroom units) units and 2 (quad-bedroom units) which repeat consistently across residential level 2-17. The central double-loaded corridor, supported by a dual-elevator core and stair shaft, anchors the circulation and provides lateral stability. Vertically stacked bathroom pods reinforce construction precision and modular efficiency, while strategically inserted communal student lounge located on level 18. Externally, the façade modulation expresses this interior logic, revealing the underlying grid and module rhythm. Overall, Brock Commons demonstrates how mass timber buildings can combine compact, repeated private units with generous, strategically placed shared spaces, forming a clear spatial hierarchy governed by modular thinking and volumetric clarity. [68]

Key Observations

1. Structural grid of 4.0 m × 2.9 m, verified in CTBUH's Tall Timber references, governs unit and structural dimensions.

2. Double-loaded corridor establishes efficient circulation and unit access.

3. Vertically stacked bathroom pods ensure construction speed and MEP clarity.

4. Two elevator shafts and stair core form the primary lateral-resisting system.

5. Façade modulation directly reflects internal modular ordering.

67 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

68 "UBC Brock Commons Tallwood House," Acton Ostry Architects, accessed November 17, 2025, https://www.actonostry.ca/work/education/ubc-brock-commons-tallwood-house.

2.4.2 Lighthouse Joeusuu, Finland



Image © Arcadia Oy Arkkitehtitoimisto.

Level 1: Sauna facilities, laundry and drying room, technical facilities, Household storage spaces,
Level 2-13: 9 apartments each (2 Units of One Bedroom apartment) + (7 units of Studio Apartments)

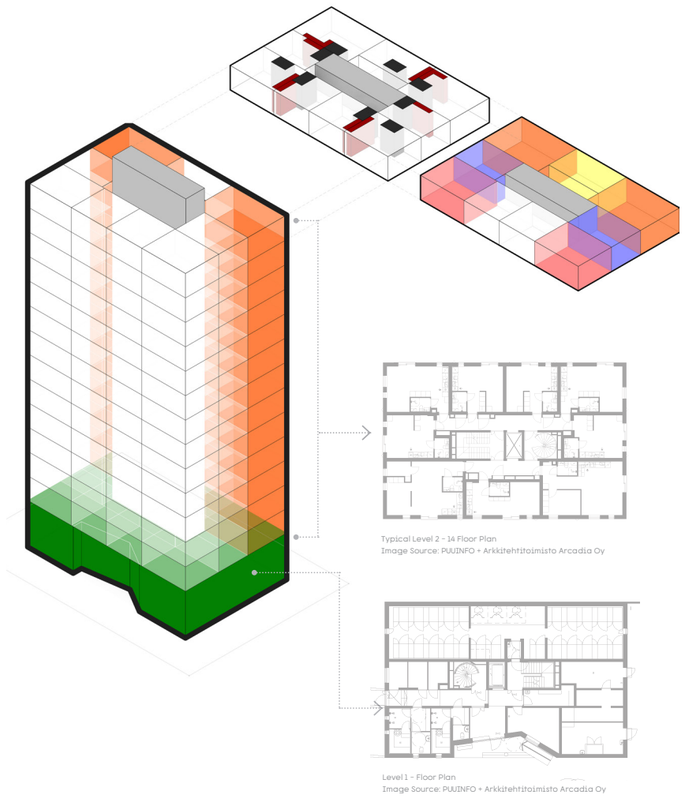


FIGURE 33: Spatial and Volumetric Modular Configuration of Lighthouse Joensuu, Finland. Authors drawing adapted from Arkkitehtitoimisto Arcadia Oy and Puuinfo.

Lighthouse Joensuu exemplifies the rigorous standardization characteristic of Finnish modular housing. Its residential floors repeat a consistent arrangement of nine units per level, seven studios and two one-bedroom apartments organized around a centralized service spine that vertically aligns kitchens and bathrooms to streamline mechanical and plumbing systems. This disciplined stacking reduces coordination complexity and enhances construction efficiency. The ground floor integrates culturally embedded communal functions, including saunas, laundry rooms, and storage, distinguishing the building from more generic modular typologies. Structurally, the project employs prefabricated CLT panels arranged within a uniform grid, enabling rapid on-site assembly and ensuring tight dimensional tolerances. Minimal variation between floors underscores the design's strategic reliance on standardized residential modules, which also contributes to a coherent and rhythmic façade expression derived from the repetitive stacking logic. [69]

Key Observations

1. Repetitive residential floor plate of nine units per level.

2. 5 unique unit modules out of the 9 unit per floor as shown in figure 33.

3. Strict vertical alignment of wet-service zones around the core.

4. Ground floor includes culturally specific communal programs (sauna, laundry, storage).

5. Prefabricated CLT system follows a disciplined and efficient structural grid.

6. Very limited spatial variation across floors due to standardized apartment types.

69 Meta Berghauser Pont and Per Haupt, Spacematrix: Space, Density and Urban Form - Revised Edition, in TU Delft OPEN Books (TU Delft OPEN Books, 2023), https://doi.org/10.59490/mg.38.

2.4.3 Mjøstårnet Brumunddal, Norway



Image © Moelven.

Level 1: Lobby and restaurant
Level 2-3: Conference Rooms
Level 4-7: Offices
Level 8-11: Hotel (one bed + Private bath)
Level 12-17: Apartments (1-2 bedrooms)
Level 18: Occupiable floor with terraces.

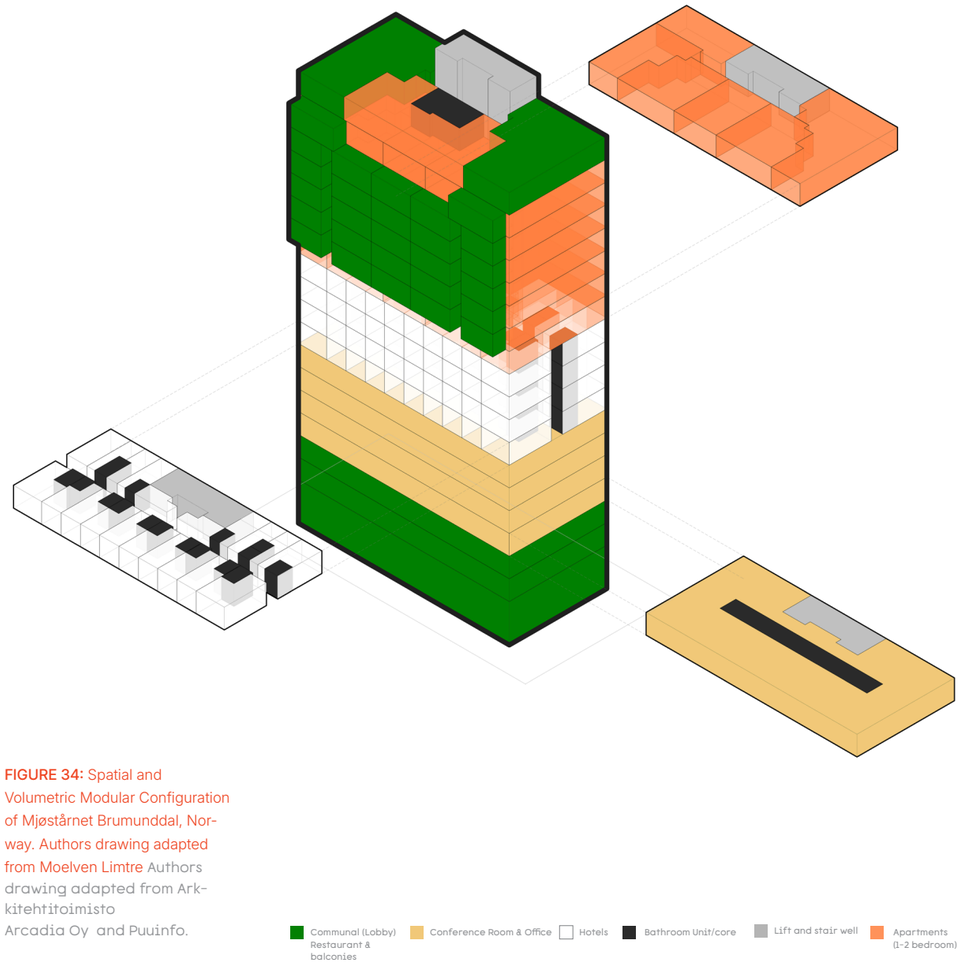


FIGURE 34: Spatial and Volumetric Modular Configuration of Mjøstårnet Brumunddal, Norway. Authors drawing adapted from Moelven Limtre Authors drawing adapted from Arkitehtitoimisto Arcadia Oy and Puuinfo.

Mjøstårnet in Brumunddal, Norway in 2020 was recognized as the world's tallest all-timber building [70] demonstrates how mass-timber construction can support complex programmatic stacking within a single vertical system.
The tower is organized into distinct programmatic bands comprising offices, hotel rooms, and residential units, with a restaurant and terrace occupying the uppermost floors. Despite this functional diversity, the project maintains continuity through consistent circulation and service cores, enabling efficient vertical distribution across changing uses. Structurally, Mjøstårnet has suspended terraces, which strategically interrupt the massing on level 12-17, introducing spatial relief and reinforcing the tower's social and environmental ambitions. Modular hotel and apartment units are inserted within the overarching timber frame, demonstrating how modular logic can coexist with a larger structural grid in tall-building applications. [71]

Key Observations

1. Repetitive vertically stacked bathroom units on Level 8-11

2. 5 unique unit modules out of the 18 unit per floor as shown in figure 34 on the hotel level 8-11.

3. Roof Top communal space

4. Perimeter Structural Core

5. Irregular unit module of the apartments on Level 12-17, although repetitive.

70 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

71 "Mjøstårnet," Moelven, accessed November 17, 2025, https://www.moelven.com/mjostarnet/.

2.4.4 Ascent Milwaukee, USA.

Level 1: Lobby, rental space, office, bicycle parking, storage and mechanical vaults.
Level 2-6: Parking
Level 7: Swimming pool, fitness centre,
Level 8-24: Residential Units
Level 25: Penthouse

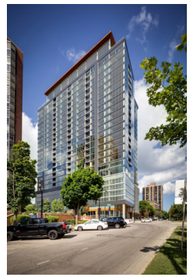


Image © Korb + Associates Architects

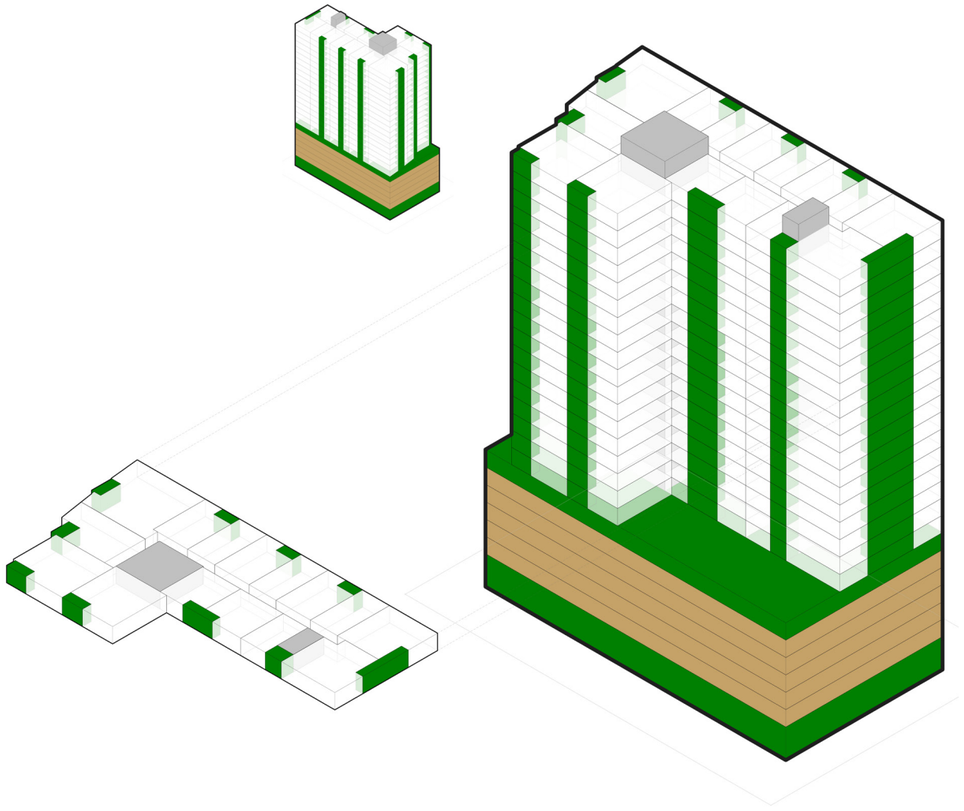


FIGURE 35: Spatial and Volumetric Modular Configuration of Ascent Milwaukee, USA. Authors drawing adapted from Korb + Associates Architects.

Ascent demonstrates a hybrid high-rise volumetric strategy in which the first seven floors form a reinforced concrete podium that supports Level 8 – 24 mass-timber tower above. Volumetrically, this podium establishes a dense, robust base sized to accommodate parking, retail programs, and mechanical rooms, creating the structural stiffness required for the lighter CLT superstructure. Above this plinth, the tower shifts into a highly repetitive modular bay system, producing a vertically stacked sequence of residential volumes whose uniformity reinforces prefabrication efficiencies and controlled dimensional tolerances.[72]

A major spatial inflection occurs at Level 7, where the amenity floor containing the pool and fitness facilities introduces a deliberate break in the volumetric rhythm. This level operates as a threshold between podium and tower, expanding floor plates and creating a moment of spatial release within the otherwise consistent vertical arrangement of units. Despite this programmed disruption, the building preserves a continuous vertical alignment of mechanical and service cores, maintaining clear spatial ordering and enabling efficient prefabricated installation of building systems. [73]

Externally, the tower's massing expresses its internal modular logic: balcony recesses, carved subtractions, and subtle façade shifts articulate the stacking of units and reveal the underlying bay structure. As shown in figure 35, These calibrated volumetric adjustments transform the repetitive structural grid into a legible architectural expression, linking interior organization to exterior form and reinforcing the building's hybrid tectonic identity.

Key Observations

1. Repetitive vertically stacked residential units on Level 8-24

2. 10 Recessed (Subtracted) Balconies around the building's perimeter

3. Double-loaded corridor establishes efficient circulation and unit access.

4. One elevator core and two stair cores form the primary lateral-resisting system

72 Korb Architecture » Ascent, n.d., accessed November 17, 2025, https://korbarch.com/projects/ascent/.

73 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

2.4.5 Treet, Bergen, Norway.

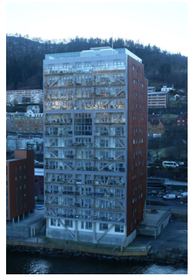


Image © Wikimedia commons Sparrow (2019)

Level 1: Apartment A & Apartment C, Mechanical rooms, Tenant storage rooms,
Level 2-14: 5 Apartments on each floor (Apartment A,B,C,D,E) 2 bedrooms in (ACDE), one bedroom in B

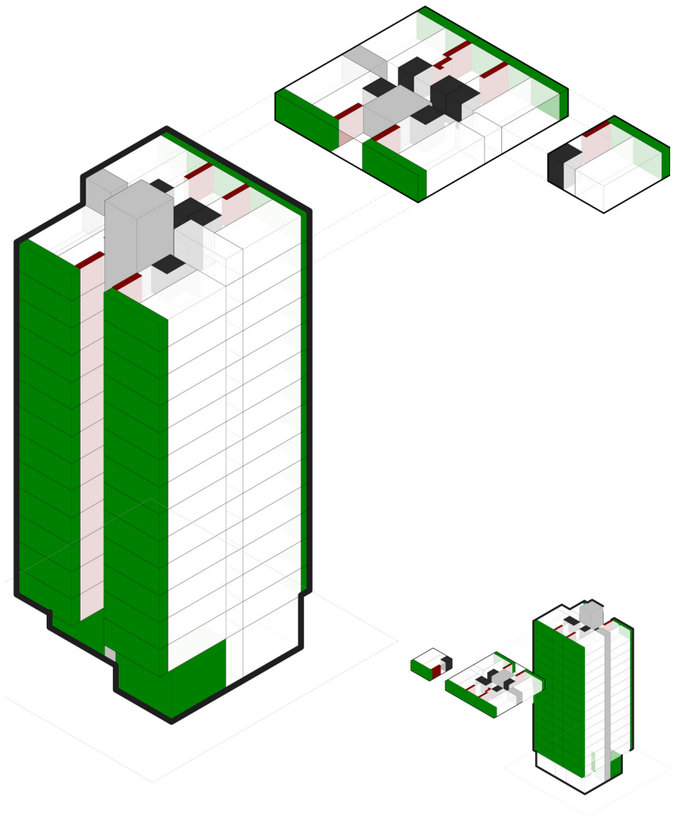


FIGURE 36: Spatial and Volumetric Modular Configuration of Treet, Bergen, Norway. Authors drawing adapted from Tall timber: Mass timber for high-rise Buildings. CTBUH Technical Guides.

Treet in Bergen operates as a fully volumetric modular timber system in which prefabricated apartment boxes form the primary spatial and structural units. As shown in (Figure 36) each residential floor is composed of five repeating modules (A–E), stacked consistently from Levels 2 to 14. Volumetrically, this repetition produces a highly regular massing profile where the building's external form directly reflects the internal aggregation of modules. Stabilization is achieved through external and internal steel trusses, which brace the stacked timber volumes and allow the modules to remain structurally autonomous while acting collectively as a high-rise system. [74]

Spatially, the arrangement of kitchen and bathroom pods along the circulation core ensures precise vertical alignment of services, streamlining prefabrication and reducing on-site coordination. The ground floor volume, expanded beyond the residential module footprint, accommodates communal and mechanical programs, creating a spatial base that anchors the lighter modular stack above. The façade's identity emerges from the volumetric logic itself: the visible stacking of modules and the rhythm of steel bracing articulate a pattern that is both constructive and expressive. [75]

Key Observations

1. Repetitive vertically stacked residential units on Level 2-14

2. Suspended Balconies around the building's perimeter Northwest & Southeast facing sides

3. Double-loaded corridor establishes efficient circulation and unit access.

4. Single elevator core and tone stair cores form the primary lateral-resisting system

5. 2 unique unit modules out of the 5 per floor. (4 units of 2 bedrooms and 1 unit of 1 bedroom)

74 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

75 Rune B Abrahamsen and Kjell Arne Malo, STRUCTURAL DESIGN AND ASSEMBLY OF "TREET" - A 14-STOREY TIMBER RESIDENTIAL BUILDING IN NORWAY, n.d.

2.4.6 Conceptual Precedent Analysis - Timber Commons (MT3)

Timber Commons (MT3) a tall-timber proposal by Ben Feldman, Carol Cochrane, Carol Phillips, Jaewon Kim, Jay Zhao, Jillian Weinberger, Kayley Mullings, Luis Quezada, Phil Silverstein, and Will Klassen of Moriyama & Teshima Architects was developed for the Urbanarium Decoding Timber Towers competition (2023). [76] **Decoding Timber Towers** is the fourth design competition by Urbanarium, advancing dialogue around housing affordability and climate-responsive construction. Like its earlier Missing Middle, Mixing Middle, and Decoding Density competitions, it asks entrants to consider how mass-timber housing innovations interact with building codes, zoning, and regulatory constraints. The competition frames a systems-thinking challenge: how to replace concrete residential high-rises with low-carbon timber alternatives that remain competitive, buildable, and socially generous, while optimizing prefabrication and modularity for buildings in the 8–20+ storey range.

Within this broader agenda, MT3 stands out as a rigorous exploration of modular tall-timber design. The project is organized around a hybrid prefabrication strategy, combining volumetric CLT service pods, panelized CLT slab cassettes, and prefabricated façade units into a coordinated kit-of-parts. This approach demonstrates how modular timber systems can balance efficiency with flexibility: volumetric pods streamline mechanical and plumbing distribution, while standardized structural bays permit variation in unit layouts and communal programs. A key contribution of MT3 as shown in Figure 36b & 36c is its clear integration of mechanical and structural logic. Mechanical risers, ventilation pathways, and bulkheads align with the module grid, enabling predictable stacking and simplifying the coordination typically required in tall-timber construction. This clarity highlights the value of treating mechanical systems as an integral part of the modular logic rather than secondary components.

MT3 also introduces subtractive massing, where selected modules are removed to create terraces, communal rooms, and shared amenity spaces. These voids soften the repetition of the structural grid and support sociability within the vertical community, demonstrating how modularity can accommodate rich spatial experience without compromising constructability. [77]

Architecturally, the project's expression emerges from disciplined grid repetition, exposed timber surfaces, and façade modularity. MT3 shows how standardized timber components can achieve both economy and identity an architectural quality relevant to ongoing mass-timber housing research.

76 "Decoding Timber Towers | Urbanarium," accessed December 3, 2025, https://urbanarium.org/decoding-timber-towers#winners.

77 "Decoding Timber Towers | Urbanarium," accessed December 3, 2025, https://urbanarium.org/decoding-timber-towers#winners.

MT3 provides a relevant and additional conceptual framework and a set of precedents that this thesis builds upon. Its systems-thinking approach, hybrid prefabrication strategy, and focus on community-oriented vertical space echo many of the themes explored here, offering a broader context for developing modular, low-carbon housing models in a Canadian urban environment.
In these ways, Timber Commons offers a broader conceptual framework for modular tall-timber design one that this thesis builds upon by exploring how similar principles of prefabrication, spatial clarity, and community-oriented massing can be adapted to the constraints, opportunities, and typological demands of affordable urban housing.

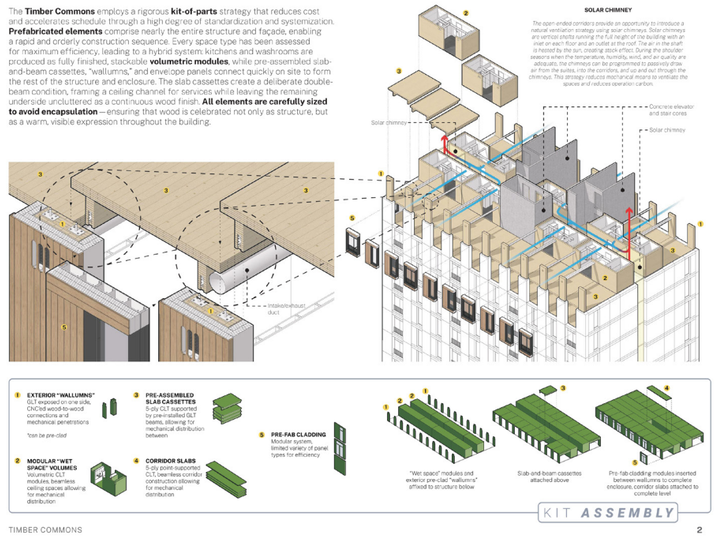


FIGURE 36b: MT3's Timber Commons. Source: Urbanarium Decoding Timber Towers competition. https://urbanarium.org/sites/default/files/2025-09/MT3_Main%20Submission.pdf

FIGURE 36c: MT3's Timber Commons. Source: Urbanarium Decoding Timber Towers competition. https://urbanarium.org/sites/default/files/2025-09/MT3_Main%20Submission.pdf

2.5 Cross-Case Pattern Recognition & Synthesis.

Synthesizing the case studies reveals several recurring architectural logics consistent across contemporary high-rise mass timber residential projects.

2.5.1 The Modular Grid as Structural & Spatial Framework

All five case study buildings demonstrate the critical role of a disciplined modular grid, which functions simultaneously as a structural framework and a spatial organizing principle. Structurally, the grid enables prefabrication precision, alignment of floor spans, and cost-effective construction, while spatially, it supports repeatable volumetric units, flexible unit arrangements, and efficient aggregation (CTBUH, Tall Timber; thesis observations, 2025). In this way, the modular grid not only ensures construction efficiency and speed of assembly but also forms the backbone of a kit-of-parts design methodology, allowing both structural discipline and compositional clarity to guide architectural form.

2.5.2 Centralized Vertical Core

All case study buildings are organized around a centralized vertical core containing elevators, stairs, and mechanical risers, except for Mjøstårnet, which has a slightly offset perimeter core. This central core not only anchors structural stability and organizes mechanical systems but also establishes a framework for the spatial and volumetric configuration of each building. By providing lateral load resistance and a stable service center, the core allows flexible floor plate layouts and frees the perimeter for architectural strategies such as façade articulation, subtractive massing, and corner voids or balconies. This approach creates opportunities for volumetric variation and spatial complexity within the constraints of high-rise construction (Figures 32–36). In Brock Commons, Ascent, and Treet, the lateral-resisting system formed by two elevator shafts and a stair core similarly shapes the spatial and volumetric logic of the building.

2.5.3 Vertical Alignment of Wet Service Units (Kitchens & Bathrooms)

In all 5 case study buildings, kitchens and bathrooms are vertically stacked, forming a consistent volumetric module across floors. Most of these wet-service pods are also positioned around the central core and lobby, integrating seamlessly with the building's primary circulation and structural spine. This alignment not only streamlines plumbing and mechanical systems but also simplifies construction, supports prefabrication, and allows rapid assembly or unit replacement. The vertical stacking of wet-service pods emerges as a dominant modular pattern, shaping both the spatial organization of individual units and the overall volumetric rhythm of the building.

2.5.4 Aggregation of Units into Clusters

In all case study buildings, individual units are rarely isolated; instead, they are organized into clusters or families of volumes. Brock Commons arranges units in quad clusters, Treet in five-module packs, and Mjøstårnet into larger programmatic blocks. This aggregation creates a layered spatial and volumetric hierarchy, fostering flexibility, visual coherence, and a sense of shared identity within repetitive modular systems. By functioning as families of interconnected volumes rather than independent boxes, the clusters define both the internal unit organization and the overall volumetric rhythm of the building.

2.5.5 Communal and Social Spaces as Volumetric Interruptions

In all 5 case study buildings, communal and social spaces are carefully integrated into the modular stack, creating moments of spatial relief and volumetric articulation. Most projects feature ground-floor and rooftop communal spaces, establishing a clear base and crown within the repetitive residential volumes. There are variations: Ascent locates a swimming pool and fitness floor on the 7th level, echoing the ground-floor communal strategy, and includes 10 carved balconies per floor around residential units. Treet introduces terraces and balconies on each floor, functioning as semi-private communal zones, while Mjøstårnet positions private balconies with apartments between levels 12–17. Brock Commons culminates with a study lounge on the 18th floor. These interventions interrupt the uniform repetition of modular units, creating a layered spatial hierarchy and enriching the volumetric configuration of each building.

2.5.6 Programmatic Vertical Zoning (Podium + Tower Logic)

All 5 case study buildings exhibit a consistent vertical hierarchy that organizes both function and volume. Typically, a podium at the base houses' public lobbies or retail spaces, the central stack contains repetitive residential units, and the upper levels accommodate amenities, terraces, or penthouses. This layering establishes a clear spatial and volumetric rhythm, creating a vertical neighborhood that balances density with livability. By stacking functions in this way, the buildings demonstrate how programmatic organization shapes volumetric identity and spatial experience within high-rise modular systems.

2.6 Lessons & Takeaways for the Thesis

Analysis of the case study buildings reveals key principles that shape spatial and volumetric configurations in modular high-rise design:

1. Variation within modularity creates identity: While repetition ensures efficiency, controlled variation generates distinct spatial experiences and a recognizable volumetric character.

2. Clustered units support adaptability: Aggregating modules into clusters allows flexible arrangements and accommodates diverse living patterns, reinforcing volumetric coherence across the building.

3. Communal voids sustain social interaction: Strategically inserted shared spaces between or around residential clusters create moments of spatial relief, enhancing both social and volumetric richness.

4. Fixed cores enable dynamic perimeters: A stable central core provides structural and service support, freeing the perimeter to explore articulated façades, balconies, and other volumetric interventions.

5. Subtractive massing amplifies architectural expression: Terraces, recesses, and carved-out voids interrupt repetitive volumes, balancing efficiency with visual and spatial interest.

6. Balancing variation and repetition for efficiency: While varied modules increase identity, extensive variation can raise construction costs and embodied carbon. Repeating modules efficiently supports affordability and sustainability by minimizing material waste and simplifying construction.

Together, these lessons translate the technical logic of modular timber construction into a framework for adaptive, socially responsive, and visually expressive volumetric design.

2.7 Derived Design Rules: Translating Case Study Insights into Generative Principles

From the cross-case synthesis, several design rules emerge as guiding principles for configuring spatial and volumetric systems in modular high-rise mass timber buildings. These rules establish the methodological bridge to Chapter 3, where they are operationalized in digital modeling to explore new configurations:

Rule 1 – Establish a Repetitive Modular Grid:
Use a fixed structural module (typically 3.6 – 4 m) to anchor volumetric decisions and support prefabrication efficiency. The grid organizes units, clusters, and communal spaces, while enabling systematic rearrangements and controlled variation through terraces, voids, or recesses. Consider module weight, crane capacity, transport logistics, CLT plant production, and site storage to ensure constructability and maintain spatial ambitions.

Rule 2 – Fix Vertical Cores and Wet-Service Walls:
Lock elevator cores, stair cores, and wet-service walls (bathrooms/kitchens) early. These elements stabilize the tower and define service distribution, while freeing perimeter and unit volumes for flexible spatial arrangements, volumetric experimentation, and architectural articulation.

Rule 3 – Treat Each Unit as a Volumetric Building Block:
Define discrete modules (studio, 1–4-bedroom units, or communal spaces) as volumetric building blocks. Aggregate them into clusters quads, five-packs, mirrored or rotated groupings to create layered compositions that enhance spatial richness and volumetric identity.

Rule 4 – Insert Communal Voids and Employ Subtractive Massing:
Introduce voids and recesses strategically to break repetition, articulate the massing, and enrich spatial experiences. Include double-height lounges, terraces, shared kitchens, gyms, laundry areas, study lounges, and other social spaces. Subtractive massing, carve-outs, cantilevers, and outdoor pockets creates three-dimensional rhythm, fosters social interaction, and produces visually dynamic volumetric compositions.

Rule 5 – Combine Modules into Clusters for Spatial Variety:
Use mirrored, rotated, stepped, or bridged clusters to transform repetitive modules into dynamic, varied configurations. Clustering creates volumetric diversity, enhances shared identity, and supports flexible unit arrangements.

Rule 6 – Programmatic Vertical Zoning:
Stack functional blocks vertically to define a hierarchy: podiums, mid-level mixed-use or amenity floors, residential stacks, and roof terraces. This layering generates a vertical community and introduces varied spatial atmospheres throughout the building.

Cross-Case Pattern Recognition & Synthesis

Summary: These rules translate the technical logic of modular mass timber construction into a flexible framework for spatial and volumetric design. They guide the creation of high-rise buildings that are structurally coherent, socially responsive, and architecturally expressive, balancing efficiency, prefabrication, and dynamic spatial composition.

Chapter 3 | Design Led Methodology

Chapter 3 - Methodology

3.1 Introduction

This chapter outlines the research methodology used to investigate mass timber as massing, that is, how modular timber volumes can operate at once as structural, spatial, and social building blocks for flexible and expressive high-rise housing. The study uses a design-led research approach, combining analytical, synthetic, and speculative modes of inquiry. Following Nigel Cross's view of design as a distinctive way of knowing, design is treated not only as a final product but as a method of inquiry, a process of thinking, testing, and discovering through iteration and visualization (Cross, 2007).[78]

The methodology is structured in three connected stages:

1. Case-study analysis of five mass-timber precedents.

2. Pattern recognition and modular grammar development, based on comparative observations across cases.

3. Iterative digital modelling using Autodesk Revit to generate, test, and refine spatial and volumetric configurations.

Together, these stages provide a clear path from empirical observation to speculative design, directly addressing the research goals and questions established in Chapter 1.

3.2 Overall Research Approach

This research follows a three-part design-led methodology, grounded in the idea that design itself is a mode of inquiry, moving from observation to synthesis to iterative speculation. Following Nigel Cross's argument that designers generate knowledge through "constructive thinking," iteration, and the manipulation of forms and representations (Cross, 2007), the study moves from analysis to synthesis to speculative exploration. Design is therefore treated not only as a way of producing outcomes but as a way of knowing a process of thinking, testing, and discovering through visual and spatial experimentation.[79]

78 Nigel Cross, "Designerly Ways of Knowing," in Designerly Ways of Knowing and Thinking, ed. Nigel Cross (Springer, 2025), https://doi.org/10.1007/978-1-4471-7541-4_1.

79 Cross, "Designerly Ways of Knowing."

Stage 1 - Analytical Mode: Studying Precedents

Five completed high-rise timber buildings; Brock Commons, Lighthouse Joensuu, Mjøstårnet, Ascent, and Treet are examined to understand how they use modular grids, volumetric units, shared spaces, and vertical organization. Through this analytical work, spatial and structural patterns begin to emerge.

Key question:

What modular and spatial patterns already exist, and what can be learned from them?

This stage aligns with Cross's emphasis on observing existing design solutions to identify underlying principles that can guide new work.

Stage 2 - Synthetic Mode: Developing a Modular Grammar

Insights from Stage 1 are translated into a modular grammar, a rule-based system describing how timber volumes combine, repeat, or vary while maintaining structural logic and constructability. This grammar serves as a design tool for organizing space, testing relationships, and formulating new configurations.

Key question:

What design rules can guide the arrangement and variation of modular mass-timber units?

Following Cross (2007), this synthetic step represents the designer's capacity to generate structured knowledge by abstracting patterns into actionable principles. [80]

Stage 3 - Speculative Mode: Iterative Digital Exploration

Using Autodesk Revit, the modular grammar is tested through iterative digital modeling. Each design iteration reorganizes, stacks, aggregate, or subtracts volumetric units to explore spatial, social, and environmental possibilities. Rather than seeking a single final solution, this stage embraces Cross's view of design as an exploratory practice where knowledge emerges through cycles of making, evaluating, and remaking.

Key question:

How can modular units be configured to create flexible and socially engaging housing, and how can digital modeling support the refinement of these configurations?

80 Nigel Cross, "Designerly Ways of Knowing," in Designerly Ways of Knowing and Thinking, ed. Nigel Cross (Springer, 2025), https://doi.org/10.1007/978-1-4471-7541-4_1.

Summary
Together, these three stages form a coherent methodology rooted in Cross's notion of designerly ways of knowing; a mode of research that advances understanding through analysis, pattern formation, and iterative design exploration. This structure provides a systematic pathway from empirical observation to spatial and volumetric speculation, directly supporting the research questions established in Chapter one (1).

3.3 Stage 1: Case Study Analysis
(Linked to Research Objective 1 and Research Question 2)

Research Objective 1
Develop a Case Study Analysis: Conduct an in-depth examination of five high-rise mass timber buildings to understand existing modular and spatial arrangements, structural strategies, and design patterns.

Research Question 2
What recurring spatial and modular patterns can be observed in existing high-rise mass timber buildings, and how can they inform adaptable and livable design strategies?

3.3.1 Purpose
The first stage aims to understand how modularity is implemented in completed mass-timber towers and to extract forms of design intelligence that support the study's broader investigation. The analysis focuses on how these buildings negotiate:

1. Livability and spatial flexibility,

2. Construction efficiency and assembly logic,

3. Spatial relationships, unit variations, and the dimensions and relationships of unique volumetric modules, and

4. Community engagement and shared space integration.

By examining built precedents, this stage establishes a foundation of empirical knowledge that informs the development of a modular grammar in Stage 2.

3.3.2 Data Examined
For each case study, architectural drawings; including plans, sections, and axonometric diagrams were redrawn or traced to isolate and compare key spatial and volumetric characteristics. The analysis focused on the following elements:

1. Structural grid: Bay spacing, modular repetition, and span efficiency.
and repetition patterns.

2. Volumetric units: Unit typologies, dimensions, stacking logic, and repetition patterns.

3. Clustering: How units combine to form families, clusters, or neighborhoods within the tower.

4. Core and services: Placement of elevators, stairs, shafts, and wet service walls.

5. Communal spaces: Distribution, type, frequency, and their social function within residential floors.

6. Programmatic zoning: The stacking and transition between public, shared, and private areas.

7. Massing strategies: Additive and subtractive manipulations that shape the building's identity and spatial rhythm.

3.3.3 Outcome
The comparative analysis of these variables revealed a set of recurring organizational patterns including modular grids, unit clusters, and communal or social voids that consistently structure the spatial and volumetric logic of mass-timber towers. These repeated configurations form the empirical foundation for Stage 2, where they are translated into a modular grammar that guides the systematic arrangement, variation, and articulation of timber volumes.

3.4 Stage 2 – Pattern Recognition and Modular Grammar
(Linked to Research Objectives 2 and 4; Research Questions 2 and 3)

3.4.1 Identifying Patterns

Comparative analysis across the five case studies revealed a recurring set of spatial and organizational strategies:

1. Repetitive structural grids supporting prefabrication.
2. Vertically aligned wet-service cores improving efficiency.
3. Modular units capable of repetition and combination.
4. Clustered groupings forming social micro-communities.
5. Periodic communal levels providing spatial and social relief; and
6. Vertical zoning that layers public, shared, and private realms.

These findings align with broader understandings of modularity and adaptable housing developed by Schneider and Till (2007), and they reinforce the view consistent with Cross's notion of design as a way of knowing that patterns in built examples can generate abstract rules useful for design inquiry (Cross, 2007).

3.4.2 Creating the Modular Grammar

From these patterns, a modular grammar was developed a rule-based system describing how mass-timber volumes can combine, cluster, and vary while maintaining constructability:

1. Base Modules: Standard volumetric units (studio, one-bedroom, family) proportioned to typical CLT spans of 3 × 6 m.

2. Cluster Rules: Guidelines for aggregating modules into pairs, L-shapes, quads, or multi-unit neighbourhoods.

3. Core and Service Rules: Consistent alignment of stairs, elevators, and plumbing risers.

4. Void Rules: Controlled subtraction to form double-height lounges, communal pockets, or shared terraces.

5. Zoning Rules: Vertical layering from public podiums to communal mid-levels and private upper bands.

This grammar becomes the operative design tool for Stage 3, aligning with research in rule-based and generative design, and echoing Cross's argument that designers construct knowledge by structuring problems through rules, patterns, and iterative exploration. [81]

81 Nigel Cross, "Designerly Ways of Knowing," in Designerly Ways of Knowing and Thinking, ed. Nigel Cross (Springer, 2025), https://doi.org/10.1007/978-1-4471-7541-4_1.

3.5 Stage 3: Iterative digital Design and spatial catalogue

(Linked to Research Objectives 3 and 5; Research Questions 1 and 4)

3.5.1 Digital workflow

Autodesk Revit was used to operationalize the grammar through eight iterative steps:

a. Establish the grid.
b. Fix the core.
c. Add base modules.
d. Form clusters and neighbourhoods.
e. Create voids as communal spaces.
f. Test programs (student, family, mixed-use).
g. Evaluate spatial outcomes.
h. Refine and regenerate.

This workflow follows the "research-through-design" paradigm described by Frayling (1993), in which iterative making becomes a means of generating knowledge. [82]

3.5.2 Purpose of Iteration

Iteration tests how small adjustments- such as cluster configuration or void as communal space placement reshape spatial quality, social interaction, and volumetric expression. The goal is exploratory: to map a "possibility space" rather than produce a single optimum solution.

3.5.3 Outcome – Catalogue of Spatial Strategies

The iterative process generates a catalogue (presented in Chapter 4) documenting:

1. Multiple cluster typologies (studio → four-bedroom).
2. Alternative arrangements around a central core.
3. Varied placements of shared vertical spaces; and
4. Subtractive massing profiles.

These outcomes demonstrate how a single modular logic can adapt to different programmatic and contextual conditions.

82 "Design Policy: An International Conference Organized by the Department of Design Research, Royal College of Art, in Association with the Design Council and Design Research Council 20–23 July 1982," R&D Management 13, no. 1 (1983): 51–54, https://doi.org/10.1111/j.1467-9310.1983.tb01128.x.

3.6 Relation to Research Goal and Housing Context

Applying this methodology to 12–25-storey buildings situate the work within Canada's contemporary housing challenges. The modular grammar enables adaptation across:

1. Compact urban cores,

2. Family-oriented neighbourhood towers, and

3. Mixed-use vertical communities.

This flexibility supports low-carbon housing objectives and echoes Lehmann's advocacy for mass-timber urbanism as a scalable circular-economy model.[83]

3.7 Conclusion

This chapter established a qualitative, design-led methodology grounded in iterative, designerly ways of knowing (Cross, 2007). The process moves from empirical observation to pattern formation to computational exploration:

Stage 1 grounds the research in built precedents.

Stage 2 extracts patterns into a modular grammar.

Stage 3 uses digital iteration to generate alternative spatial typologies.

This balanced yet flexible approach reveals how modular mass-timber systems can produce diverse, socially connected, and environmentally responsive forms of vertical housing. Chapter 4 applies this methodology through the resulting spatial catalogue. [84]

83 Steffen Lehmann, Urban Regeneration: A Manifesto for Transforming UK Cities in the Age of Climate Change (Springer International Publishing, 2019), https://doi.org/10.1007/978-3-030-04711-5.

84 Nigel Cross, "Designerly Ways of Knowing," in Designerly Ways of Knowing and Thinking, ed. Nigel Cross (Springer, 2025), https://doi.org/10.1007/978-1-4471-

Chapter 4 | Design Development

Chapter 4 - Design Development

Design Development and Proposed Mass Timber Housing System

This chapter presents the design development of the proposed affordable mass-timber housing system, using the Downtown Kitchener site at 12 Victoria Street South as its primary test case. The design is grounded in a unified approach that addresses affordability, sustainability, and community by leveraging a flexible, low-carbon, prefabricated kit-of-parts construction system. The project demonstrates how mass-timber modular housing can respond to contemporary urban constraints while remaining replicable across varying Canadian contexts.

It further applies the modular grammar developed in Chapter 3 to a series of speculative design explorations. These studies demonstrate how mass timber as massing understood as a modular system of volumetric and secondary panelised units can generate a diverse catalogue of spatial configurations for quiet, efficient, and expressive high-rise housing.

The objective is not limited to proposing a multi-unit residential housing project with mass timber but to establish a catalogue of typological possibilities, each revealing how spatial richness and social engagement can emerge from disciplined modular repetition rather than formal excess.

Each design iteration prioritizes constructional clarity and material economy, adhering to the principles of prefabrication, repetition, and subtractive spatial articulation identified in previous chapters. [85] The resulting catalogue explores how modular timber volumes can support housing that is:

1. Quiet & Quick to fabricate
2. Efficient to construct
3. Affordable and replicable
4. Volumetrically expressive without structural complexity
5. Suitable for diverse households (Studio unit to 1 Bed – 4 bedrooms)

This chapter thus extends the thesis inquiry:

How can modular mass timber volumetric and modular panels be arranged to support social life, adaptability, and expressive architectural form in high-rise housing?

85 Charles Saumarez Smith, review of Review of The Royal College of Art, One Hundred and Fifty Years of Art and Design, by Christopher Frayling, The Burlington Magazine 130, no. 1023 (1988): 474–474

The Kitchener site located behind the University of Waterloo's Health Sciences Campus & The University of Waterloo's School of Pharmacy offers direct access to transit, walkable amenities, and established urban infrastructure. The design responds by maximizing density, minimizing parking, and promoting low-carbon living. Rather than relying on automobile-centric planning, the project positions itself as a visible timber landmark within the Kitchener downtown fabric. Community is a central objective. The building is conceived as a vertical village, where shared indoor and outdoor spaces support interaction, daily needs, and collective life. These communal moments are distributed throughout the tower and paired with essential services to reinforce social connection.

4.1 Determining an Appropriate Building Typology Using Municipal Density and FSI Requirements

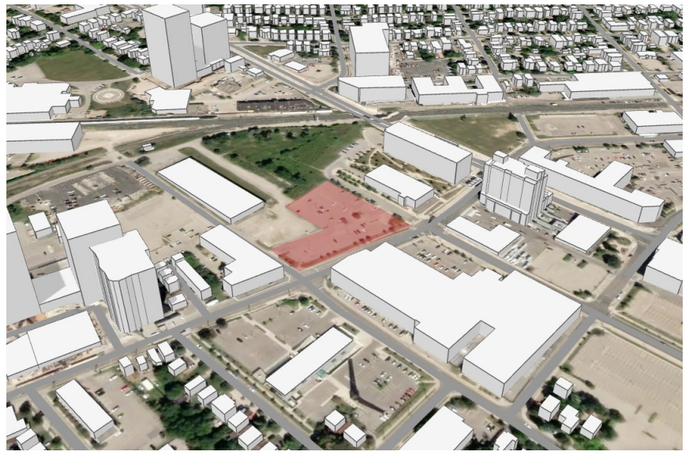


FIGURE 37: Site Context Model of 12 Victoria Street South, Kitchener. Image exported from Autodesk Forma using basemap data © Mapbox, © OpenStreetMap contributors, and © Esri, accessed 2025.

The selection of a building typology for the site marked in (figure 37) 12 Victoria Street South site is guided by the City of Kitchener Official Plan: A Complete and Healthy Kitchener (2014), which designates the area as part of the Downtown Innovation District and subject to High Rise Residential policies. [86] These policies establish quantitative controls on density and floor space ratio (FSR), as well as qualitative expectations around built form, urban design, and affordable housing. [87]

86 "Official Plan," November 21, 2025, https://www.kitchener.ca/en/development-and-construction/official-plan.aspx.

87 Council for the Regional Municipality of Waterloo, "City of Kitchener Official Plan - A Complete & Healthy Kitchener," 2014, https://www.kitchener.ca/en/development-and-construction/official-plan.aspx.

4.1.1 Policy Framework: Density, FSR, and Innovation District Context

Within the Innovation District, the Official Plan encourages a dense, contemporary urban setting anchored by high-tech employment, post-secondary institutions, and transit-oriented development (Policies 15.D.2.41–2.44). Permitted uses include offices, institutional and residential uses, studios, exhibition space, and complementary commercial uses such as restaurants, services, and specific forms of retail along Victoria and King Streets. New development is expected to support walkability, active streetscapes, cultural heritage conservation, and high-quality public realm treatments. [88]

For lands designated High Rise Residential, the Official Plan further requires:

1. A minimum residential density of 100 units per hectare (Policy 15.D.3.23);

2. A minimum FSR of 2.0 and maximum FSR of 4.0 (Policy 15.D.3.24);

3. Predominantly multiple-dwelling residential use, with complementary non-residential uses permitted internal to the building (Policy 15.D.3.25); and

4. Built forms that preserve natural features, capitalize on views, function as neighbourhood landmarks, and are located within walking distance of transit, nodes, and mixed uses (Policy 15.D.3.26).

The Plan also promotes innovative, transit-supportive, and affordable housing models including inclusionary zoning near protected major transit station areas and encouragement of designs that support complete communities, alternative energy, and reduced parking where appropriate (Section 4, Part C; Section 13). [89]

4.1.2 Interpreting Floor Space Ratio and Density to Guide Form

Floor Space Ratio (FSR) expresses the relationship between buildable floor area and lot area.[90] On a relatively compact site such as 12 Victoria Street South, achieving an FSR in the upper portion of the permitted range (2.0–4.0) implies either:

1. A mid-rise building with very high site coverage, or
2. A slender high-rise / point tower with more modest coverage.

88 "Official Plan," November 21, 2025, https://www.kitchener.ca/en/development-and-construction/official-plan.aspx.

89 Council for the Regional Municipality of Waterloo, "City of Kitchener Official Plan - A Complete & Healthy Kitchener."

90 Pont and Haupt, Spacematrix.

On constrained urban parcels, courtyard or perimeter-block buildings can struggle to reach FSR values near 4.0 without deep unit plans and compromised daylight. In contrast, tower typologies concentrate floor area vertically, freeing ground plane for public realm improvements while still achieving the required density. This logic is consistent with the Innovation District's ambition for a dense, contemporary setting and a future regional transportation hub.[91]

4.1.3 Typology Evaluation

Three typologies tested on the Kitchener project site were evaluated against the Official Plan framework:

1. Bar Mid-Rise

A 6–8-storey bar building aligned with Victoria Street offers efficient linear floor plates and is compatible with modular construction. However, reaching an FSR approaching 4.0 would require very high lot coverage, limiting open space, reducing flexibility for landscape and stormwater strategies, and intensifying overshadowing on neighbouring lots. This typology comfortably meets the minimum FSR but struggles to exploit the full potential of the designation. The buildable site area after the setbacks is 2,353sqm, to attain the maximum Floor Space Ratio (FSR) of 4, the target Gross Floor Area (GFA) for the proposed building is approximately 9,412 square meters. The most suitable configuration that closely aligns with this target is a mid-rise bar building featuring a base footprint of 995 square meters and a total of 10 floors, resulting in a cumulative GFA of 9,950 square meters. Total FSR is 4.2. This configuration is illustrated in Figure 38.

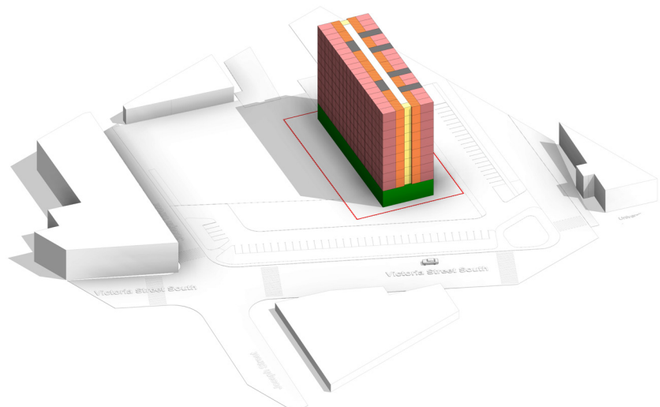


FIGURE 38: Author's drawing of a mid-rise bar typology featuring vertically stacked base modules. FSI – 4.2 Located on project site (Kitchener Downtown)

91 Council for the Regional Municipality of Waterloo, "City of Kitchener Official Plan - A Complete & Healthy Kitchener."

2. Courtyard / Perimeter Block

A courtyard form supports strong communal space at grade but depends on substantial site area. On this site, the depth of perimeter units becomes inefficient and daylight access to the courtyard is constrained. Achieving an FSR above roughly 2.0–2.5 would demand deep floor plates inconsistent with the project's daylight and livability goals. The buildable site area after the setbacks is 2,353sqm, to attain the maximum Floor Space Ratio (FSR) of 4, the target Gross Floor Area (GFA) for the proposed building is approximately 9,412 square meters. The most suitable configuration that closely aligns with this target is a courtyard/perimeter block building featuring a base footprint of 1314 square meters and a total of 7 floors, resulting in a cumulative GFA of 9,198 square meters. Total FSR is 3.9. This configuration is illustrated in Figure 39.

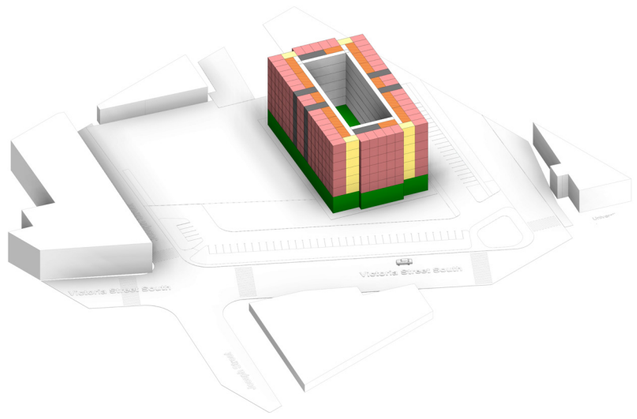


FIGURE 39: : Author's illustration of a courtyard / perimeter block typology featuring vertically stacked base modules. FSI – 3.9

3. Point Tower with Podium (Selected)

A slender point tower rising from a low podium concentrates floor area into a compact footprint, easily achieving an FSR within the 2.0 - 4.0 range while preserving ground-level open space and view corridors. The tower naturally acts as a neighbourhood landmark, capitalizes on views along the rail corridor and King/Victoria intersection, and aligns with the Innovation District's intent for high-density residential and mixed uses near transit. The buildable site area after the setbacks is 2,353sqm, to attain the maximum Floor Space Ratio (FSR) of 4, the target Gross Floor Area (GFA) for the proposed building is approximately 9,412 square meters. The most suitable configuration that closely aligns with this target is a Point Tower with podium building featuring a base footprint of 554 square meters and a total of 17 floors, resulting in a cumulative GFA of 9,418 square meters. Total FSR is 4.0 This configuration is illustrated in Figure 39b.

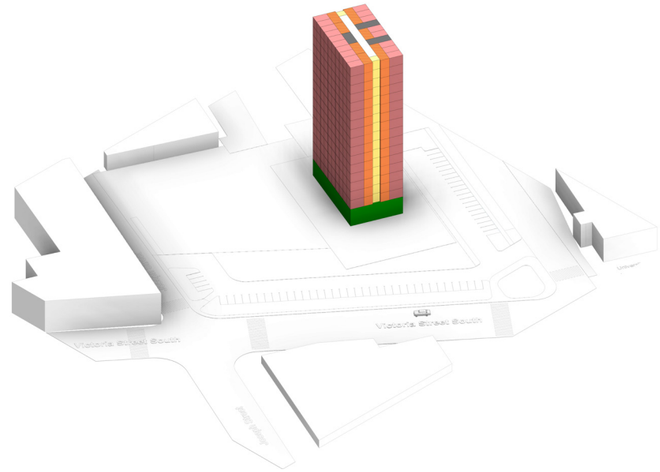


FIGURE 39b: Author's illustration of a point tower with podium typology featuring vertically stacked base modules. FSI – 4.0
Located on project site (Kitchener Downtown)

4.1.4 Rationale for Selected Typology

The thesis therefore adopts a hybrid point-tower typology with a mass-timber structure on a concrete podium as the most appropriate response to the policy framework. This configuration:

1. Efficiently achieves the required FSR range without over-building the site.
2. Supports transit-oriented, mixed-use urbanism within the Innovation District.
3. Aligns with municipal goals for innovative, affordable housing near major transit; and
4. Organizes the tower floorplate around a standardized 3.05 m × 7.62 m structural grid, which is well suited to modular mass-timber construction.

The Official Plan does not prescribe a single form but clearly steers design toward a compact, vertical, high-density building capable of acting as both a housing prototype and an urban marker for the Innovation District. [92]

4.2 Base Module and Modular Assembly System

The proposed mass-timber housing system is developed as an off-site prefabricated kit-of-parts, optimized for rapid assembly and repeatability.
The proposed building at 12 Victoria Street South is organized on a 3.05 m × 7.62 m (10′ × 25′) grid, sized to align with recommended spans for CLT floor panels in residential buildings as documented in the 2019 CLT Handbook and Mass Timber Design Manual.[93]

92 Council for the Regional Municipality of Waterloo, "City of Kitchener Official Plan - A Complete & Healthy Kitchener."

93 Erol Karacabeyli, ed., CLT Handbook: Cross-Laminated Timber, U.S. edition, with Brad Douglas (FPInnovations, 2013).

The modular system is structured around three design objectives:

1. Affordability – using standardized elements, minimized on-site labour, and efficient unit planning to reduce per-unit cost.

2. Sustainability – employing mass timber as the primary structural material, reducing embodied carbon and enabling carbon storage.[94]

3. Community – distributing shared interior and exterior spaces throughout the vertical stack to create a “vertical village” rather than a purely repetitive tower.

94 Michael Green Architecture, The Case for Tall Wood Buildings.

Kit-of Parts Logic

4.2.1 Kit-of-Parts Logic

Justification for Panelised & Volumetric Systems

Volumetric modular construction was evaluated during the design process, particularly for full apartment units. However, it was not pursued for the primary strucural system due to several constraints:

1. Transport & dimensional limits - restrict volumetric modules to 3-4m widths, which would constrain the dweling layouts envisioned for this high-rise project.

2. Stacking tolerance in tall buildings - compound over multiple storeys, making full-volumetric systems less suitable beyond mid-rise height.

3. Lateral Load resistance is more efficiently achieved through large-format CLT shear walls rather than discrete volumetric boxes.

4. Architectural flexibility - panelized systems allow varied unit types, adaptable layouts, and the spatial porosity central to the design concept.

Consequently, the project adopts a hybrid kit-of parts: Large panelised CLT walls and slabs for the primary structural frame, complemented by volumetric wet-core pods where off-site prefabrication offers the greatest benefit.

Rather than treating each apartment as a full volumetric module, the project adopts a hybrid system that combines panelized CLT structure with targeted volumetric pods for wet areas. The principal elements as shown in figure 40 and Figure 41 are:

a) Exterior CLT Wall Panels (EW1)

- 220 mm, 7-ply CLT panels act as load-bearing façade and party walls. This thickness is consistent with tall-wood guidance for exterior shear walls and provides a robust combination of structural capacity, fire resistance, and acoustic performance.
- Panels are CNC-machined with vertical tongue-and-groove or spline joints, window openings, and pre-cut penetrations for mechanical services.
- Exterior faces receive factory-applied air/vapour control, continuous insulation, and rainscreen battens, with cladding either pre-installed or attached on site.
- Interior faces are left as exposed timber, finished with a clear intumescent coating.

b) Pre-Assembled CLT Slab Cassettes (S1)

- 160 mm 5-ply CLT floor cassettes span each 3.05 m bay, consistent with span tables and vibration criteria for residential occupancy in CLT design guides. [95]
- Cassettes bear on exterior CLT walls and on the CLT wet pods via steel angle brackets and self-tapping screw connections; additional steel knife plates or concealed hangers are used where required by local shear or rotation demands, following connection strategies described in the Mass Timber Design Manual. [96]
- A 40–60 mm concrete or gypcrete topping provides acoustic mass, and a 75–100 mm suspended ceiling zone below accommodates sprinklers and small-diameter ducts.

c) Volumetric Wet-Space Pods (WP)

- Compact CLT shell volumes (typically 152 mm CLT walls and floor) contain bathrooms and, where required, kitchen components.
- Pods are factory finished, including plumbing, fixtures, waterproofing, tile, exhaust fans, and lighting, and stacked along the corridor-side service wall to create a continuous riser spine.
- Structural design follows typical mass-timber box behaviour with vertical load paths through the CLT walls and concentrated bearing at the floor cassette level. [97]

d) Prefabricated Façade Panels and Juliet Rails

- Window units, insulation, and cladding are integrated into façade sub-panels that fit between CLT wall segments.
- Juliet balcony railings bolt directly into the CLT wall or an edge beam, avoiding the added cost, fire detailing, and thermal bridging associated with projecting balconies.
- Wood like aluminium cladding.

This kit-of-parts keeps the structural system planar and repetitive, while reserving volumetric prefabrication for compact, high-value elements that benefit most from factory completion.

95 FPInnovations et al., Technical Guide for the Design and Construction of Tall Wood Buildings in Canada 2022 -, Second Edition (FPInnovations, 2022).

96 "PLATES AND CONNECTORS FOR TIMBER," accessed November 27, 2025, https://www.rothoblaas.com/catalogues-rothoblaas/plates-and-connectors-for-timber.

97 FPInnovations et al., Technical Guide for the Design and Construction of Tall Wood Buildings in Canada 2022

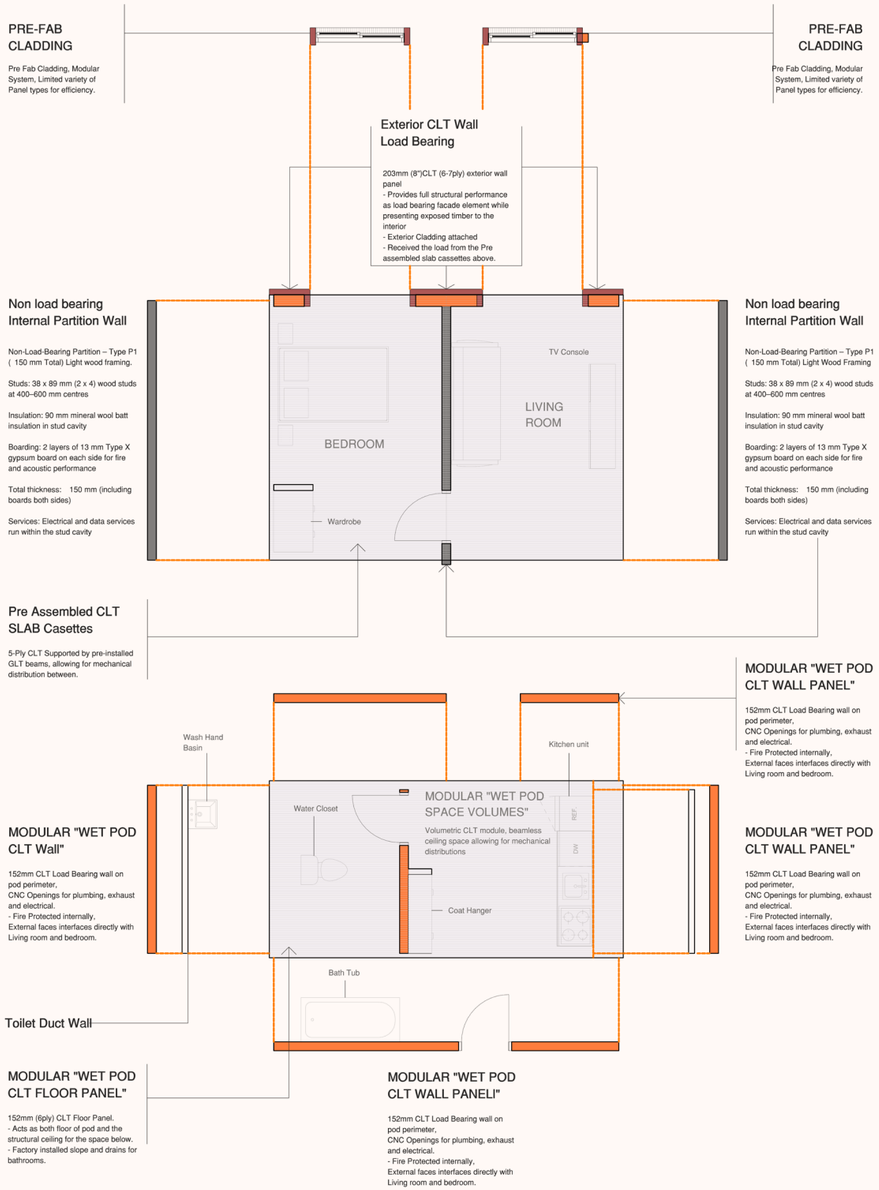
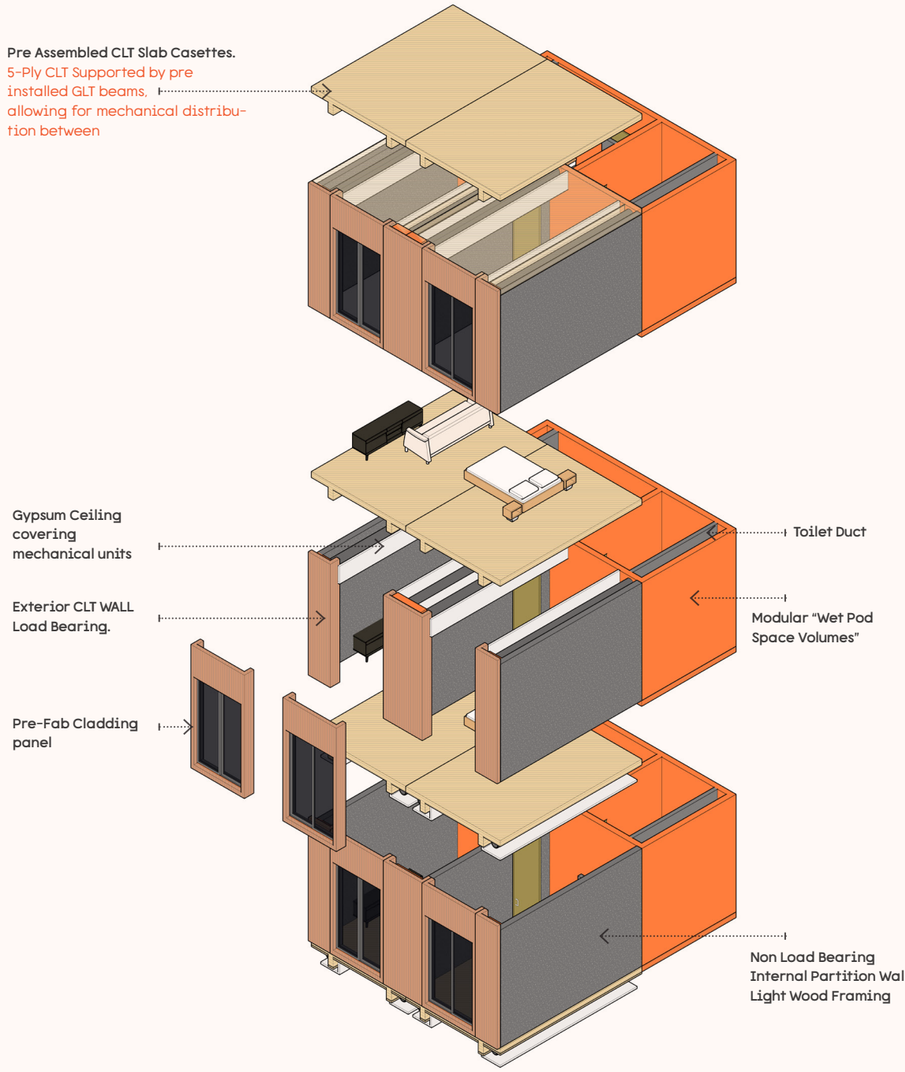


FIGURE 40: : Author's drawing of The Kit-of-Part Logic of the proposed project base module.



THE SEQUENCE – ONE BEDROOM

FIGURE 41 : Author's 3D - exploded drawing of The Kit of Part Logic of the proposed project's base module

4.2.2 Volumetric vs Planar (Panelised) Modules

Two approaches were evaluated for the living and bedroom spaces:

- **Option A – Full Volumetric Living/Bedroom Modules**
  Each dwelling would be a complete volumetric unit with integrated structure, façade, and finishes. While such systems exist in modular construction, the resulting units are heavy, difficult to transport in an urban context, and require complex inter-module joints for fire, acoustics, and tolerance control particularly in tall buildings. [98]

- **Option B – Planar Living/Bedroom Zones on a CLT Frame (Selected)**
  In the adopted approach, only wet areas are volumetric. Living and sleeping spaces are formed by:

  1. 160 mm CLT slab cassettes
  2. 220 mm exterior CLT wall panels
  3. Light-frame non-structural partitions
  4. Prefabricated aluminium façade panels and Juliet rails

  Interior finishes (flooring, gypsum, paint) are installed in the factory as far as practicable, but the spatial volume is created on site by stacking standardized structural components.

Option B was selected because it:

1. Reduces lifting weight and crane time, making construction more manageable on a constrained downtown site.

2. Simplifies detailing at vertical and horizontal joints, because planar CLT elements behave similarly to traditional plate-and-wall structures.

3. Increases flexibility in unit planning; the same grid can generate studios, 1, 2, and 3-bedroom units simply by aggregating bays.

98 Waugh Thistleton Architects, "Timber Typologies, Understanding Options for Timber Construction."

4.2.3 Modular Floorplate and Communal Distribution

Using the base grid, the typical floorplate is composed of modular bays arranged around a compact central core and corridor as shown in figure 42:

- **Unit Composition**

  - **A 1-bedroom unit** generally occupies two 3.05 m bays: one for the living/kitchen zone and one for the bedroom/wet pod.

  - **A 2-bedroom unit** combines three bays, and a 3-bedroom unit four bays, as illustrated in the unit diagrams in figure 42
    (Typical One Bedroom, Typical Two Bedroom, Typical Three Bedroom).

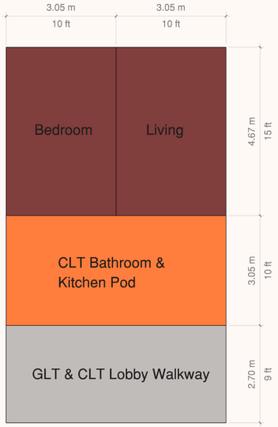
  Each configuration keeps wet pods aligned with the corridor/service wall; while living and bedrooms occupy the perimeter bays to maximize daylight and natural ventilation.

- **Daylight and Orientation**

Bedrooms and living rooms are placed along the **perimeter CLT wall,** where large windows within pre-clad façade panels maximize daylight and views. The section in figure 43 shows how the floor-to-ceiling height and window dimensions are coordinated with the 3.05 m grid, with a clear zone at the perimeter free of bulkheads.

- **Communal Voids**

Rather than adding balconies to every unit, selected bays are omitted or reprogrammed to create communal terraces, shared kitchens, laundry/work rooms, and game or lounge spaces. These are distributed vertically so that every few floors residents encounter a shared interior–exterior zone. This strategy compresses private unit area, improves affordability, and supports social interaction while remaining compatible with the repetitive modular structure. These are structurally identical to normal bays using CLT slabs and walls but programmed as common spaces. The stacked diagrams of aggregating brocks common tallwood house in (figure 44) shows modules in orange and grey modules indicating residential and green modules indicating communal/void locations in the student housing project. This strategy keeps per-unit floor area compact and promotes social interaction, while maintaining a legible, repetitive structural pattern.



Typical One bedroom



Typical One bedroom



Typical Two bedroom



Typical Three Bedroom

FIGURE 42: : Author's typical floor plan drawing of the modular unit composition

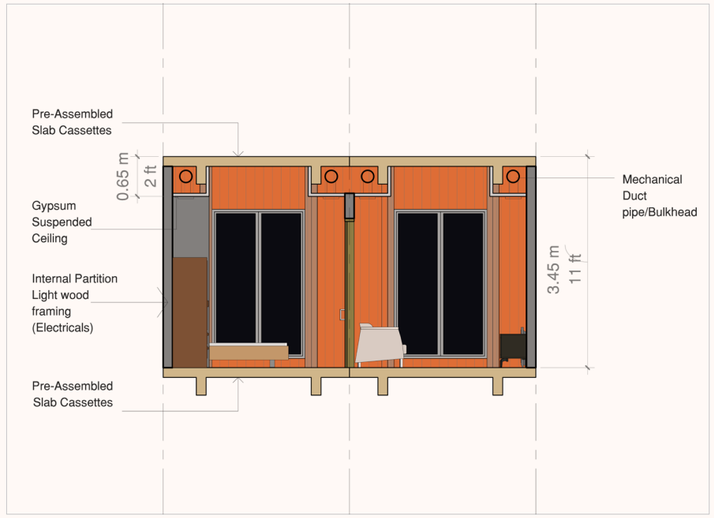


FIGURE 43: Author's section drawing of the Modular Unit Composition showing the floor to ceiling height of 3.29m to maximize daylight.

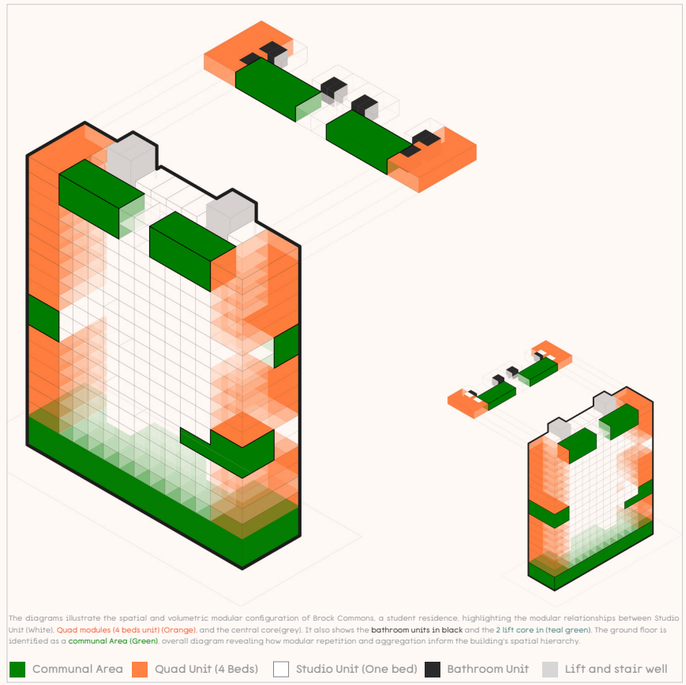


FIGURE 44: Author's drawing of brock commons project in Vancouver showing aggregation of communal spaces. Adapted from "UBC Brock Commons Tallwood House & Acton Ostry Architect"

These communal zones pair everyday pragmatic functions with opportunities for gathering, play, work, and relaxation:

- Barbecue & Kitchen Terrace: Indoor–outdoor cooking and dining.
- Dog Wash & Hot desk Zone: Combining pet care with flexible workspace.
- Party & Game Room: A social hub for recreation and small events.
- Laundry & Workstations: Encouraging casual interaction while multitasking.
- Laundry & Table Tennis Space: Blending domestic activity with leisure.

4.2.4 Assembly and On-Site Sequence

The assembly sequence mirrors the logic of the exploded construction axonometric diagram in (figure 41):

1. Concrete Podium and Cores

- In British Columbia, 45% of five- to six-storey wood multifamily buildings were constructed with concrete podium ground floors, in 2016. As mid-rise construction is adopted across Canada, it is expected that podium floors will continue to be used, as many of these buildings will be for mixed use. A reinforced concrete podium slab and core are constructed first, providing lateral stability, fire separation at grade, and a precise bearing surface for the mass-timber superstructure.
- Because the concrete podium remains stable while the mass-timber superstructure compress over time, the interface incleds slotted steel plates compressible gaskets which allows the CLT panels to settle independetly of the concrete podium.

2. CLT Exterior Wall Panels

- Pre-clad 220 mm CLT exterior wall panels are craned into position and fixed to the podium and core using steel plates with hollow structural steel attached to steel plate attached to the concrete podium bolts and nuts and self-tapping screws where needed.

- Panels are temporarily braced until the floor cassettes are installed.

3. Placement of Volumetric Wet Pods

- Prefabricated kitchen and bathroom pods are set along the corridor-side service line, stacked directly on top of one another.

- Plumbing, exhaust, and electrical risers align through pre-cut openings in the CLT slabs.

4. Installation of CLT Slab Cassettes

- Pre-assembled CLT floor panels are laid across the walls, tying the frame together and acting as diaphragms that connect back to the concrete core.
- The beamless ceiling condition allows ducts and pipes to run above the suspended gypsum ceiling without interfering with the CLT. This is visible in the section diagrams in (Figure 43) where mechanical ducts sit within the 0.65 m service zone.

5. Facade Panels and Juliet Rails

- Window and façade panels are craned into place between CLT wall segments, and Juliet balcony rails are fixed to pre-installed brackets.
- As soon as one level is enclosed, interior works can progress regardless of weather.

6. Interior Fit-Out and Communal Spaces

- Light-frame non-load-bearing partitions, interior finishes, and built-in furniture are installed.
- Where bays are designated as communal spaces, timber ceilings and floors are left more exposed, and larger openings are created to neighbouring bays or terraces.

7. Mechanical and Service Logic

- All mechanical risers plumbing stacks, exhaust shafts, and main ductwork are concentrated along the corridor-side wall. Supply air enters each unit from this side; bathroom and kitchen exhaust ducts connect directly into vertical shafts above the wet pods, as recommended in mass-timber services integration guides. [99]

8. Repeat for Subsequent Levels

- The process is repeated floor by floor, with predictable cycles of wall, pod, slab, and façade installation.
- The massing diagrams on pages 8, 10, and 12 show how this stacked logic generates the final bar, courtyard, and tower forms.

Because every component belongs to the same standardized kit, erection is rapid, and sequencing is straightforward. The hybrid system therefore combines the precision and speed of modular construction with the robustness and adaptability of a CLT frame.

99 FPInnovations et al., Technical Guide for the Design and Construction of Tall Wood Buildings in Canada 2022 -.

4.2.5 Element Specification

The detailed element sheet in figure 40 summarizes the relationship between the kit components.
In text, the key specifications are:

- **Exterior CLT Wall Panel (EW1)** - 200 mm CLT, exposed timber interior, CNC joints, factory-applied membranes, exterior insulation and rainscreen cladding; can be delivered fully pre-clad.

- **Non-load-bearing Partition (P1)** - 38 × 89 mm timber studs at 400–600 mm centres, 90 mm mineral wool insulation, and two layers of 13 mm Type X gypsum board each side, overall thickness ≈150 mm; services run within the cavity.

- **Pre-Assembled CLT Slab Cassette (S1)** - 160 mm 5-ply CLT with 40 mm topping and 65 mm suspended ceiling; ducts and sprinklers run in the ceiling zone.

- **Modular Wet Pod Volume (WP)** - volumetric CLT shell with 152 mm walls and floor, beamless ceiling, complete bathroom or kitchen fit-out and aligned service risers.

These specifications ensure that each element is constructible, code-compliant, and compatible with the others within the modular grid.

4.3 Corridor Structural System

The project incorporates several exterior-access walkways and shared terraces distributed vertically through the massing depending on the typology (as shown in the service and unit-access diagrams in figure 45). These walkways are not suspended from the tower but instead supported by a simple, system consistent with tall wood precedent such as brock commons.



Typical One bedroom

FIGURE 45: Author's drawing showing Corridor Structural system showing the corridor span (Grey) attached to the volumetric wet pod.

4.3.1 Structural Support Strategy

Walkways are supported by a three-part structural system:

1. Primary Support at the CLT (Volumetric Pod) Superstructure
   - Walkways bear directly on the 203.2 mm CLT wall panels using steel angle brackets, knife plates, or concealed side-mounted connectors.
   - These connection types are standard in mass-timber construction, recommended in the Mass Timber Design Manual and CLT Handbook, which document the use of steel angle seat connectors and self-tapping screws to transfer vertical and shear loads between horizontal and vertical CLT elements. [100]
2. Secondary Glulam or CLT Edge Beam
   - A slender glulam/CLT edge beam runs parallel to the walkway slab, receiving the 160 mm CLT slab cassette through a notched bearing similar to the cassette seating condition used for interior floors.
   - This corresponds to the configuration shown in the exploded cassette drawings, where floor panels land on CLT and are reinforced by concealed steel.

100 FPInnovations et al., Technical Guide for the Design and Construction of Tall Wood Buildings in Canada 2022.

3. Glulam Post or Diagonal Brace (Where Needed)

- Where spans exceed ~2.5–3.5 m, a timber post or steel tube brace supports the outer edge.[101]

This hybrid system ensures that the walkways remain lightweight and compatible with the modular installation sequence.

4.3.2 Lateral Stability

Corridors are laterally restrained by:

- Horizontal diaphragms formed by the slab cassettes,
- Shear transfer through steel connectors into the CLT walls, and
- The concrete core, which serves as the building's primary lateral system.

This method follows the model established in Brock Commons Tallwood House, where CLT elements transfer lateral forces to a reinforced concrete core. [102]

4.4 Cost and Advantages of Mass-Timber Modular Construction

4.4.1 Cost Rationale

Exact costing requires quantity take-offs, leveraging on industry literature notes that mass-timber modular construction delivers measurable savings in the followings ways:

1. Construction Time (10–25% faster)

- Prefabricated CLT panels and volumetric pods reduce on-site duration.
- The U.S. Mass Timber Construction Manual reports that modularized timber buildings can reduce schedules by 10–20% due to "off-site parallelization of wet trades, enclosure and interior finish work." [103]

2. Labour (Reduced Site Labour by 20–30%)

- A significant portion of labour is shifted to factory settings, where assembly is repetitive and efficient.
- FPInnovations notes that pre-assembly of CLT slabs and walls reduces skilled on-site labour and crane time. [104]

101 "PLATES AND CONNECTORS FOR TIMBER"; KL&A Engineers & Builders, OZ Architecture & Swinerton Builders., WoodWorks Index of Mass Timber Connections (WoodWorks: Wood Product Council, 2021).

102 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

103 "U.S. Mass Timber Construction Manual," WoodWorks | Wood Products Council, n.d., accessed November 27, 2025, https://www.woodworks.org/resources/u-s-mass-timber-construction-manual/.

104 FPInnovations et al., Technical Guide for the Design and Construction of Tall Wood Buildings in Canada 2022 -.

3. Total Cost Competitiveness

Current case studies (e.g., Ascent, Brock Commons) demonstrate that mass timber achieves a similar or slightly lower total cost than concrete for mid- and high-rise structures when schedule savings and reduced labour are included. [105]

4.4.2 Advantages Over Conventional Construction

Category	Advantage of Mass Timber (supported by research)
Speed	Faster erection due to prefabrication and light components (WoodWorks Manual). [106]
Labour Efficiency	Reduced skilled labour needs; simplified on-site equipment. [107]
Carbon Reduction	Stores carbon + less embodied carbon than concrete.[108]
Thermal & Acoustic	High thermal performance with exterior insulation and CLT mass provides acoustic damping. [109]
Indoor Environment	Exposed timber provides biophilic benefits and higher occupant satisfaction.1 [110]
Precision & Quality	CNC fabrication produces tolerances far tighter than on-site concrete.

Table 6: Advantages of Mass Timber

4.4.3 Why This Building system is Better Than Conventional Construction

This hybrid building approach is superior to conventional reinforced concrete construction for the following reasons:

105 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

106 Think Wood and Woodworks, "Mass Timber Design Manual, Vol 2."

107 FPInnovations et al., Technical Guide for the Design and Construction of Tall Wood Buildings in Canada 2022 -.

108 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

109 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

110 United Nations Environment Programme et al., "Building Materials and The Climate: Constructing a New Future."

- **Parallelization:** Wet pods, façade panels, and slab cassettes are manufactured off-site simultaneously.
- **Low Carbon:** CLT and glulam dramatically reduce embodied carbon compared to concrete.
- **Adaptability:** The 3.05 m × 7.62 m mass-timber grid supports multiple typologies (bar, courtyard, tower).
- **Affordability:** Smaller units, shared terraces, and repetitive structural bays reduce per-unit construction and lifecycle cost.
- **Speed:** Installation of one full floor in a few days is achievable based on case-studies of similar modular mass-timber towers.[111]

4.4.4 Unit Mix Justification

The unit mix for this project responds directly to the demographic and housing needs of Kitchener and the broader Waterloo Region. Local data shows that single-person households (26.7%) and two-person households (32.5%) make up nearly 60% of all households in the city (Point2Homes, 2023). [112] This strongly supports the inclusion of a significant number of 1-bedroom and 2-bedroom units, which align with the needs of young professionals, couples, and small households the dominant demographic segment.

At the same time, Kitchener's average household size of 2.6 persons, combined with the fact that 24.8% of households include four or more people, indicates a meaningful demand for family-sized 3-bedroom units. These larger units are introduced in limited but strategic numbers to address the shortage of family-oriented rental housing while maintaining the efficiency of the tower's compact floorplate.

Given that 40.3% of Kitchener households rent and the region continues to experience high demand for purpose-built rental housing, a balanced mix of 1-bedroom, 2-bedroom, and selected 3-bedroom units offers the best alignment with both local housing needs and the economic logic of a point-tower mass-timber building. This approach supports affordability goals while remaining attractive and feasible for developers. [113]
Accordingly, the building adopts the following unit ratio:

- **30% - One-bedroom units,** serving singles, couples, and new entrants to the rental market.
- **50% - Two-bedroom units,** accommodating the region's average household size and providing the most flexible and in-demand housing type.
- **20% - Three-bedroom units,** introduced in strategic locations to address the documented shortage of family-sized rental homes.

111 Think Wood and Woodworks, "Mass Timber Design Manual, Vol 2."

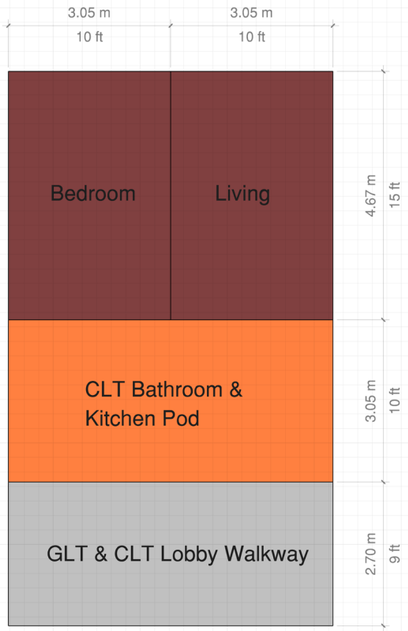
112 "Kitchener, ON Demographics: Population, Income, and More | Point2Homes," accessed November 27, 2025, https://www.point2homes.com/CA/Demographics/ON/Kitchener-Demographics.html.

113 "Kitchener, ON Demographics: Population, Income, and More | Point2Homes," accessed November 27, 2025, https://www.point2homes.com/CA/Demographics/ON/Kitchener-Demographics.html.

Design Development - Kit-of-Parts Logic

4.5 Proposed Design

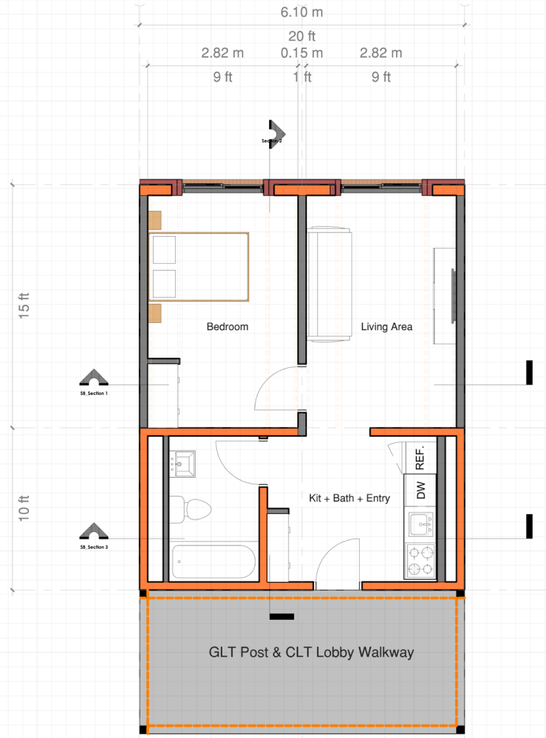
4.5.1 Base Module Layout - The layout of the Module is design to accomodate a seamless transition of each the spaces keeping the Wet Pod next to the lobby or entrance corridor, keeping the services along the central lobby. While next to the wet module is the bathrooom and living unit, which is flexible and can be repurposed into shared social and communal space.



Typical One bedroom

FIGURE 46:
Base Module layout. (10ft x 25ft)

4.5.2 Typical One Bedroom - The floor plan of the Module is design to accomodate a seamless transition of each the spaces with the kitchen and toilet along the entrance lobby to the living area and from the living area, the bedroom can be access. The one bedroom unit uses two bays for it layout.



Typical One bedroom

FIGURE 47:
Typical One Bedroom layout.
(2 bays)

4.5.3 Typical Two Bedroom - The layout of the two bedroom with two bathrooms is design with 3 bays as a build up on the one bedroom by adding an extra bedroom unit and also increasing the width of the wet module to make up a unit while considering the ducts fot plumbling.



Typical Two bedroom

FIGURE 48:
Typical Two Bedroom layout.
(3 bays)

4.5.4 Typical Three Bedroom - The three bedroom unit with two bath is a build up of the two bedroom unit with an additional bedroom unit added.

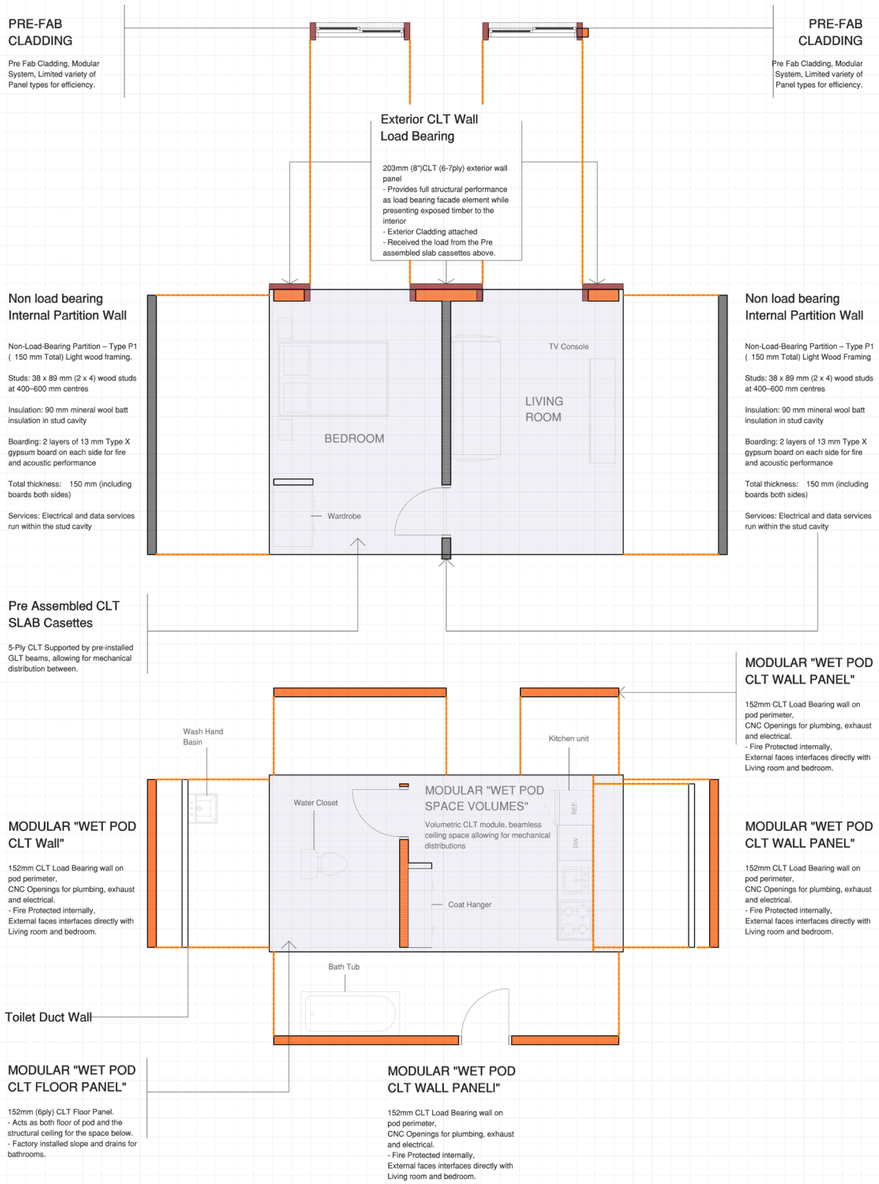


Typical Three Bedroom

FIGURE 49:
Typical Three Bedroom layout.
(4 bays)

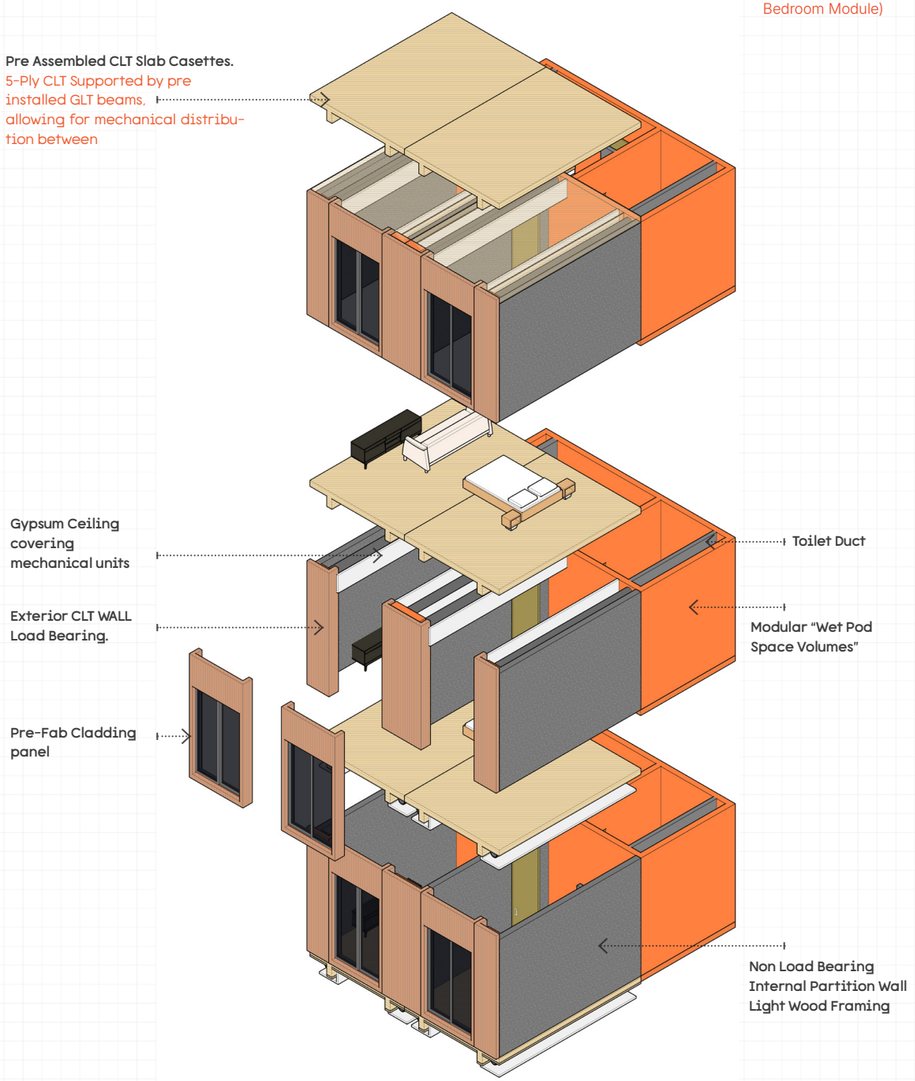
FIGURE 50:
Product Specification.
(One Bedroom Module)

4.5.5 Product Specification - An exploded diagram in Figure 50 showing the product details of the one bedroom unit.



4.5.6 Assembly Diagram - (Figure 51 and Figure 52) shows the sequence of assembly showing how the components of the one bedroom unit sits and connects with each other.

FIGURE 51: 3D Axonometric diagram, product Specification. (One Bedroom Module)



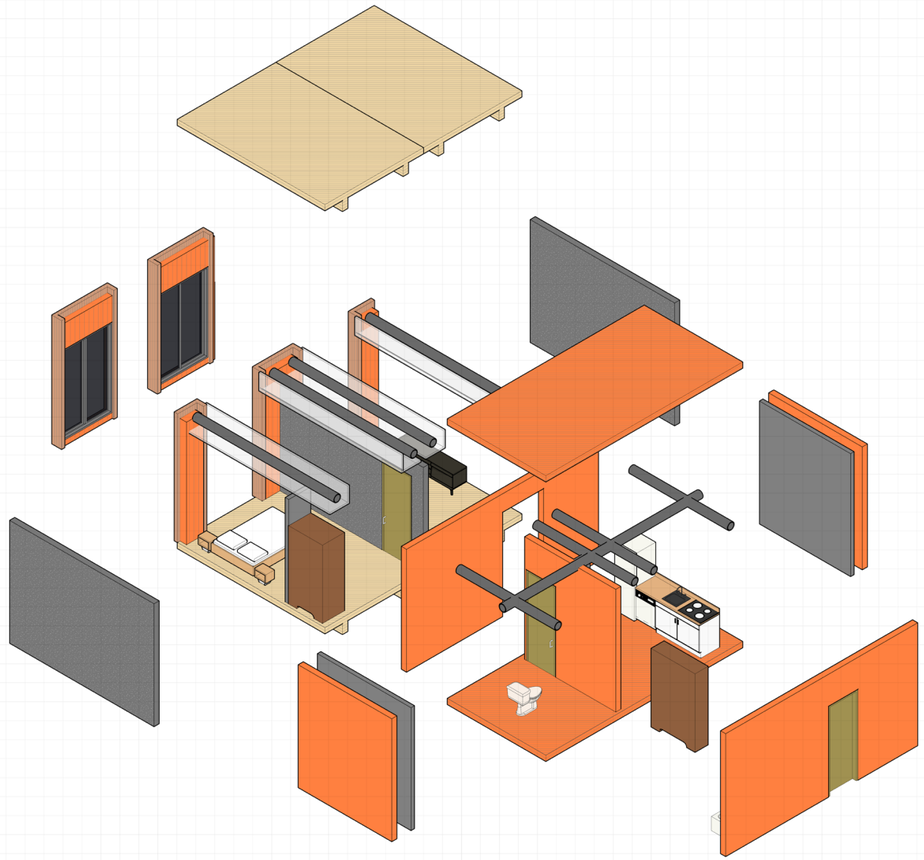


FIGURE 52:
Exploded diagram of the one-bedroom modular unit

4.5.7 Sections through Base Module - (Figure 53 and Figure 54) shows the section through the base module showing how the mechanical ducts runs beneath and along the pre-assembled slab cassettes and covered with gypsum ceiling which can also be left exposed to save material cost and labour.

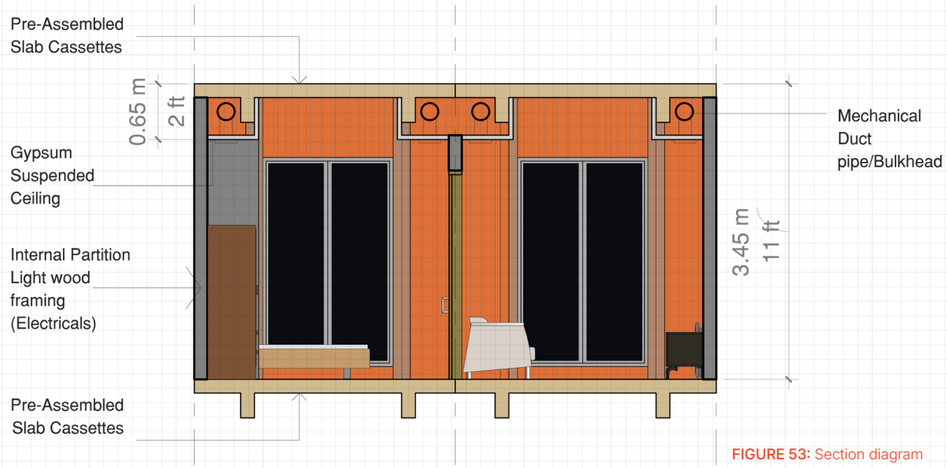


FIGURE 53: Section diagram showing the slab cassettes and mechanical duct (One Bedroom Module)

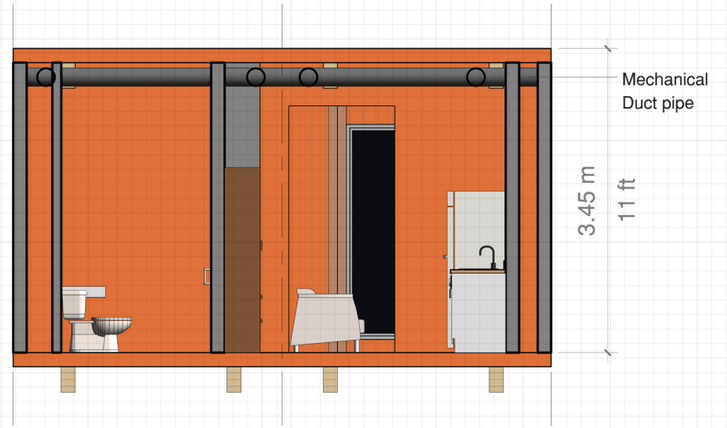


FIGURE 54: Section diagram showing the kitchen and bath-room duct and mechanical duct (One Bedroom Module)

Design Development - Proposed Design



FIGURE 55:
Site Contextual Analysis of buildings around the test project site.

4.5.8 Site Contextual Analysis

The diagram in (Figure 55) shows the project site within the broader Kitchener Innovation District, highlighting the proximity of key institutions, commercial buildings, and major residential towers. The site sits at the intersection of Victoria Street South and Joseph Street, directly across from the University of Waterloo School of Pharmacy and within walking distance of major anchors such as the Google Office (11 storeys), The Tannery innovation complex, and multiple high-rise residential developments including Tek Tower (44 storeys) and One Hundred Condominiums. The GO Transit rail line establishes a strong regional mobility corridor, reinforcing the site's suitability for dense, transit-oriented modular housing. The aggregation of academic, commercial, and residential uses in the surrounding area emphasizes the project's role in serving students, researchers, and tech workers while contributing to the district's urban intensification vision.

1. Site Context Plan & Elevation

(Figure 56) shows an annotated plan identifying major landmarks around the project site, including the UW Health Sciences Campus, The Tannery, Station Park condominiums, and Central Station LRT. The adjacent structures illustrate a skyline characterized by a mix of mid-rise institutional buildings and high-rise residential towers, underscoring the district's ongoing densification. The elevation diagram further reveals the site's unique condition as an open foreground within a growing high-rise cluster, making it a prime location for an architecturally distinct, modular mass-timber residential tower. Its adjacency to institutional buildings also creates opportunities for integrated student housing and community programming.

2. Walking Distance Analysis

This circular walking-distance diagram (Figure 57) illustrates the site's strategic proximity to key destinations within the Kitchener Innovation District. The location lies approximately 83–150 meters from the University of Waterloo Health Sciences Campus, The Tannery, and surrounding commercial services equating to a 2–3 minute walk. The site is also within three minutes of Central Station LRT and the Grand River Transit bus network, providing high-frequency regional connectivity.

Together, this concentration of multimodal transit options establishes the site as a transit-oriented, pedestrian-supportive environment,

reducing reliance on private vehicles and reinforcing the project's emphasis on affordability, sustainable mobility, and reduced parking demand. The surrounding pedestrian and cycling networks further support the site's suitability for compact, modular housing serving students, healthcare workers, and professionals engaged in the district's expanding innovation ecosystem.

3. Cycliing Path Network

This diagram in (Figure 58) maps the dedicated cycling and pedestrian network surrounding the project. The site aligns with the Cherry Park Trail, a significant east–west green corridor, and connects directly to key cycling routes along Charles Street West, King Street, and Joseph Street. The design ensures continuity for cyclists moving between residential neighbourhoods, UW campuses, and the tech district. Prioritizing bicycle access supports sustainability goals, reduces vehicular dependency, and promotes healthy mobility key considerations for both student housing and innovation-district development.

4. Building Positioning (Setbacks, Access & Edges)

This drawing in (Figure 59) outlines the primary constraints and opportunities influencing building placement. A 9m setback from Victoria Street shapes the tower footprint, while a 30m buffer from the UW campus preserves daylight, privacy, and pedestrian comfort. Placing parking and service functions toward the rear minimizes conflict with active public edges. The south-facing portion of the site is reserved for community and urban activation spaces, strengthening visual and functional links to the UW campus corridor. This spatial strategy positions the building as a gateway element and contributes to a more connected Innovation District.

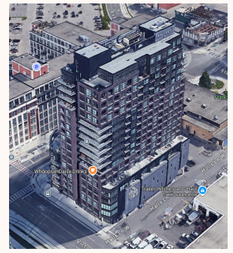
5. Building Positioning with Solar Orientation

The solar study in (figure 61) confirms and supports the decision to orient the building's longer façades toward the south, ensuring maximum daylight access and reduced winter heating demand. This deliberate massing strategy provides consistent solar exposure throughout the day while maintaining setbacks and alignment with the surrounding street network. The podium further reinforces this orientation by shaping sunlit public spaces along Victoria Street South, while the naturally shaded northern edge is reserved for circulation, cycling routes, and service functions. Together, these choices establish a clear, performance-driven response to the site's solar conditions.



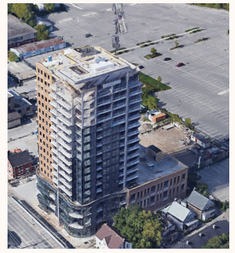
Site Context Elevation
(Showing the downtown kitchner building height)

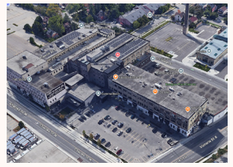
Residential Buildings | Project Site | University of waterloo, Campus facilities | Commercial Offices | Access road | GO Transit Rail


01


06


02


07

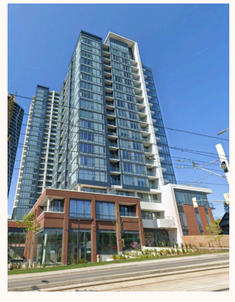

03


08


04


09


05


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11

Aerial views of the buildings around the project site showing surrounding landmarks.

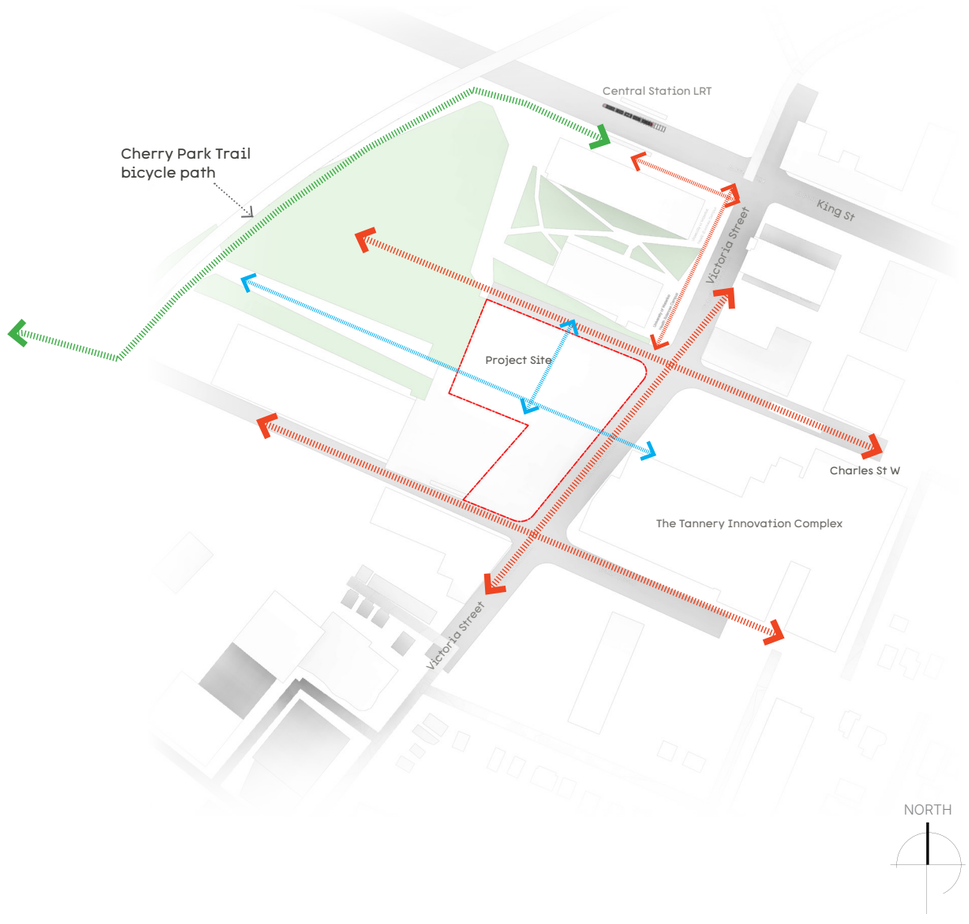
Image Source: Google Maps
(aerial view & Street view),
image cropped for academic use.
Accessed December 1, 2025.

01 - 1 Victoria St S Condominium
02 - UW School of Pharmacy & Health Science Campus.
03 - The Tannery
04 - Google Office Kitchener
05 - CBRE Office Building
06 - Green Area Behind site
07 - One Hundred Condo.
08 - Project Site (12 Victoria st s, Kitchener
09 - GO Transit Rail
10 - 15 Wellington Street South, Kitchener.
11 - Station Park Condominium (Residential)
12 - Central Station LRT

FIGURE 56:
Site Contextual Analysis showing Site Context Plan, images and Elevation.
Image Source: Google Maps
(aerial view & Street view),
image cropped for academic use.
Accessed December 1, 2025.



FIGURE 57:
Walking Distance Analysis showing the site's strategic proximity to key destinations within the Kitchener Innovation



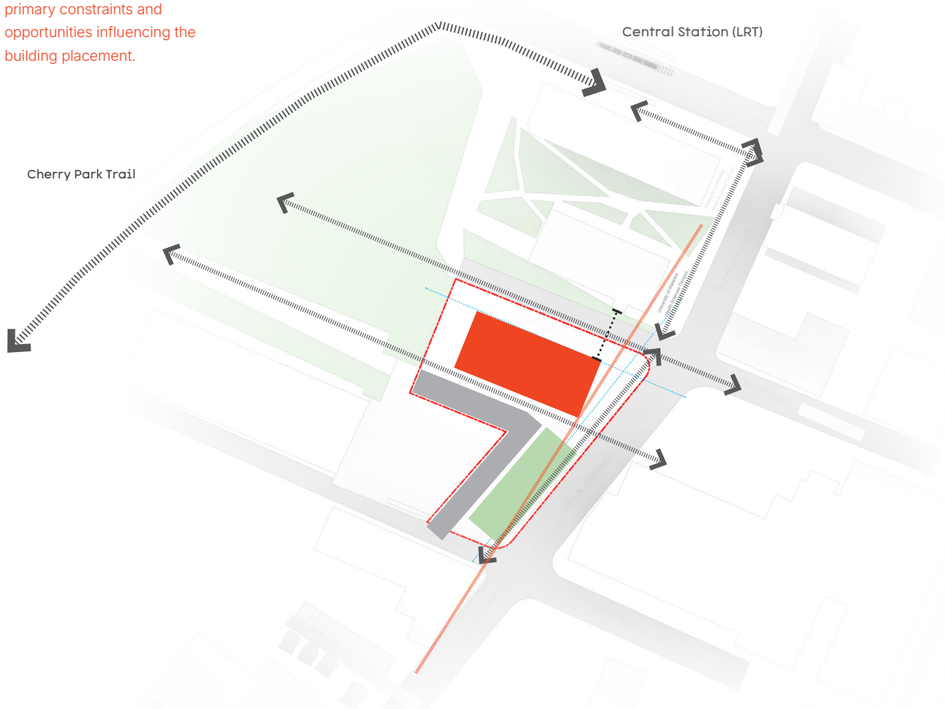
Existing Cyclist & Pedestrian Path around project Site

New Cyclist & Pedestrian Path around project Site, with Priority to maintian connection to trail at the west of the Project location from the tannery commercial

Cherry Park Trail

FIGURE 58:
Cycliing Path Network showing dedicated cycling and pedestrian network surrounding the project district.

FIGURE 59:
Building Positioning (Setbacks, Access & Edges) showing the primary constraints and opportunities influencing the building placement.



30m distance from UW campus building

9m Setback Line from the access road

Victoria Street Edge Consideration

Proposed Residential Tower
Large building footprint, to maximise the size of the site while allowing for some pedestrian circulation

Parking and Service Zoning to Building's Rear

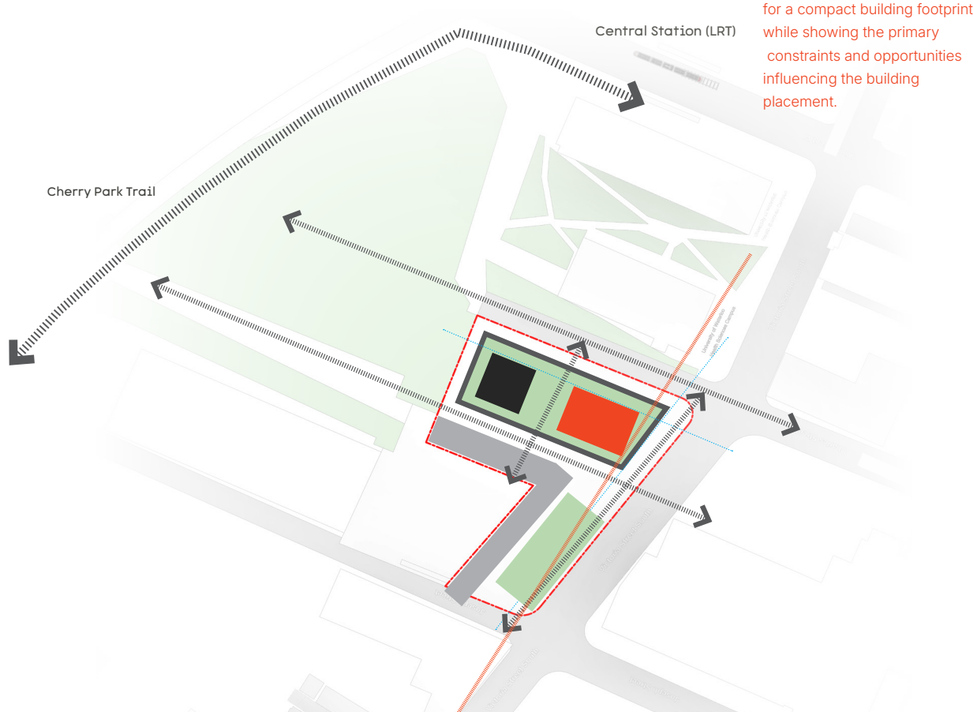
Community + Urban Activation Spaces along the UW campus coridor

Cyclist & Pedestrian Access to connect trail at the rear of the building

Project Site Boundary

NORTH

FIGURE 60:
Modified Building Footprint subdividing previous footprint to allow for a compact building footprint, while showing the primary constraints and opportunities influencing the building placement.



9m Setback Line

Victoria Street Edge Consideration

Proposed Compact Residential Tower
Keeps Longer side of building Facing south while following city setback and street edge

Deep Site to allow for additional compact Building for Student housing

Concrete Podium that serves as a base and covered walkway, provide communal community space within the vertical village.

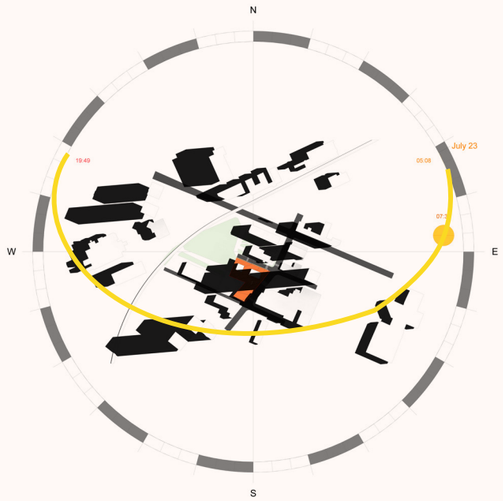
Parking and Service Zoning to Rear

Community + Urban Activation Spaces along the UW campus corridor. (Doubles as a muster point)

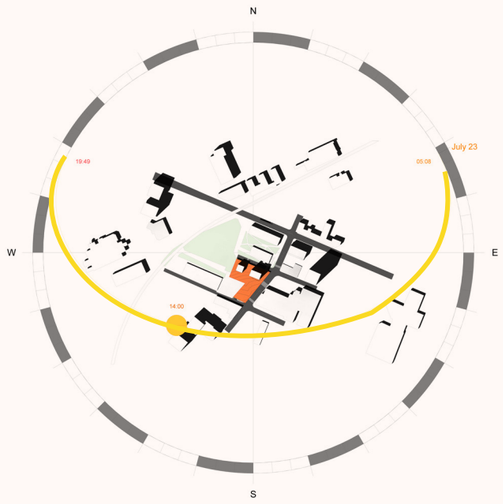
Cyclist & Pedestrian Access to connect trail at the rear of the building

Project Site Boundary

NORTH

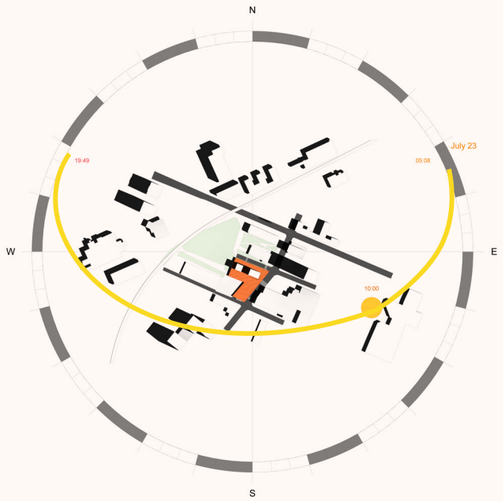


Shadow study illustrating building orientation relative to the sun at **7:30 am.**

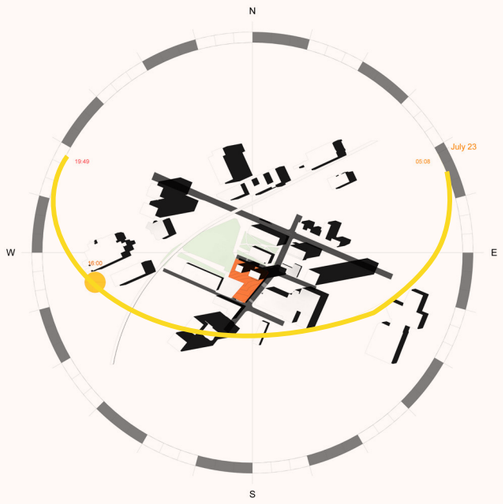


Shadow study illustrating building orientation relative to the sun at **2:00 pm.**

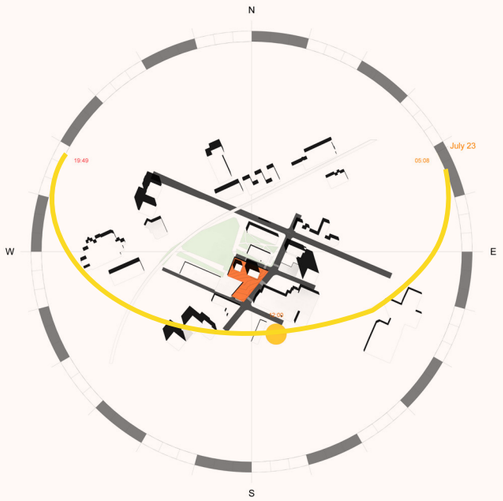
FIGURE 61:
Shadow study illustrating building orientation relative to the sun at 7:30 AM, 10 AM, 12 noon, 2 PM, 4 PM, and 6 PM, confirming the south-facing orientation of the building's longer façades.



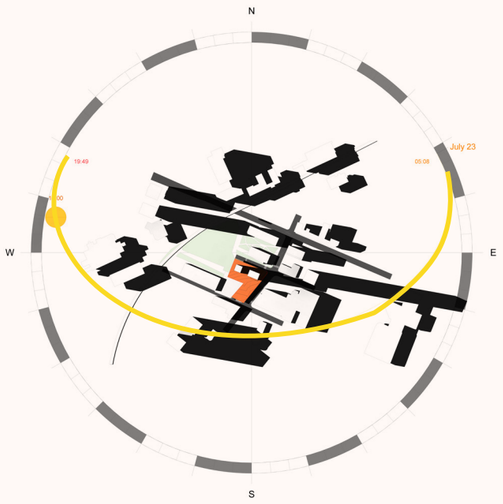
Shadow study illustrating building orientation relative to the sun at **10:00 am.**



Shadow study illustrating building orientation relative to the sun at **4:00 pm.**



Shadow study illustrating building orientation relative to the sun at **12:00 noon.**



Shadow study illustrating building orientation relative to the sun at **6:00 pm.**

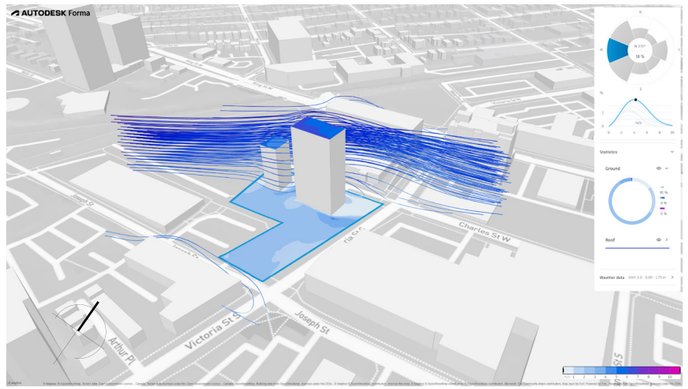


FIGURE 62:
Wind direction simulation showing as the strongest prevailing wind from the west of the two towers. Simulated with Autodesk Forma.

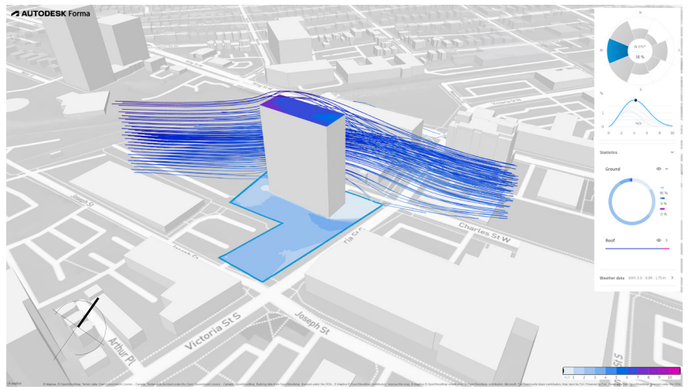


FIGURE 63:
Wind direction simulation showing as the strongest prevailing wind from the west of the single tower. Simulated with Autodesk Forma.

6. Strongest prevailing Wind Simulation

(Figure 62) shows the west-wind simulation illustrates how the proposed massing uses the podium and tower arrangement to manage the site's strongest prevailing wind. As the wind approaches from the west, the taller residential tower lifts a portion of the flow up and over the roof, while the podium footprint slows and diffuses wind at ground level, preventing uncomfortable acceleration at the Victoria Street frontage.

The two-tower configuration creates a leeward zone toward the east side of the site, where reduced wind speeds support the outdoor plaza, pavilion, and cycling routes as comfortable, year-round public spaces. Localized areas of higher velocity are pushed to the north and away from primary pedestrian gathering zones, reinforcing the project's aim to prioritize walkability and microclimate comfort in the heart of the Innovation District.

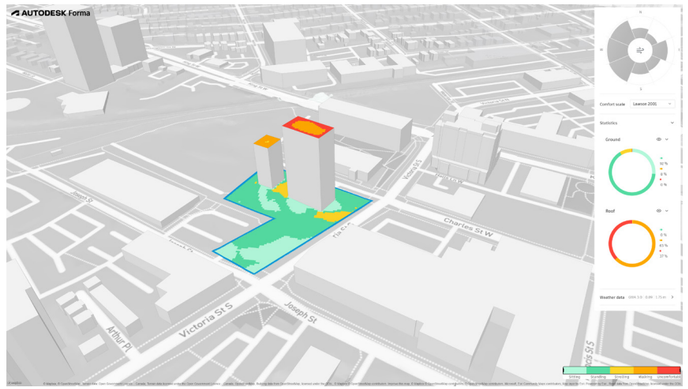


FIGURE 64:
Wind comfort analysis for the two-tower scheme showing that most ground-level areas remain comfortable for everyday use.

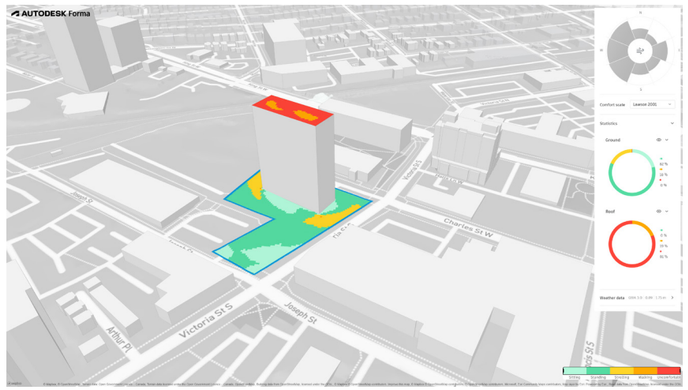


FIGURE 65:
Wind comfort analysis for the single-tower option, illustrating pedestrian comfort levels around the base of the building.

7. Wind Comfort Simulation

Using Autodesk Forma's computational wind simulation coupled with the Lawson (2001) pedestrian wind comfort criteria, [114] the analysis evaluates how the proposed massing performs in relation to expected pedestrian activities at grade. The results indicate that the majority of publicly accessible areas including the south-facing plaza, podium perimeter, and primary circulation paths consistently fall within the "standing" and "strolling" comfort categories. These thresholds confirm that the public realm can support everyday movement and passive outdoor use without excessive wind exposure. Higher wind speeds appear only at the tower corners and roof levels, where increased turbulence is expected and does not affect pedestrian comfort at street level. The design's continuous podium, offset tower configuration, and recessed ground edges collectively diffuse downwash and mitigate wind acceleration along Victoria Street.

114 "Kitchener, ON Demographics: Population, Income, and More | Point2Homes," accessed November 27, 2025, https://www.point2homes.com/CA/Demographics/ON/Kitchener-Demographics.html.

4.5.9 Site Plan Strategy

The site plan organizes the project around a clear urban and environmental strategy that responds directly to its position within the Kitchener Innovation District. The design orients the primary public frontage toward Victoria Street South, where a **south-facing community plaza** and **modular timber pavilion** establish an activated civic edge. This plaza becomes the social interface between the development, the UW Health Sciences Campus, and the surrounding tech ecosystem, benefiting from consistent sunlight throughout the day.

The placement of **Residential Tower A** and **Student Housing Tower B** is structured around a central podium courtyard, creating a legible circulation hierarchy and intuitive movement from public to semi-public to private spaces. Entrances to both towers are oriented toward this courtyard, reinforcing pedestrian access and ensuring that residents move through shared social spaces before transitioning into the residential core. The podium further supports this organization by providing sheltered walkways, outdoor seating zones, and direct links to the broader cycling network.

Landscape buffers with continuous tree planting and softscape define the perimeter of the site, providing acoustic protection from Joseph Street and the rail corridor while enhancing microclimate comfort for outdoor activities. These buffers also frame pedestrian routes that connect the development to the Cherry Park Trail and nearby cycling infrastructure, strengthening the project's transit-oriented character and supporting active mobility for students, workers, and residents.

Vehicular access is distributed to minimize conflict with pedestrian areas. The north edge accommodates a dedicated drop-off and luggage offloading zone, ensuring efficient short-term circulation for both towers. Along the south service lane, waste disposal, loading operations, and a small number of visitor parking spaces are discreetly positioned. This separation keeps all functional and service activities away from the primary public frontage, allowing the southern edge to remain unobstructed, walkable, and socially active.

Together, these strategies produce a site program that balances public amenity, residential functionality, and modular construction efficiency. By combining a strong landscape, clear circulation logic, and a performance-driven orientation, the design reinforces the project's goal as an affordable, sustainable, and community-focused development embedded within Kitchener's rapidly evolving innovation district.

Parking Strategy Justification

This project intentionally limits on-site parking to prioritize a transit-oriented, student-focused housing model. The site sits within a high-access mobility zone, with immediate connections to ION LRT, major bus routes, cycling infrastructure, and walkable daily amenities along Victoria Street and Joseph Street. For residents who own vehicles, parking demand is accommodated through a combination of perimeter short-term spaces, shared municipal/adjacent parking facilities, and off-site long-term leased stalls, a common strategy in dense, transit-supported urban contexts. By reducing on-site parking, the project reallocates land toward outdoor communal spaces, plazas, landscaping, and pedestrian networks, aligning with Kitchener's intensification and sustainable mobility policies. [115]

115 "Official Plan," November 21, 2025, https://www.kitchener.ca/en/development-and-construction/official-plan.aspx.

4.6 Site Plan

Design Development - Proposed Design

NORTH



FIGURE 66: Site plan illustrating the project's overall spatial strategy, including a south-facing community plaza and pavilion, defined pedestrian and cycling routes, clearly marked tower entrances, and a rear service zone with waste disposal and visitor parking. Landscaped tree buffers frame the site and support a protected, transit-oriented public realm.



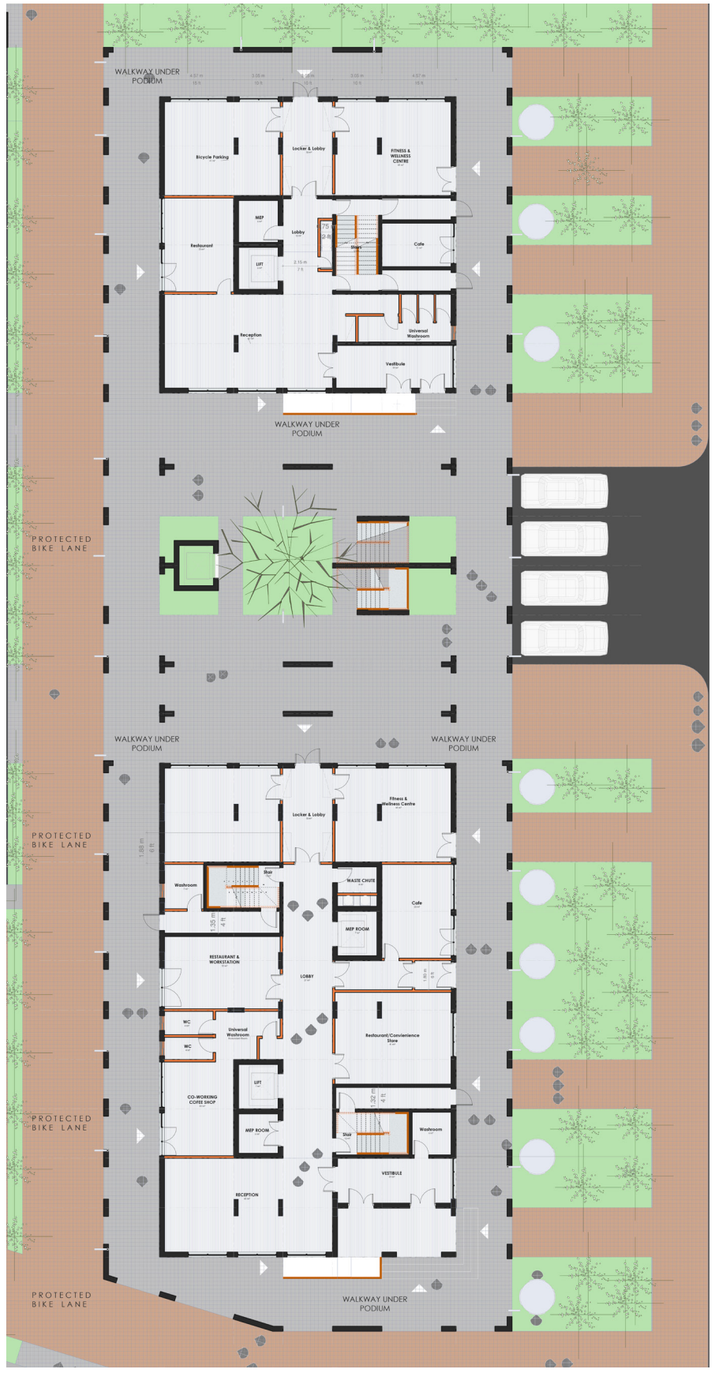


FIGURE 67: Level 1
Ground floor plan showing public programs, tower entrances, and site circulation.





FIGURE 68: Level 2
First Floor Plan, showing the modular unit clusters and distribution of student and residential housing types.
(Concrete Podium Level)





FIGURE 69: Level 3
Typical First Floor Plan, showing the modular unit clusters and distribution of student housing. Typical for Levels 2, 3, and 4 of the **Student Housing.**



FIGURE 70: Level 3
Typical First Floor Plan, showing the modular unit clusters and distribution of residential housing types. for Levels 2, 3, 4, 7, 10, 12, 13, and 19 of the **Residential Tower.**





FIGURE 71: Level 5
(5th Floor above grade)
Student housing showing shared laundry, workstation, and outdoor terrace spaces located at the building's west-facing corners, positioned to capture afternoon sunlight and provide out-ward-facing communal amenities.



FIGURE 72: Level 5
(5th Floor above grade)
residential tower showing shared laundry, workstation, and outdoor terrace spaces located at the building's west-facing corners, positioned to capture afternoon sunlight and provide out-ward-facing communal amenities.



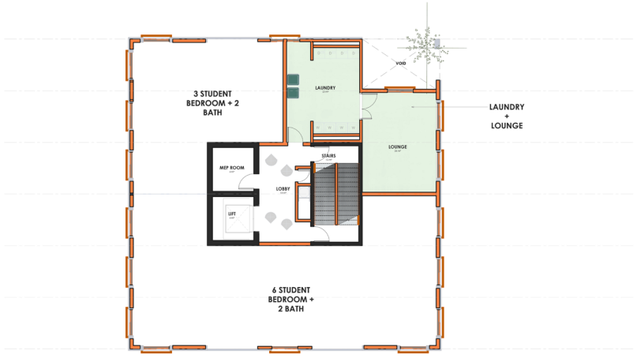


FIGURE 73: Level 6
Showing the introduction of double height corner void above the outdoor terrace to complement with a nice view from the Lounge.



FIGURE 74: Level 6
(6th Floor above grade)
showing the introduction of a double-height corner void and west-facing shared amenities, creating a transitional community floor between typical residential levels.





FIGURE 75: Level 7
(7th Floor above grade)
Student housing showing shared study rooms for individuals and groups located at the building's east-facing corner.





FIGURE 76: Level 8
(8th Floor above grade)
Student housing showing the introduction of double height corner void above the outdoor study terrace to complement with a



FIGURE 77: Level 8
(8th Floor above grade)
showing the residential tower with an outdoor party and games shared terrace on the east-facing





FIGURE 78: Level 9
(9th Floor above grade)
Student housing showing a multipurpose lounge with an outdoor terrace at the south facing corner to allow for views to the outdoor plaza



FIGURE 79: Level 9
(9th Floor above grade)
Showing the residential housing shows a shared party and games rooms with a double height space above the terrace.



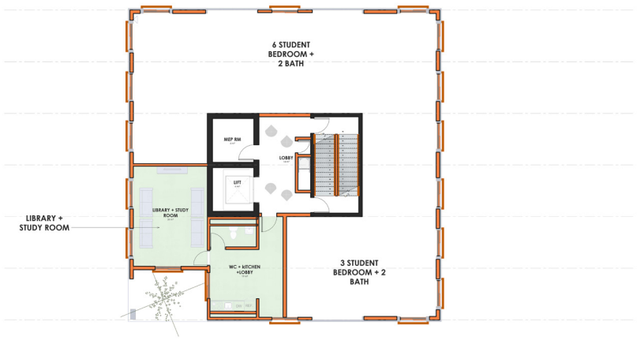


FIGURE 80: Level 10
(10th Floor above grade)
Student housing showing shared study rooms for individuals and groups located at the building's south-facing corner. to allow for views to the outdoor plaza.

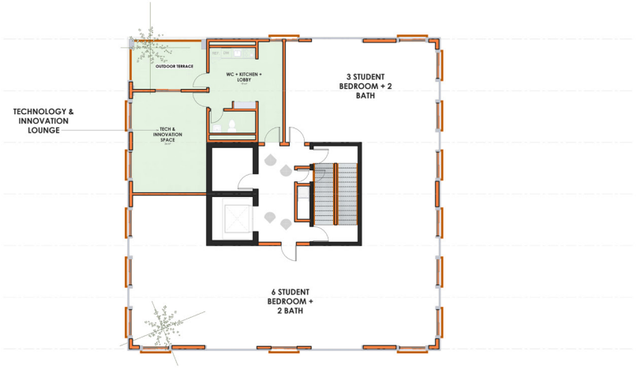


FIGURE 81: Level 11
(11th Floor above grade)
Student Housing showing shared technology and innovation lounge at the building's south-west corner, positioned to capture the evening's sunset and provide outward-facing views to the Kitchener GO transit and Cherry park trail .



FIGURE 82: Level 11
(11th Floor above grade)
showing the Residential Housing tower with a mini double height basketball hall on the north side of the building to reduce interference from the sun while it shows a double height community garden on the south side to harness the sunlight during the summer.



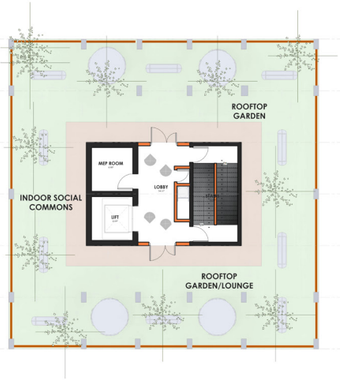


FIGURE 83: Level 12
(12th Floor above grade)
the student housing showing the roof top garden that allows multiple views around the down-town core and various study club events and gatherings.



FIGURE 84: Level 12
(12th Floor above grade)
The Residential tower shows the double-height central void on the north and south facing side right above the basketball hall and community garden respectively.

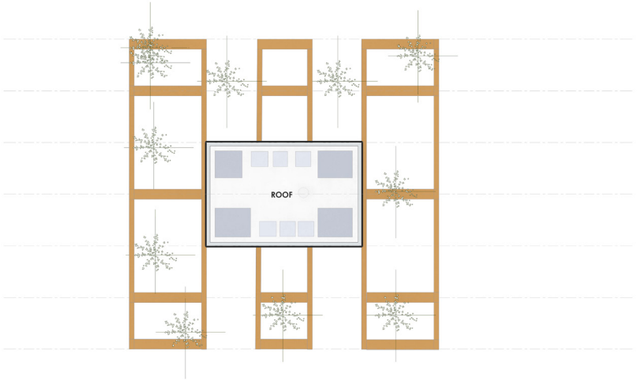




FIGURE 85: Level 13
(13th Floor above grade)
Student Housing showing glulam post and beams above the roof top garden as well as the roof that receives the roof top unit.





FIGURE 86: Level 14
(14th Floor above grade)
The Residential tower showing the double height outdoor terrace for barbecue, grills and outdoor dining events.



FIGURE 87: Level 15
(15th Floor above grade)
The Residential tower showing double volume height above the terrace for barbecue, grills and outdoor dining events.





FIGURE 88: Level 16
(16th Floor above grade)
Residential Tower showing dog-wash and hotdesk shared amenities at the south-west corner of building.



FIGURE 89: Level 17
(17th Floor above grade)
Residential Tower showing double height volume above dogwash and hotdesk shared amenities at the south-west corner of building.





FIGURE 90: Level 18
(18th Floor above grade)
Residential Tower showing tripple height volume above dogwash and hotdesk shared amenities at the south-west corner of building. to allow more sunlight at sunset.



FIGURE 91: Level 20
(20th Floor above grade)
The Residential tower showing roof top community garden that allows for events and large parties. Which allows booking of multiple gardens depending on the scale of the event.





FIGURE 92: Level 21
(21st Floor above grade)
Residential Tower showing roof, and roof top units above. The Lift and stairs allows for maintenance and installations of roof top units.

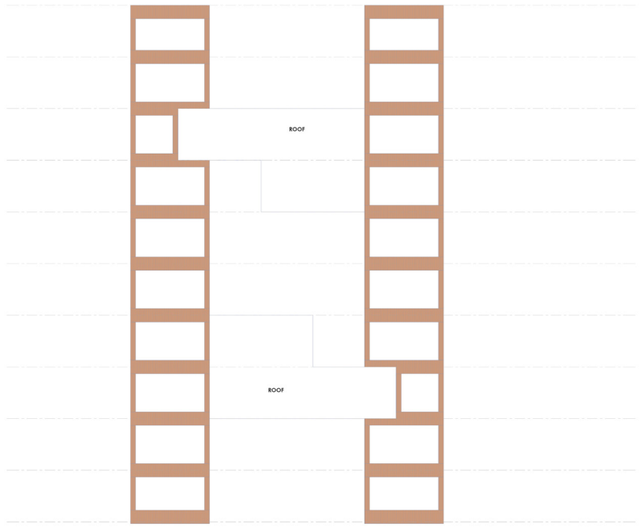


FIGURE 93: Level 22
(22nd Floor above grade)
Residential Tower showing glulam pergolas about roof top garden.



FIGURE 94: Approach Elevation (North Elevation)
showing the access road from charles street



FIGURE 95: Rear Elevation (South Elevation)
showing the waste disposal on the far left and an open pedestrian access through the courtyard beneath the podium.



FIGURE 96: Right Elevation (West Elevation)



FIGURE 97: Left Elevation (East Elevation)

Design Development - Proposed Design



FIGURE 98:
(Longitudinal Section)
showing the section through the waste chute, and the alignment of the service ducts.

Design Development - Proposed Design

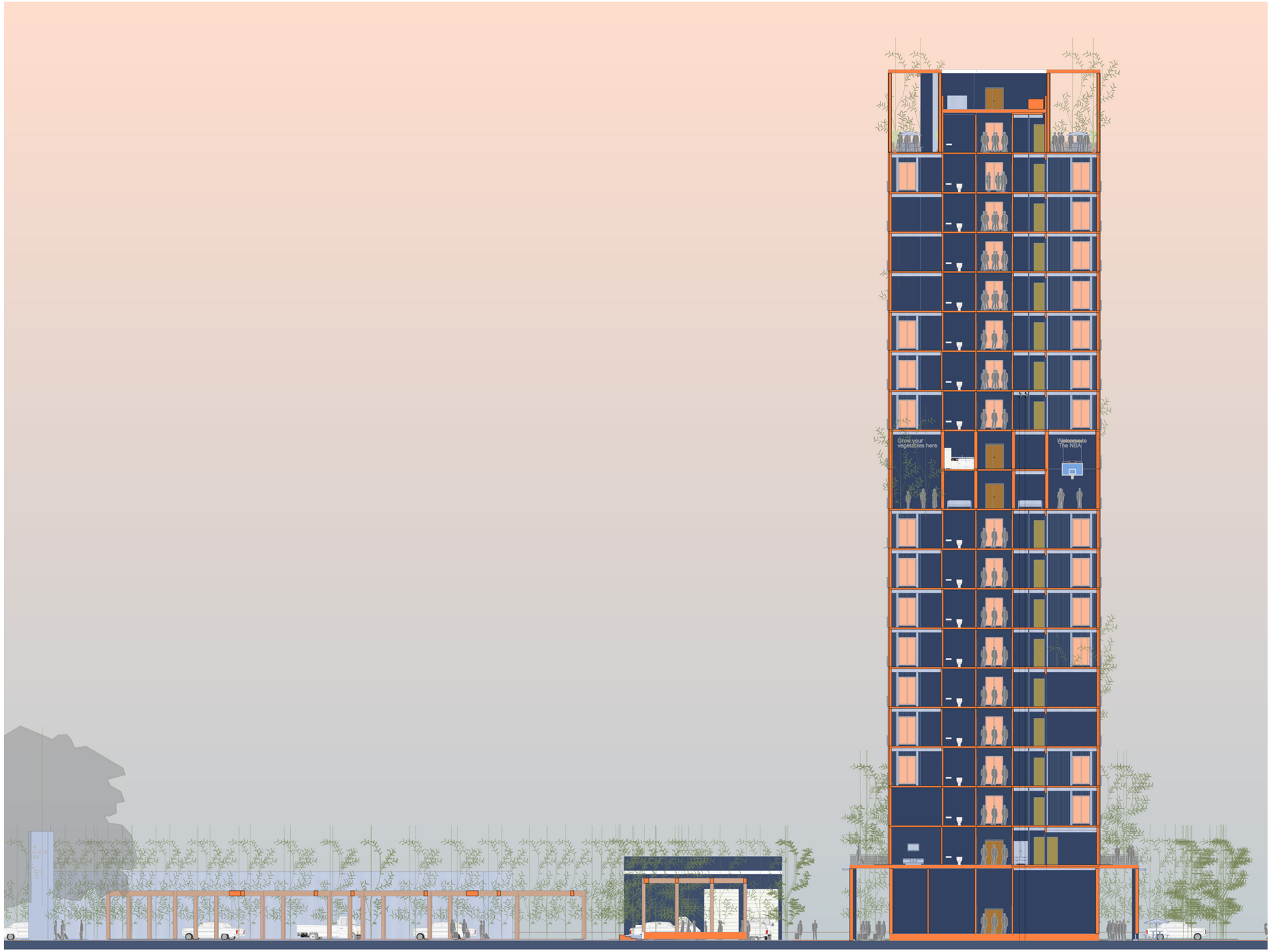


FIGURE 99:
(Transverse Section)
through the residential tower showing the Shared amenities such as the basketball court, community garden and other shared distributed with double height spaces.

4.7 Ground Floor Layout Strategy

The ground floor layout is organized to support clear circulation, safe egress, and modular construction efficiency while responding to the site's public-realm conditions. At the most immediate scale, the plan avoids dead-end corridors by establishing a continuous circulation loop around both building cores. This ensures that travel distances to exits remain compliant with life-safety requirements and provides multiple egress routes for residents, staff, and visitors.

In the student housing building, stair cores and elevators are centrally located, allowing equal access in all directions and ensuring straightforward wayfinding for a high-turnover resident population. In the residential tower, by contrast, the vertical circulation cores are more strategically distributed to reduce walking distances for long-term residents while still aligning vertically with the project's modular stacking system. This distinction allows the circulation strategy to respond to the differing needs, usage patterns, and occupancy characteristics of the two building types.

At the programmatic scale, ground floor uses are arranged to support daily resident activity and to create an active edge along the south-facing public plaza. Community-oriented spaces such as the reception, co-working café, wellness areas, and parcel rooms are placed prominently near primary entrances to reinforce natural movement flows and encourage social engagement.

The layout reflects the project's modular construction strategy, using a repeated 3.05 m × 7.6 m grid to structure walls, columns, circulation paths, and service zones. This modular rhythm reduces construction complexity and supports clean vertical alignment with the residential units above. Ground floor walls, corridors, and shafts directly support the volumetric modules, preserving material efficiency and enhancing construction speed.

At the urban scale, the ground floor strengthens the project's connection to the broader Innovation District. South-facing entrances open directly onto the community plaza, encouraging residents to move through and occupy the outdoor public realm. Walkways beneath the podium provide sheltered pedestrian routes linking the site to adjacent sidewalks, cycling paths, and the Cherry Park Trail.

4.8 Typical First Floor Layout Strategy

The first-floor layouts for both the student housing tower and the residential tower reflect a unified strategy that responds to documented housing needs in the Kitchener-Waterloo region while maintaining modular consistency across multiple floors. Statistical data from the City of Kitchener and the Region of Waterloo indicates an increasing demand for small-family units, particularly two-bedroom and three-bedroom apartments, which represent the fastest-growing segment of renter households.[112] This demand is driven by young professionals, newcomers, and multi-generational or shared households seeking affordability without sacrificing usable space.
The proposed unit mix on the first floor directly addresses this need by prioritizing a larger proportion of 2-bedroom and 3-bedroom units within the residential tower's modular framework.

1. Student Housing Tower Strategy
In the student housing building, the first floor functions as a typical layout for Floors 1, 2, and 3, reflecting the predictability and efficiency required for high-density student accommodation. Students are grouped into six-bedroom clusters with shared bathrooms and living rooms. The centrally located stair and elevator core enables equal access across the plan and supports straightforward wayfinding for a high-turnover student population. Mechanical and service rooms are positioned around the core to ensure clean vertical alignment and reduce construction redundancy across repeated modular floors.

2. Residential Tower Strategy
In the residential tower, the first floor acts as a typical level for Floors 1, 2, 3, 6, 9, 11, 12, and 18, establishing the baseline unit distribution for the building. The layout gives prominence to 2-bedroom and 3-bedroom units, which occupy the four corners to maximize natural light, cross-ventilation, and privacy. One-bedroom and one-bedroom-plus-den units fill the central portions of the plan, offering flexibility for singles, couples, or small households.

112 "Kitchener, ON Demographics: Population, Income, and More | Point2Homes," accessed November 27, 2025, https://www.point2homes.com/CA/Demographics/ON/Kitchener-Demographics.html.

A key feature of the modular strategy is transformability: one-bedroom units can be easily combined into two-bedroom units or delivered as open-plan shells that can be subdivided later based on tenant or family needs. This adaptability made possible by the standardized 3.05 m × 7.6 m volumetric grid accommodates shifting demographics, future-proofs the building, and enhances affordability by reducing the need for costly structural alterations.

Circulation and Modular Consistency

Circulation strategies reinforce both safety and modular clarity. In the residential tower, vertical cores are strategically distributed to minimize walking distances for long-term residents while maintaining alignment with the volumetric stacking system. In contrast, the student housing tower uses a centralized core to simplify movement for high-occupancy users.

Corridors remain straight and free of dead ends, ensuring compliant egress routes and intuitive navigation. All structural walls, shafts, and modules align vertically, enabling efficient prefabrication and clean stacking logic across typical floors.

Urban and Social Dimensions

Surrounding landscape buffers soften the tower edges and integrate the first-floor residential environment with the podium-level amenities. These buffers offer privacy without isolating residents, while south-oriented windows engage visually with the community plaza and the broader Innovation District. This approach promotes natural surveillance, urban vibrancy, and a sense of belonging.

Summary

The typical first-floor layouts create a modular, flexible housing model that responds directly to Kitchener's current demographic needs. The student tower uses shared clusters to provide affordable, community-oriented living, while the residential tower prioritizes larger two- and three-bedroom units, reflecting local demand for small family housing. One-bedroom units are designed to be easily combined or subdivided, allowing the building to adapt to changing household needs over time.



FIGURE 100:
East Facade along victoria street south

Design Development - Proposed Design



FIGURE 101:
Aerial view of the project site showing an overall flow and program on site.

Design Development - Proposed Design

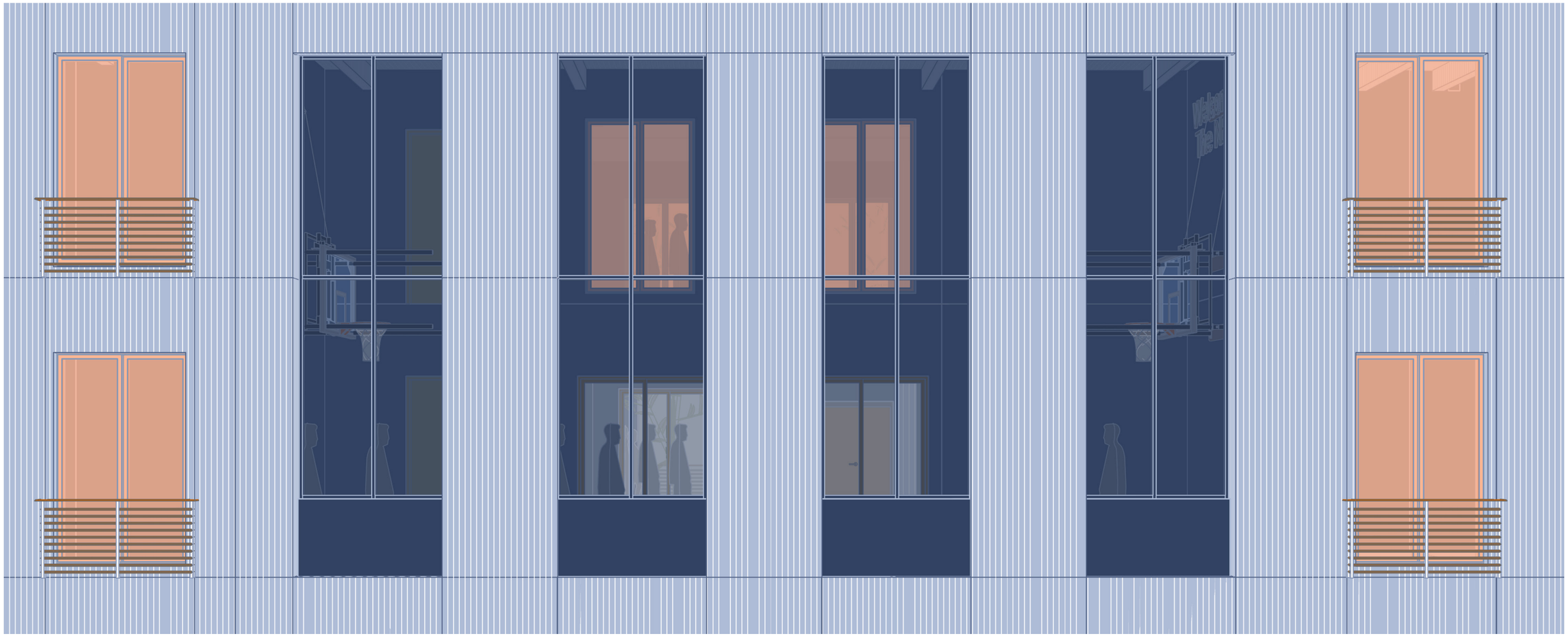


FIGURE 102: View showing the basketball hall with the neighbouring unit with Juliet balconies.

Design Development - Proposed Design

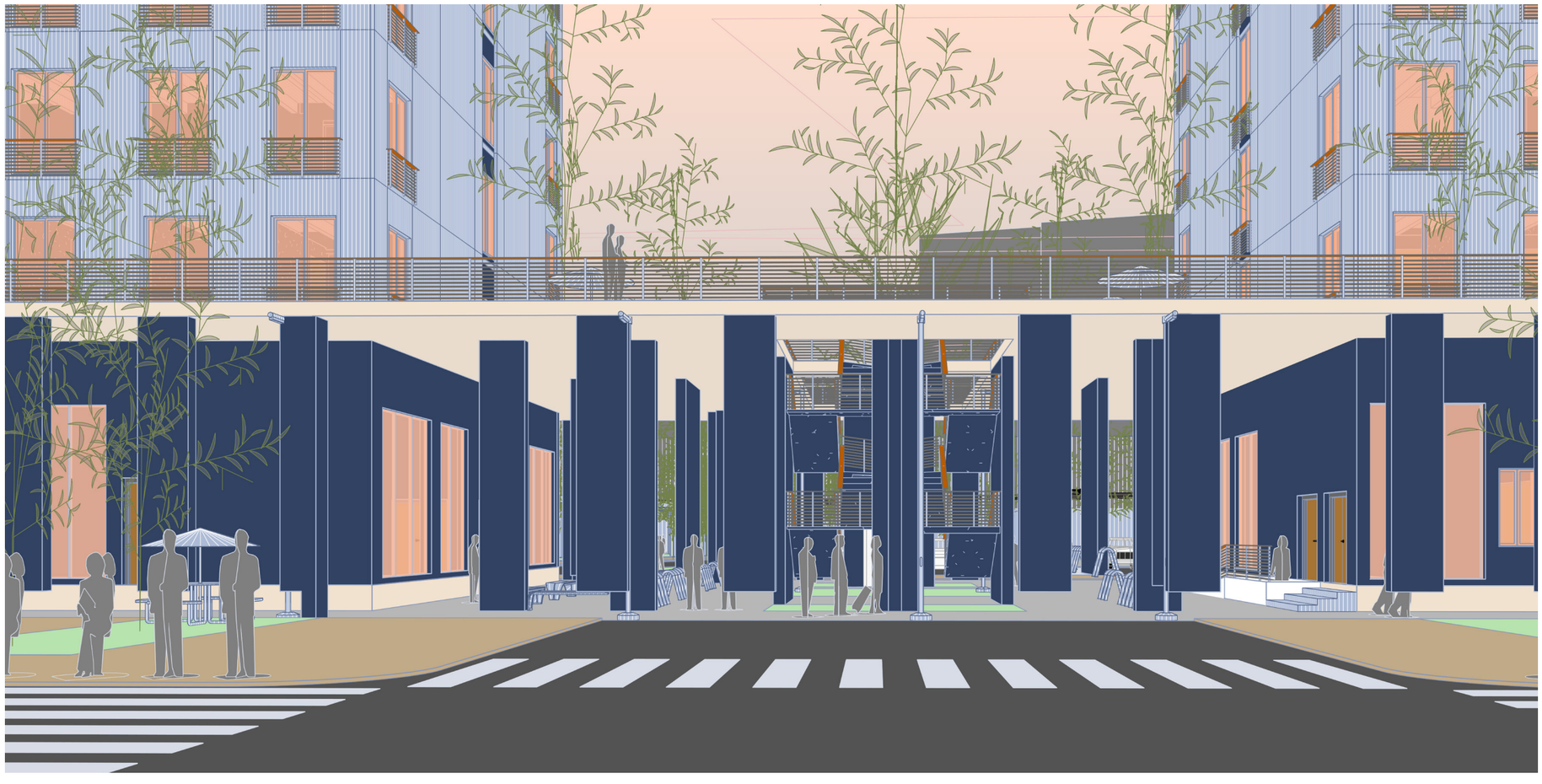


FIGURE 103: View from the University of Waterloo Health Science campus.
The Courtyard within the podium the connects the service access and waste disposal at the rear.

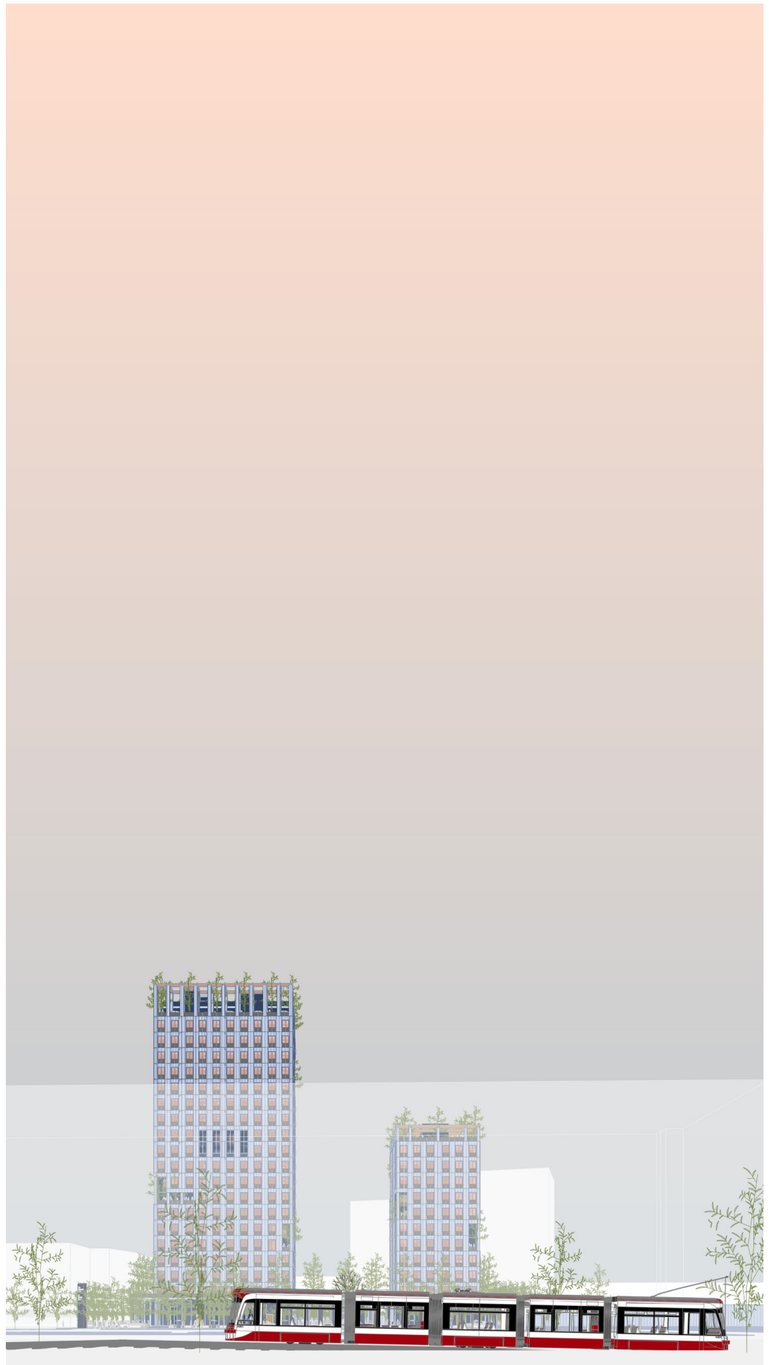


FIGURE 104: View from Central Station, LRT showing the sequence place. while showing the projects scale in relation to the UW school of Pharmacy

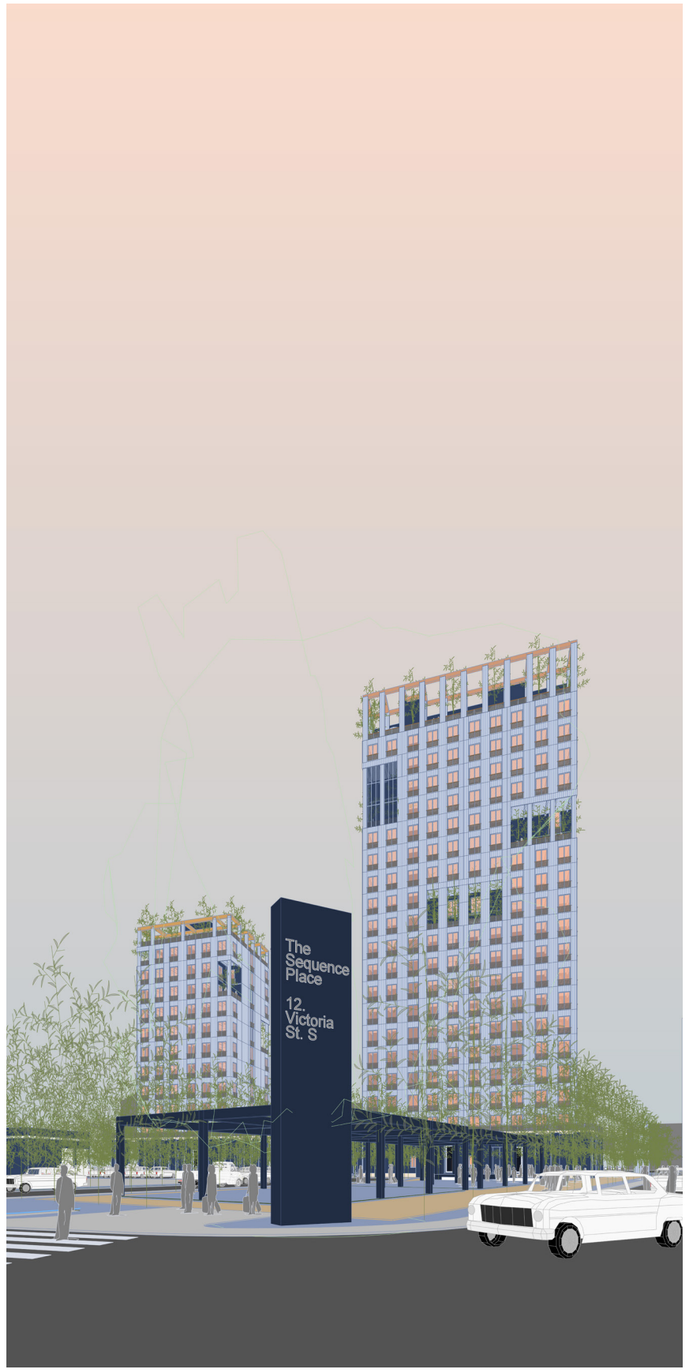


FIGURE 105: View from Joseph Street, showing the sequence place, and the timber pavillion as a backdrop for the innovation

Design Development - Proposed Design

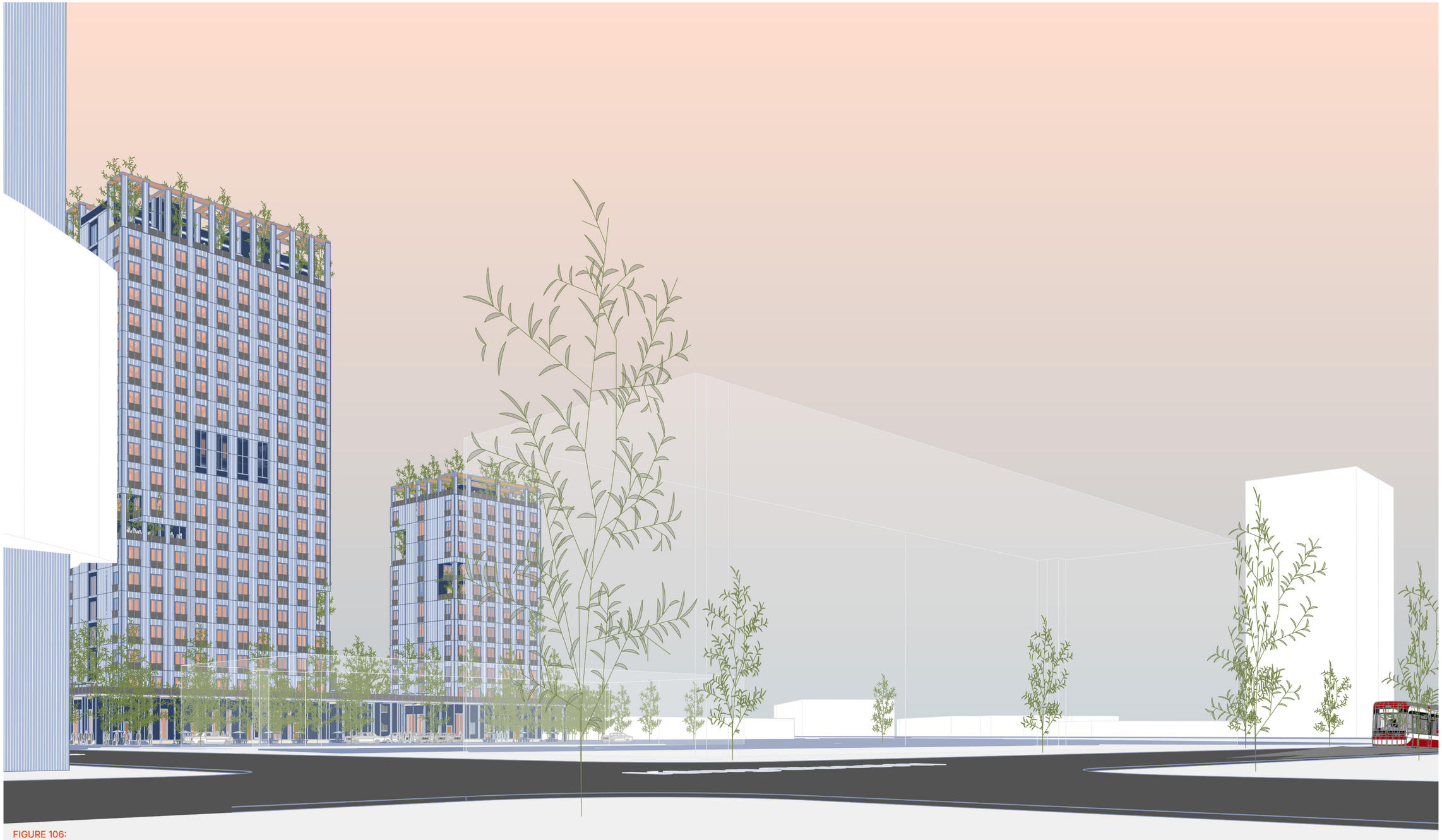


FIGURE 106:
View from the intersection of King st w, and victoria street south



FIGURE 107.
Interior view of shared terraced on Level 8 (Party & games terrace))

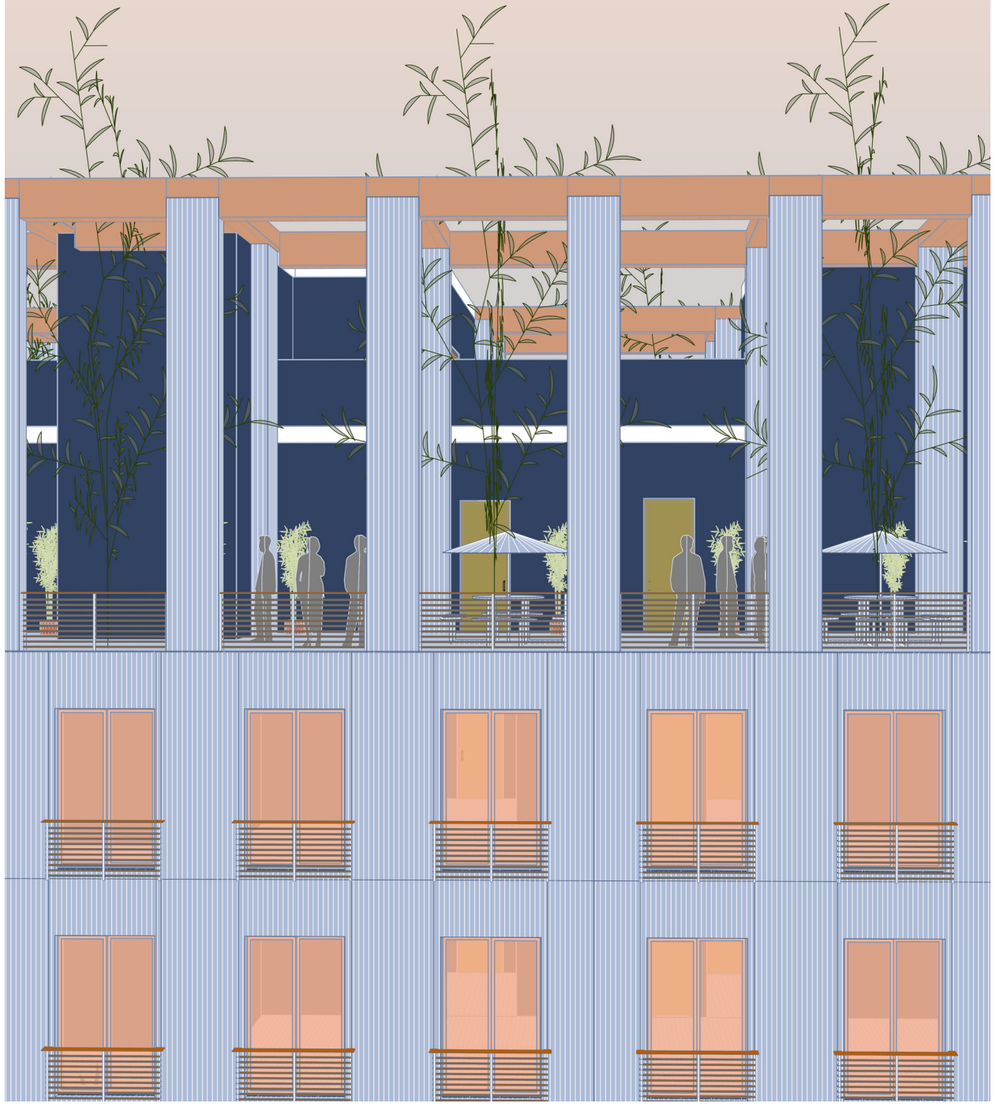


FIGURE 108.
Interior view of the courtyard beneath the podium.

FIGURE 109:
View from the intersection of Victoria street and Charles street w.



FIGURE 110:
View of the roof top garden, of the residential tower.



Design Development - Proposed Design

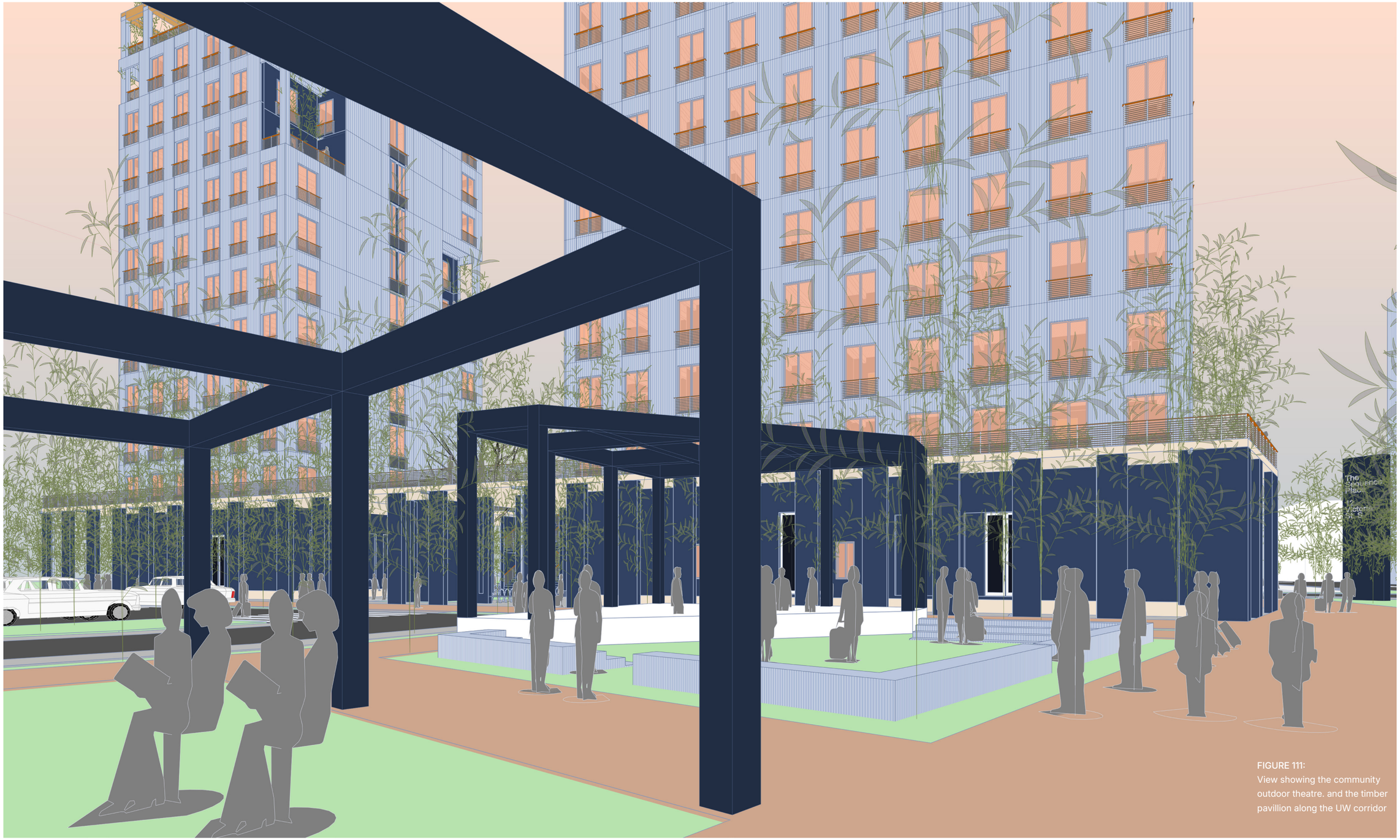


FIGURE 111:
View showing the community outdoor theatre. and the timber pavillion along the UW corridor



FIGURE 112:
View showing the double height interior of the basketball hall.

FIGURE 113:
View showing the pockets of shared spaces within the vertical village.



Design Development - Proposed Design

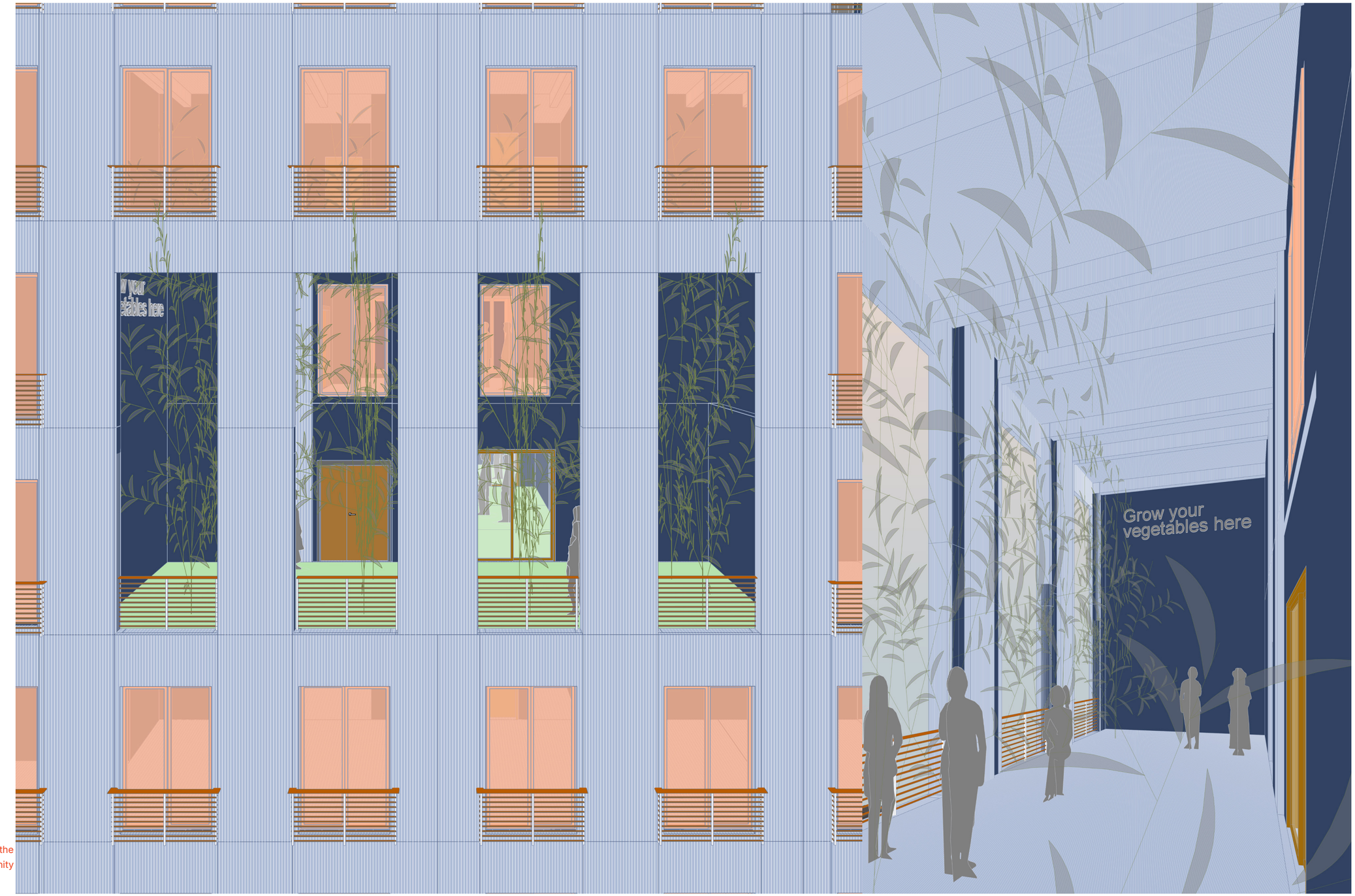


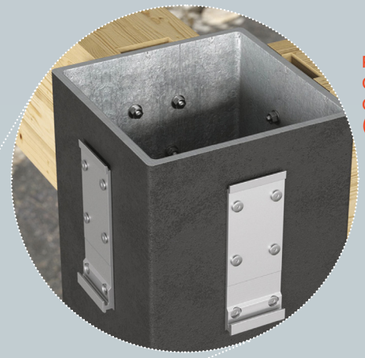
FIGURE 114:
South facing facade showing the double height shared community garden.

Design Development - Proposed Design

Structural Components & Rothoblaas Steel connectors



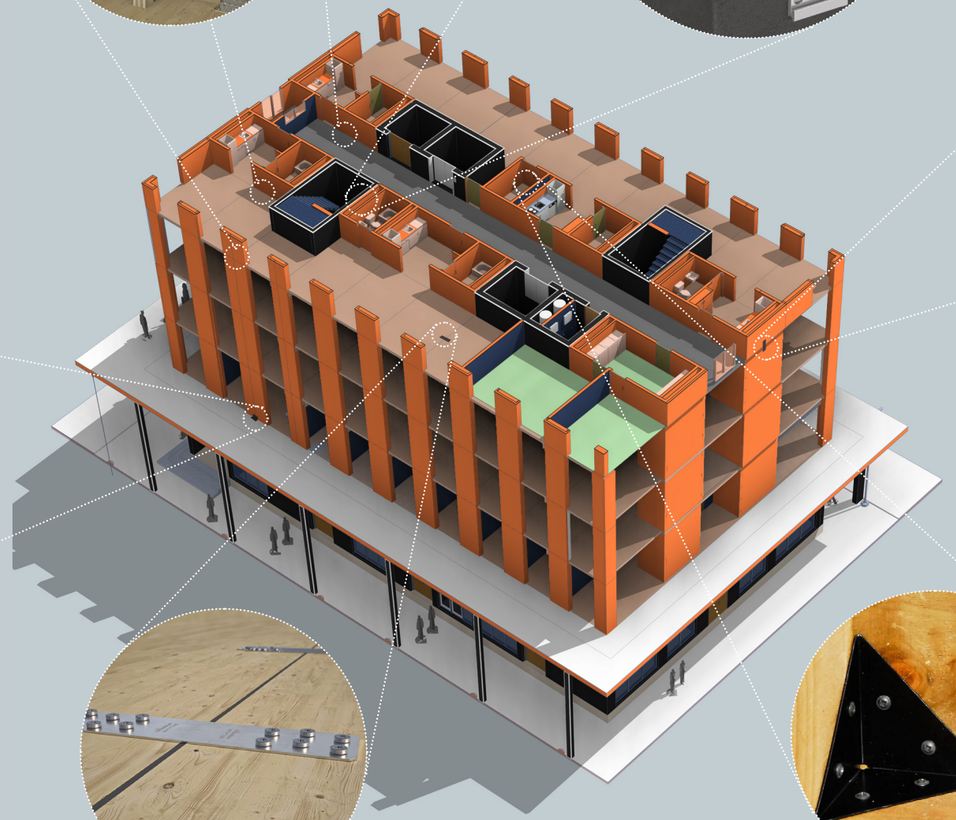
ROTHOBLAAS TITAN S
Angle Bracket for shear and tensile forces (Carbon Steel)

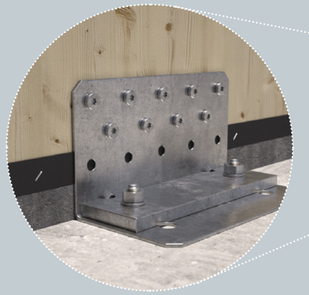


ROTHOBLAAS LOCK C
Conceled Hook TImber to Concrete Connector.
(Aluminium Alloy)



ROTHOBLAAS WHT PLATE T
(Carbon Steel)



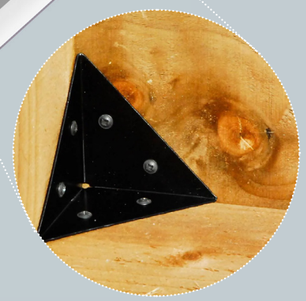


ROTHOBLAAS TITAN S
Angle Bracket for shear and tensile forces (Carbon Steel)

Volumetric & Panelised Encapsulated Timber System on Concrete in accordance with Ontario Building code.

- CLT Perimeter Shear wall
- SLab Casette (CLT floor + Glulam Beam)
- CLT Wet Pod Module
- Cast in Place Concrete Core

ROTHOBLAAS WHTPT530
For Tensile loads
(Carbon Steel)



Steel Pyramid Corner Bracket
(Prefabricated off site)
For Wet Pod Module

FIGURE 115: Structural Components with Rothoblaas steel connections

Design Development - Proposed Design



Kitchen



Bedroom



Living Room

FIGURE 116: Interior View of Typical Kitchen, Bedroom & Living Room.



FIGURE 117: Project View from victoria st s, along the UW Health Science campus.



FIGURE 118: Project Aerial View showing the relationship of the outdoor social spaces with the building.



FIGURE 119: Project View from the intersection of Joseph st and Victoria st. s. showing the community timber pavillion.

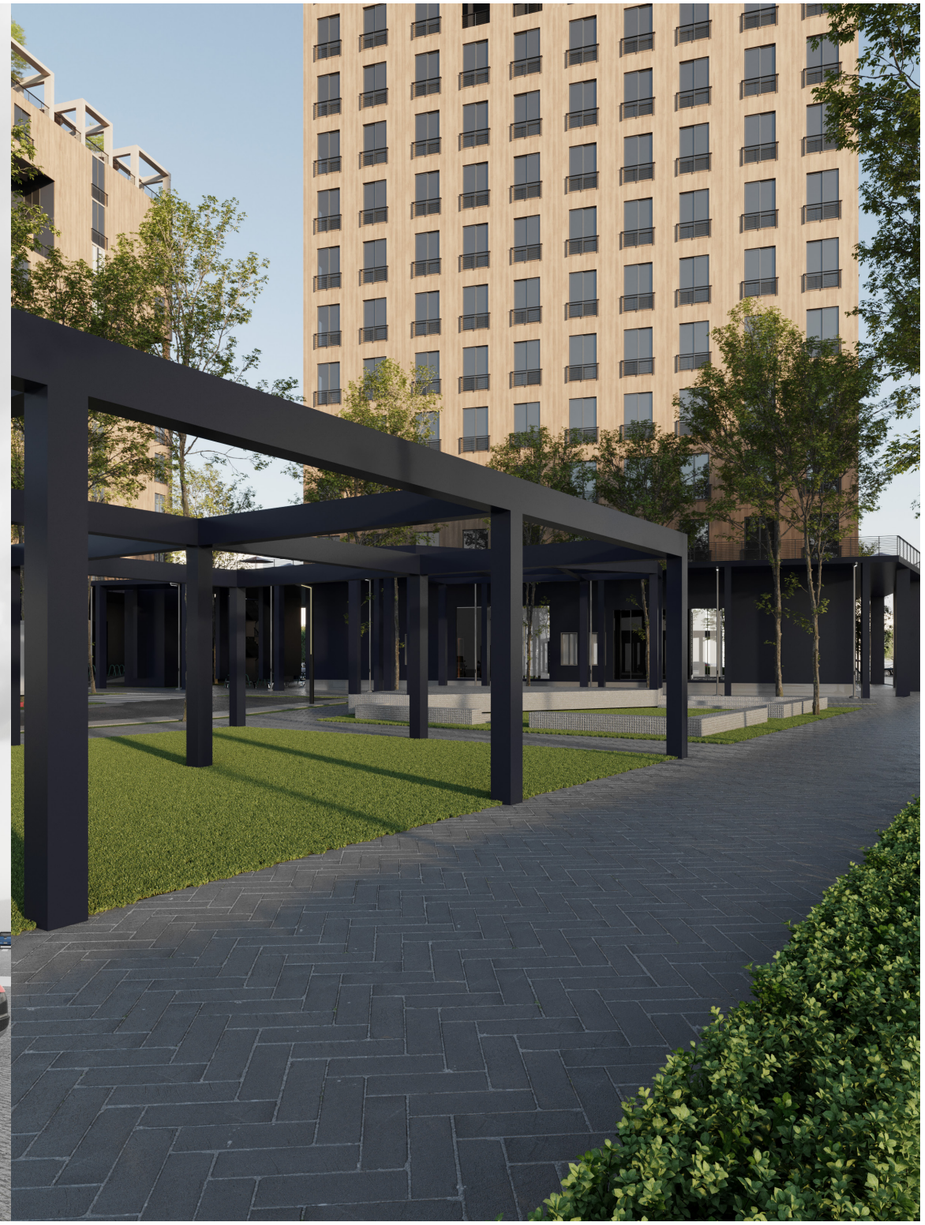


FIGURE 120: View of the project showing the community timber pavillion and the outdoor theatre.

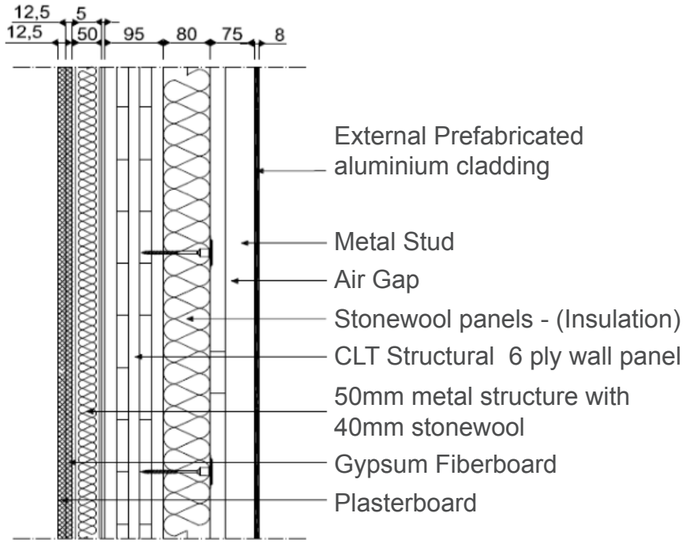


FIGURE 121: Modified drawing detail of the exterior wall assembly.

Source: Pagnoncelli, Luigi and Fabian Morales. "Cross-laminated timber system (CLT) : laboratory and in situ measurements of airborne and impact sound insulation." (2016).

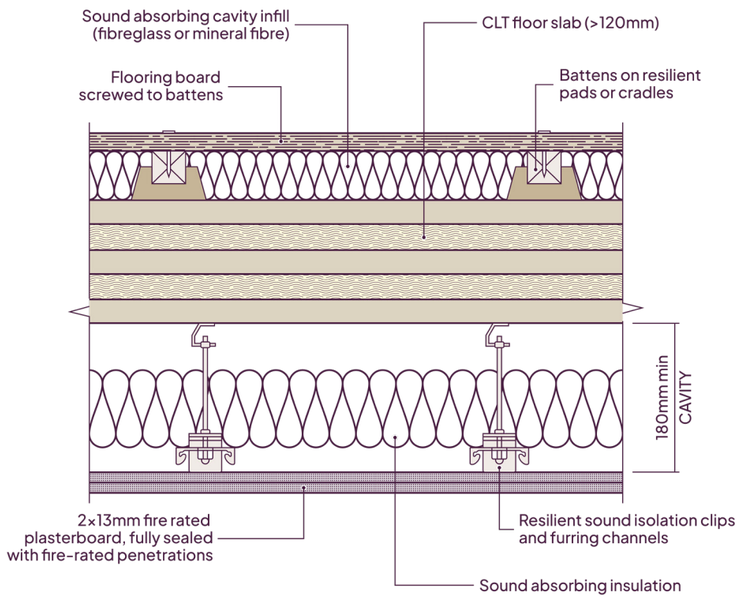
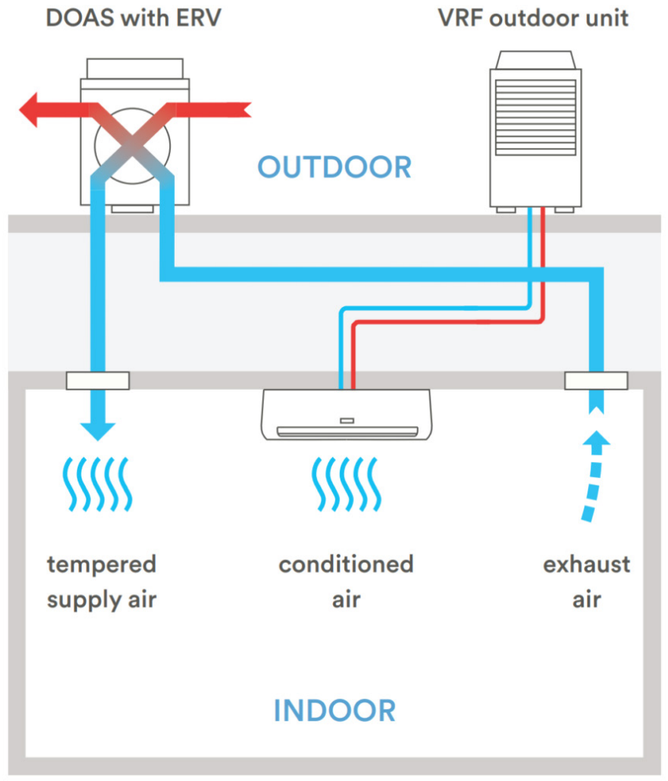


FIGURE 122: drawing detail of the CLT Floor assembly (Slab Casette).

Source: Figure 42. A generic lightweight floating floor system on CLT" of NZ Wood Design Guides, Chapter 13.5: Acoustics, May 2020



Heating & Cooling System.
DOAS handles fresh air
VRF handles heating and cooling

FIGURE 123: A roof top air-source heat-pump VRF System paired with a roof top DOAS unit with and ERV (Energy Recovery Ventilator).

Source: https://be-exchange.org/

Chapter 5 | Conclusion

Chapter 5 - Conclusion

5.1 Introduction

This thesis set out to examine how modular mass-timber systems can operate simultaneously as structural, spatial, and social frameworks for high-density urban housing. The research responds to two intersecting pressures in Canadian cities: an intensifying housing affordability crisis and the urgent need for low-carbon construction alternatives. Through precedent analysis, modular pattern studies, and the design of a high-rise mixed-use housing proposal in Downtown Kitchener as a test site, the thesis demonstrates that modular mass timber when treated not only as a structural solution but as a design tool can generate housing that is efficient, community-oriented, and architecturally expressive.

While current tall-timber precedents tend to employ modularity primarily for construction rationalization, this study advances a broader proposition: that modularity can become a tool to support spatial flexibility, social infrastructure, and climatic responsiveness, expanding the architectural possibilities of high-rise mass timber.

5.2 Summary of Research

5.2.1 Research Context

The thesis responds to the dual challenge facing Canadian cities today:
(1) a deepening housing affordability crisis, and
(2) the urgent need for low-carbon construction alternatives.

Mass timber offers an integrated response: its low embodied carbon relative to concrete, [111] compatibility with industrialized prefabrication, and potential for biophilic and community-oriented design make it uniquely suited to contemporary housing demands. Simultaneously, municipalities such as the City of Kitchener as a test location face requires more affordable, flexible, and socially supportive housing, especially within transit-oriented innovation districts. These overlapping demands frame the central question of the thesis.

5.2.2 Research Process

The study progressed through three interconnected phases:

1. Precedent Analysis

Tall-timber precedents, including Brock Commons (Vancouver), Ascent (Milwaukee), Mjøstårnet (Brumunddal), Lighthouse Joensuu (Finland), and Treet (Bergen) were evaluated for:

111 Antony Wood, Daniel Safarik, Will Miranda, Jake Elbrecht, Tall Timber: Mass Timber for High-Rise Buildings.

- structural systems
- modularity and repetition
- volumetric strategies
- façade and envelope logic
- social and spatial organization

This analysis revealed a shared pattern: while the most advanced tall-timber buildings prioritize structural standardization over spatial or social variety. Most lack large and shared terraces, communal voids, or unit flexibility due to span constraints and the efficiencies of repetitive stacking.

2. Modular Grammar Development

From these precedents, a modular grammar was distilled, comprising:

- a repeatable 3.05 m × 7.62 m grid,
- clustering techniques (pairs, trios, quads),
- subtractive voids for daylight and community space,
- vertical zoning and massing differentiation.

This grammar was tested through volumetric studies to understand how modularity might be used creatively rather than restrictively.

3. Integrated Design Proposal

The modular system was applied to the project site in Downtown Kitchener to produce a two-tower mixed-use housing proposal with:

- Student housing
- Family apartments
- Communal terraces and voids
- A public podium
- A mass-timber pavilion extending modular logic into the landscape

This design phase became a proof-of-concept demonstrating how modular timber can deliver affordable housing while also enhancing public realm and community life.

5.3 Key Findings

1. Modularity Enables Both Efficiency and Architectural Variety
A major finding is that modular mass-timber systems do not inherently limit architectural expression. By strategically clustering and subtracting modules, the project demonstrates that rich spatial variety including terraces, shared communal spaces, and double-height openings can be achieved without compromising structural efficiency.
This diverges from Brock Commons and Treet, which rely heavily on flat repetition with minimal articulation.

2. Flexible Unit Logic Supports Demographic Needs
The proposal introduces transformable one-bedroom units that can be combined into two-bedroom units, reflecting contemporary housing preferences in Kitchener, where the demand for family-oriented units and multi-occupant affordability is rising. This approach improves on precedents like Lighthouse Joensuu, where unit adaptability is minimal due to rigid modular constraints.

3. Subtractive Voids Resolve the Social Limitations of Tall Timber
Precedents such as Ascent use subtractive massing primarily for structural balancing or façade variation. This thesis expands on the subtractive logic to create:

- Mid-level gardens
- Shared laundries and workstations
- Podium-level community space
- A pavilion derived from modular logic

These voids transform tall timber from purely residential stack into a vertical neighborhood with social infrastructure an area where existing precedents underperform.

4. Vertical Zoning Enhances Livability
Organizing the building into public podium, communal mid-levels, and shared amenities embedded within the units enables mixed programming while reinforcing community formation. This aligns with urban theorist Steffen Lehmann's argument for vertical urbanism but is rarely executed in tall timber due to structural conservatism. [113]

113 Lehmann, Urban Regeneration.

5. Modular Systems Improve Urban Integration
The combination of a public plaza, cycling infrastructure, and a modular pavilion demonstrates how modular logic can extend beyond the building envelope to activate the ground plane.
This addresses a gap in many precedents, where the base of tall-timber towers remains underdeveloped or disconnected from public life.

5.4 Contribution to knowledge

This research advances the architectural discourse in five key ways:

1. Expanding the Semantic Role of Mass Timber
The thesis reframes mass timber not only as a sustainable structural system but as an architectural language a syntax capable of generating form, community, and identity.

2. Proposing a Modular Grammar for High-Rise Timber Housing
The formalized grammar (grid, clusters, voids, vertical zoning) provides a reusable toolkit for designers working with modular timber in diverse urban contexts.

3. Demonstrating Architectural Flexibility Within Structural Repetition
The project illustrates that standardized modules can support expressive façades, terraces, social spaces, and varied unit types challenging the assumption that modularity equals monotony.

4. Linking Spatial Design with Social Infrastructure
By integrating community laundries, shared workspaces, terraces, and pavilion programming, the project foregrounds social life as a design driver, an area underdeveloped in current tall-timber practice.

5. Showing How Mass Timber Can Advance Affordable, Community-Oriented Housing
The proposal demonstrates how rapid prefabrication in sequence, adaptable units, repeatable, reusable and transferable building components and shared infrastructure can reduce costs and support affordability within high-rise urban living.

5.5 Limitations

Several limitations shape the scope of the findings:

- Structural and fire engineering were guided by precedent and codes but not empirically tested.
- Costing and life-cycle assessment were not performed through industry partners and remain theoretical.
- Mechanical performance and envelope behavior (condensation, airflow, acoustics) require further simulation.
- The design remains speculative, shaped by city planning guidelines but not formally submitted for approval.

These limitations identify boundaries while clarifying areas for future research.

5.6 Directions for Future Research

1. Structural and Environmental Prototyping

Testing full-scale modules would allow validation of fire resistance, vibration performance, acoustics, and thermal behavior.

2. Municipal and Industry Collaboration

Partnerships with manufacturers and building officials would help translate the modular grammar into construction-ready systems.

3. Integration of Passive and Mechanical Systems

Future research should explore how solar chimneys, decentralized ventilation, and operable façades can be synchronized with modular mass-timber grids.

4. Sociological Evaluation of Vertical Communities

Long-term behavioral studies could measure how shared terraces, voids, and workspaces influence resident well-being.

5. Neighborhood-Scale Replication

The modular grammar could serve as a basis for district planning, supporting networks of timber towers integrated with transit, open space, and community amenities.

5.7 Final Reflections

This thesis positions modular mass timber as a growing architectural paradigm a system capable of delivering sustainable construction, expressive form, and socially connected housing. By challenging the structural and spatial conservatism of existing tall-timber precedents, the research shows that modularity can be both rational and imaginative.

In summary the key benefit of the proposed design compared to conventional high-rise buildings include the following.

1. Construction Efficiency & Cost Advantage.

-Design Enables parallel off-site fabrication and on site assembly, significantly reducing construction timeline.

-Repetitive CLT geometry modules minimizesformwork, labour intensity, and on site waste.

2.Carbon Performance and Carbon Impact,

-Mass timber significanty reduces high carbon concrete and steel with a renewable, carbon sequestering structural system.

-Prefabrication reduces masterial waste, transportation in-eficiency and embodied emissions across the construction cycle.

3. Resident Experince and Housing Quality.

-Integrated communal terraces, shared amenities and vertical social spaces foster daily interaction and community cohesion, particular for students and families.

-Units are designed for adaptability over time, allowing one bedroom units to ber combined, subdivided or reconfigured in response to changing household needs.

4. Spatial Flexibility and Long Term Value.

-The Repeatable kit of part enables building to evolve witouht demolition, extending service life beyond conventional building.

-Structural and service alignment allows selective floor-by-floor transformation rather than full building replacement.

-This flexibilty supports long term affordability by reducing future renovation and redevelopment costs.

Design Development

5.8 Overall Summary

This thesis investigates how modular mass-timber systems can serve as a structural, spatial, and social framework for high-density urban housing. Through precedent analysis, modular pattern development, and the design of a mixed-use housing proposal in Downtown Kitchener, the research demonstrates that modular mass timber typically treated as a construction efficiency tool can instead operate as a flexible architectural language capable of generating livable, community-oriented high-rise environments.

The study finds that modular systems, when paired with a disciplined grid and strategic subtractive massing, can support both construction efficiency and architectural variety, challenging the conservative tendencies seen in tall-timber precedents such as Brock Commons and Treet. The proposed design introduces adaptable units, communal voids, shared terraces, and a modular pavilion, showing how modular logic can create social infrastructure and spatial richness within structural repetition.

Key contributions include:

- Expanding mass timber from a structural material into a generative design syntax.
- Establishing a reusable modular grammar for high-rise housing.
- Demonstrating how standardized modules can produce flexible, diverse units and communal spaces.
- Linking modularity to social programming through shared amenities and vertical community rooms.
- Advancing a model for affordable, low-carbon housing responsive to demographic needs in cities like Kitchener.

Limitations relate to the absence of full structural, fire, and mechanical testing, as well as the speculative nature of the proposal. Future research should explore prototyping, municipal collaboration, integrated environmental systems, and post-occupancy evaluation of vertical communities.

Overall, the thesis argues that modular mass timber can redefine high-density housing by enabling buildings that are faster to construct, lower in carbon, more socially connected, and architecturally expressive. Through modular intelligence, timber becomes not merely a structural solution but a catalyst for new forms of urban living.

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